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SCIENCE AND TRAFFIC DEVELOPMENT
NEXT GENERATION TRANSPORT INDUSTRY INNOVATIONS

9th – 10th May, Opatija, Croatia

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	Authors	Papers	Page
1.	K. Andrić S. Babić E. Missoni K. Shabanaj	**THE IMPACT OF SPEED ON ROAD SAFETY AND THE ENVIRONMENT**	**1-10**
2.	F. Aybek Cetek B. Antulov-Fantulin P. Frost K. Donmez Z. Kaplan T. Rogošić	**PROJECT ATCOSIMA: PRELIMINARY RESULTS AND ANALYSIS OF REAL-TIME ATC AND FLIGHT COCKPIT SIMULATIONS**	**11-22**
3.	Darko Babić M. Modrić Dario Babić M. Fiolić	**EVALUATING THE INFLUENCE OF ROAD MARKINGS' RETROREFLECTIVITY ON ROAD SAFETY IN LOW VISIBILITY CONDITIONS**	**23-30**
4.	T. Badrov M. Nikšić D. Šipuš	**HYBRID-POWERED AND ALTERNATIVE-FUELED HAULING RAILWAY VEHICLES**	**31-37**
5.	V. Basarić V. Bogdanović J. Mitrović Simić N. Garunović	**THE ANALYSIS OF THE EFFECTS OF ECOLOGICAL VEHICLES INTRODUCTION INTO THE PUBLIC PASSENGER TRANSPORT SYSTEM IN NOVI SAD**	**39-44**
6.	V. Bogdanović V. Basarić J. Mitrović Simić N. Garunović	**TRAFFIC MANAGEMENT FOR DELIVERY VEHICLES IN NOVI SAD PEDESTRIAN ZONE**	**45-54**
7.	D. Bokulić M. Ivaković S. Lovrić	**ANALYSIS OF DRIVING SCHOOLS SERVICE DEMANDS IN THE REPUBLIC OF CROATIA**	**55-66**
8.	P. Brlek I. Cvitković A. Globočnik Žunac	**COSTS AND BENEFITS OF DEPLOYING COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS IN THE EUROPEAN UNION**	**67-73**

	Authors	Papers	Page
9.	G. Budimir Šoško K. Buntak D. Gregurević	**ANALYSIS OF SUSTAINABLE URBAN MOBILITY SOLUTIONS AS AN IMPERATIVE IN 21ST CENTURY**	**75-86**
10.	L. Bukvić J. Pašagić Škrinjar M. Jakara	**POSSIBLE APPLICATION OF ELECTRIC VEHICLES IN ZAGREB CITY LOGISTICS**	**87-92**
11.	C. Cetek B. Juričić T. Feuerle T. Radišić	**DEVELOPMENT OF COMMON ATC SIMULATION TRAINING ASSESSMENT CRITERIA BASED ON FUTURE PAN EUROPEAN SINGLE-SKY TARGETS (ATCOSIMA): A PROJECT OVERVIEW**	**93-104**
12.	O. Cokorilo L. Tomic	**CORSIA- CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION: CHALLENGE AND PRACTICE**	**105-112**
13.	D. Cvetek V. Bojić N. Jelušić M. Muštra	**INITIAL BLUETOOTH PROBE VEHICLE PENETRATION RATE ANALYSIS: A CASE STUDY IN THE CITY OF ZAGREB**	**113-123**
14.	A. Dlesk D. Kučić D. Puljek	**AN AIRLINE VIEW OF NAVIGATIONAL AND ECOLOGICAL TRENDS**	**125-136**
15.	M. Drljača	**REVERSIBLE SUPPLY CHAIN IN AGRICULTURAL PRODUCTION**	**137-146**
16.	M. Fiolić M. Ferko M. Ružić H. Dijanić	**REVIEW – DRIVING SIMULATOR AS A TOOL TO IMPROVE TRAFFIC SAFETY**	**147-154**
17.	M. Fiolić A. Stažnik I. Habuzin S. Šarčević	**AUTOMATIC DETECTION AND IDENTIFICATION OF TRAFFIC SIGNS: A REVIEW OF EXISTING SOLUTIONS**	**155-163**

	Authors	Papers	Page
18.	M. Furdi R. Stanković J. Pašagić Škrinjar	**IMPROVING EFFICIENCY OF THE PARCEL DISTRIBUTION BY DYNAMIC REGIONALIZATION**	**165-174**
19.	M. Jakara M. Emanović T. Bubalo B. Abramović	**THE PROMOTION MEASURES FOR COMBINED TRANSPORT IN THE EUROPEAN UNION**	**175-183**
20.	K. Jerinić B. Juričić P. Andraši I. Francetić	**THE EFFECT OF LUČKO CTR UPPER LIMIT EXTENSION ON AIR TRAFFIC INDICATORS IN ZAGREB TMA – A PRELIMINARY ANALYSIS**	**185-196**
21.	A. Jodejko-Pietruczuk F.J. Restel	**RELIABILITY ISSUES IN RAILWAY OPERATION PROCESS PLANNING AND OPTIMIZATION – A LITERATURE REVIEW**	**197-207**
22.	T. Kljak J. Janković V. Štefković	**CONCEPT OF MULTILEVEL AND MULTILAYER CONSIDERATION OF PHILATELY DEVELOPMENT IN E-ENVIRONMENT**	**209-217**
23.	N. Lakhmetkina A. Oleinikov	**DRY PORTS SIGNIFICANCE FOR THE TRANS-EURASIAN LAND TRANSPORT CORRIDORS**	**219-230**
24.	B. Maretić B. Abramović	**USING PUBLIC TRANSPORT IN RURAL AREA: CASE STUDY ŠIBENIK KNIN COUNTY**	**231-240**
25.	D. Maretić T. Rožić B. Ivanković	**OPTIMIZATION OF DISTRIBUTION NETWORK USING METHODS FOR SOLVING THE PROBLEM OF VEHICLE ROUTING**	**241-254**
26.	M. Mehanović A. Ahmić D. Ezgeta	**MANAGEMENT OF COMPANIES FOR TRANSPORT OF PASSENGERS IN DIGITAL TRANSFORMATION CONDITIONS - INNOVATION IN TRANSPORT AND TELECOMMUNICATIONS**	**255-263**

	Authors	Papers	Page
27.	M. Mikulčić T. J. Mlinarić M. Viduka Milas	**NEW SPECIFIC TRANSMISSION DEVICE FOR PROVIDING THE REQUIRED SAFETY LEVEL BETWEEN ETCS AND INDUSI TECHNOLOGY**	**265-274**
28.	A. Muminović I. Grofelnik M. Obrecht M. Knez	**KEY FACTORS INFLUENCING CONSUMERS' WILLINGNESS TO PURCHASE ELECTRIC VEHICLES: A STUDY OF CROATIA**	**275-290**
29.	D. Novak S. E. Zaharia M. Pavlinović R. Romanović	**RECOGNITION OF PRIOR LEARNING BASED ON COMPETENCE-BASED TRAINING IN AVIATION SECTOR**	**291-300**
30.	S. Petar A. Globočnik Žunac A. Klečina	**INTEGRATED PASSENGER TRANSPORT AS A MEASURE OF INCREASING QUALITY IN PUBLIC TRANSPORT SERVICE**	**301-308**
31.	I. Periša M. Habuš M. Šafran G. Kolarić	**POSSIBILITIES OF IMPROVING TRANSPORT PROCESS IN THE COLD CHAIN**	**309-323**
32.	M. Petrović I. Ljubaj T. J. Mlinarić	**INCREASING QUALITY OF SERVICE IN RAILWAY PASSENGER TRANSPORT - CASE STUDY**	**325-335**
33.	V. Rajič K. Juršić I. Grgurević M. Vlajčić	**TESTING WIRELESS TELECOMMUNICATION NETWORK IN PUBLIC URBAN PASSENGER TRANSPORT VEHICLES IN THE CITY OF ZAGREB**	**337-348**
34.	K. Rogić R. Stanković M. Ružić G. Kolarić	**ANALYSIS OF WASTE TRANSPORT IN CITY OF VELIKA GORICA**	**349-359**
35.	B. Rüger N. Ostermann	**EFFICIENT PASSENGER TRAINS**	**361-370**

	Authors	Papers	Page
36.	A. Schöbel C. Schöbel J. Blieberger M. Stefan	**BENCHMARK OF DELAYS SIMULATED BY OPENTRACK AND CALCULATED BY KRONECKER ALGEBRA ON ZAGREB-RIJEKA LINE**	**371-375**
37.	M. Slavulj J. Jurak M. Emanović I. Jelić	**INCENTIVE MEASURES FOR ACQUISITION OF ELECTRIC AND HYBRID VEHICLES IN EUROPEAN UNION**	**377-383**
38.	S. Steiner T. Mihetec Z. Rezo	**RESOLUTION OF OPERATIONAL CONSTRAINTS IMPOSED BY FRAGMENTATION OF EUROPEAN AIRSPACE**	**385-395**
39.	A. Szeląg M. Lewandowski M. Steczek T. Maciołek	**FROM TRAMS TO HIGH-SPEED TRAINS AND ELECTROMOBILITY – 140 YEARS OF DEVELOPMENT OF ELECTRIC TRACTION**	**397-408**
40.	S. Šinko M. Knez M. Obrecht	**ARE WE READY FOR AUTONOMOUS VEHICLES?**	**409-422**
41.	S. Škerlič	**ANALYSIS OF LOGISTICS AND WAREHOUSING ERRORS BY TYPE OF WAREHOUSING TECHNOLOGY USED IN THE SLOVENIAN MANUFACTURING COMPANIES**	**423-429**
42.	M. Šoštarić D. Beganović M. Jakovljević M. Švajda	**ELECTRIC VEHICLES IN THE FUNCTION OF MODELLING PARATRANSIT FOR AREAS WITH SIGNIFICANT DEVIATION BETWEEN CYCLE TIME – CASE STUDY OF JASTREBARSKO (CROATIA)**	**431-438**
43.	J. Vertlberg I. Krajnović M. Ševrović	**METHODOLOGY FOR DETERMINING CONCEPTUAL LOCATIONS OF PARK&RIDE TERMINALS IN THE WIDER ENVIRONMENT OF THE CITY OF ZAGREB**	**439-449**
44.	G. Vojković M. Milenković R. Jovančević	**NOVELTIES IN PASSENGER ROAD TRANSPORT IN THE REPUBLIC OF CROATIA**	**451-459**

	Authors	Papers	Page
45.	P. Zajac O. A. Gavrish M. Zajac	**INLAND TRANSPORT, TECHNICAL AND ECONOMIC ANALYSIS, ON THE EXAMPLE OF THE ODRA RIVER**	**461-469**
46.	M. Živičnjak I. Bajor M. Matijević F. Buturić	**PICK-BY-VISION IN WAREHOUSE USING AUGMENTED REALITY GLASSES**	**471-481**

KRUNOSLAV ANDRIĆ, Student[1]
E-mail: kandric1@hotmail.com
SLAVIŠA BABIĆ, M.Sc.[2]
E-mail: slavisa.babic@hrvatske-ceste.hr
EDUARD MISSONI, Ph.D., M.D.[1]
E-mail: emissoni@fpz.hr
KAMER SHABANAJ, M.Sc.[3]
E-mail: kamershabanaj@gmail.com
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb
[2] Hrvatske ceste d.o.o.
Vončinina 3, 10000 Zagreb
[3] Republic of Kosovo, Ministry of Infrastructure and Transportation
Ul. Kole Lleshi b.b., Priština

THE IMPACT OF SPEED ON ROAD SAFETY AND THE ENVIRONMENT

ABSTRACT

Road traffic accidents are becoming a major death cause in the world. The main cause of these accidents is inappropriate and excessive speed. In addition, speed has a negative impact on the environment, particularity in terms of noise and increased fuel consumption, which implies that good speed management results in enhanced traffic safety and lower negative impact on the environment.

KEYWORDS

Road safety; speed management; environmental impact; noise pollution; energy consumption

1. INTRODUCTION

Needs for mobility in modern society are becoming bigger and more challenging in means of traffic management, road safety management and pollution reduction, especially when taking in consideration world population growth and growth of motorization.

Every year 1.35 million people die in road traffic accidents globally. [1] Considering that the population of the Republic of Croatia is 4,284,889, [2] it would mean that a little more than a third of its population would annually be killed in road traffic worldwide. Road fatalities are the eighth leading cause of death for people of all ages and the number one cause of death for children and young adults from ages 5 to age 29! It should be emphasized that more than half of global road fatalities are amongst pedestrians, cyclists and motorcyclists.

Out of all mistakes made by drivers, "speed", or excessive speed and inadequate speed regarding road conditions, is the most common cause of road traffic accidents and fatalities. In 2017, out of 34,368 traffic accidents that occurred on roads in the Republic of Croatia, 32,673 were caused by drivers. Furthermore, in 1,009 of those accidents, the error was excessive speed and in 6,675 it was inadequate speed regarding road conditions, in percentages, 2.9 % and 19.4 %. Total number of people killed in traffic accidents in 2017 in the Republic of Croatia is 307. The number of people killed in accidents caused by excessive speed is 15 (4.9 %), and of those caused by inadequate speed regarding road conditions is 102 (33,2 %). To put these numbers in perspective, excessive and inadequate speed were the cause of 22.3 % of all road accidents in the Republic of Croatia 2017, resulting in 38.1 % of the total fatal casualties in these accidents. [3]

2. IMPACT OF SPEED ON ROAD SAFETY

The Road safety act in the Republic of Croatia mandates vehicle speed limit, stating that in a populated area, the driver must not operate a vehicle with a speed higher than 50 kph or the speed greater than the one limited by a traffic sign in the populated area, which cannot exceed 80 kph. In the same Act it is stated that outside the populated area, the driver must not operate a vehicle with a speed greater than the one limited by a traffic sign. [4]

Improper speed is any speed that is greater than the one regulated by a traffic sign or rule. However, not every improper speed is in fact penal. The Act of traffic safety on roads does not mandate a ticket for improper speed that is greater by 10 kph from the regulated speed. Meaning that if the driver is driving 110 kph outside a populated area, with a speed limit of 100 kph regulated by a traffic sign, he/she is driving with improper, but still not penal speed! [4]

With the Road safety Act, there is also the Regulation on requirements for equipment used for speed enforcement, which mandates the safety difference and defines it as a value expressed in "kph", or "%" which is to be subtracted from the measured speed value to correct the speed measuring device, i.e. measuring method error. [5] Subtraction of the safety difference points out that on a part of the road, with a regulated speed limit of 100 kph, driver can be operating a vehicle with a speed of 122 kph and still not be in the penal speed area, which will be mathematically proven in the next chapter.

2.1 Calculating improper and penal speed

For example, if the regulated speed limit is 100 kph, what would be the maximum speed limit that is still in the improper speed area?

If we take the equation: $V_{mo} – V_{tol} – 10$ km/h = V_{lmt}, and define the factors as follows:

V_{mo} – recorded speed, V_{lmt} - speed limit (130 kph), V_{tol} - difference tolerated by law (10 kph for speeds up to 100 kph, i.e. 10% for speeds greater than 100 kph)

The recorded speed in this case is 122 kph, and the equation states:

122 kph –1.2 kph(10% of 122 kph)-10 kph = 99.8 kph < 100 kph ,

By driving 122 kph in a 100 kph area outside a populated area, the driver is still not driving in the penal speed field, meaning that the penal speed area starts at 123 kph.

What is even more interesting, for the highest penal threshold (50 kph above the limit) in this same area, the recorded speed would have to be 178 kph or higher.

178 kph – 17.8 kph – 10 kph = 150.2 kph

2.2 Case studies

During a period of seven days, from 30th December 2013 to January 5th 2014, a case study [6] was conducted by Rijeka - Zagreb Motorway PLC on the "Mihačeva Draga" viaduct on the A7 highway in the Republic of Croatia, with the aim to analyze traffic flow speed. Speed limit on the viaduct is mandated by a traffic sign, set on 60 kph. The device used to gather data was a radar – camera "Cordon" with the ability to monitor vehicle speed on all 4 traffic lanes. The device monitored each traffic lane separately, and could also detect vehicle direction and automatically scan license plates of the vehicle along with its captured speed.

Out of the 120,668 vehicles captured during the study, 95% had their speed correctly scanned, or 114,634 in numbers. The average traffic flow speed was 80.4 kph, with the range from 10 to 155 kph.

Almost all drivers, 97%, or 111,195 in numbers, were recorded driving with a speed greater than 60 kph, meaning only 3%, or 3,439, were abiding the speed limit. Out of those 111,195 vehicles, 53%, or 58,933 vehicles, were driving in the improper speed range, while 47%, 52,262 were in the penal speed range.

Company that manages state roads, Croatian Roads Ltd., conducted a study [7] in 2017 to see how drivers obey speed limits in periods of free flow. Data was collected by automatic traffic counters based on inductive loop technology. For the 50 kph speed limit sections, the average speed in free flow was higher than the limit on 91% of locations (154 out of 170), while highest average speed was 88 kph. On sections with the speed limit of 60 kph, the average speed was higher than the speed limit on 94% of locations (83 out of 88), while average speeds on sections with the speed limit of 70 kph were higher on 67% of locations (39 out of 58).

3. THE IMPACT OF SPEED ON THE ENVIRONMENT

Ecology is becoming one of the biggest concerns of modern society. Road traffic has great negative impact to air and noise pollution. Several European directives have chosen to limit air pollution from road transport by setting emission performance standards for different categories of vehicles, such as cars, light commercial vehicles, lorries, buses and motorcycles, and by regulating the quality of fuel. EU regulation on the sound level of motor vehicles introduces a new test method for measuring noise emissions, lowers the valid noise limit values, and includes additional sound emission provisions in the type-approval procedure. Other regulations set noise limits for mopeds and motorcycles. Nevertheless, negative impact on both air and noise increases with increasing speed.

3.1 Noise pollution

One of the impacts of speed, excessive and/or inadequate, on the environment is noise.

From a medical point of view there are two noise effects:

- The aural effect - that directly affects the hearing organ
- Extra aural - that affects the human body

The value of 80 dB (noise due to heavy road traffic) is taken as a boundary above which the aural effect appears i.e. does direct damage to the hearing organ, and below that border the extra aural effect is formed. [8]

Vehicle noise can be divided into five groups:

1. Engine noise – comes from the gas formed in the piston during the compression and expansion processes in the engine cylinder, which produces vibrations of the outer walls of the engine block to emit noise. It depends on the working volume of the engine, its structural load and number of revolution. [Figure 1]
2. Noise inlet system - is formed in the opening and closing of the intake valve, and its intensity depends on the mode of engine operation, the load and the engine speed, the type of air filter and silencer.
3. The noise of the exhaust system – is formed by opening the exhaust valve and the rapid release of gas in the exhaust system. The level of exhaust noise is determined by, e.g. the pressure in the engine cylinder, the lifting speed of the valve, the diameter of the valve, etc.
4. Fan noise – while working, the fan emits broadband noise
5. Tire noise - occurs upon contact of tires with the pavement, and depends on the type of pavement, construction of the pneumatic and vehicle speed. By increasing the speed by one-quarter, the noise level doubles. [Figure 2] [9] Therefore, even with electric cars, with greater speeds negative effect on noise will still be present.

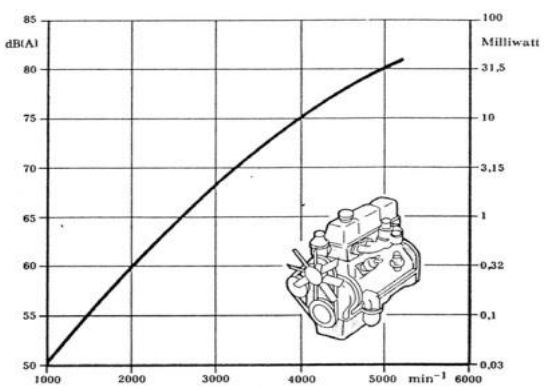


Figure 1 – Engine noise
Source [8]

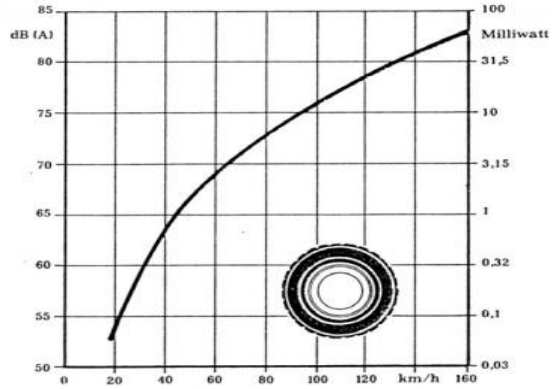


Figure 2 – Pneumatic noise
Source [8]

Traffic flow factors effects on noise pollution are:

a. Volume – 2,000 vehicles per hour produce twice the noise as 200 vehicles per hour.

b. Speed – Traffic flow with an average speed of 105 kph produces twice the noise as the one with an average speed of 50 kph.

In addition, it is important to stress that composition of the traffic flow can differently affect noise pollution because a single heavy goods vehicle moving at the speed of 70 kph produces the same noise level as 28 passenger vehicles. [7]

3.2 Energy consumption and air pollution

With mankind's insatiable need to progress and evolve, the consumption of energy is violently increasing. The transportation of people and goods accounts for about 25 percent of all energy consumption in the world. [10] In 2017, only in the U.S., road traffic has consumed an approximate of 44 quadrillion British petrol units of fuel, [11] with the numbers increasing to this day.

Since fossil fuels are only getting more expensive, the trend of "fuel-efficient" driving is growing in popularity, since it reduces vehicles' fuel consumption. It implies the following: gentle acceleration, coasting to decelerate (rather than using brakes), maintaining a steady speed and keeping a comfortable distance between the vehicle in front to better anticipate traffic, etc. [12]

One of the most common misconceptions regarding speed is driving faster to save time.

For instance, the driver has to go from Zagreb (Lučko) to Split (Dugopolje) via the A1 highway. The trip length is 378 km, [13] and he will be operating a 100 HP petrol engine vehicle with a 6-speed manual transmission.

If he was to drive abiding the speed limit, considering that there is no construction on the highway and the weather is optimal, with a constant speed of 130 kph, fuel consumption would be an average of 7.8 litres per 100 km. [14] To put numbers in a simple formula:

$$378/130 = 2.9 \text{ hours} * 60 \approx 175 \text{ minutes}$$

By increasing speed to 150 kph, fuel consumption would spike to 9.8 litres per 100 km. [14]

$$378/150 = 2.5 \text{ hours} * 60 \approx 151 \text{ minutes}$$

In the second scenario, the driver arrived 24 minutes earlier, but he spent 37.04 litres of petrol, which is 7.56 litres more than in the first one (29.48 litres). With the average cost of 9.91 HRK per litre [15], that is an increase of 75 HRK, which means that an hour costs about 190 HRK (~25€), almost four times more than an average gross salary per hour in Croatia. [16] Considering the driver "saved" 24

minutes, the cost of fuel per minute ratio rises from 1.67 HRK to 2.43 HRK per minute, i.e. fuel consumption has increased by 25.6 %.

Additionally, taken in consideration that a car produces 2.29 kg/L of CO_2, for 24 minutes the driver "saved", the vehicle emits 17,3 more kilograms of CO_2. [17]

4. TRAFFIC FLOW MANAGEMENT

Traffic flow is a simultaneous movement of several traffic entities on the traffic infrastructure defined by certain legalities. Due to high numbers of complex interactions between these entities, models and simulation are used to describe traffic flow. [18]

Traffic flow consists of four main parameters; vehicle flow, density, speed and volume. There are numerous theories regarding traffic flow management, but we will be focusing on the effect of speed on traffic flow.

Speed would be the most important parameter of traffic flow, simply because if mandates vehicle flow, there cannot be any flow without vehicle movement. That being said, if we want to manage traffic flow, we need to manage its speed.

4.1 Speed management

Speed management [Figure 3] combines engineering, enforcement, and education to reduce speed-related crashes and promote an orderly movement of road users [19]. The ultimate goal of speed management is to increase safety on roadways by reducing fatal crashes. This is not necessarily accepted as true. Speed management is not synonymous with speed reduction, it rather entails planning and designing the road layout and the road network in such a way that appropriate speed is obtained. [20]

Engineering, enforcement, and education, the three E's of speed management, must be integrated and coordinated to effectively accomplish the goals of a speed management program. [19]

3.1.1 Engineering

The engineering component of speed management varies widely and comprises numerous roadway aspects. Approaches that fall into this category include changes in roadway design, traffic operations, and infrastructure improvements. The engineering effort should be based on congruence between highway design and the road user's expectation of proper speeds. [21]

Traffic Calming Techniques:

The Institute of Transportation Engineers defines traffic calming as "the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior, and improve conditions for non-motorized street users". [22] Speed bumps, roundabouts, and lane narrowing ("road diet") are examples of traffic calming techniques used to control traffic speed in residential areas.

The basic objective of these physical measures, the idea for which originated in Europe, is to achieve calm, safe local streets with improved environmental conditions. The primary concern that led to the use of traffic calming was for pedestrian and pedal cyclist safety on local streets. Since the risk of injury and death increases for vulnerable road users as vehicle speeds increase, keeping speeds low on streets shared by pedestrians and pedal cyclists is imperative for safety. [18] Problems that arise as a result of these physical traffic calming measures are: reduced emergency medical and fire vehicle response time, plowing difficulties in heavy snow due to raised curbs or humps, and even liability issues among the residents. [18]

Passive Speed Control Measures:

Perceptual techniques, such as road narrowing through pavement markings and optical speed bars, attempt to influence speed behavior by changing the sensory information available to drivers. These perceptual countermeasures, or *passive speed control* measures, serve to alter drivers' perceptions of the correct speed for a particular road, so that drivers' assumption of a lower speed is more appropriate. While regulatory measures require enforcement, traffic calming and passive speed control measures are intended to be self-enforcing. In addition, most passive speed measures are low-cost treatments and less intrusive than traditional speeding countermeasures. [23]

Both longitudinal and transverse pavement markings can be used to perceptually modify the spatial geometry of a roadway, encouraging drivers to slow down by altering their perception. Some research has evaluated the effectiveness of passive speed control measures showing promising results, especially for transverse pavement markings, such as optical speed bars and converging chevrons. [23]

3.1.2 Enforcement

Police engagement is important for the success of any speed management program. Even if speed regulations are accepted as legitimate by most motorists, enforcement is still essential to ensure conformity of the remaining drivers who will only comply with them if they believe they are likely to be punished.

Speed enforcement is designed to affect speeds via a deterrent effect on drivers. The effect of deterrence on the driver's speed choice depends on the perceived risk of being caught, and fear of a resulting punishment. One of the important limitations of traditional speed enforcement is their short term effect; drivers tend to slow down where high levels of enforcement are perceived –whether ticketed or not– and then speed up again. This is known as the "halo effect" and it can be temporal, if happening during a period of time, or spatial, if happening at a particular location. Extending the effect to keep higher compliance with speeds requires more enforcement resources, which makes it expensive. A multidisciplinary approach that includes not only enforcement efforts but rational engineering to design roads in consistency with user's expectations and public awareness regarding speeding has greater potential to succeed in managing speed. [21]

3.1.3 Education

Speed management requires involving the public for many obvious reasons. First, changes in attitudes and behaviors of road users are essential to accomplish the objectives of the speed management strategy. Secondly, if the speed program is well understood and supported by road users, it would be more likely to succeed. And finally, local people can provide a valuable view of the problem providing positive ideas for transportation planners and traffic engineers. The ways to involve the public in speed management practices range from sharing information on decisions already made by the road authority to public participation in the decision making process.

Three possible levels of public involvement are: [20]

Information – A one-way process delivering relevant measures/schemes via local newspapers, TV, radio, etc.

Consultation – A one-way process with feedback seeking public viewpoints throughout the speed management process.

Participation – A two-way dialogue between professionals and the public.

Educating the public is paramount in speed management, especially in gaining compliance with speed. When road users understand, for example, why speed limits are needed, they are more likely to accept and comply with them. Traffic safety programs that include highly visible Public Information and Education (PI&E) campaigns, that accompany law enforcement efforts, have proven to both increase positive public impressions toward police activities and result in safer driving habits. [21]

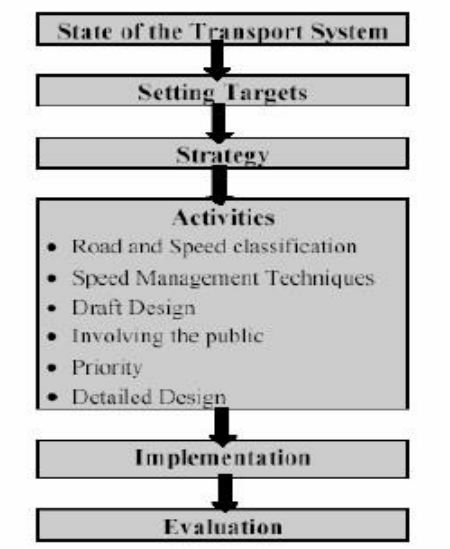


Figure 3 – The speed management process
Source [20]

4.2 VMSs and traffic flow harmonization

Variable Message Signs (VMSs) are traffic control devices used to provide motorists en-route traveler information. The information is most often displayed in real-time and can be controlled either from a remote centralized location or locally at the site. [25]

Variable message signs are the key to traffic flow harmonization, but it would also imply that all speed management processes have already been implemented in the process. If a VMS is put in function as a speed limit regulation sign, then whenever an unnatural event, such as rain, fog, snow etc., would occur, road maintenance personnel could adjust the speed limit accordingly. It would not only increase road safety, but decrease road maintenance cost in general, meaning that there would be no need to physically replace the sign, hence diminishing the expense of the sign and the replacement crew personnel.

A study [26] made by Autoceste Rijeka – Zagreb d.d. in 2015 was aimed to analyze the characteristics of the traffic flow, mainly its speed, in the Tuhobić tunnel on the A6 highway and to detect the number of drivers who abide by the regulated speed limit inside the tunnel and the possibilities of traffic flow management via variable message signs (VMS). The study has been conducted with a stationary radar device, placed inside the tunnel tube, which would measure speed and photograph vehicle`s license plates and the speed limit was 100 kph.

Out of the 55,442 vehicles recorded via the measuring device, 28,503 (51.4 %) were driving inside the allowed speed limit and 26,939 (48.6 %) were driving above the speed limit. 22,696 (35.9 %) drivers were operating their vehicles in the improper speed area, while 4,243 (7.7 %) were operating their vehicles in the penal speed area. [Figure 4] This is an alarming result from the perspective of road safety, especially since driving in tunnels is the most complex and mind-straining task for drivers.

Entering a tunnel, the human eye has to make a period of adjustment to the change of light, from sunlight to the tunnel lights, not to mention if you are driving by night, when vision is impaired due to lack of light, thus forming the possibility of being blinded by the tunnel lights. There is also a factor of being “trapped” in a manner of saying, where some people may develop a sort of claustrophobic tendencies which reduce their sane thinking, making them a risk to other drivers.

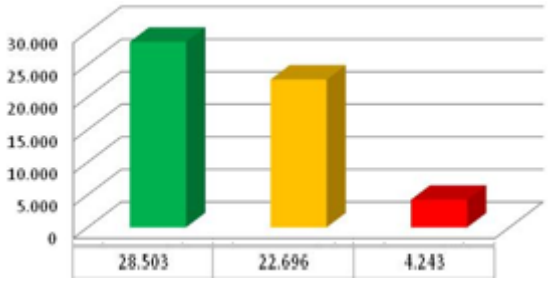


Figure 4 – The distribution of speed by proper, improper and penal order [26]

The second subject of the study listed [26] was the possibility of traffic flow management via variable message signs (VMS). The idea was to study drivers' behavior on different speed limit values set on VMSs during those conditions that require a reduction in speed (strong winds on one side of the tunnel and snowing on the other).

During the 80 kph speed limit, out of the total of 485 vehicles, only 21% of the drivers were abiding the speed limit. The average speed was 95 kph, with the highest recorded speed of 163 kph.

When the speed limit was 60 kph, 1,760 vehicles were recorded and the average speed was 95 kph, same as it was during 80 kph speed limit. The highest recorded speed was 163 kph (2.7 times the speed limit!), with only eight drivers abiding the speed limit, which in percentages would be less than 0.5 %.

With the speed limit set to 40 kph, only one driver obeyed the speed limit, and it was a road patrol vehicle. The average speed was about 90 kph and the highest recorded speed of 167 kph (4.5 times the speed limit!).

Theoretically, variable message signs are an excellent way to harmonize traffic flow, but in real life, its effect depends on drivers' will to obey speed limits displayed on VMS. The reason would be the lack of public awareness about the importance of driving by traffic regulations, or in this case, speed limits mandated by VMS. If the speed limit on a certain road section is changed, it means that the conditions on that section have changed, and vehicle speed must be corrected accordingly, but, unfortunately, most drivers continue driving with the same speed, disregarding new speed limits. Therefore, measures like public awareness, additional text messages combined with traffic signs and, in the end, introduction of speed enforcement should be considered. Likewise, taking in consideration the fact that a great percentage of drivers are not obeying VMS speed limits, this should be alarm to traffic engineers managing the roads to revise speed limit scenarios. Speed limits on VMS are activated by weather conditions, traffic flow density, and other events that influence traffic flow drivers frequently are not fully informed on why they should drive slower. Therefore, when possible, DMS (display message signs) should be used instead of using VMS because DMS can provide additional text information to drivers alongside speed limit, and therefore additionally motivate drivers to obey speed limits.

5. CONCLUSION

Safety, mobility and environment impact are becoming the greatest challenges of today's traffic. With all the facts stated about the dangers of speeding and impact of speed on the environment, the biggest problem left is to reduce speed without affecting mobility. There are certain "tools" road operators can use in terms of speed management, especially VMSs, to actively, and according to real traffic flow characteristic or to data collected on air pollution and noise level, reduce speed limits or reroute traffic. Effect of such traffic flow management, as described, greatly depends on driver's will to obey speed limit, especially when speed limits are reduced significantly. Therefore, education, but

also enforcement, should be considered as part of traffic safety and environment policies. On a national level, a fund should be formed with the sole purpose of collecting means produced from speeding and speed related tickets. The idea is quite simple, whenever a police officer would fine a driver for speed related offenses in traffic, that driver would be paying the fine directly in the said fund, and not in the state's budget. This way, the funds means could be used solely for improving road safety and financing environmental improvement projects.

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FULYA AYBEK CETEK, Ph.D.[1]
Corresponding author
E-mail: faybek@eskisehir.edu.tr
BRUNO ANTULOV-FANTULIN, mag.ing.aeronaut.[2]
E-mail:bantulov@fpz.hr
PAUL FROST, Dipl.Ing.[3]
E-mail: p.frost@tu-braunschweig.de
KADIR DONMEZ, M.Sc[1]
E-mail: kadirdonmez@anadolu.edu.tr
ZEKERIYA KAPLAN, B.Sc in EE[1]
E-mail: zekeriyakaplan@eskisehir.edu.tr
TEA ROGOŠIĆ, univ.bacc.ing.aeronaut.[2]
E-mail: tea.rogosic@student.fpz.hr
[1] Faculty of Aeronautics and Astronuatics
Eskisehir Technical University
Iki Eylul Kampusu, 26555 Tepebasi, Eskisehir, Turkey
[2] University of Zagreb
Faculty of Transport and Traffic Science
Vukelićeva 4, 10000 Zagreb, Croatia
[3] Institute of Flight Guidance,
Technische Universität Braunschweig
Hermann-Blenk-Str. 27, 38108 Braunschweig, Germany

PROJECT ATCOSIMA: PRELIMINARY RESULTS AND ANALYSIS OF REAL-TIME ATC AND FLIGHT COCKPIT SIMULATIONS

ABSTRACT

This paper presents the preliminary results and analysis of real-time ATC radar and integrated ATC-flight cockpit simulations as a baseline study to develop the new assessment criteria for ATCo radar simulation training. A new airspace model and set of generic exercises were developed to test ATCo trainees' performance as well as to acquire flight efficiency and task load date through these simulations. Statistical correlation analysis was done to determine relationships between the selected performance metrics. Preliminary results show strong relations between ATCo instructions and flight efficiency parameters.

KEY WORDS

Air Traffic Control; Radar Control Simulation Training; Human-in-the Loop Simulations; Fight Cockpit Simulations; Assessment Criteria.

1. INTRODUCTION

European Union's Single European Sky (SES) initiative aims to create an integrated Pan-European Air Traffic Management (ATM) according to air traffic flows rather than national boundaries in order to handle the ever-increasing air traffic safely, efficiently and economically [1]. This integration, however, requires not only adaptation of a common legislative framework and technological infrastructure but also standardized and enhanced air traffic controller (ATCo) training to reach its operational and economic targets for the sustainable growth of air transportation industry. Although EU and EUROCONTROL documents state a set of general performance objectives for the training [2,3], they have two important shortcomings: neither they define any standard metrics and scoring for the assessment process nor they include SESAR's targets regarding efficiency and economics of traffic flow. ATCOSIMA (Development of Common ATC Simulation Training Assessment Criteria Based on Future Pan European Single-Sky Targets) project aims to address this issue and proposes an innovative

approach to measure the performance of ATCo trainees in radar approach simulations based on integrated ATC radar and flight deck simulations. This paper presents the preliminary results and analysis of real-time ATC radar and integrated ATC-flight cockpit simulations as a baseline study to develop the new assessment criteria for ATCo radar simulation training.

2. RESEARCH METHODOLOGY

Simulation experiments have been done for the project's first and second stages which involve with the baseline analysis to evaluate performance of ATC trainees using current assessment criteria. First stage consists of ATC radar simulations done at the Faculty of Aeronautics and Astronautics at Eskisehir Technical University (ESTU) and at the Faculty of Transport and Traffic Science at University of Zagreb (ZFOT). Total 19 ATCo trainees (14 from ZFOT and 5 from ESTU) participated simulations under the supervision of 4 ATC instructors (3 from ZFOT and 1 from ESTU). The trainees were selected among the enrolled students of ESTU or ZFOT and they were required to pass radar approach control course before. Each student participated in 10 exercise runs with increasing level of difficulty per exercise based on the traffic complexity. The experiments were not interrupted or no guidance was provided by the ATC instructors except individual or group briefings and debriefings prior to or after the simulations. In the second stage, 5 trainees were selected by each institution for the integrated ATC radar and flight cockpit simulations at TUBS. For the TUBS experiments it was agreed between ESTU and ZFOT that the exercise number nine should be used for each trainee using the TUBS simulation setup.

2.1 Airspace and Simulation Exercise

A new airspace model was developed to be used in the generic exercises during the ATC radar and integrated ATC and flight cockpit simulations. It is based on Frankfurt TMA which is different from the existing airspaces used in ATC simulation courses at ESTU and ZFOT yet it was easy to adapt for trainees. Its large size and convex boundaries provides relatively longer time window for planning and execution of the tasks during the exercises. Therefore, the difficulty of the exercises can be set according to the traffic density and mixture rather than the airspace structure. The test exercise was selected among the previously prepared 10 exercises for radar approach control simulation and assessment. The selected exercise includes 9 arriving and 3 departing aircraft within the TMA as presented in Figure 1.

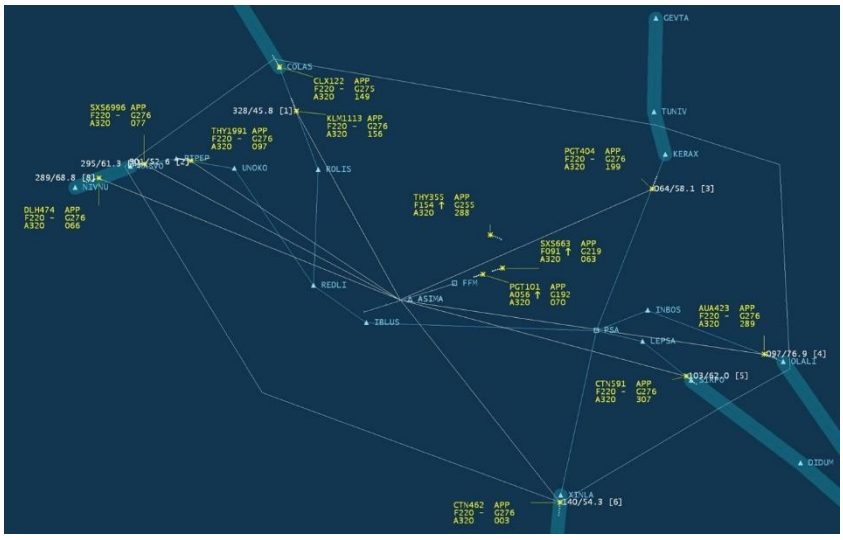


Figure 1 – Example of the exercise number 9

Callsigns, simulation start times, initial positions and flight level of the arriving and departing aircraft are presented in Table 1. All these arriving aircraft have similar estimated flyover times at REDLI fix

near ILS course. There are also four arriving aircraft to be sequenced with respect to PSA fix. This exercise requires advance decision-making skills regarding effective and timely use of vectoring, airspeed adjustments and flight level change. A single aircraft type (i.e. Airbus A320) has been simulated in all exercises. Aircraft performance data used in simulation are based on EUROCONTROL Base of Aircraft Data (BADA 3.14) [4].

Table 1 – Flight Information List for the Simulation Exercise to be run

	Number of Aircraft		Exercise Characteristics	
Exercise Number	**Arrival**	**Departure**	**Duration (min: sec)**	**Difficulty Level**
9	9	3	31:00	9
Aircraft Callsign	**Start Time**	**Arrival/Departure**	**Flight Level**	**Start Position**
PGT101	06:00	D	0	FFM
SXS663	05:00	D	0	FFM
THY355	03:00	D	0	FFM
CTN591	06:00	A	220	SIRPO-10DME
AUA423	05:30	A	220	OLALI-10DME
PGT404	05:00	A	220	TUNIV
CTN462	06:30	A	220	XINLA-10DME
CLX122	04:30	A	220	COLAS-20DME
KLM1113	04:30	A	220	COLAS-10DME
DLH474	04:00	A	220	RASVO-30DME
SXS6996	04:00	A	220	RASVO-20DME
THY1991	04:00	A	220	RASVO-10DME

2.2 ATC Radar Simulations

ATC radar simulation experiments have been conducted in two parallel groups at Area and Approach Radar Control Simulation facilities of ESTU and ZFOT between the period of February-April 2018. Both partners use MicroNav BEST ATC Radar Simulators which provide enhanced ATCo training environment as well as extensive real-time simulation capabilities for ATC research. The simulators allow generation of any real or synthetic airspace, exercise scenarios for area and approach control services and flight data using a detailed aircraft performance database. The systems consist of ATCo and pseudo-pilot controller workstations. While trainees at ATCo workstations perform tasks related to air traffic services within the airspace of their jurisdiction, pseudo-pilots simulate movement aircraft defined in the exercise. Trainees and pseudo-pilots communicate via radiotelephony communication. Trainees used printed flight strips to note all clearances and instructions given to aircraft during the simulations. Simulation exercises have been conducted under the supervision of air traffic controller instructors (Figure 2).



Figure 2 – ATC Radar Simulations at ESTU (on the left) and ZFOT (on the right)

The following data sets have been collected during the exercises: exercise replay files and exercises logs from the BEST system manager (sysman), video screen capture files from ATCo workstation, radio-telephony communication and Human-Machine Interaction via Mousotron. Replay files were used by instructors to assess the trainees' performance based on ATCO assessment validation criteria during the exercises. Flight trajectory metrics (i.e. arrival sequence, distance flown by each aircraft, exercise duration and aircraft spacing on the ILS course) were also obtained through visual analyses of replay files. Simulation logs were analyzed to determine the number of instructions (i.e. flight level, heading and speed) given by trainees in each exercise. Video screen capture files were also analyzed to find out the number of tasks (i.e. distance measurement between aircraft, distance measurement between aircraft and the ILS course, heading measurement and relocating aircraft labels) performed by trainees.

2.3 Integrated ATC Radar-Flight Cockpit Simulations

Integrated Air Traffic Control (ATC) and flight cockpit simulations were conducted at the Institute of Flight Guidance of the Technische Universität Braunschweig (TUBS) in June 19-22, 2018 with the participation of teams from Eskisehir Technical University (ESTU), University of Zagreb (ZFOT) and Technische Universität Braunschweig (TUBS). The test bed used in simulations consists of the flight deck and ATC radar control simulators.

The flight cockpit simulator (Figure 3) is a fixed based simulator containing a full-replica mock-up of an Airbus A320 cockpit. The cockpit layout of the simulator is based on the appearance and structure of the real airframe systems to provide realistic representation of different simulation scenarios. Furthermore, it is possible to integrate several computer-aided work stations for air traffic controllers in the simulation structure. The computational units of the simulator consist of commercial off-the-shelf computers which are not certified by authority. The software modules are primarily based on commercially licensed programs and additional applications which are self-developed by research engineers of the Institute of Flight Guidance. The specific architecture permits modification of individual components and is therefore particularly suitable for the execution of scientific studies.

Air Traffic Control Radar Simulator provides a generic aircraft simulation environment for air traffic controller trainees with its two fully functional air traffic controller workstations. Air traffic controller workstations have three monitors offering a touch screen surface and the lower screen is capable to recognize pen input methods as well (Figure 4). A push to talk headset can be used for the radio communication. As an air traffic controller position the screens can depict radar screens and in future development steps even flight strips and aircraft information. The ATCO-User can interact with this system via touch, pen or mouse inputs. These input methods enable map navigation, label reordering and the generation of simulated Controller-Pilot Data Link Communications (CPDLC) messages.



Figure 3 – Flight cockpit simulator of the Institute of Flight Guidance at TUBS
(Picture © TU Braunschweig/Kocks)



Figure 4 – Air Traffic Controller Workstations at TUBS

Schematic overview of the simulation setup for the integrated flight cockpit and air traffic control simulators is presented in Figure 5. In order to provide a familiar graphic user interface (GUI) to air traffic controller trainees, a set of modifications had been done in the system modules such as distance and bearing measurement tool, aircraft prediction line and adoption of color themes compatible with BEST Radar Simulator GUI. This should provide a similar look and feel of the user interface. The existing terminal airspace (TMA) and waypoints had to be replaced by a generic airspace based on the director sector S in Frankfurt (EDDF). The traffic simulation 5 uses the EASA BADA [4] model to calculate the performance and flight dynamics parameters. The software includes a plugin interface to extend their functionalities. To integrate the traffic simulation into the simulation framework containing the flight deck simulator two additional plug-ins (i.e. Plug-In A and Plug-In B) had to be developed. One plugin connects the traffic simulation with the air traffic controller radar screen and the other plugin enables controlling the traffic via the pseudo pilot station.

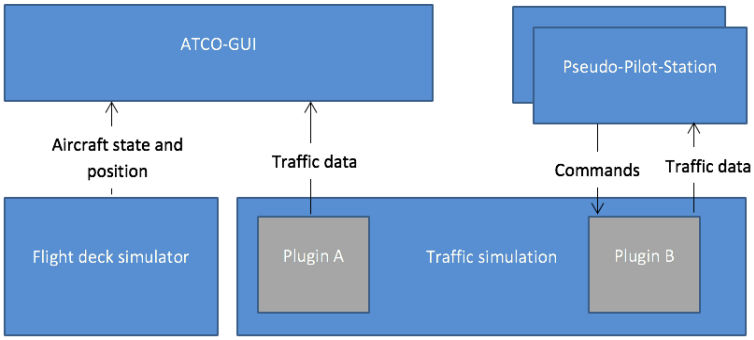


Figure 5 – Schematic overview of the simulation modules

The following data sets have been collected during the exercises: flight cockpit simulator flight data recorder (FDR) data, cockpit video recordings for pilot actions, ATC simulator log files, video screen capture files from ATCo workstation, Radio-Telephony communications, Human-Machine-Interactions via Mousotron and NASA task load index questionnaire data [5] administrated to the flight cockpit simulator pilot and ATCo trainees. In this study, relationships between NASA TLX questionnaire results and selected flight cockpit FDR data (i.e. flight time, distance flown and fuel consumption) were analyzed only.

3. RESULTS AND ANALYSIS

3.1 ATC Radar Simulation Results

The collected simulation data were analyzed in two steps. In the first step, flight and traffic performance metrics (i.e. spacing between aircraft, flight time and distance flown), ATCo instructions (i.e. flight level, heading and airspeed) and assessment scores were analyzed for all 19 trainees. The descriptive statistics of the first data set are presented in Table 2. Average aircraft spacing on the ILS course indicates the distance between two successive arriving aircraft when both of them intercept the ILS course. Although 5 NM separation minima is required between aircraft pairs, the mean spacing provided by trainees is about 8 NM per pair. This result indicates vectoring instructions ensures safety constraint yet they are not efficient in terms of spacing arrival sequence along the ILS course. Exercise duration corresponds to handoff time of the last arriving aircraft to EDDF tower over ASIMA fix. Mean of exercises duration is over 37 minutes which corresponds to more than 4 minutes of flight time for each arrival. The difference between the minimum and maximum exercise durations is six minutes which indicates large variations between trainees in handling arrival sequence. Total distance flown indicates the sum of the distances of arrival aircraft from their TMA entry point to handoff point at ASIMA fix. This value directly affects airborne total delays and fuel consumption; therefore, it is an important indicator of efficiency. Number of total flight level, heading and speed instructions given by trainees during the exercises provides an important indicator to understand their approach to handling the traffic. These values also indicate large variations among the trainees.

Table 2 – Descriptive statistics of flight efficiency, instructions and assessment scores of all trainees

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Average aircraft spacing on the ILS course	19	7.1	9.2	8.01	0.57
Exercise duration	19	33.5	39.5	37.27	1.78
Total distance flown	19	78.3	96.5	84.59	5.34
Total flight level instructions	19	26	52	36.00	6.77
Total heading instructions	19	24	52	32.21	6.79
Total speed instructions	19	5	35	25.47	9.99
Assessment score	19	65	100	91.68	9.11

The next step focuses on the ATC radar simulations results for 10 trainees who also participated in the integrated ATC and flight cockpit simulations at TUBS. Their video screen capture files were analyzed through visual analysis in order to determine what kind of ATC tasks they performed during the same exercise. The descriptive statistics show that individual variations are relatively less in efficiency metrics, ATCo instructions and assessment scores. Besides these indicators, number of ATC tasks (i.e. heading and distance measurements and relocating aircraft labels) performed by trainees are also presented in Table 3. The results indicate that tasks performed by trainees are remarkably different during the exercise.

Table 3 – Descriptive statistics of flight efficiency, instructions, scores and task count of the selected trainees

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Average aircraft spacing on the ILS course	10	7.06	8.33	7.78	.38
Average exercise duration	10	33.53	38.37	36.10	1.49
Average of total distance flown	10	78.30	96.53	86.65	6.48
Total flight level instructions	10	32	52	40.40	5.91
Total heading instructions	10	24	52	34	9.10
Total speed instructions	10	5	35	20.30	11.36
Distance measurement between aircraft	10	5	38	14.60	9.05
Distance measurement between aircraft and ILS course	10	0	22	11.60	6.38
Heading measurement	10	4	52	22.30	18.76
Relocating aircraft labels	10	33	99	60.60	24.68
Assessment score	10	70,00	100,00	92.00	8.35

Before performing correlation analysis, Kolmogorov-Smirnov and Shapiro-Wilk normality tests [6] were implemented to the first and second data sets of which descriptive statistics presented in Table 2 and 3, respectively. The Shapiro-Wilk Test is more appropriate for small sample sizes (< 50 samples). If significance value of these tests is greater than 0.05, the data can be accepted as normally distributed. Table 4 and 5 present the results of two tests for the data sets.

Table 4 – Normality test for ATC simulation data of all trainees (the first data set)

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Aircraft spacing on the ILS course (NM)	.097	19	.200*	.975	19	.877
Exercise duration (min)	.151	19	.200*	.937	19	.229
Total distance flown (NM)	.210	19	.027	.897	19	.043
Total flight level instructions	.125	19	.200*	.934	19	.206
Total heading instructions	.302	19	.000	.720	19	.000
Total speed instructions	.231	19	.009	.808	19	.002
Assessment score	.303	19	.000	.692	19	.000
*. This is a lower bound of the true significance.	a. Lilliefors Significance Correction					

Table 5 – Normality test for ATC simulation data of the selected trainees (the second data set)

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Average aircraft spacing on the ILS course (NM)	.200	10	.200*	.930	10	.449
Exercise duration(min)	.166	10	.200*	.959	10	.773
Total distance flown (NM)	.151	10	.200*	.928	10	.429
Total flight level instructions	.260	10	.055	.881	10	.133
Total heading instructions	.244	10	.094	.847	10	.053
Total speed instructions	.218	10	.197	.891	10	.173
Distance measurement between aircraft	.326	10	.003	.741	10	.003
Distance measurement between aircraft and ILS course	.101	10	.200*	.988	10	.994
Heading measurement	.261	10	.052	.852	10	.062
Relocating aircraft labels	.236	10	.120	.871	10	.102
Assessment score	.300	10	.011	.732	10	.002
*. This is a lower bound of the true significance. a. Lilliefors Significance Correction						

Correlation analyses were performed for all possible variable pairs presented in Table 4 and 5. Pearson correlation coefficient or Spearman's rank correlation coefficients is used to measure and interpret the strength of the relationship between two variables. In order to do Pearson or Spearman correlation analysis, the data should be in the form of ordinal or scale [6]. In case the data of both variables are normally distributed, Pearson correlation coefficient is used to interpret the results. When the data of one variable is not normally distributed Spearman's coefficient (rho) is used instead. The coefficient values between 0 and 0.3 indicate a weak relationship, values between 0.3 and 0.7 indicate a moderate relationship and finally values between 0.7 and indicate a strong relationship between selected variables [7]. Besides negative signs of values indicate descending relation whereas positive values indicate ascending relations. Table 6 presents the results of correlation analysis for ATC simulation data of all trainees. The comparisons with significant results were provided in the table.

Table 6 – Results of the correlation analysis for ATC simulation data of all trainees

Variable Pairs	Sig.	Pearson /Spearman Correlation Coefficient (r)
Average aircraft spacing on the ILS course (NM)* Exercise duration (min)	.004	.630**
Exercise duration (min) * Total flight level instructions	.002	-.670**
Exercise duration (min) * Total speed instructions	.021	.524*
Total distance flown (NM) * Assessment score	.032	-.494*
Total distance flown (NM) * Total speed instructions	.000	-.759**
Total flight level instructions * Total speed instructions	.001	-.711
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). All other comparisons were non-significant.		

According to the results in Table 6, positive moderate relationships are observed between average aircraft spacing on the ILS course and exercise duration (r=.630, p=.004) as well as total speed instructions and exercise duration (r=.524, p=.021). These results indicate that excess spacing between aircraft on the ILS course and increased use of speed instructions may tend to reduce number of aircraft served per unit time (i.e. throughput). Besides there is also strong negative relationship between total speed instructions and total distance flown (r=-.759, p=0.000). Considering the correlation coefficient's explained variance (r2) it can be said that 57% of total variance in total distance flow is due to total speed instructions. Similarly, a strong negative relationship is also

observed between total speed and flight level instructions. Moderate negative relationship is observed between exercise duration and flight level instructions (r=-.670, p=.002). Therefore, timely use of flight level changes by trainees may tend to increase the flow rate of arriving traffic during the exercises. It is also observed that there is a moderate negative relationship between assessment scores and total distance flown. Similar results can be observed for the results of correlation analysis of ATC simulation data for the selected trainees in Table 7. Because of the reduced sample size, correlation coefficients became higher. The results also show the strong positive relationship between total flight level instructions and heading instructions/heading measurement actions (i.e. r=.820 and r=.852, respectively). Besides heading measurement actions can also help to reduce exercise duration and therefore increase the throughput.

Table 7 – Results of the correlation analysis for ATC simulation data of the selected trainees

Variable Pairs	**Sig.**	**Pearson correlation (r) /Spearman's rho**
Average exercise duration * Total speed instructions	.038	.660*
Average exercise duration * Heading measurement	.007	-.790**
Average of total distance flown * Total flight level instructions	.029	.685*
Total flight level instructions * Total speed instructions	.002	-.853**
Average of total distance flown * Heading measurement	.001	.852**
Total flight level instructions * Total heading instructions	.004	820**
Total flight level instructions * Total speed instructions	.036	-.665*
Total flight level instructions * Heading measurement	.004	.811**
Total heading instructions * Heading measurement	.003	.826**
Total speed instructions * Heading measurement	.001	-868**
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). All other comparisons were non-significant.		

3.2 Integrated ATC Radar and Flight Cockpit Simulation Results

The perceived mental, physical, and temporal demand and performance, frustration and effort of the A320 cockpit flight simulator pilot and air traffic controller trainees (12 persons) were measured using NASA task load index (TLX) [5] for the selected radar approach control exercise. The data obtained were analyzed by using independent samples t test to determine whether there was a significant difference between the workload perceptions of the pilot and the controllers. In addition, the correlation coefficients between the workload perceptions of the pilots and the controllers and the flight time, distance flown and fuel consumption of the A320 flight cockpit simulator were also examined. Descriptive results of these data are presented in Table 8.

Table 8 – Descriptive statistics of NASA-TLX scores and flight data of the A320 cockpit simulator

Category	**Variable**	**N**	**Mean**	**Std. Deviation**
ATC Trainee's Task Load Scores	Mental Demand	12	60.41	3.75
	Physical Demand	12	31.25	19.20
	Temporal Demand	12	57.91	23.40
	Performance	12	39.17	19.98
	Effort	12	68.33	15.27
	Frustration	12	43.75	21.76
	Overall	12	57.05	11.75
Pilot's Task Load Scores	Mental Demand	12	57.50	7.83
	Physical Demand	12	32.08	5.42
	Temporal Demand	12	25.00	5.22
	Performance	12	25.00	8.85

	Effort	12	66.25	8.83
	Frustration	12	22.50	11.38
	Overall	12	46.28	6.57
Flight Cockpit FDR Data	Flight Duration (min)	10	30.50	3.75
	Distance Flown (NM)	10	138.61	8.20
	Fuel Consumption (kg)	10	784.13	75.80

All variables were found normally distributed as a result of Kolmogorov-Smirnov and Shapiro-Wilk test. Given the normality assumption, the results of the t-test for the workload perceptions of the pilot and the controllers are presented in Table 9 for significance level α=0,05.

Table 9 – T-test results of the task load scores of ATC trainees and the pilot

Variable	Task	N	Mean	Std. Deviation	df	t	p
Mental Demand	Pilot	12	57.50	7.83	22	-.687	.501
	ATCo Trainee	12	60.41	3.75			
Physical Demand	Pilot	12	32.08	5.42	22	.145	887
	ATCo Trainee	12	31.25	19.20			
Temporal Demand	Pilot	12	25.00	5.22	22	-4.756	.000
	ATCo Trainee	12	57.91	23.40			
Performance	Pilot	12	25.00	8.85	22	-2.259	.039
	ATCo Trainee	12	39.17	19.98			
Effort	Pilot	12	66.25	8.83	22	-.409	.686
	ATCo Trainee	12	68.33	15.27			
Frustration	Pilot	12	22.50	11.38	22	-2.998	.007
	ATCo Trainee	12	43.75	21.76			
Overall	Pilot	12	46.28	6.57	22	-2.772	.011
	ATCo Trainee	12	57.05	11.75			

Significant differences can be observed between the pilot and air traffic controller trainees for three factors: temporal demand, performance and frustration. For these factors, mean values of the controllers are significantly higher than that of the pilot. When the overall scores are examined, it can be said that there are significant differences between the overall task load perceptions of the pilot and controllers (t=-2.772, p=0.011). When the mean values for this variable are examined the average of overall task load of the controllers (57.05) is significantly higher than that of the pilot (46.28). Based on these results, the effect size measure for the independent samples of t-test can be estimated using Cohen's D which is defined as:

$$D=(Mean_1-Mean_2)/S_W \quad (1)$$

Where Mean1 and Mean2 are the mean values of the samples and *Sw* is the estimated standard deviation. Cohen's D is the number of standard deviations between the two sample means. The following rules of thumb have been proposed to find the magnitude of the effect such that D = 0.20 indicates a small effect; D = 0.50 indicates a medium effect and D = 0.80 indicates a large effect [8,9]. The Cohen D for the temporal demand, performance, frustration and overall scores are calculated as 1.94, 0.92, 1.22 and 1.13, respectively.

Correlation analysis was performed for the A320 cockpit flight simulator pilot and air traffic controller trainees separately. In the first step, the correlation analysis was done for the NASA-TLX scores of the pilot and the flight duration, distance flown and fuel consumption data of the aircraft controlled by the pilot (Table 10). When the flight data and task load factors of the pilot are analyzed, the highest positive correlations are observed between fuel consumption and physical demand (r=0.831), and flight distance and physical demand (r=0.720). When the task load factors of pilot are analyzed in pairs, the highest positive correlations are observed between mental demand and overall score (r=0.901), mental demand and performance (r=0.851), and performance and overall score (r=0.812).

Table 10 – Correlation analysis results for the pilot

Variable Pairs	Sig.	Pearson correlation (r)
Flight duration (min)* fuel consumption (kg)	.021	.713*
Flight duration (min)* overall	.014	.742*
Flight distance* fuel consumption (kg)	.026	.695*
Flight distance*Physical demand	.019	.720*
Fuel consumption* Physical demand	.003	.831**
Mental demand*Performance	.000	.851**
Mental demand*effort	.036	.608*
Mental demand*overall	.000	.901**
Performance*effort	.027	.634*
Performance*frustration	.036	.609*
Performance*overall	.001	.812**
Effort*frustration	.009	.713**
Effort*overall	.003	.780**
Frustration*overall	.036	.607*
***Correlation is significant at the 0.05 level (2-tailed).** ****Correlation is significant at the 0.01 level (2-tailed).** **All other comparisons were non-significant.**		

In the second step, the correlation analysis was done for the NASA-TLX scores of air traffic controller trainees and the flight duration, distance flown and fuel consumption data of the aircraft controlled by the pilot (Table 11). When the flight data and task load factors of air traffic controller trainees are analyzed, a large negative correlation can be observed between flight duration and physical demand. When the task load factors are analyzed in pairs, the highest positive correlations are observed between mental and temporal demand (r=0.857), temporal demand and overall score (r=0.860), and effort and overall score (r=0.775).

Table 11 – Correlation analysis results for ATC trainees

Pairs	Sig.	Pearson correlation (r)
Flight duration (min)* fuel consumption (kg)	.021	.713*
Flight duration (min)* physical demand	.008	-.776**
Flight distance* fuel consumption (kg)	.026	.695*
Mental demand*temporal demand	.000	.857**
Mental demand*overall	.037	.605*
Temporal demand*effort	.008	.721**
Temporal demand*overall	.000	.860**
Performance*frustration	.015	.682*
Effort*overall	.003	.775**
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). All other comparisons were non-significant.		

4. CONCLUSION AND DISCUSSION

Preliminary results of ATC radar simulation show a significant difference among the trainees' approaches to handle arriving traffic in terms of the number of instructions. Observed moderate positive relationship between exercise duration and average aircraft spacing on the ILS course indicates that effective use of radar vectoring techniques can increase service throughput. Therefore, arrival separation management on the ILS course can be one of the possible developments in the new assessment criteria. Similarly, the number of speed instructions have a negative impact on exercise duration and therefore on the throughput because most of the speed adjustments were observed as speed reduction. Trainees can be encouraged to use alternative techniques depending on the traffic complexity but still more extensive analyses are required over the larger set of data to determine efficient combination of different instructions. Task load analysis also showed that there is strong relationship between flight duration and fuel consumption while moderate relationship between flight distance and fuel consumption. Therefore, ATCo instructions reducing flight duration should be studied

more thoroughly in order to increase flight efficiency. Task load analysis also indicated a strong negative relationship between flight duration and physical demand of ATC controller tasks. This can be interpreted as effective traffic management requires more heading and distance measurement actions to estimate efficient arrival sequencing and conflict resolution. For the future work similar analyses will be done for all ATC radar exercises and traffic complexity metrics such as number of aircraft, arrival-departure mix, conflict encounter geometries and time separation between departing aircraft will be considered.

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DARKO BABIĆ, Ph.D.[1]
E-mail: darko.babic@fpz.hr
MAJA MODRIĆ, mag. eng. traff.[1]
E-mail: maja.modric@fpz.hr
DARIO BABIĆ, Ph.D.[1]
E-mail: dario.babic@fpz.hr
MARIO FIOLIĆ, Ph.D.[1]
E-mail: mario.fiolic@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

EVALUATING THE INFLUENCE OF ROAD MARKINGS' RETROREFLECTIVITY ON ROAD SAFETY IN LOW VISIBILITY CONDITIONS

ABSTRACT

During night-time, driver's field of vision, visual acuity and colour hue reduces which is why good road markings are needed. Although there are mixed opinions in scientific literature regarding the relationship between the road markings retroreflectivity and traffic accidents, it is generally considered that they have a positive impact on traffic safety. The aim of this article is to analyse how road markings retroreflectivity affects the frequency of traffic accidents in low visibility conditions, i.e. when it is most needed. For this purpose, 10,417.4 km single carriageway roads were analysed across the Republic of Croatia in the period between 2012 and 2016. The research included accidents that may be significantly affected by markings retroreflectivity: head-on collisions, running off the road, hitting a stationary object on the road and hitting a stationary roadside object. The results show that the retroreflectivity levels are negatively correlated to the total number of accidents and the number of fatalities and injuries, which ultimately means that the risk of traffic accidents and severe consequences reduces with the increase of road markings retroreflectivity. These results confirm that road markings play a significant role in increasing night-time traffic safety.

KEY WORDS

retroreflectivity; road markings; traffic accidents; traffic safety;

1. INTRODUCTION

While driving, drivers scan the environment in order to gather enough relevant information based on which they, in most cases, adjust their behaviour. As road markings indicate the vehicle's trajectory and provide information about road contours, limitations and obligations, for a safer and comfortable drive, it is essential that they are visible.

In daytime, the visibility of road markings usually does not pose a problem, given that there is a sufficient amount of light and contrast between the colour of the marking and road surface. During night-time, the illumination decreases significantly which means that there is a reduction in the driver's visual stimulus compared to the daytime, i.e. the driver's ability to visually detect and recognize objects is decreased [1]. Because of this, night driving, from the visual point of view, is most complex and demanding [2]. Although the share of night driving is considerably lower compared to daytime, more than half of the traffic accidents with fatal consequences occur during the night [3]. Despite the fact that less light during the night shortens and narrows the field of vision and reduces visual acuity, people

are usually capable of relatively safe night driving because ambient light, headlights, and lighted or reflective objects ensure visibility [1].

For this reason, it is necessary that road markings are visible, i.e. have satisfactory retroreflective properties. In general, retroreflectivity is a phenomenon where light, after hitting the retroreflective surface, reflects back to its source at the same entrance angle. Since most of materials in nature have mixed reflective properties (combination of diffuse and mirror reflection), road markings retroreflectivity must be ensured with special materials (glass beads). The light from the vehicle's headlights reflects off the glass beads and returns to the driver's eyes allowing him to see the markings.

In order to describe the retroreflective properties, the coefficient of retroreflectivity (R_L) is used. It is defined as a quotient of the luminance (L) of the field of the road markings in the direction of observation by the illuminance (E) at the field perpendicular to the direction of the incident light in $mcd*m^{-2}*lx^{-1}$ [4].

In time, road markings retroreflectivity decreases with the influence of various factors such as: type of material, marking position, marking age, average annual daily traffic, road type, number of road markings (lines), type of road surface, speed limits, the amount of salt and abrasive material, winter road maintenance activities as well as quantity and quality of glass beads [5].

Reduced retroreflectivity decreases markings visibility and thus the driver's ability to efficiently perceive and follow their trajectory. For this reason, several studies assessed the minimum levels of markings retroreflectivity needed by driver's during night-time. Based on subjective estimations of road markings retroreflectivity, the minimum values vary between 100 and 150 $mcd*m^{-2}*lx^{-1}$ [6], [7], [8], [9].

The defined minimum retroreflectivity values, apart from affecting the driver's perception and thus the traffic safety, also affect the cycle of renewal, i.e. marking maintenance activities. According to [10], a *'good road marking'* is a marking that always remains visible both to the driver and the intelligent vehicle, irrespective of light conditions (day and night), weather conditions (dry, wet and rainy) and age (young and old). Therefore the European Road Federation [10] propose a 150*150 formula which means: retroreflectivity of 150 $mcd*m^{-2}*lx^{-1}$ in dry conditions together with a 150 mm marking width for all roads. Also, the minimum retroflectivity value in wet and rainy conditions should be 35 $mcd*m^{-2}*lx^{-1}$.

For these reasons, the aim of this paper is to analyse how road markings retroreflectivity level influences the frequency and consequences of traffic accidents.

2. LITERATURE REVIEW

Given the complexity of traffic accidents and the number of factors that influence their occurrence, it is very difficult to determine the exact impact of road markings and their retroreflectivity on traffic safety. Generally, the prevailing opinion is that road markings have a positive impact on traffic safety.

The Royal Society for the Prevention of Accidents [11] analysed a number of low-cost engineering interventions carried out in the United Kingdom from which forty-three were road markings. Before and after comparison showed a 43 % reduction in the number of accidents. The authors in [12] performed a similar "before and after" analysis of the impact of adding edge road markings on traffic safety on a two-lane roads in Texas. Based to the results, authors concluded that roads without edge markings have an 11 % higher risk of traffic accidents than roads with edge lines. Also, the presence of edge markings showed positive effects on traffic safety in night-time and low visibility conditions.

Apart from the presence of road markings, the effect of the their retroreflectivity on the overall traffic safety was studied as well. With the new regulation that defines the minimum retroreflectivity at 70 $mcd*m^{-2}*lx^{-1}$ on the New Zealand roads, a study was carried out to compare the number of accidents before the introduction of the new regulation and after its implementation, thus gaining an

insight into how a higher level of markings retroflectivity affects traffic safety. The conclusion of the study is that there is no statistically significant correlation between the number of traffic accidents and markings retroreflectivity [13]. A similar study conducted in [14] also concluded that the difference in traffic safety during night-time conditions on roads with high and low markings retroflectivity is approximately equal to zero.

Mixed results were obtained in [15] where it was concluded that the markings with retroreflectivity higher than 200 $mcd*m^{-2}*lx^{-1}$have a small negative correlation with the number of traffic accidents. On other hand, markings with the low retroreflectivity did not show statistically significant correlation with the number of accidents.

The three afore-mentioned studies [13], [14] and [15], however, have certain limitations that ultimately affect their results. In the New Zealand study [13], authors also took into account roads with raised reflective pavement markers. In the second study [14], the markings retroreflectivity was modelled (not measured); while in the third study, markings retroreflectivity was measured on an area about 60 m long and the average measured value in that area was taken as a reference for a whole road section (about 8 km long). Since retroreflectivity may vary within a few meters, it is possible that the retroreflectivity values, used in the study, are not compliant with the actual state. Also, as a limitation to the third study [15], the author emphasizes the lack of complete data on traffic accidents.

The last-mentioned study was continued in 2010 and concluded that markings retroreflectivity is a significant factor which affects the frequency of traffic accidents when only the data collected from interstate roads was taken into account and when it was divided into three subsets according to line type: white edge line, yellow edge line and yellow central line. Finally, by analysing the white edge and yellow central markings, it was concluded that the likelihood of traffic accidents increases when the value of the markings retroreflectivity [16] decreases.

In 2013, authors studied the traffic accidents that occurred during the night on parts of roads with no intersections and during dry conditions. Traffic accidents taken into account were: night-time, single vehicle night-time, fatal plus injury night-time, and single vehicle night-time fatal plus injury. The results support the opinion of the positive impact of road markings retroreflectivity on traffic safety [17].

Study published in 2014, gave similar conclusions: areas with higher road markings retroreflectivity are associated with less traffic accidents than areas with lower retroreflectivity. Also, areas with lower retroreflectivity of central lines, compared to retroreflectivity of edge lines on the same roads, are related to a more frequent occurrence of traffic accidents [18].

The most recent research was published in 2016, in which the authors looked into the influence of road section length, marking type and their retroreflectivity value on the frequency of traffic accidents. The results show that the expected annual number of traffic accidents is significantly reduced by increase of the retroreflectivity of white and yellow edge lines. The results also suggest that maintaining road markings has significant positive effects on traffic safety [19].

Although previous research has mixed and mutually contradictory results, an opinion prevails that road markings retroreflectivity has a positive impact on traffic safety. Due to the complexity of traffic accidents and the number of factors contributing to their occurrence, the determination of the exact impact of markings retroreflectivity on traffic safety is a complex task and further research is needed.

3. METHODOLOGY

For the purpose of this research, the data on traffic accidents which occurred in dry low visibility conditions on a single-lane state roads in the Republic of Croatia in the period from 2012 to 2016 was used. Low visibility conditions in this research include night, dusk and dawn when marking retroreflectivity is most needed. The included traffic accidents are divided into groups according to

fatalities, injuries (severely and easily) and material damage. Several types of traffic accidents were included: head-on collisions, running off the road, hitting a stationary object on the road and hitting a stationary roadside object. These accidents are recognized in available literature [15], [17], [18] as accidents where markings retroreflectivity can have a significant effect. It is also important to emphasize that the included accidents occurred on the road sections without road lightning and intersections. Colour of both edge and central road markings on all roads is white and their width is 15 cm.

In addition to traffic accidents data, markings retroreflectivity value was assigned to each road for each year. On every road, all markings (central and edge) were measured and the arithmetic mean of measured values was taken as the reference retroreflectivity for specific road in a specific year. Markings retroreflectivity was measured using dynamic retroreflectometer (Zehntner ZDR 6020) mounted on a vehicle (left or right side) which enables continuous measurements during driving as described in [20]. Before each measurement, the device was calibrated according to the manufacturer's instructions (Zehntner, Switzerland), and the accuracy of the measurement and calibration was verified using a handheld retroreflectometer (Zehntner ZRM 6014). In order to gain insight into the impact of markings retroreflectivity on the frequency of traffic accidents, all markings were measured twice. The first time when markings were renewed, that is between the 30th and 60th day after the renewal, and the second time after winter - in spring when the markings were existing (old). Since roads, included in this study, had solventborne paint markings, their retroreflectivity was reduced after the winter. In this way authors tried to analyse the change in road safety when the markings had the best visibility (in the period when they were renewed) and when their visibility was lower (in the period when they were old).

A total of 10,417.4 km, i.e. 182 state roads along the Republic of Croatia were analysed in the period from 2012 to 2016. For both marking statuses (renewed and existing), the number and consequences of traffic accidents were obtained from the traffic accident database managed by the Ministry of Interior. Accidents which were associated with renewed markings occurred in the period between the date of the retroreflectivity measurement (first measurement) and the end of November of the same year. On the other hand, for existing markings, included accidents occurred in the period between December of the previous year (i.e. from the end of the period of the renewed markings, end of the November) and the date when the retroreflectivity of the existing markings was measured (second measurement).

4. RESULTS

The carried-out analysis showed that in low visibility conditions (night, dusk and dawn) on 10,417.4 km of state roads in Croatia between 2012 and 2016, 390 traffic accidents occurred in the period when the markings were renewed, of which 226 resulted in material damage while a total of 164 people were killed or injured. The average retroreflectivity of the renewed markings (R_L) on the analysed roads was 286.86 mcd*m^{-2}*lx^{-1}. On the roads with existing markings, 463 traffic accidents occurred in the same period in which 176 people were injured or killed and 289 accidents resulted in material damage. The average retroreflectivity value of the existing markings was 134.51 mcd*m^{-2}*lx^{-1}.

During their service life, road markings retroreflectivity gradually reduces, so the retroreflectivity of renewed markings fell from an average value of 286.86 mcd*m^{-2}*lx^{-1} to 134.51 mcd*m^{-2}*lx^{-1}or 53.10 %.

Comparing the number of killed and injured people as well as the material damage and the total number of accidents, one can conclude that overall safety was reduced during the period when markings were existing, i.e. had lower retroreflectivity (Fig. 1).

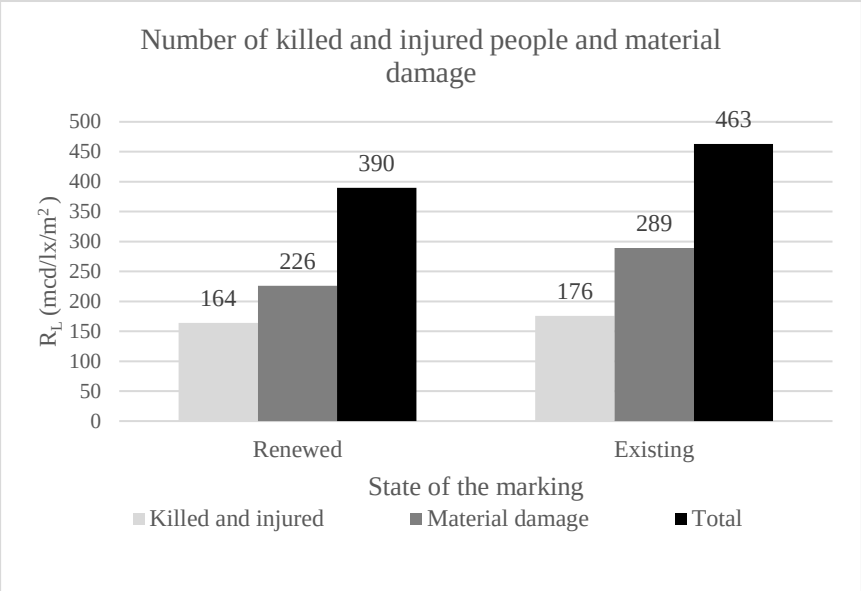


Figure 1 – Comparison of killed and injured persons, material damage and total number of traffic accidents between 2012 and 2016 during renewed and existing markings

In order to investigate the relationship between the road markings retroreflectivity and the frequency of traffic accidents in low visibility conditions, a correlation analysis was performed. Apart from the markings retroreflectivity, number of killed and injured people and total number of traffic accidents (killed + injured + material damage), the influence of annual average daily traffic (AADT), average speed limit and overall length of the road was also analysed. The correlation analysis was carried out separately for renewed and existing markings.

Table 1 shows the results of the correlation analysis for renewed road markings. If the total number of accidents and the number of people killed and injured is taken into account, one can conclude that these variables are positively correlated to the length of the road and the AADT, which is logical. Namely, with a longer road, higher AADT is expected (a positive statistically significant correlation is established as well) which ultimately creates more chances for traffic accidents and hence potentially more fatalities and injuries. On the other hand, the total number of accidents and the number of killed and injured is negatively correlated to the retroreflectivity level of renewed markings (Pearson = -0.397 and -0.338).

Table 1 – Correlation between renewed markings retroreflectivity and frequency of traffic accidents

		Road length	**AADT**	**Retroreflectivity**	**Killed+Injured**	**Average speed**	**Accidents - total**
Killed+Injured	Pearson Cor.	**0.690****	**0.482****	**-0.338****	1	0.030	**0.912****
	Sig. (2-tailed)	0.000	0.000	0.001		0.764	0.000
	Samples number	102	99	102	102	102	102
Accidents - Total	Pearson Cor.	**0.706****	**0.566****	**-0.397****	**0.912****	-0.036	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.722	
	Samples number	102	99	102	102	102	102

***. Correlation is significant at the 0.01 level (2-tailed).*
a. Marking Status = Renewed

For the period when the markings were existing the analysis showed similar results. The number of traffic accidents and the number of killed and injured are positively correlated with the length of the road and the AADT, while negatively correlated with the retroreflectivity level of existing markings (Pearson = -0.410 and - 0312) as shown in table II.

These results in fact imply that with the decrease of road markings retroreflectivity, the number of accidents and the seriousness of their consequences increases, i.e. overall traffic safety reduces.

Table 2 – Correlation between existing markings retroreflectivity and frequency of traffic accidents

		Road length	AADT	Retroreflectivity	Killed+Injured	Average speed	Accidents - total
Killed+Injured	Pearson Cor.	**0.431****	**0.341****	**-0.312****	1	-0.106	**0.834****
	Sig. (2-tailed)	0.000	0.002	0.005		0.349	0.000
	Samples number	80	80	80	80	80	80
Accidents - Total	Pearson Cor.	**0.524****	**0.412****	**-0.410****	**0.834****	-0.206	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.066	
	Samples number	80	80	80	80	80	80

***. Correlation is significant at the 0.01 level (2-tailed)*

a. Marking status = Existing

5. DISCUSSION AND CONCLUSION

Although in the last ten years, by implementing a broad spectrum of measures, the number of deaths on EU roads has reduced, still about 80 people die daily on European roads which ultimately costs over € 250 billion or about 2 % of the EU GDP [10].

Considering that road markings are located in the driver's central field of vision, they provide much needed spatial awareness by delineating the boundaries of the road and as such represent one of the most cost-effective safety solutions. However, in order to perform their function, markings must be visible, especially in low visibility conditions when the driver's field of vision is considerably shorter and narrower, and the acuity as well as vision distance are decreased.

Previous research on the impact of markings retroreflectivity on traffic accidents have mixed and mutually contradictory results, precisely because of the complexity of traffic accidents and a number of factors contributing to their occurrence.

The aim of this paper is to analyse how the retroreflectivity level affects the frequency and consequences of traffic accidents. A total of 10,417.4 km, or 182 state roads along the Republic of Croatia, were analysed in the period from 2012 to 2016. From traffic accident statistics, the number and consequences of accidents were obtained, for the period when markings were renewed, by looking at the accidents occurring between the date of retroreflectivity measurement and the end of November of the same year. For the period when markings were existing, included accidents occurred in the period from the December of the previous year (end period of renewed marking) to the date when the existing markings were measured. The research covered traffic accidents on which, according to previous research, the markings retroreflectivity may have a significant impact: head-on collisions, running off the road, hitting a stationary object on the road and hitting a stationary roadside object.

The correlation analysis, for both markings' statuses (renewed and existing), shows that the number of traffic accidents and the number of killed and injured are positively correlated with the road length and the AADT which was expected considering that longer roads will have higher AADT which ultimately creates more chances for traffic accidents and thus potentially more fatalities and injuries. In both cases, the retroreflectivity level was negatively correlated with the total number of accidents and number of killed and injured. This ultimately implies that the risk of traffic accidents and fatalities and/or injuries will be higher on the roads where road markings retroreflectivity is lower.

These results confirm that road markings play a significant role in increasing night-time traffic safety and, as such, may assist the road authorities in defining the minimum values of retroreflectivity that the markings must meet at all times as well as the appropriate technologies and materials for their implementation in accordance with geographic-climatic-traffic situation in which the road is located. Also, these results provide another confirmation that road markings are indeed an efficient tool to increase traffic safety, especially in low visibility conditions.

Considering that in the research, the retroreflectivity values were measured only twice (when the markings were renewed and existing), it should be noted that this is one of the limitations. In order to

obtain a more accurate and detailed insight into the influence of markings retroreflectivity on road safety, further investigations, which should combine retroreflectivity values (measured after the accident occurred) and other possible causes (road geometry, driver's characteristics, pavement conditions etc.) are recommended.

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TOMISLAV BADROV, B.Sc. [1]
(Corresponding author)
E-mail: tomobadrov@ymail.com
MLADEN NIKŠIĆ, Ph.D. [1]
E-mail: mladen.niksic@fpz.hr
DENIS ŠIPUŠ, Ph.D. student [1]
E-mail: denis.sipus@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

HYBRID-POWERED AND ALTERNATIVE-FUELED HAULING RAILWAY VEHICLES

ABSTRACT

A global problem of pollution and the restrictions of non-renewable resources have forced railway experts to change their attitudes and facilitate the development of hybrid-powered hauling vehicles and vehicles using alternative fuel. Although railway transport remains the environmentally-friendliest branch of transport, research has shown that nowadays it is focused on finding acceptable energy sources which would improve the environmental advantage of the method of transport even more. This paper analyses the performance of hybrid-powered hauling vehicles and the alternative-fuel hauling vehicle variants. After the analysis, the paper summarises the benefits and drawbacks of hauling vehicles in the railway and presents the main objectives in a further development of railway transport.

KEY WORDS

railway vehicles; hybrid fuel; alternative fuel; harmful gas emissions;

1. INTRODUCTION

Technological development has ensured a faster development of hybrid vehicles and the increase in the number of researches on alternative fuels and renewable energy sources in railway transport. Such development has led to a reduction in fuel consumption, the use of alternative fuels, a reduction in harmful gas emissions, and an increase in the preservation and protection of the environment. Hauling vehicles in railway transport now have a hybrid engine comprising two types of thrust, mostly combining electricity and diesel engines. The aim is to replace the traditional fossil fuels because they do not meet the requirements of environmental protection laid down by modern ecology. Fuels based on compressed natural gas, hydrogen, rapeseed methyl esters, bioethanol, and alcohol are being developed to reduce pollution. Unfortunately, these renewable energy resources are still largely inaccessible for them to be used efficiently and for a functional infrastructure to be built. The ecological protection in railway transport does not only encompass the issues related to trust and fuels, but also other relevant changes in railway hauling vehicles and the belonging infrastructure. The benefits of railway transport include space saving, environmental friendliness, greater safety, and relatively low external expenses. With the except of the environmentally acceptable trust and fuel, the railway's biggest problem is noise. The aim of the paper is to give a review of benefits and drawbacks of hauling vehicles in the railway and present the main objectives in a further development of railway transport according to environmental protection.

2. HYBRID-POWERED RAILWAY HAULING VEHICLES

The development of technology and more and more frequent technological innovations in combination with the use of standard fossil fuels have led to an increase in the intensity of pollution. The awareness of the issue has brought about research on the ecologically and economically-acceptable fuels that may become the new standard of the near future. Aims to develop hybrid vehicles was firstly started in the auto industry. However, with technological development, innovations have spread to the railway. The project of implementing hybrid hauling systems into railway is not an easy task and it requires long-term planning of conversion investments. Hybrid vehicles [1] use a mixed fuel system, and in most cases, it is a mixture of two types of fuels. The most common pair is the combination of electric and diesel fuel. The possibility of connecting diesel and electric motor is carried out in a series, parallel, or series-parallel manner. The most common is the series connection because it is the simplest of the three. The hauling wheels are powered solely by the electric motor, and the energy is obtained from the generator that is powered by a smaller diesel engine, which in turn collects energy from the source of the electric energy when the load is higher. In a parallel connection, the motor and the energy source power the vehicle together. In this case, the electric engine is charged during braking and deceleration, which convert the kinetic into electric energy, and the electric engine is used only in cases of lower efficiency of the diesel engine. A series-parallel connection is a combination of series and parallel which enables the system to change the fuel configuration depending on the train driving regime. General Electric [2] started manufacturing the Evolution series of hybrid locomotives in 2013 which use the principle of storing the energy into built-in batteries with the possibility of utilising all three possible connections. A conventional locomotive generates energy by hauling and the unused energy is dispersed freely, whereas a hybrid locomotive stores that excess energy into batteries.



Figure 1 – GE's hybrid locomotives
Source: [3]

On the Figure 1 is showed how the GE's hybrid locomotives works. In conventional locomotive, energy generated by the traction motors (A) during broking is dissipoted entirely as heat through resistor grids (B). In contrast, in a hybrid locomotive, some of that energy is captured in a series of rechargeable batteries (C). The captured energy can then be used to provide power in one of three ways:

- In combination with diesel – electric power provided by the engine (D) and the electrical system (E) to consistenly deliver the required horsepower,

- As on addition to full diesel – electric power for quick acceleration from a full stop,
- As the primary power source.

A classic diesel-powered locomotive is much simpler than the hybrid one. It fuels a diesel engine and uses hydraulic converters to transport the energy on the axial transmitter which powers the axles and the vehicle itself [4]. A lot of usable energy is lost and remains unused. The loss is most evident when the vehicle decelerates, stops, or halts suddenly, i.e. brakes, which creates unusable thermal energy.

Due to the amount of the energy required to power great dimensions and masses in railway transport, there arises the issue of using a hybrid-powered locomotive for hauling cargo trains. Such locomotives are, in fact, very useful for powering shunting locomotives and light suburban motor trains. The development of an energy storage unit soon might lead to hybrid-powered hauling of cargo trains. There needs to exist the possibility of fast charging and emptying of the energy storage unit in a very short time, and a greater number of cycles. JR East from Japan [5] developed in 2003 a light motor hybrid train. Its hybrid system ensures a fuel-consumption reduction of 10 percent by using the energy collected from braking. The noise at stations has been reduced by 20 dB for light driving, and by 30 dB for accelerated driving. The nitrogen emissions have been reduced by 60 percent, which has also reduced maintenance requirements.

The most important thing in hybrid vehicles that use a combination of electric and diesel engine is the quality of the use of electric energy when it is used for powering the vehicle. Trains used batteries, generators of electric energy, contact lines, fuel cells, collectors with great efficiency, and flywheels.

3. VARIATIONS IN THE PERFORMANCE OF ALTERNATIVE-FUELED HAUL VEHICLES

The greater use of fossil fuels has led to the exhaustion of its resources and findings. To prevent the exhaustion of all sources of fuels which are still used as primary fuels, people began to explore alternative options. Furthermore, fossil fuels and harmful and do not meet the modern requirements laid down by ecology, which in future demand switching to alternative fuels. The most common alternative fuel that successfully power vehicles are rapeseed methyl esters and biodiesel, compressed natural gas, hydrogen, bioethanol or alcohol. The railway industry is currently considering using hydrogen and CNG as main alternatives to conventional fuels. The transfer to alternative fuels [6] is a slow and continuous process which will continue over the course of several years, which include research and development. Diesel engines have replaced steam engines decades after introduction, and there is a slight chance that an alternative fuel will dominate the same way diesel fuel has before. According to use those types of fuels, the first need to satisfy the demands and standards in terms of the emission of harmful and greenhouse gases and consumption. Alternative fuels are divided into short-term and long-term. The former includes liquified gas, while the latter is hydrogen.

Natural gas can be used as alternative fuel due to its supply options and low emission of harmful gasses compared to diesel. The motors powered by natural gas meet the UIC standards [7] for railway vehicles as they have a fifteen-time lower emission of CO2, three-time lower emission of HC, more than seventeen-time lower emission of NOx and a minimum of SO2 emission. When used as fuel, natural gas has a greater volume and significantly greater mass of the storage unit compared to traditional diesel fuels. This is particularly true for compressed natural gas, while the liquified gas is more acceptable. The greatest obstacles are expenses and the time required to set up the infrastructure of liquefied natural gas on rail sections. Further research reveals that if railway companies were to switch to liquified natural gas, the capital short-term expenses would soar, even though this solution would pay off in the long term. Based on the prices of the natural gas, the savings related to transformation [8] amount to around 200,000 USD per locomotive per year. Therefore, based on the age and maintainability of a locomotive, the companies could expect the return of investments in the next 2–5 years. The most significant changes that would

have to be undertaken have to do with diesel engines so that the new locomotives could be powered by LNG. These changes include modifying an engine to be a four-cycle, spark-ignition engine. When using CNG, locomotives would not need to undergo great changes.

Hydrogen is generally considered to be a long-term solution for the railway industry, mostly because hydrogen-powered locomotives emit only water. Despite the existing knowledge of hydrogen cells, hydrogen as a fuel is still in its developmental phase and has had only few demonstrations across the world. The operation of the hydrogen cell is as follows: the fuel, most commonly compressed hydrogen, is brought to fuel cells along with oxygen or a mixture of oxygen and helium. Electrolytes are used to generate electricity. Passing through the separator panel, the hydrogen molecules join the anode, and oxygen molecules the cathode, while electrons travel in the external circuit generating electricity that fuels the electric motor and charges batteries. Electrons and protons create water steam on the cathode by reacting with the exiting oxygen from the cells and the exhaust. Hydrogen is the only fuel that is thought to be capable of dominating like diesel has until the middle of this century. The ecological advantages of hydrogen are abundant, mainly due to the insignificant amount of greenhouse gas emissions compared to diesel engines. Hydrogen technology is on a rapid rise and becoming more and more complex, worth the cost, and directed to heavy rail and high-speed railway.

Rapeseed methyl ester is a biofuel obtained from processing biomass. This form of biodiesel is considered a cleaner fuel because it is derived from natural oils obtained from algae, animal fat, oilseed rape, and soybeans. In Europe, the most commonly used in biodiesel-production is the rapeseed and sunflower oil, while in the United States the most common is soybean oil. In Asia, the most common is palm oil. Algae grow 50–100 times faster than traditional cultures used in biofuel production. The production of fuel obtained from algae is the best replacement for fossil fuels and such fuels are expected to completely replace fossil fuels in the future. The term biodiesel was a term patented in 1947 when a Belgian scientist Chavanne patented the procedure of transesterification of plant oils by using alcohol and calcium hydroxide to extract fatty acids from glycerol. Biodiesel is not poisonous, it is biodegradable, which comes handy in case of an accident when fuel leaks into the environment. Biodiesel releases 10–50 percent less carbon monoxide and up to 12 percent more nitrogen oxide than fossil fuels. Carbon monoxide emissions vary depending on the oil from the biodiesel is derived, and carbon dioxide, also released, is used in the photosynthesis process. The sulphur emission is almost insignificant. Biodiesel has a higher cetane number than fossil diesel which makes its fueling features somewhat poorer at cold start. Without modification, every diesel engine can use diesel fuel with a 5 percent share of biodiesel. Its advantages include cleaner exhaust and a house production possibility. Biodiesel is an extremely fat fuel and can clog the injectors of the engine, which poses its disadvantage. Further drawbacks include a high freezing point, it is hygroscopic which can cause failure and early onset of corrosion, degradation of painted surfaces, the need for special materials to be used in ducts and gaskets to prevent their degradation during exhaust as the emission of aldehyde causes strong exhaust odour. For every ton of biodiesel, 100 kilograms of glycerol is produced. As hydrogen, biodiesel does not have a good infrastructure and it pollutes the environment with plant pesticides. Due to all its drawbacks, biodiesel is hardly applicable in the railway industry as a fuel for heavy rail. The first biodiesel-power train was the Royal Train bio-train, operated for the first time on 15 September 2007 in Great Britain, using nothing but a 100 percent biodiesel. The British company Virgin Trains began operating a train powered by 80 percent diesel and 20 percent biodiesel in 2011, while in Disneyland in the USA, trains are powered by a 98 percent biodiesel derived from recycled edible oils. Similarly, India has commenced the research of biodiesel by exploring the transition from 5 percent biodiesel trains to 100 percent biodiesel trains in the near future [9].

Ethyl alcohol used with an appropriate share of petrol was initially used in the 1970s for trains in Brazil. Bioethanol was used as fuel and derived from sunflower, sugar cane, sugar rapeseed and other plants. Its features include a lower calorific value than leadless petrol. To achieve the same effect, it needs 34 percent

more ethyl alcohol. Bioethanol is derived from the simultaneous processes of fermentation, distillation, dehydration, hydrolysis, and saccharification. A single hectare of cultivated land can yield around 2500 litres of ethyl alcohol. Because of its higher-octane number (>111), ethanol can lead to an increase in the level of compression and engine capacity. The most common form of the fuel is E85. Its advantages include a cleaner exhaust and greater engine capacity. The disadvantages, however, larger consumption, and the need for modifying the engine for the fuel to be used. Reports [10] have shown that the use of bioethanol may actually prove worse for the environment than standard fossil fuels. The reports have also concluded that the production of biofuels may reduce greenhouse gas emissions by up to 30–90 percent, and there are other elements that must be considered. In the year 2000, more than 90 percent of the corn crops in the USA were used to feed the livestock and people, while only 5 percent was used in the production of bioethanol. In 2013, the crops used for bioethanol increased to 40 percent, and 45 percent was used for feeding livestock, and 15 percent for feeding people. It is worth noting that the USA is the producer of 40 percent of the world's corn supply, which goes to show that ethanol production has been causing controversy in developing countries.

4. THE BENEFITS AND DRAWBACKS OF HAULING VEHICLES FROM AN ENVIRONMENTAL STANDPOINT

The increase in the intensity of transport has brought with it the increase in pollution, which is why changes are required to preserve the environment. As railway is the least polluting method of transport and the safest, it needs to be utilised in a way that it replaces road transport, transferring all the traffic onto itself. Such transfer is not a complete solution since the railway still needs to fully utilise its capacities and eliminate all its drawbacks.

The basic advantages of the railway include energy-saving, space-saving, low emission of greenhouse and harmful gasses, and low external expenses. The energy consumption of the railway transport is half of that of the road transport, and one-fifth of road cargo transport. In some European countries with developed railway systems, the purchased tickets, apart from the departure and arrival times, also print the energy consumption for that route and its carbon footprint. To increase the energy efficiency of the railway, the mass of railway vehicles needs to be reduced. It is essential, thereby, to consider the aerodynamics and friction of hybrid vehicles by implementing regenerative braking systems which accumulate the energy and increase the usable space on the vehicle themselves. The training of the train drivers has a massive impact on fuel consumption – their familiarity with the railway section and route, adjustment to the route, the techniques of driving, and the technical features of the locomotives. Therefore, many railway companies educate their train drivers to operate the locomotives in a fuel-saving manner. There are devices being installed that measure energy consumption and provide ways to lower the consumption whilst maintaining the timetable requirements. The fuel-consumption data is stored in a central unit for monitoring, and through further processing of the data, railway operators obtain insight into the consumption of certain types of trains, on certain routes, and certain types of driving. There are meetings being organised for train drivers, where they are presented the fuel-consumption analyses and encouraged to improve their driving [11].

Fuel consumption depends on the utilisation of acceleration and deceleration of the train. One of the ways to accelerate is to increase speed rapidly and continuously to a certain point after which the driving is based on inertia with hauling turned off, and the braking is used to decelerate. Another way is to gradually increase speed, which leads to inertia-driving, and rapid and sudden braking. Such ways aim to achieve the same journey time with equal consumption of the fuel. When driving on steep hills, the driving must adjust to the configuration of the terrain and route to ensure efficiency. The space that a railway track takes up is 3.2 ha/km, while a four-lane motorway takes up 9.1 ha/km. A fast-suburban railway

transports 32400 passengers per hour on a railway surface of 5 meters in a single hour, and to achieve the same result, a motorway would need to have 16 lanes of 55 meters in width. The railway is one of the most efficient and environmentally most acceptable methods of transporting passengers and cargo. Even though it does have low harmful gas emission levels, it has vowed to reduce those levels by 30 percent by the year 2020.

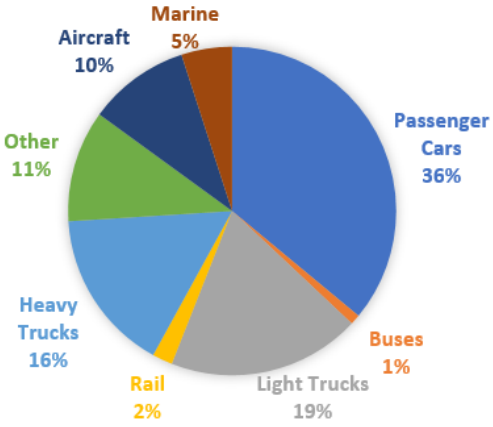


Figure 2 – Transportation Greenhouse Gas Emissions
Source: [12]

Harmful gas emission levels in railway transport have been on the fall since 1990. No other branch of transport can demonstrate the same efficiency. Since 1990, railway transport has reduced the carbon dioxide gas emissions, while all other methods of transport have seen a rise therein. Most of the vehicle fleets of EU member states use electric energy (around 80 percent), which does not hurt the environment. Yet the remaining 20 percent of diesel haul vehicles produce around 1–2 percent of solid particles, and 1–3 percent of nitrogen oxides. In 2005, the railway transport had a 1.6 percent share in the emission of carbon dioxide based on the 6 percent passenger and 10.3 percent cargo transport. To reap the environmental benefits of the railway, a concept named Europrocurement has been accepted by the manufacturers of railway vehicles, railway operators, and creators of transport policies. The concept aims to procure, produce, and use trains with high energy efficiency, low levels of harmful gas emissions in diesel vehicles, and low noise levels. In a publication by UIC [7], the concept has been highlighted under "Environmental specifications for new rolling stock", in 2006, following a heated debate on with the manufacturers of trains and the train industry. An essential environmental benefit of the railway is external expenses, the parameters of which include accidents, air pollution, climate changes, and noise in the railway transport. Even though these expenses are on the rise, the increase is insignificant. The main reasons for the increase are transport intensity, the ever-higher train speeds, the noise level which is increased amidst those high speeds, the noise level on bridge crossings, aqueducts, etc. Railway transport is responsible for 1.9 percent of the entire external expense in transport, while road transport generates 87 percent, and air transport 14 percent thereof. Only the waterway transport generates fewer – 0.4 percent. This is the reason for diverting all transport to railway transport [13].

5. CONCLUSION

The increase in transport efficiency and the optimal level of harmful gas emissions are the challenges of further transport development. A solid solution, therefore, are hybrid-powered train vehicles which successfully reduce emissions. It is believed that hybrid fuels will become the most utilised soon, but only after the issue of storing energy and other materials has been solved. The storage units are still being upgraded by researching various solutions, such as batteries, flywheels, high-power condensers, etc. At

the same time, alternative fuels are being developed, the most promising of which is hydrogen due to its long-term potential. Notable also is the use of rapeseed methyl ester, natural gas, and bioethanol, even though some of these are considered short-term solutions. Railway has several benefits which place it above all other methods of transport, which may lead to transport being transferred to the railway. Relevant advantages of the railway include greater transport volume per meter squared, lower external expenses, a lower surface area required to set up its infrastructure, and lower levels of gas emissions. On the other hand, the drawbacks include noise levels, which are lower than air and road transport, and the ability to transport harmful materials, as well as the requirement to treat the railway track with herbicides.

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VALENTINA BASARIĆ, Ph.D. [1]
E-mail: plast@uns.ac.rs
VUK BOGDANOVIĆ, Ph.D.[1]
E-mail: bogdanovic_vuk@yahoo.com
JELENA MITROVIĆ SIMIĆ, Ph.D. [1]
E-mail: mjelena@uns.ac.rs
NEMANJA GARUNOVIĆ, M.Sc. [1]
E-mail: garunovic@uns.ac.rs
[1] University of Novi Sad
Faculty of Technical Sciences, Department of Traffic Engineering
Serbia, 21000 Novi Sad, Trg Dositeja Obradovića 6

THE ANALYSIS OF THE EFFECTS OF ECOLOGICAL VEHICLES INTRODUCTION INTO THE PUBLIC PASSENGER TRANSPORT SYSTEM IN NOVI SAD

ABSTRACT

The city public passenger transport company "JGSP" has a long tradition in passenger transport on the territory of the city of Novi Sad. The vehicles used for the passenger transport on the town territory annually cover around 15.2 million kilometres, out of which 10.6 million kilometres within the central town area. In the structure of the bus fleet there are mostly vehicles with diesel engines. Due to the performed transport by the vehicles that use diesel fuel, JGSP is one of the greatest polluters in the town traffic system. Within the paper, the basic characteristics of the public transport system in Novi Sad have been shown, as well as the results of the energy consumption and pollutants emission analysis. Based on the analysis of the results, measures for the introduction of environment friendly vehicles into the system of public transport have been considered, as well as the effects of those measures on the reduction of fossil fuels consumption and CO2 emission.

KEY WORDS

public transport; emission; clean vehicle

1. INTRODUCTION

Apart from positive effects of the evident rise of the traffic volume on the economic prosperity of cities and regions, the negative consequences of the traffic policy diminish the importance of the economic growth and development. The negative effects are the most distinct in urban environments. The continuous increase of the number of residents in cities and the level of motorization result in growing traffic congestion in the street network, as a consequence of more common use of cars and inability of further meeting the demand by building new capacities of traffic supply of the city. The disbalance between the supply and demand, apart from the increase in time losses with in the traffic system, also results in more intensive disturbance of life quality in cities. The most prominent and quantified negative effects of the rise of traffic volume and more intensive use of cars in cities are: emission of harmful gases, energy consumption, communal noise, traffic accidents, space and time occupancy in already limited urban environments, reducing the possibility for doing other activities.

Previous analyses of harmful gases occurring as a product of the work of internal combustion engine imply the existence of about 200 different harmful organic and non-organic compounds. The gases with the greenhouse effect are the gases which absorb and re-emit infrared radiation and they reach the atmosphere as a consequence of natural processes, but also as a consequence of human activities.

The scientific predictions warn that avoidance of future global warming disaster is possible only if during the next 50 years the current emission of CO_2 is reduced for at least a half.

According to the statistical data of EU from 2011, the activities in the field of traffic produce approximately 20% of the total emission of gases with the greenhouse effect. The gas which contributes most to the creation of the greenhouse gas is CO_2, and its main source is the combustion of fossil fuels. Out of the total quantity of CO_2 created in traffic activities in the states of EU, more than 70% originates from road motor vehicles [1].

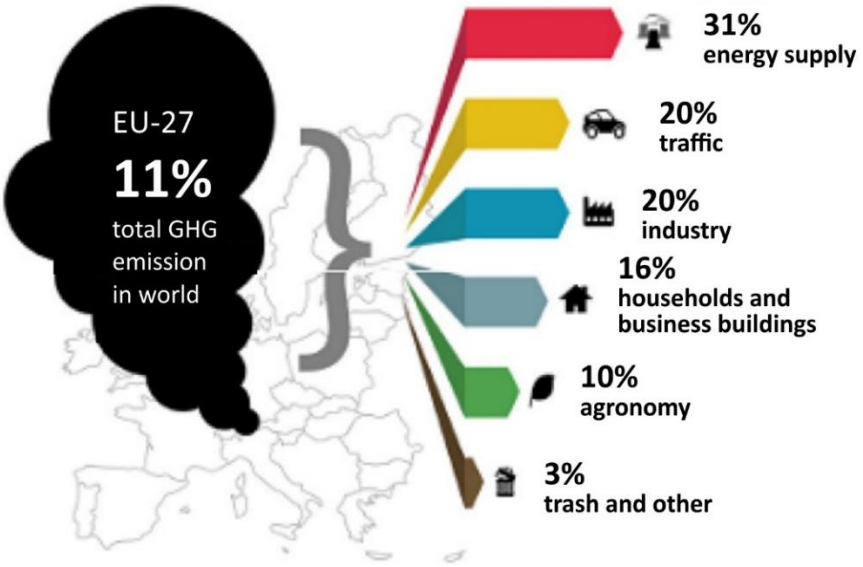


Figure 1 – Emission of CO_2 in EU [2]

A special attention within White Paper Road map to a Single European Transport Area – Towards a competitive and resource efficient transport system from 2011 [3] was given to the environment, that is, the emission of gases with the greenhouse effect (greenhouse gases – GHG) and the reduction of energy dependence. Ten goals were defined and their realization is expected to lead to structural changes in traffic system of the European Unity by the year of 2050, with temporary goals for the year of 2030. These goals comply with the goals for the reduction of GHG emissions for 20 % by 2030 and 70 % by 2050 in relation to the level of these in the year of 2008. Achieving the planned goals means redirection of a part of road traffic to other means of transport, replacement of passenger cars which use petroleum and petroleum products as their power fuel with hybrid and electric vehicles. As one of the basic aims set is a drastic reduction of the number of cars with the classic (fossil) fuels combustion in the city traffic by the year 2030. The aim is the introduction of clean vehicles and the methods for traffic demand management by an adequate application of restrictive measures in order to reduce that number by half. One of the basic reasons for setting these high goals in the fight with the challenge of increasing the accessibility and economic efficiency of cities is, primarily, a high price of petroleum and its derivatives as well as high petroleum fuel dependence of traffic system of EU (approximately 96%).

This paper displays the results of general analysis of the possibility of conducting the measures for the reduction of fuel consumption in the system of the public city transport in Novi Sad, Serbia. The primary measures relate to the introduction of the electric power buses. The aim of the analysis is considering possibilities and defining the framework plan for the reduction of CO2 emission complying with the defined aims of the European Union. Consequently, the potentially achievable results the reduction of CO2 emission in the urban area of the city of Novi Sad have been shown, with the framework proposal of the measures.

2. THE CURRENT STATE ANALYSIS

The public town passenger transport company (JGSP) from Novi Sad is the transporter in the public town transport of passengers on the territory of the city of Novi Sad, suburban and intermediate traffic between Novi Sad and a certain number of neighbouring municipalities. By the defined timetable and the lines network, JGSP vehicles from Novi Sad perform the transportation of passengers in 22 town and 34 suburban and intermediate lines. Considering the system volume of the transported passengers, based on the available data, in the system of public town transport, 249,000 passengers are transported in the city lines, suburban and intermediate transport, while the estimated value of the number of transported passengers in town lines only during one week is about 1,060,000 passengers [4].

The bus fleet consists of 271 vehicles which use diesel as their power fuel, or compressed natural gas (CNG). JGSP Novi Sad owns buses of different engine power, ranging from 100 kW to 243 kW, whereby over 80.0% of buses have the engine of the power ranging between 180 kW and 228 kW.

The analysis of the fuel consumption of the buses owner JGSP Novi Sad has been on the basis of the available data for the year of 2017, by the winter timetable. On the basis of the timetable data, static line elements and data on the bus fleet operation for the period of last three years, the average annual volume of the planned kilometres in town, suburban and intermediate lines has been determined. The average number of the planned kilometres which includes the number of the covered kilometres with the passengers and the number of kilometres of the driving without passenger in the lines network of JGSP Novi Sad is 15,188,650 km. Analysing the planned volume of driving by the lines, it has been determined that 6,979,750 km is done in town lines, and 8,208,900 km totally in suburban and intermediate lines.

Considering the fact that all suburban and intermediate lines begin or finish their routes on the territory of the city of Novi Sad, a part of the covered kilometres in these lines can be attributed to town lines. The length of every suburban and intermediate line has been analysed separately, thus the distribution of the number of kilometres covered on the territory of the town of Novi Sad outside the borders of the master plan. The referential length of a line in the town area was the distance between the starting station to the last bus stop within the borders of GUP (Master plan). On the basis of this analysis it has been determined that the average annual volume of the planned kilometres on the territory of the City of Novi Sad is 10,602,537 km, and the average annual volume of the planned kilometres outside the territory of the City of Novi Sad is 4,586,113 km.

By the conditions of vehicles exploitation in relation to the position of the route of the public transport line, the operation of vehicles can be divided into the operation of vehicles in the conditions of city driving and driving outside the city. For the vehicles operation in the conditions of city driving, a short distance driving between two stops is typical. Traffic in the city network with frequent time losses at intersections, common occurrence of the driving regime “stop-go”. The operation of vehicles in driving outside the city is characterized by the operation on lines with a greater inter-station distances. Traffic on the road and street network mostly outside residential areas, with a possibility to maintain the constant speed during a longer period of time. One of the major indicators of the differences between these two ways of vehicles operating is primarily reflected in the average fuel consumption which is in city conditions in average for about 25% higher with the diesel fuel buses, that is, three times higher for the vehicles which use CNG. The following table shows the average fuel consumption by the fuel type and characteristic driving conditions.

Table 1 – Average fuel consumption of JGSP Novi Sad buses depending on driving conditions

Type of power fuel	City driving conditions (l/100 km)	Driving conditions outside city (l/100 km)
Diesel fuel	52.9	41.9
CNG	48.0	15.7

It should be mentioned that the comparison of CNG consumption is not absolutely relevant due to the fact that in suburban and intermediate lines there are buses whose CNG engine power is 100 kW, and on city lines the buses whose CNG engine power is from 180 kW to 213 kW. Thus, the average consumption by a vehicle is not under the exclusive influence of driving conditions.

Based on the average consumption and average annual volume of the planned kilometres, an assessment of the annually used fuel, which is 7,440,083 l. Taking into consideration the average density and specific volume of the assessed types of power fuels [5], the used quantities have been in kilograms.

Table 2 – the quantities of the used fuel of JGSP Novi Sad buses by emission place

Power fuel type	City area (kg/year)	Area outside the city (kg/year)	Total (kg/year)
Diesel fuel	4,756,358	1,642,722	6,399,080
CNG	293,898	36,097	329,995

In the structure of fuel consumption it has been determined that 95.6% is diesel fuel, and 4.4% is CNG. On the basis of the adopted emission factors and the quantity of the used fuel, the quantity of CO2 emission has been determined for JGSP Novi Sad buses in the city and the area outside the city. For defining the emission factors the procedures defined by COPERT (Computer Programme to calculate Emissions from Road Transport) program have been used.

Table 3 – The adopted factors for the assessment of CO_2 emission depending on the fuel type

Power fuel type	$kgCO_2$/kg of the used power fuel
Diesel fuel	3.14
CNG	2.75

Table 4 – CO_2 emission of JGSP Novi Sad buses on annual level

Power fuel type	City area (t)	Area outside the city (t)	Total (t)
Diesel fuel	14,935.0	5,158.1	20,093.1
CNG	808.2	99.3	907.5

It can be stated that out of the total CO2 emitted by JGSP Novi Sad buses, 75% is emitted in the city area and the remaining 25% in the parts of suburban and intermediate lines outside the borders of the master plan.

3. MEASURES AND EFFECTS OF FUEL CONSUMPTION AND CO_2 EMISSION REDUCTION

The reduction of fuel consumption in the system of public passenger transportation is possible to achieve by lines network rationalization, whereby the quality of the public transport system can be questioned, as well as the possibility of the rationalization in accordance with the real demands for the passenger transportation. Complying with EU plans, whose aim is the reduction of CO2 emission, and in accordance with contemporary trends of the public transport system innovations, the reduction of pollutants whose source are public transport vehicles, is achievable by the introduction of electric power vehicles.

Within the presented analysis, the effect of CO2 emission reduction was evaluated to 20.0% in relation to the presented state. This measure of reduction complies with the defined goals of u White Paper Road map to a Single European Transport Area for the period by the year of 2030. It was

presumed that by the realization period (the target year) the public transport system will stay at the same level in the sense of static and dynamic elements of lines operation.

Table 5 – Comparation of annual quantity of the used fuel - the existing state and after the consumption reduction by 20%

Power fuel type	Base consumption (kg/year)	Targeted consumption (kg/year)	Difference after the reduction (kg/year)
Diesel fuel	6,399,080	5,119,264	1,279,816
CNG	329,995	263,996	65,999

With respect to the adopted emission factors, if the difference of the used fuel was around 20.0%, the reduction of 4,200.1 t of the emitted CO2 would be achieved, which makes 20% of the currently achieved emission. Observing the achieved benefit reflected through the reduced CO2 emission, in total 4,018.6 t (95.7%) is achieved with the reduction of diesel fuel use, while the remaining reduction of 181.5 t (4.3%) is achieved through the reduced CNG consumption.

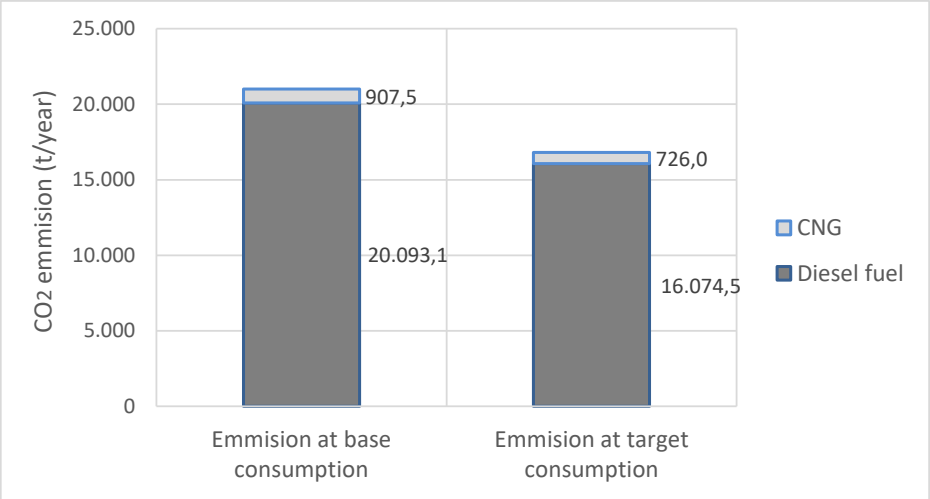


Figure 2 – Emission of CO_2 at base and target fuel consumption

Considering the fact that 75.0% of the total CO2 emission is achieved within the borders of the territory of the city of Novi Sad, the activities related to the reduction of the fuel consumption should be directed to those parts of the public transport system which have been related with this area. Analysing the operation of a part of the bus fleet in city lines, it has been determined that the average annual consumption of the diesel bus is 52.9 l/100km, and the average planned number of the covered kilometres of a bus, including driving with passengers and zero driving, is 55,537 km. In accordance with the stated, the achieved annual consumption of a bus in the city is 29,379 l of diesel fuel. The planned reduction of the used diesel fuel could be achieved by replacing 49 diesel engine buses with electric power buses. The average consumption of the bus with CNG power in the city is 48 l/100km. In accordance with the average number of the vehicle kilometres in the city, it can be concluded that the annual consumption of a bus with CNG power in the city is 26,658 l. The planned reduction of 65,998 litres of CNG annually is achievable only by replacing 3 solo CNG power engine buses with electric power buses.

3. CONCLUSION

Previous research have shown that 20% of total of CO2 emission in the countries of EU is generated from motorized traffic. In the United States of America CO2 emission as a negative product of traffic is

almost 50% higher than in the countries of the European Union. In Europe, as well as in the USA, the only greater pollutant than traffic are power plants. Observing by the types of transport, over 70% of the generated CO2 is the product of road traffic vehicles.

City of Novi Sad aims to improve its transport system in order to decrease emissions and get closer to representative EU cities. Apart from private passenger cars in the network, public transport vehicles are the greatest pollutants in traffic system. In this paper we determined that JGSP buses annually emit 15,743 t of CO2 in the city area of Novi Sad, and 5,257 t of CO2 outside the city area where it services.

Within the defined aims of the European Commission, for achieving a more efficient traffic system in the countries of the European Union, a need for the reduction of emission of gases which create greenhouse effect (GHG) has been defined. Guided by temporary goals that by the year of 2030 the emission of these gases reduce for at least 20%, the analysis has been done for the possibility of electric power buses and the replacement of the current diesel fuel power and CNG power buses. The results have implied that the reduction of CO2 emission of 4,200 t is achievable through the replacement of at least 49 existing diesel power buses and 3 CNG power buses. This distribution by the vehicle type is based on the assumption that desired reduction is achieved for every category of the used power fuel.

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VUK BOGDANOVIĆ, Ph.D.[1]
E-mail: bogdanovic_vuk@yahoo.com
VALENTINA BASARIĆ, 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
[1] University of Novi Sad
Faculty of Technical Sciences
Department of Traffic Engineering
Serbia, 21000 Novi Sad, Trg Dositeja Obradovića 6

TRAFFIC MANAGEMENT FOR DELIVERY VEHICLES IN NOVI SAD PEDESTRIAN ZONE

ABSTRACT

Within this article, there is the analysis of the current traffic regulation method regarding delivery vehicles in pedestrian zones of Novi Sad and also there are the proposed solutions based on the principles of sustainable mobility. Due to the existence of numerous highly attractive constructions, there is a need for a constant delivery of different kinds of goods. In Novi Sad, as well as in many other European cities, the admission of delivery vehicles into the pedestrian zone is possible only according to the specially defined regime. The existing regime enables the admission of delivery vehicles into the pedestrian zone only with a special license and within the time limit. However, there are no limitations and standards regarding the noise level and the emission of exhaust fumes. Considering world experiences and good practice examples, there are suggested solutions in this article that would contribute to the change in the structure of delivery vehicles and to the reduction of emission of exhaust fumes and the reduction of noise.

KEY WORDS

Pedestrian zone; delivery vehicle; emission; noise;

1. INTRODUCTION

Since goods delivery is one of the basic needs of contemporary cities, delivery regulation is a significant part of traffic system management. Namely, delivery vehicles unfavorably influence the traffic flow because of their dimensions, and the process of loading and unloading requires a certain traffic surface and time, which in many cities represents a serious problem, which is manifested in unfavourable traffic conditions and traffic jams. Apart from these, delivery vehicles may represent a significant source of pollutant emission if they use fossil fuels for their power. In order to reduce the influence of delivery vehicles on the traffic conditions, very often certain limitations are applied, regarding delivery vehicles capacity and dimensions, as well as the type of fuel used as a source of power [1,2,3].

In almost all central parts of Novi Sad trade and catering industry are very developed, and a lot of shops and restaurants are in pedestrian zones and slow traffic zones. For this reason, it is necessary to define the regime of goods delivery into the central parts of Novi Sad and the periods of delivery [4]. In this paper the way of motor traffic organizing in the central city area of Novi Sad will be described and analysed, that is, in its pedestrian zone, with a special review of the regulation of delivery vehicles movement, as well as suggesting solutions for the optimization of vehicle numbers, which in the future

would lead to the improvement of life quality and citizens safety and the reduction of exhaust fumes in the city pedestrian zone.

2. METHODOLOGY

For the purpose of the analysis of the problem of the regulation of delivery vehicles movement in the central zone of Novi Sad, an information data base was formed, which contains data on functioning and characteristics of the goods delivery system in the pedestrian zone, as well as the data on traffic load by these vehicles in the pedestrian zone.

The pedestrian zone of the City of Novi Sad, which is in the very centre of the city, includes the area shown in the Picture 1. In the marked area traffic is forbidden for all motor vehicles except the vehicles with a special licence. The access to the pedestrian zone for the vehicles with a special licence is possible at the approach to the streets Modena and Gimnazijska. Both approaches are secured with retractable bollards, that is, a ramp, so that the admission is allowed only to those vehicles which own the “device” for identification - a control card issued by an authorized person. Passing, that is, passing and stopping of motor vehicles in the pedestrian zone in the city centre can be approved to the residents of this zone and other vehicles which approach the pedestrian zone for performing certain jobs.



Figure 1 – Space coverage of the pedestrian zone in the central part of City of Novi Sad

The analysis of the way traffic is performed in the pedestrian zone was done on the sample formed on the basis of passing licence, that is passing and stopping in the pedestrian zone in the very centre of the city, issued in the period from 1 September 2017 to 31 August 2018. In this part of the analysis the basic characteristics of the regulation system of traffic in the pedestrian zone were determined and they include data on the number of issued approvals, the category, type and the capacity of the vehicle, type of delivery and the type of goods transported.

After the analysis of the results of the performed research studies, the measures were defined to match the characteristics of the traffic system in Novi Sad, complying with European recommendations.

3. CURRENT STATE ANALYSIS

The movement of vehicles in the pedestrian zone has been regulated by Decision on the protection and establishing a special traffic regime in the centre of Novi Sad, issued by City Administration for Traffic and Roads. This decision determines a special traffic regime in the very city centre, by which City Administration for Traffic and Roads can approve passing and stopping to the owners and users.

The approach itself is regulated by a physical obstacle in the form of a retractable bollard which enables passing of vehicles when it is in the downward position ("in the ground"). In order to approach the pedestrian zone, it is necessary that the control unit, which has been installed within the device for accessing the central pedestrian zone, scans the data from the user's electronic card.



Figure 2 – Entrance to the pedestrian zone from Modena Street



Figure 3 – Exit from the pedestrian zone from Modena Street



Figure 4 – Entrance into the pedestrian zone from Gimnazijska Street

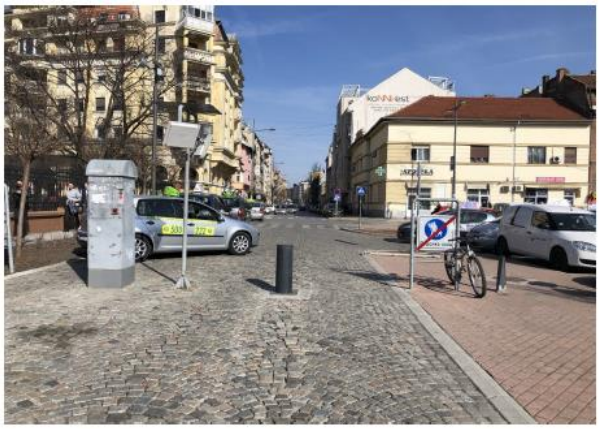


Figure 5 – Exit from the pedestrian zone from Gimnazijska Street

The following figure shows the number of issued licences by years in the period from 01.01.2011 to 31.08.2018 and it can be noticed that the number of issued licences did not significantly vary during the previous years.

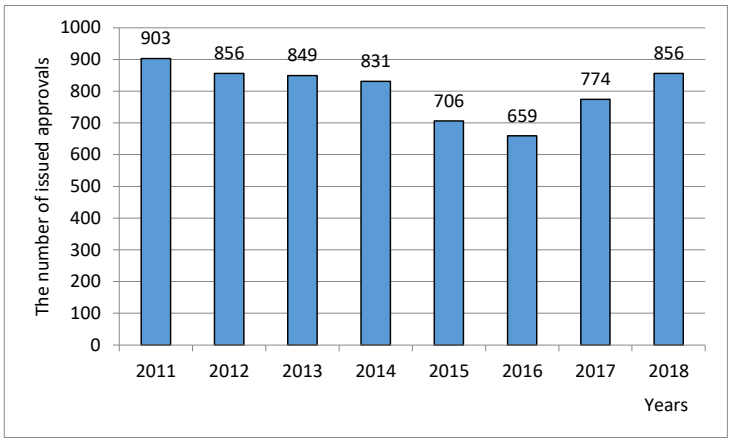


Figure 6 – The number of issued approvals (Decisions) for the admission to the pedestrian zone by years

On the basis of the approvals issued in the period from 1 September 2017 to 31 August 2018, it has been determined that the number of vehicles with the licence for the admission to the pedestrian zone was 856. The users being given the licence for passing and stopping in the pedestrian zone in the central part of Novi Sad are divided into 13 different categories, and the distribution of different categories of users is shown in the following figure.

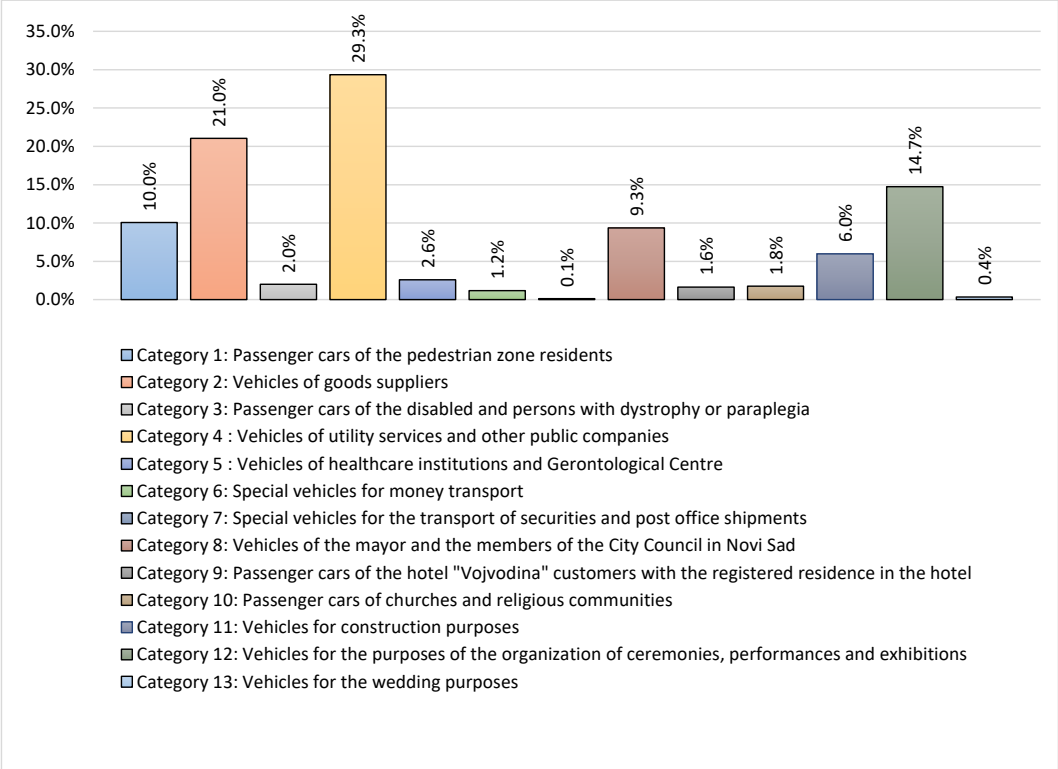


Figure 7 – The distribution of the number of issued licences for passing and stopping in the pedestrian zone

The greatest part in this distribution by categories is for the vehicles of public utility services and other public companies (29.3%), then for the vehicles of goods suppliers (21%), vehicles for the purposes of the organization of ceremonies, performances and exhibitions (14%), passenger cars of the pedestrian zone residents (10%) etc. Depending on the category they belong to and the needs of the pedestrian zone users who are given the approval, there is a difference in the type of the vehicle which is allowed the admission. On the basis of the available data, it can be said that over 50.0% of licences for passing and stopping of the vehicles in the pedestrian zone is issued for passenger cars, while the participation of heavy goods vehicles is about 43.0%.

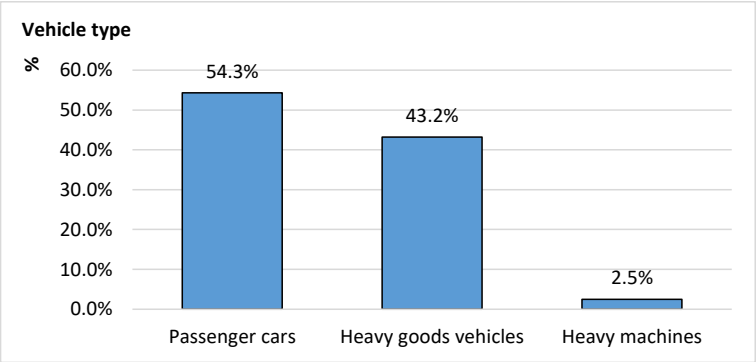


Figure 8 – Distribution of the number of issued licences for passing and stopping in the pedestrian zone by the vehicle type

The distribution, that is, categorization of heavy goods vehicles is possible to carry out by the vehicle's maximum capacity and the maximum permissible mass for which the vehicle was registered (data from the vehicle registration). Taking into consideration the fact that traffic for heavy goods vehicles whose total mass is more than 5.0 tonnes is forbidden in the street network which encircles the pedestrian zone, and in the very pedestrian zone, we can say that 44.1% of heavy goods vehicles with the access to the pedestrian zone are treated as heavy goods vehicles with a special licence. This group of vehicles(whose greatest allowed mass is over 5 tonnes) mostly includes utility services vehicles and other public companies vehicles, vehicles for the purposes of ceremonies, performances and exhibitions, and vehicles for the purposes of construction, works and moving house. The remaining 55.9% of heavy goods vehicles belong to the category for which there is no restriction in the sense of maximum permissible total mass. Taking into account only the category of heavy goods vehicles which are used for supplying (heavy goods delivery vehicles) about 80.0% are in the group of vehicles whose maximum permissible mass is up to 5 tonnes of capacity, and 73.1% of vehicles belong to the vehicles whose maximum permissible mass is not over 3.5 tonnes.

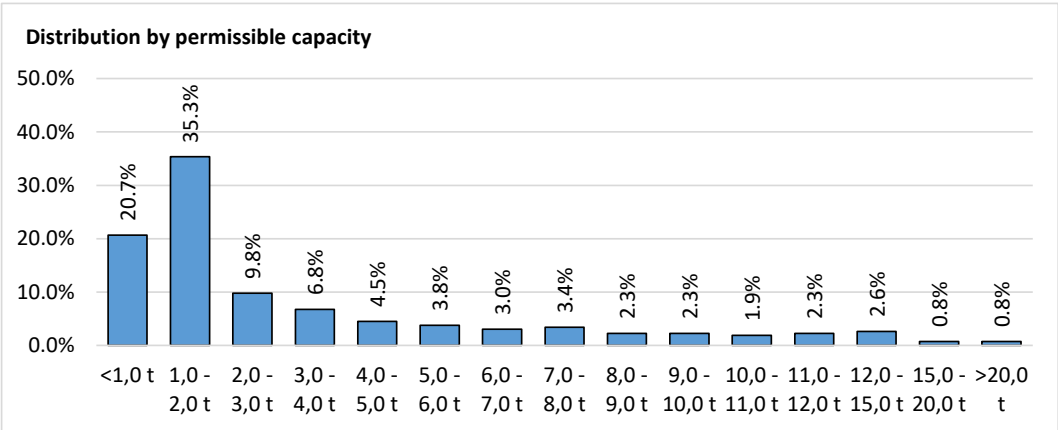
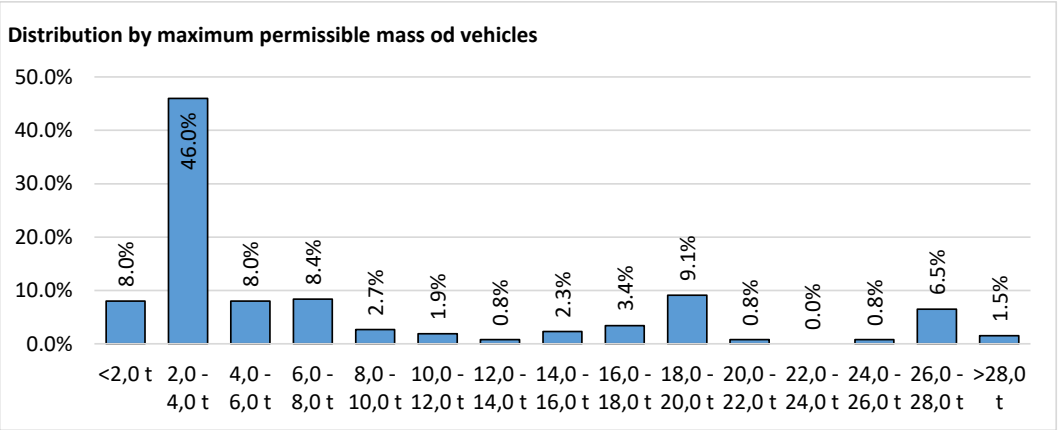


Figure 9 – Distribution of the number of all heavy goods vehicles by permissible capacity



Picture 10 – Distribution of the number of heavy goods vehicles by maximum permissible mass of vehicles

The participation of different types of goods in the total amount of the goods delivered to the users in the pedestrian zone has been determined. It is important to mention that by the issued approvals about 20.0% of the delivered goods to the pedestrian zone is done by a passenger car. This is mostly the goods which does not require special transport conditions and which is delivered in very small quantities. The goods classification has been done in the following way:

- Courier service and money transport
- Groceries
- Alcoholic and non-alcoholic beverages
- Textile products, clothes and shoes
- Equipment for ceremonies
- Equipment for moving house, maintenance of buildings and building material
- Books, newspapers and paper
- Chemical and plastic products
- Electrical products
- Others.

The most common type of goods delivered to the central zone is food and drink, which together in total number participate with about 38%, then the equipment for ceremonies (19.6%), equipment for moving house, maintenance of buildings and building material (18.5%) etc.

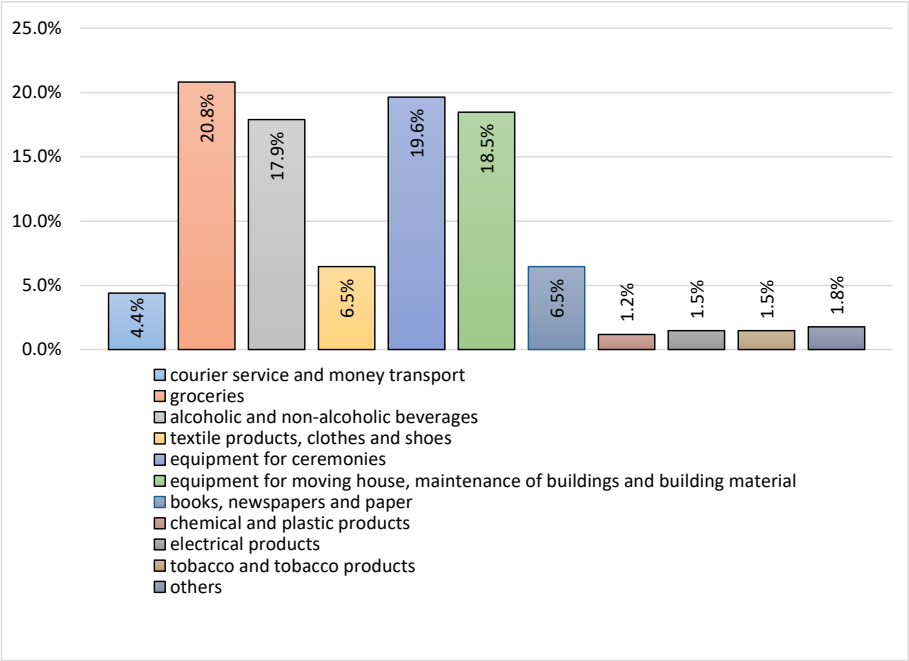


Figure 11 – Distribution of the quantity of the delivered goods by the goods types

An important item in the analysis of the vehicles which enter the pedestrian zone is to determine their movement and length of stay. Although it is difficult to precisely determine the vehicle movement, from the data base it was possible to determine if the heavy goods vehicles carry out the supplying for their own needs, that is, for one shop with their own vehicle, or they distribute the goods for more shops. By analyzing the available data, it has been determined that a larger number of vehicles are the vehicles which distribute goods (67%), which need much more time and they stay much longer so that they could service all the shops, in relation to the vehicles for your own needs (33%).

Licence for the admission of vehicles into the pedestrian zone is issued for two possible approaches (ramps): entrance into Modena Street and entrance into Gimnazijska Street. Analysing the issued decisions for the licence for the admission into the pedestrian zone, it has been established that these two approaches are not equally burdened. Out of the total number of the issued licences in the period of a year, 93.7% of licences were issued for the entrance into Modena Street. The distribution of vehicles by the type at the approach in Modena Street corresponds the general distribution for the whole pedestrian zone (Picture 8), and at the approach to Gimnazijska Street more than 60% of the issued licences are for passenger cars. Considering the fact that it has not been noticed that the number of vehicles which currently use one approach or the other causes any unfavourable traffic conditions, the data on the number of the issued licences by approaches can be used in further analyses and proposals of further measures relating to the redistribution of the flow on the network.

4. MEASURES PROPOSAL

Apart from determining the number and the type of vehicles which have the approval for the admission to the pedestrian zone, this paper highlights delivery vehicles. For the purposes of creating conditions for an efficient goods delivery, it is necessary to consider the changes in the way of the regulation of the movement of delivery vehicles in the pedestrian zone in Novi Sad.

Complying with CIVITAS recommendations [5], within this paper certain measures have been proposed relating to the regulation of traffic of delivery goods, which would contribute to the organization of this issue and which would contribute to the improvement of traffic conditions,

regarding market and financial measures. Within this group of measure, the city of Novi Sad has a possibility to stimulate the use of electrical vehicles, vehicles with hybrid engines and vehicles using fuels which do not affect greenhouse effects, for delivery purposes.

In the central zone of Novi Sad there is a pedestrian ramp, with the restriction for the admission of delivery vehicles into the pedestrian zone from 23:00 to 09:00 h. There are two entrances to the pedestrian zone and the approaches are controlled with the ramps in Modena Street and Gimnazijska Street. This measure of time limit has been accepted by the users of the delivery and it is restrictive enough, thus there is no need for further time restrictions for the delivery.

The pedestrian zone is in the historical part of the city with numerous commercial and cultural-historical contents, but with a certain number of flats, as well. Applying the experience of the cities which have the controlled admission to the pedestrian zone, the city of Novi Sad can use the possibility and by conducting financial measures it can stimulate the so called green and quiet delivery. In that sense, the introduction of "Green NS Zone" delivery has been proposed, which would initially include the current area of the pedestrian zone for the purposes of total control. The zone would be marked at both entrance-exit directions with a traffic sign which is shown in the following picture.

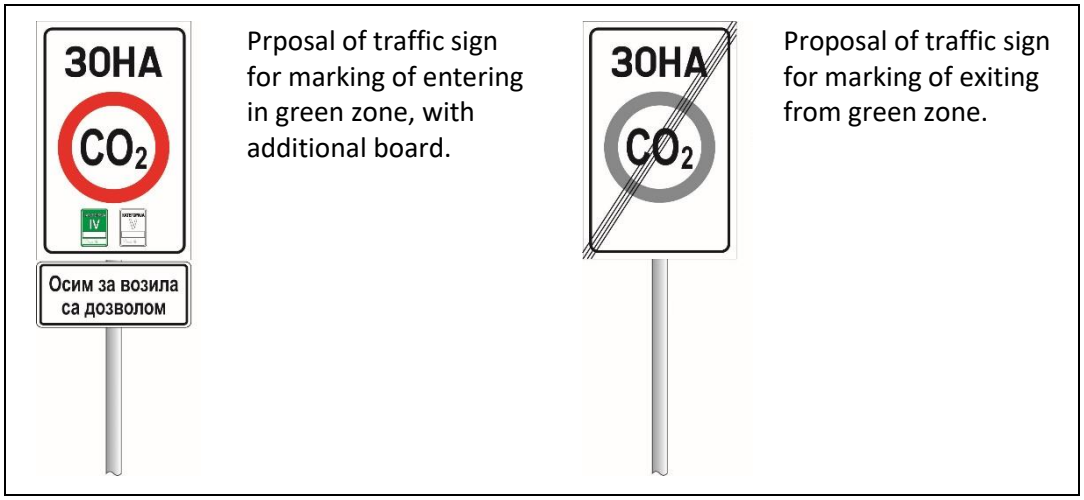


Figure 12 – The appearance of the traffic signs for green zone marking

The distributors and the users of the delivery would be stimulated to use green and quiet vehicles for night delivery, and for the vehicles with a high emission of gases which cause the greenhouse effect non-stimulative measures would be applied. The categorization of the vehicles has been done in accordance with the measures applied in Berlin [6], which is shown in the following table.

Table 1 – Categorization of vehicles for the admission to the green zone

Category 1	Euro 1
Category 2	Euro 1 (with a special filter) or Euro 2
Category 3	Euro 2 (with a special filter) or Euro 3
Category 4	Euro 3 (with a special filter) or Euro 4, Euro 5, Euro 6
Category 5	**Hybrid and electric vehicles**

The delivery vehicles of the category 1 would not be issued the licences for the admission to the pedestrian zone, that is, they would be prohibited from the admission. In accordance with the current categorization, the following sticky labels, shown in the picture 13, have been proposed for the delivery vehicles which enter the pedestrian zone.



Figure 13 – The proposal for the delivery vehicles labels by categories

In accordance with the proposed categorization, the stimulative measures, which mean different prices for the delivery vehicles licence, have been suggested. The basic price would be formed for the category IV. In the following table there is a taxing proposal for the licences for the admission of delivery vehicles to the central zone.

Table 2 – Stimulative measures for the use of ecological vehicles

Category 1	Euro 1	It is forbidden to enter in the pedestrian zone
Category 2	Euro 2	150% compared to the base price
Category 3	Euro 3	120% compared to the base price
Category 4	Euro 4,5,6	100% the base price
Category 5	**Hybrid vehicles**	60% compared to the base price
	Electric vehicles	30% compared to the base price

5. CONCLUSION

Apart from the description of the way of traffic regulation in the pedestrian zone of the city of Novi Sad, the paper also reviews the functioning of the current system of goods delivery with the basic characteristics of the number and the structure of the delivery vehicles, the distribution type as well as the type of the goods delivered. Considering the delivery time, the admission is allowed from 23.00 to 09.00 o'clock, which is acceptable and there is no need for further restrictions. However, considering the fact that in Novi Sad there is no restriction regarding vehicles, in the sense of categorization and obeying European standards regarding emission of exhaust fumes, a solution has been proposed which would mean the introduction of green zone into the pedestrian zone. The categorization has been based on EURO standard emission of exhaust fumes and it implies five categories. For each category there is a label (sticker) in a certain colour, and a certain price is charged, that is, an ecological tax.

As the final outcome, it is expected that the distributors are stimulated for using newer vehicles, with less emission of exhaust fumes. Also, it is considered that the introduction of delivery vehicles into the green zone and their categorization are only a starting point for creating conditions for a better quality and safer life of people in the city. After this initial step, it would be planned to introduce the categorization for other vehicles which have the licence for the admission to the pedestrian zone and further the application to other roads in the city. The applied measures would definitely affect the increase of the attractiveness of Novi Sad central zone, with the reduction of emission of all pollutants and noise.

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DARKO BOKULIĆ, mag.ing.traff.[1]
E-mail: darko.bolid@gmail.com
MORANA IVAKOVIĆ, mag.ing.traff.[2]
E-mail: morana.ivakovic@mmpi.hr
SANDRA LOVRIĆ, mag.ing.traff.[2]
E-mail: sandra.lovric@mmpi.hr
[1] University of Zagreb, Faculty of Transport and Traffic Sciences
Vukelićeva 4, Zagreb, Croatia
[2] Ministry of the Sea, Transport and Infrastructure
Prisavlje ul. 14, 10000, Zagreb, Croatia

ANALYSIS OF DRIVING SCHOOLS SERVICE DEMANDS IN THE REPUBLIC OF CROATIA

ABSTRACT

The services provided by driving schools, on the market of all other services in the traffic domain, have very specific features. They are an interactive process that takes place between the participants of the driving school on the one hand and the technological process on the other. This process should ultimately lead to the training of candidates, and it takes place in the interaction of users (ie candidates) of services and service providers. The success of such a traffic-technological process is reflected in the speed of service delivery and ultimate user satisfaction with the overall effects of service, ie training. For longer-term demand planning, the factors affecting the market of driving school services in the Republic of Croatia are researched, such as regulatory measures, the impact of demographic trends, and the methodological and statistical forecasts analyze the collected or processed data.

KEYWORDS

driving schools; training of candidates; demand planning; analytic hierarchy process (AHP);

1. INTRODUCTION

The services provided by driving schools, on the market of all other traffic and transport services, have a very specific character. They are an interactive process that takes place between the participants of the driving school on the one hand and the technological process on the other. This process should ultimately lead to the training of candidates, and it takes place in the interaction of users (ie candidates) of services and service providers. The success of such a traffic-technological process is reflected in the speed of service delivery and ultimate user satisfaction with the overall effects of service, ie training.

The demand for driving school services in the Republic of Croatia was ranked by applying the method of analytic hierarchy process (AHP method) used as a support for multi-criteria decision making, ie in multi-criteria analysis. Accordingly, the impact of the potential number of driving school candidates in the Croatian counties, the number of active driving schools, the average net salary level per county, and the quality of public transport on demand for driving schools was researched.

2. DRIVING SCHOOLS SERVICE PROVISION SPECIFICATIONS

Driving school candidates evaluate the encounter with the candidates training service through two dimensions: technical, regarding the outcome or the result of service delivery, and through functional, regarding the process-oriented dimension of the service encounter. Economic theorists also introduce

the third dimension, ie the human dimension, which they describe as incentives that come from people such as: language, behavior, enthusiasm and appearance. [1]

This is an emotional encounter with the service and it has to be considered very seriously when designing a service offer in driving schools. Driving schools services are equally labor-intensive and capital intensive so it requires a very high level of adjustment for a particular candidate. Adaptations need to be implemented through the appropriate application of internal marketing elements in terms of engaging professional, patient and tolerant driving instructors, and by applying a number of elements of empathy and understanding for different candidates.

Practical field experiences indicate that driving instructors showed a higher inclination towards younger female population compared to older ones and so on. [2]

2.1 Environment impact on the services provided by driving schools

Each candidate training service is realized in a particular physical environment and this environment directly influences the training process itself as an atmosphere is created that directly influences the creation of elements that will help create a complete candidate training service. [3]

The efforts of the concept of service in creating services are to achieve the balance of its elements:

- vehicle and technical equipment,
- instructor,
- candidate,
- candidate training.

The process of candidate training system functioning can be somewhat compared to the production system, and then ask the question what is needed to create or "produce" a candidate training service.

This concept is easiest to explain by observing the elements of the material production process, namely:

- manpower,
- material elements that correspond to factory installations and tools used in the material goods production,
- service user.

In the case of driving schools, an interactive process takes place between candidates on the one hand and the visible and invisible elements of the organization of driving schools on the other. The process is a dynamic dimension that leads to experience, and takes place in the presence of candidates and instructors as service providers. [4] The quality of the process will be reflected in the speed of service delivery and ultimate satisfaction of the candidate with the overall impact of the training service. Thus, the process will be evaluated with quality if the candidate completes the training in the short term that will reach the ultimate goal of successful driving exams. The elements of the physical environment, in turn, assist the physical conceptualization of the service as an exchange object. The visible elements are the physical environment, classrooms, reception offices, equipment for theoretical and practical teaching, ie cars, motorcycles, etc. In addition, the instructors themselves, the regulations lecturers and the administrative staff also belong to the visible elements. Invisible elements of driving school are organizations and processes that support visible components, namely the establishment of schools as a company and their action plans, as well as the organization system of driving schools in the Republic of Croatia.

All present elements in the system as well as candidates influence each other by forming candidate experiences. Since providing a candidate training is a one-time service, there are no previous experiences, so knowledge and knowing about the potential service by passing the information through previous users is a very important element of. Studies conducted in driving schools in Croatia

show that good word promotion is an extremely important factor in choosing a particular driving school. [5]

3. THE IMPACT OF DEMOGRAPHIC TRENDS ON THE MARKET OF DRIVING SCHOOL SERVICES AND PLANNING DEMAND

In the Republic of Croatia is an evident trend of population declining. Compared to 2008, when the population estimates by the end of the year was 4.3 million, in ten years, more precisely by the end of 2017, this number decreased for 204 300 residents. Since 2000, there has been a trend of fewer births and for the first time that number fell below 40 000 in 2003. That every year fewer children are born, confirming the latest available data in 2017 when they were born 36.6 thousand.

Table 1 – Number of children born in the Republic of Croatia from 2000 to 2013

YEAR	NUMBER OF CHILDREN BORN IN THE REPUBLIC OF CROATIA	NUMBER OF ENROLLED CANDIDATES IN DRIVING SCHOOLS IN THE REPUBLIC OF CROATIA
2000.	43,746	---
2001.	40,993	---
2002.	40,094	---
2003.	39,668	---
2004.	40,307	---
2005.	42,492	---
2006.	41,446	---
2007.	41,910	76,750
2008.	43,753	69,062
2009.	44,577	57,912
2010.	43,361	45,618
2011.	41,197	47,267
2012.	41,771	46,255
2013.	39,939	54,911
2014.	39,566	54,254
2015.	37,503	---
2016.	37,537	---
2017.	36,556	---

Source: [6, 7]

Table 1 shows the data for number of children born in the Republic of Croatia from 2000 to 2013 and the number of candidates enrolled in driving schools in the Republic of Croatia from 2007 to 2014. According to the above data, Table 2 shows the relationship of number of enrolled candidates in driving schools in the Republic of Croatia compared to the number of children who were born 18 years ago.

In the Republic of Croatia there is a noticeable population decline, which is significantly reflected in demand planning for driving school services.

The two relevant components to such demand planning are:

- Number of children born 18 years ago or later
- Population migration younger than 18 years.

The number of children born 18 years ago is an indicator that explains how many children are getting mature in the year and gains the right to take the driving exam, while migration of the population under the age of 18 or with respect to ages indicates the deviations from the number of children will become mature and take a driving exam of the observed years.

Table 2 – Rate between the number of enrolled candidates in driving schools in the Republic of Croatia compared to the number of children who were born 18 years ago

YEAR	NUMBER OF CHILDREN BORN IN THE REPUBLIC OF CROATIA 18 YEARS AGO	NUMBER OF ENROLLED CANDIDATES IN DRIVING SCHOOLS IN THE REPUBLIC OF CROATIA THAT SAME YEAR
1989 / 2007.	about 57,000	76,750
1990 / 2008.	about 57,000	69,062
1991 / 2009.	about 57,000	57,912
1992 / 2010.	about 49,000	45,618
1993 / 2011.	about 49,000	47,267
1994 / 2012.	about 49,000	46,255
1995 / 2013.	about 55,000	54,911
1996 / 2014.	about 49,000	54,254
1997 / 2015.	37,503	---

Source: [6] [7]

Table 2 calculates the coefficient of correlation r according to the formula:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}} \quad (1)$$

where:

x – is independent variable (number of children born in Croatia 18 years ago)
y – is dependent variable (number of enrolled candidates in driving schools of the observed years).

The coefficient of correlation is r = - 0.05753. The correlation coefficient extends between -1 and 1, -1 means totally negative correlation, 1 means that there is completely positive correlation. Between -0,20 and 0,20 are minor correlations - so there is a slight negative correlation in this case.

Newer trends of increased migration of the population after the accession of the Republic of Croatia to the European Union require a more extensive analysis that would come out of the scope of the seminar work at the postgraduate study. For long-term planning of demand on the market of driving school services in the Republic of Croatia, important projections of the population are needed to allow enough time to adapt to the new situation. Demand planning is not only the number of population but the age composition. Demographers use multiple hypotheses to make projections, with the key ones assuming the continuation of negative demographic trends. The current attitude to demographic issues is supported by this assumption.

Population projections are based on the total number and age composition of the population census in 2011 and the series of vital statistics. [6] [7] Projections are based on the age and sex composition set out in the 2011 census, according to which all counties have an extremely regressive age structure type. Table 3 shows the projection of the number of population by counties until 2051.

Table 3 – Population projection by counties until 2051

CITY/COUNTY	POPULATION 2011 and projected POPULATION until 2051. YEAR				
	2011.	2021.	2031.	2041.	2051.
ZAGREB	317.606	324.867	327.532	325.986	321.871
KRAPINA-ZAGORJE	132.892	128.879	123.207	115.566	106.798
SISAK-MOSLAVINA	172.439	150.230	126.037	99.367	71.784
KARLOVAC	128.899	116.311	102.913	88.661	73.893
VARAŽDIN	175.951	172.553	166.621	158.221	148.008
KOPRIVNICA-KRIŽEVCI	115.584	111.481	106.128	99.124	91.206
BJELOVAR-BILOGORA	119.764	109.920	99.028	86.295	72.738
PRIMORJE-GORSKI KOTAR	296.195	287.181	272.590	255.036	238.860
LIKA-SENJ	50.927	43.577	36.630	29.710	22.715
VIROVITICA-PODRAVINA	84.836	78.281	70.764	61.451	51.217
POŽEGA-SLAVONIA	78.034	69.809	61.067	50.754	39.601
BROD-POSAVINA	158.575	148.032	136.727	122.576	106.496
Zadar	170.017	173.513	176.267	178.038	179.715
OSIJEK-BARANJA	305.032	293.087	276.336	254.088	229.136
ŠIBENIK-KNIN	109.375	97.548	85.973	73.520	61.194
VUKOVAR-SRIJEM	179.521	165.647	150.177	131.398	110.394
SPLIT-DALMATIA	454.798	446.244	434.294	415.360	392.471
ISTRA	208.055	205.481	199.256	190.885	182.207
DUBROVNIK-NERETVA	122.568	120.614	118.241	114.560	110.238
MEĐIMURJE	113.804	111.459	107.488	101.644	94.256
CITY OF ZAGREB	790.017	796.835	787.113	771.259	752.066
CROATIA	4.284.889	4.151.550	3.964.385	3.723.497	3.456.866

Source: [7]

Table 4 –Population of Croatia by large age groups in 2011 - 2051 (variant of medium fertility and medium migration)

AGE GROUPS	Population					Index 2051/2011 = 100,0
	2011.	2021.	2031.	2041.	2051.	
0 – 14 YEARS	652.428	600.622	527.491	464.412	420.669	64,48
15 – 64 YEARS	2.873.828	2.662.624	2.433.506	2.225.168	1.968.064	68,48
65+ YEARS	758.633	888.304	1.003.388	1.033.917	1.068.133	140,80
TOTAL:	4.284.889	4.151.550	3.964.385	3.723.497	3.456.866	80,68
STRUCTURE (IN %)						
0 – 14 YEARS	15	14	13	12	12	
15 – 64 YEARS	67	64	61	60	57	
65+ YEARS	18	21	25	28	31	
TOTAL:	100	100	100	100	100	

Source: [7]

Based on the increase / decrease of the total number of population until 2051, counties can be divided into five groups: the first, with two counties with an increase in the number of population (Zadar and Zagreb); second, with eight counties that have a total population reduction of 0 to 20%. From the point of view of demand research for driving school services in the Republic of Croatia, it is important to observe estimates for age group young people (0-14 years old), as the largest number of candidates comes from that age group population. Age group youths (0-14 years and not until 18 years old) are taken into account because we can obtain separate statistical data according to the methodology of the Croatian Statistics Institute for this age group. [7] [8]

This age group decreases in all counties, from 11.4% range in Zadar County to even 75.6% in Sisak-Moslavina County, which is an important indicator for planning demand for driving school services over the next 30 years. [8]

4. HIERARCHY MODEL OF DEMAND IN THE DRIVING SCHOOL SEVICE MARKET BY COUNTIES IN THE REPUBLIC OF CROATIA

4.1 Analytic hierarchy process (AHP)

The AHP method is a specific tool for forming and analyzing the hierarchy of decision making that allows interactive creation of problems hierarchy as preparation of decision scenarios, then comparing the hierarchy elements (goals, criteria and alternatives) in the top-down or bottom-up directions, and in the end, the synthesis of all rankings is performed and the weight coefficients are determined by the mathematical model, ie all elements of the hierarchy are standardized. The sum of all the coefficients at each level of the hierarchy is one (1), which enables the decision maker to rank all elements by importance [9] [10] [11]

Table 5 – Saaty fundamental scale of relative importance

Intensity of Importance	Definition	Explanation
1	Equally important	Two activities equally contribute to the goal
2	Intermediate value	
3	Moderately important	Experience and impression are moderate on the side of one activity
4	Intermediate value	
5	Strictly important	Experience and impression are strictly on the side of one activity
6	Intermediate value	
7	Very strict importance	One activity is very dominant over the other
8	Intermediate value	
9	Extreme importance	One activity is extremely dominant over the other

Source: [11]

To make comparisons, it is necessary to have a scale of numbers that represent weight, ie how many times more important or dominant one element is in relation to the other, respecting the same criteria. This scale of relative importance was created by the creator of the AHP method Thomas L. Saaty and consists of 5 levels and 4 intermediate levels of verbally described intensity and can be seen in Table 5.

4.2 Development of decision making model in the Expert Choice tool

Expert Choice is a decision support system based on AHP method. After introducing into the basic processes and principles of the decision support system and the methodology and the mathematical background of the AHP method, Expert Choice comes as a logical continuation that combines these two areas and also serves as a tool for the practical part of this article. The popularity of the AHP method can also be attributed to the development of this computer program that visualized and brought users closer to using the method for prioritizing alternatives and making decisions easier.

In order to successfully and efficiently carry out modeling the for driving school services demand in the Republic of Croatia, it is first necessary to clearly define the criteria. Below are the criteria that were used in further analysis:

- County market potential
- Average salary in the county

- Quality of public transport in the county.

Criteria have been determined based on past experience and consultation with experts in driving school activities. The results of the evaluation ie comparison of the criteria pair are written in the form of the matrix. Figure 1 presents the decision criteria and standard matrixes.

decision criteria matrix

	Market potential	Average wage	Quality of public transport	Geometric mean	Priority vector
Market potential	1,000	5,000	7,000	3,271	0,730
Average wage	0,200	1,000	3,000	0,843	0,188
Quality of public transport	0,145	0,333	1,000	0,364	0,081
	1,345	6,333	11,000	4,479	

Standard matrix

			Weight vector	Weight/ prior
0,743	0,790	0,636	2,169	2,970
0,149	0,158	0,273	0,579	3,076
0,108	0,053	0,091	0,251	3,091

λmax - 3,046

CI - 0,023

CR = 0,044

Priorities with respect to:	
LOCATION CHOICE TO OPEN DRIVING SCHOOL	
MARKET POTENTIAL	,731
AVERAGE WAGE	,188
QUALITY OF PUBLIC TRANSPORT	,081
Inconsistency = 0,06 with 0 missing judgments.	

Figure 1 – Ranking of decision-making criteria
Source: Authors

From the assessment of the relative importance of the appropriate hierarchy level elements, the local weights of criteria and alternatives are calculated based on which the optimal alternative is chosen. These calculations are based on a vector-specific method.

The market potential is estimated by the number of potential candidates per number of driving schools per county in the Republic of Croatia as shown in Table 6.

Table 6 – Relationship of the number of potential candidates to the number of driving schools per county in the Republic of Croatia.

Correlation between number of potential candidates and the number of driving schools per county in the Republic of Croatia			
Regional unit	M+F from 15-19 years	Number of current driving schools	Correlation between number of potential candidates and the number of driving schools per county
Republic of Croatia	218887	303	722
Zagreb County	17508	14	1251
Krapina-Zagorje County	6976	8	872
Sisak-Moslavina County	8470	12	706
Karlovac County	5768	13	444
Varaždin County	9335	8	1167
Koprivnica-Križevci County	6114	5	1223
Bjelovar-Bilogora County	6230	10	623
Primorje-Gorski kotar County	11980	24	499
Lika-Senj County	2426	3	809
Virovitica-Podravina County	4596	3	1532
Požega-Slavonia County	4450	6	742
Brod-Posavina County	9384	15	626
Zadar County	9286	14	663
Osijek-Baranja County	16192	35	463
Šibenik-Knin County	5396	8	675
Vukovar-Srijem County	10177	14	727
Split-Dalmatia County	25370	25	1015
Istra County	9007	10	901
Dubrovnik-Neretva County	6369	7	910
Međimurje county	6558	13	504
City of Zagreb	37295	56	666

Source: Authors

Based on Table 6 and Saaty fundamental scale of relative importance, comparisons are made between counties and a table of weight ratios according to the market potential criterion was made (Table 7).

Table 7 – Weight ratios according to the market potential criterion

	Z	ZC	KC	SMC	BBC	KKC	VC	KZC	Geometric mean	Priority vector
Z	1,000	5,000	0,333	1,000	1,000	5,000	5,000	3,000	1,829	0,166
ZC	0,200	1,000	0,143	0,200	0,200	1,000	1,000	0,333	0,374	0,034
KC	3,000	7,000	1,000	3,000	3,000	7,000	7,000	5,000	3,830	0,348
SMC	1,000	5,000	0,333	1,000	1,000	5,000	5,000	1,000	1,594	0,145
BBC	1,000	5,000	0,333	1,000	1,000	5,000	5,000	3,000	1,828	0,166
KKC	0,200	1,000	0,143	0,200	0,200	1,000	1,000	0,333	0,374	0,034
VC	0,200	1,000	0,143	0,200	0,200	1,000	1,000	0,333	0,374	0,034
KZC	0,333	3,000	0,200	0,333	0,333	3,000	3,000	1,000	0,817	0,074
									11,019	

Source: Authors

According to the criterion of market potential, Karlovac County is the highest ranked, followed by the City of Zagreb, Bjelovar-Bilogora, Sisak-Moslavina, Krapina-Zagorje Counties, while Zagreb, Koprivnica-Križevci and Varaždin Counties while equally well-ranked.

Data on average NET salary of employees per counties in the Republic of Croatia were drawn up according to the statistical data managed by company Poslovna Hrvatska were and presented in Table 8.

Table 8 – Average NET salaries of employees per county in the Republic of Croatia

Average NET salary per employee by counties		
Year	Regional unit	Average salary in county
2018	Republic of Croatia	6.283 HRK
2018	Zagreb County	6.025 HRK
2018	Krapina-Zagorje County	5.590 HRK
2018	Sisak-Moslavina County	5.342 HRK
2018	Karlovac County	5.627 HRK
2018	Varaždin County	5.731 HRK
2018	Koprivnica-Križevci County	5.428 HRK
2018	Bjelovar-Bilogora County	5.267 HRK
2018	Primorje-Gorski kotar County	5.921 HRK
2018	Lika-Senj County	5.697 HRK
2018	Virovitica-Podravina County	5.152 HRK
2018	Požega-Slavonia County	5.200 HRK
2018	Brod-Posavina County	5.421 HRK
2018	Zadar County	5.872 HRK
2018	Osijek-Baranja County	5.502 HRK
2018	Šibenik-Knin County	5.733 HRK
2018	Vukovar-Srijem County	5.361 HRK
2018	Split-Dalmatia County	5.857 HRK
2018	Istra County	6.148 HRK
2018	Dubrovnik-Neretva County	6.125 HRK
2018	Međimurje county	5.569 HRK
2018	City of Zagreb	6.396 HRK

Source: Authors

Based on Table 8 and Saaty fundamental scale of relative importance, average salary per counties were compared and a table of weight ratios was made according to NET salary criterion (Table 9).

Table 9 – Weight ratios according to the average salary criterion per counties

	Z	ZC	KC	SMC	BBC	KKC	VC	KZC	Geometric mean	Priority vector
Z	1,000	0,333	0,200	0,143	0,143	0,200	0,200	0,200	0,240	0,025
ZC	3,000	1,000	0,333	0,200	0,200	0,333	0,333	0,333	0,443	0,047
KC	5,000	3,000	1,000	1,000	1,000	1,000	3,000	1,000	1,609	0,169
SMC	7,000	5,000	1,000	1,000	1,000	1,000	1,000	1,000	1,560	0,164
BBC	7,000	5,000	1,000	1,000	1,000	1,000	1,000	3,000	1,789	0,188
KKC	5,000	3,000	1,000	1,000	1,000	1,000	1,000	1,000	1,403	0,147
VC	5,000	3,000	0,333	1,000	0,333	1,000	1,000	1,000	1,066	0,112
KZC	5,000	3,000	1,000	1,000	1,000	1,000	1,000	1,000	1,403	0,147
									9,512	

Source: Authors

According to the average salary criterion, the highest ranked was Bjelovar-Bilogora County, followed by Karlovac, Sisak-Moslavina, Koprivnica-Križevci, Krapina-Zagorje, Varaždin, the City of Zagreb and the Zagreb Counties.

Based on the available information on the coverage of the lines and timetables of the public transport of passengers, according to the Saaty scale of relative quality, urban public transport in the counties was compared and a table of weight ratios was made according to the public transport quality criteria (Table 10).

Table 10 – Weight ratios according to public transport quality criteria

	Z	ZC	KC	SMC	BBC	KKC	VC	KZC	Geometric mean	Priority vector
Z	1,000	0,333	0,200	0,143	0,143	0,143	0,200	0,143	0,220	0,023
ZC	3,000	1,000	0,333	0,200	0,200	0,200	0,333	0,200	0,390	0,041
KC	5,000	3,000	1,000	0,333	0,333	0,333	1,000	0,333	0,810	0,085
SMC	7,000	5,000	3,000	1,000	1,000	1,000	3,000	1,000	2,053	0,216
BBC	7,000	5,000	3,000	1,000	1,000	1,000	3,000	1,000	2,053	0,216
KKC	7,000	5,000	3,000	1,000	1,000	1,000	3,000	1,000	2,053	0,216
VC	5,000	3,000	1,000	0,333	0,333	0,333	1,000	0,333	0,810	0,085
KZC	7,000	5,000	3,000	1,000	1,000	1,000	3,000	1,000	2,053	0,216
									10,439	

Source: Authors

According to the criterion of public transport quality, the highest ranked are Sisak-Moslavina, Bjelovar-Bilogora, Koprivnica-Križevci and Krapina-Zagorje Counties, followed by Karlovac and Varaždin County as well as Zagreb County and City of Zagreb. The choice of criteria in this multi-criteria decision model is based on the personal preference of decision-makers. After defining selection and evaluation criteria, the hierarchy AHP model is created in the Expert Choice computer program.

Figure 2 shows a hierarchy model that shows the structure of the problem (goal, criteria and alternatives)

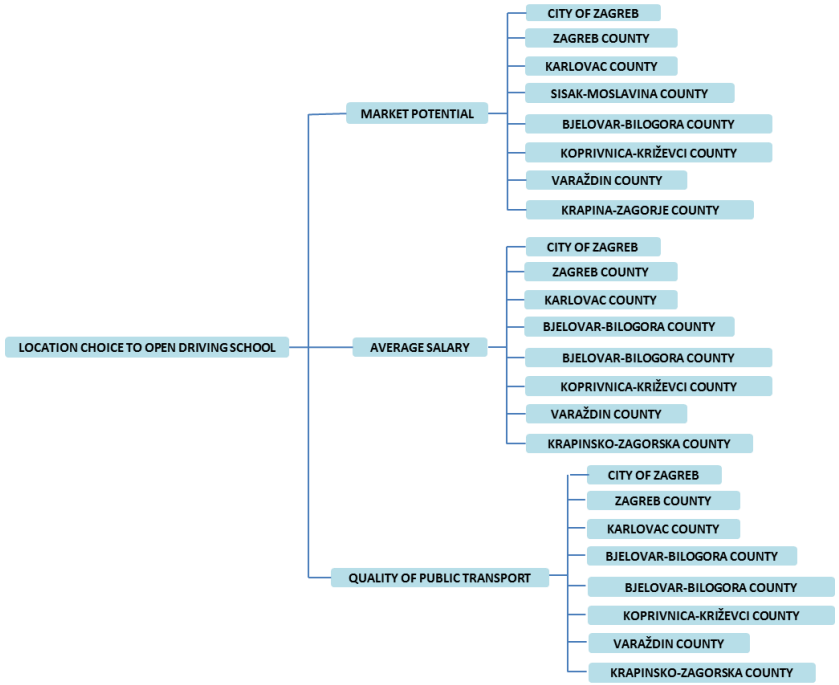


Figure 2 –The hierarchy structure of the demand ranking problem by Counties
Source: Authors

Ranking results according to the criterion of public transport quality, as shown in Figure 4, three counties come out the best because in these locations the quality of public transport is at a low level, ie it is more necessary to open a new driving schools than in the city of Zagreb where there is a high level of public transport.

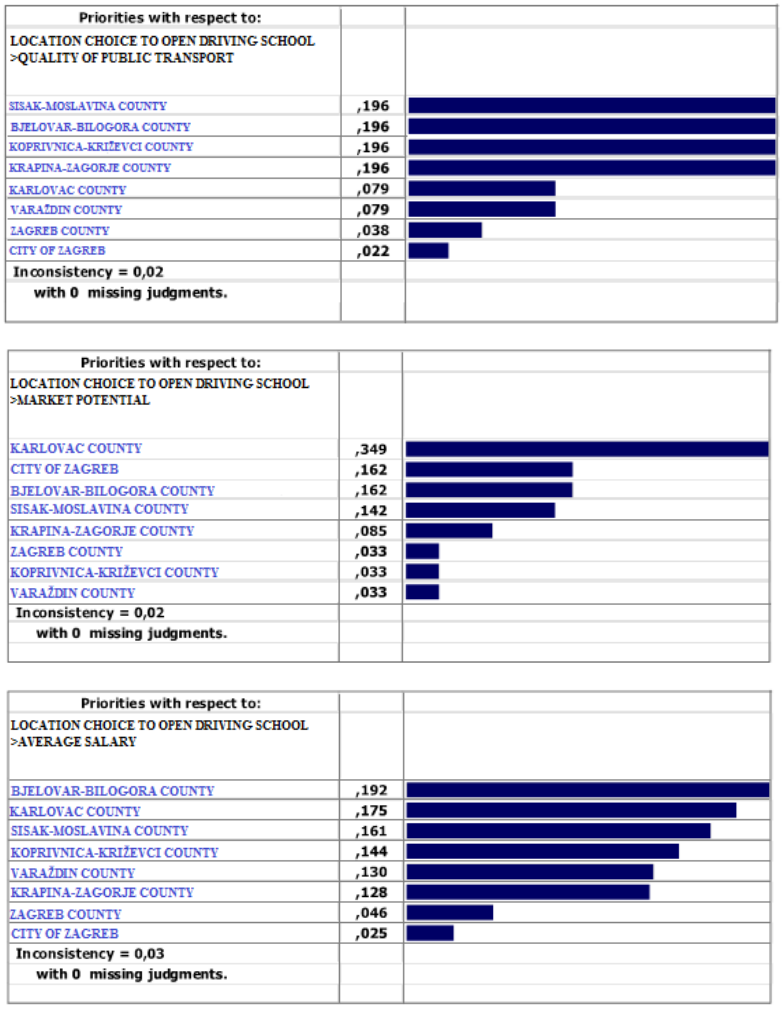


Figure 3 – Ranking by criteria of public transport quality, market potential and average salary
Source: Authors

Table 11 – Total ranking by criteria and alternatives

Alternative	Total	Market potential	Average salary	Quality of public transport
City of Zagreb	0,373	0,465	0,129	0,111
Zagreb County	0,135	0,094	0,214	0,196
Karlovac County	0,935	1,000	0,912	0,402
Sisak-Moslavina County	0,535	0,405	0,839	1,000
Bjelovar-Bilogora County	0,609	0,456	1,000	1,000
Koprivnica-Križevci County	0,291	0,094	0,749	1,000
Varaždin County	0,229	0,094	0,676	0,402
Krapina-Zagorje County	0,386	0,245	0,669	1,000

Source: Authors

After unification of all the analyzes carried out, Table 11 shows tabular and graphically displayed results of ranking according to criteria and alternatives and shows ranked demand by counties. The

best ranked was Karlovac County, followed by Bjelovar-Bilogora, Sisak-Moslavina, Krapina-Zagorje Counties and the City of Zagreb, Koprivnica-Križevci, Varaždin and Zagreb County.

5. CONCLUSION

Using the analytic hierarchy process (AHP) and work in the Expert Choice computer program, which brings together all the above, according to established criteria, a hierarchical model of demand for driving schools services by counties has been created.

Using the quantitative variables and qualitative estimates of the relative criteria weighting, the results of this research were obtained in terms of demand ranking for driving school services by counties in the Republic of Croatia, as a recommendation and support in assessing the market justifiability of the number of existing driving schools, ie the need to open new driving schools by counties in Republic of Croatia.

Consequently, the use of AHP-based Expert Choice computer expert system really facilitates and improves the quality of decision-making on the choice of location for opening driving school, as it allows structuring of complex problems and thus provides the user with a wider picture, as well as the possibility of detailed "what if" analysis of various scenarios and thus enables you to discover the strengths and weaknesses of all alternatives. Precisely the ability to perform sensitivity analysis of individual criteria and direct reflection of changing input settings to output results makes the AHP method a powerful tool for application in modeling.

On the other hand, the disadvantages of this method are mostly related to the decision makers' preferences that come to light when selecting criteria in the model and especially when defining the relative importance of each criterion. Such a subjective assessment may sometimes be called into question if the decision maker does not know the problem entirely. To some extent, this disadvantage can be avoided by including additional criteria and by employing more experts from relevant areas that team up for evaluation.

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PREDRAG BRLEK, Ph.D.[1]
E-mail: predrag.brlek@unin.hr
IVAN CVITKOVIĆ, B.Sc.[1]
E-mail: ivan.cvitkovic@unin.hr
ANA GLOBOČNIK ŽUNAC, Ph.D.[1]
E-mail: ana.globocnik.zunac@unin.hr
[1] University North
Trg Žarka Dolinara 1, 48000 Koprivnica

COSTS AND BENEFITS OF DEPLOYING COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS IN THE EUROPEAN UNION

ABSTRACT

The coordinated and rapid deployment of cooperative, connected and automated vehicles in road transport urgently requires EU action. If successful, deploying these vehicles will make an important contribution to improving road safety, increasing the efficiency of road transport, and ensuring the competitiveness of EU industry. This paper evaluates the economic, social and environmental impacts of the widespread deployment of cooperative intelligent transportation systems (C-ITS) in Europe through cost-benefit analysis.

KEY WORDS

C-Roads; C-ITS; cost-benefit analysis

1. INTRODUCTION

In many aspects today's vehicles are already connected with various devices. However, in the near future, they will also communicate directly with each other and with road infrastructure. This interaction is the domain of Cooperative Intelligent Transport Systems (C-ITS), which will enable traffic participants and traffic managers to exchange information and use it to coordinate their activities. It is expected that this element of cooperation - facilitated by the digital connection of the vehicle and between the vehicle and the traffic infrastructure - will significantly improve road safety, traffic efficiency and driving comfort, in this way helping the driver to make the right decisions and adapt to the traffic situation. Communication between vehicles, infrastructure and other traffic participants is also crucial to increasing the safety of future automated vehicles and their full integration into the overall traffic system. Collaboration, connectivity and automation are not just complementary technologies; they intensify each other and, over time, will be fully merged.

2. EUROPEAN STRATEGY FOR MOBILITY OF THE FUTURE

The goal is to make Europe a world leader in the introduction of related and automated mobility, to make a step-by-step approach to reduce the number of road deaths, reduce emissions from traffic and reduce congestion. It is expected that driving mobility without drivers - when fully integrated into the entire transport system and accompanied by appropriate support measures and synergies between driver mobility and decarbonisation measures - will significantly contribute to achieving these key social goals. Ultimately, it is expected that this will lead to the achievement of the so-called zero goal, i.e. without fatalities on European roads by 2050. [1] Automated vehicles are not yet ready for human-free operation. There are still many technical challenges that need to be solved to ensure that the vehicle can fully feel its environment, understand it, and take the right actions as it does to the human driver. Different levels of automation are described in the following figure.

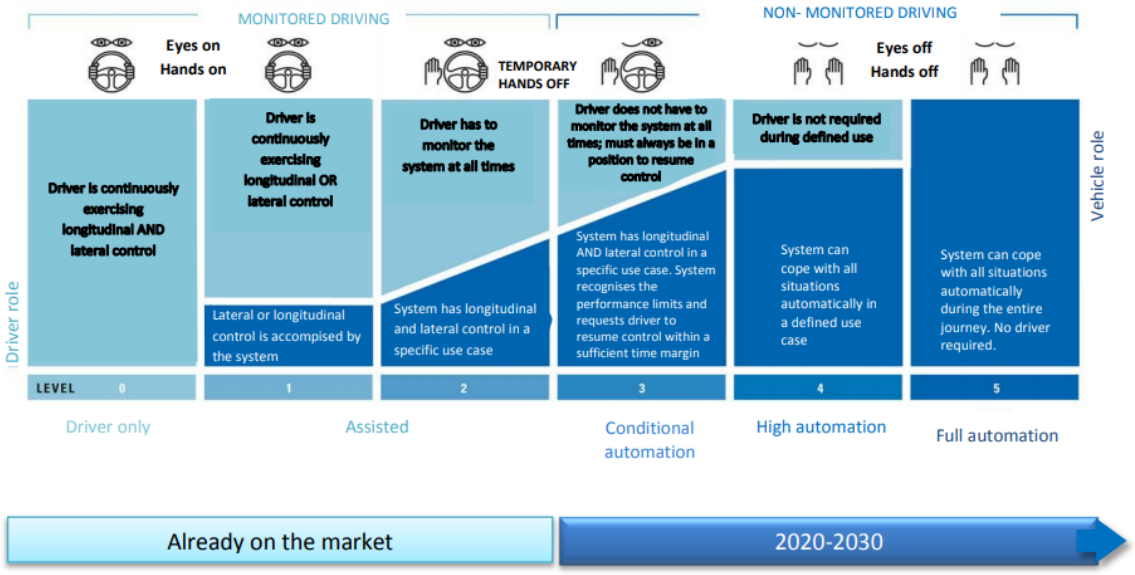


Figure 1 – Different levels of automation
Source: Society of Automotive Engineers-SAE

3. C-ROADS PLATFORM

The C-Roads Platform brings together road authorities and operators currently covering 16 European Member states. The C-ROADS platform as the leading initiative in introducing and harmonizing C-ITS services at European level has aim to contribute to the safe and sustainable road and transport objectives outlined in the EU transport policy document with a view to reduce the number of casualties and reduce congestion and their impact on the environment by using technology of intelligent transport systems. The main objective is to create a platform for the introduction of interoperable C-ITS services between various public / private sector stakeholders, such as national bodies, automotive industry, telecommunications operators and road authorities.

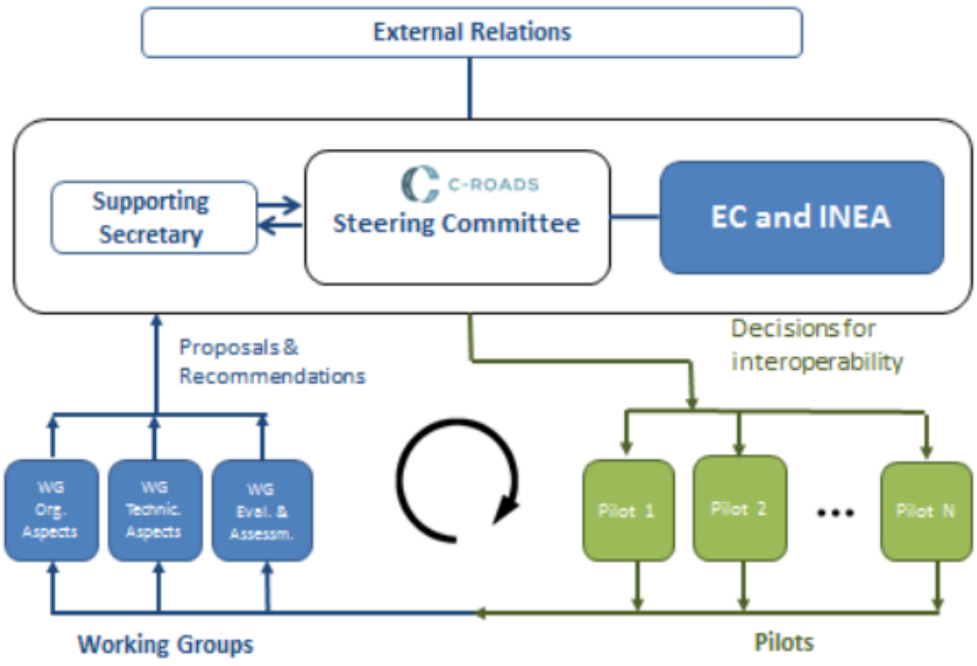


Figure 2 – C-Roads Structure
Source: Report on Legal and Organisational Structures for C-ITS Operation

The key element which is the base for such theory is a set of harmonized specifications for cooperative intelligent transport systems (C-ITS). Member States and infrastructure operators as implementing bodies are represented in the C-Road Steering Committee (SCOM) which provides an interface to all internal and external stakeholders, including European Services (European Commission and INEA). They are closely related to the C-road platform through the guidelines and the legislative framework of C-ITS. In addition, the Steering Board is leading and ensuring interaction with external stakeholders through dedicated workshops as well as the EU-C-ITS Platform and acts as the ultimate decision-making body on the C-platform platform. In order to allow for appropriate decisions on interoperable deployment, the working groups are set up as a decision-making support to the Steering Board, bringing together experts from member states and individual experts participating in individual pilots and appointed by the C-Road Steering Board. Different working groups are focused on validation and consolidation in light of the preparation of the recommendations.

4. SAFETY C-ITS SERVICES

4.1 In-vehicle (dynamic) speed limits

This type of service would notify the speed limitation vehicle that is applied to the road you are currently driving. One example of the vehicle technology that would use this service is Intelligent Speed Assistance (ISA), of which those using dynamic speed limits can be considered C-ITS. ISA is an oversized system that transfers the current speed limit with digital cards and speed sign recognition to the driver and helps the driver to keep the limitations. Excessive speed is the biggest factor contributing to fatal traffic accidents, and ISA is expected to reduce collisions by 30% and death by 20% [2].

Significant advantages of safety and efficiency can therefore be expected from the use of vehicle speed limitations associated with ISA, provided that dynamic information is used. The ETSC therefore urges Member States and the European Parliament in the upcoming revision of the General Safety Regulation 661/2009 to propose an excessive system of intelligent assistance at speeds that cannot be included for all new passenger cars by 2020. New commercial vehicles are expected to be equipped with auxiliary ISA system by 2020, in line with European Commission evaluation study. [3] The system should be locked up to 100 km / h for buses and 90 km / h for trucks, in accordance with existing EU legislation on speed limiters. In addition, although the speed limit icons are generally well understood, consideration should be given to how the temporary speed limits are displayed in the vehicle.

4.2 Weather conditions

This C-ITS service would inform drivers of dangerous weather conditions such as fog, rain, and ice. It would be particularly useful if the service is related to speed limits in the vehicle, thereby informing the driver and the vehicle of the appropriate speed for the driving conditions. In addition, the system will alert you to these dangerous weather conditions which is hard to notice visually by the driver, such as wind rains. However, it is still necessary to develop clearly understandable messages and symbols.

4.3 Road works warning

This service will inform drivers about upcoming road works, including possible limitations and reduced speed limits. Therefore, it will improve safety for workers, especially if speed limitations around the site are announced in the intelligent vehicle assistance system.

4.4 Emergency electronic braking light

When the driver suddenly breaks, the vehicle will turn on the emergency braking lights. This service should warn the next drivers at the moment of sudden speed reduction, so that the speed can then be adjusted to avoid crashes. The service has the potential to reduce collision as an extended warning

system for collision ahead, especially in weather conditions where visibility is weak, such as fog. However, there is a possibility that drivers will rely solely on the system and therefore drive at a higher speed, thereby increasing the risk of collision again. Drivers should therefore be informed about the safe operation of the system. Additionally, the HMI of this service should also be specified because there is a possibility that drivers will not understand why they are warned without consistency. In addition, low latency and high signal reliability are required for this system to function effectively.

4.5 Intersection safety

Intersection crashes are a major problem and tend to be quite severe. With this service, drivers will be warned when they are in danger of violating the red light, or when another road user will make such a violation of the red light. Drivers can also receive warnings and get help negotiating unsolved intersections. In addition, consideration should be given to the combination of automatic braking technology. Extensive research is still needed to determine how negative impacts, such as possible signalling violations, may be limited and its benefits maximally increased. In order to achieve maximum benefits and prevent drivers from expecting assistance when it is unavailable, additional vehicle equipment is likely to be required.

5. COST BENEFIT ANALYSIS OF COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS (C-ITS)

Cooperative Intelligent Transport Systems (C-ITS) use technologies that allow road vehicles to communicate with other vehicles, traffic signals and road infrastructure, as well as other traffic participants. Systems are also known as communication from vehicle to vehicle, or communication from vehicle to infrastructure. Along with the warnings generated from increased available information, these systems have a strong potential to improve road safety and road traffic efficiency. Due to these expected benefits and given the overall relatively moderate costs associated with deployment, there is a strong interest in facilitating rapid European-level trends that will turn into market production and early deployment. The European industry traditionally occupies a competitive position globally in the field of intelligent transport systems. Maintaining this privileged position in the area of cooperative systems is key: new business cases are emerging, and a greater number of participants at the international level is a challenge for Europe's competitiveness.

5.1 Economic Impacts

In all the scenarios that connect new vehicles (i.e., the installation of vehicle communication modules) aftermarket is the dominant cost element (see Figure 3). It is estimated that up to 30 million cars will be connected annually, representing the cost of equipment up to € 3Bn per year, with 1/6 of it costs from the aftermarket device (although not as sharp as in the chart, they are expected to be phased out as all future cars will be connected to the OEM).

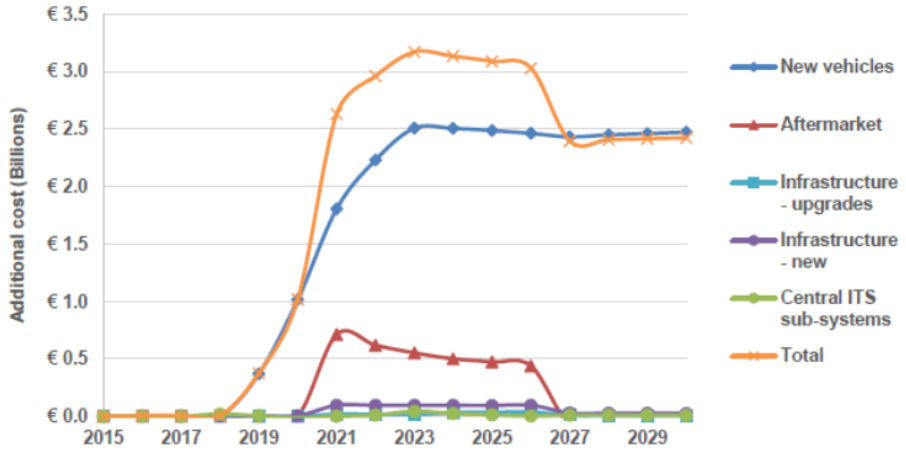


Figure 3 – Costs for C-ITS deployment [4]

Infrastructure costs, on the other hand, are limited to annual investments of around 95m €, so that while many questions about real infrastructure upgrade costs remain and infrastructure investments may still be indicative of a particular local application, it is clear that they will not have a major impact on the overall cost and benefit analysis at EU level. The impact of 2 billion hours or 3% of total time spent on the road, on the other hand, benefits approximately ⅔ total annual fees or 10 billion €. Most of these savings are realized through services related to crossings, parking information, and smart routing, which are not well-understood or supported by empirical data, particularly in the urban environment. While there is no doubt about the potential of such services and the positive cost ratio, it is also clear that there are a number of additional benefits, some of which are small, and we cannot all quantify them. For example, although the learning curves applied in this analysis, competition can quickly push prices faster than expected (note examples from the past include ABS and ESC). Also, initial feedback from pilot projects reported that drivers feel less stress, but this cost and benefit analysis did not assign (monetary) value to that. Another potentially big, but unprecedented benefit is that improved traffic flows can remove or at least delay investment in new infrastructure. [5]

5.2 Social impacts

Despite the substantial reduction in accidents in the baseline scenario (+/- 5% per year), specific safety services such as hazardous location warnings, vehicle speed limits and intersection safety are expected to reduce additional 7% in fatalities, as well as serious and minor injuries. It is the second largest contributor on the side of the fee of up to 3.5 billion €, which is saved annually by 2030.

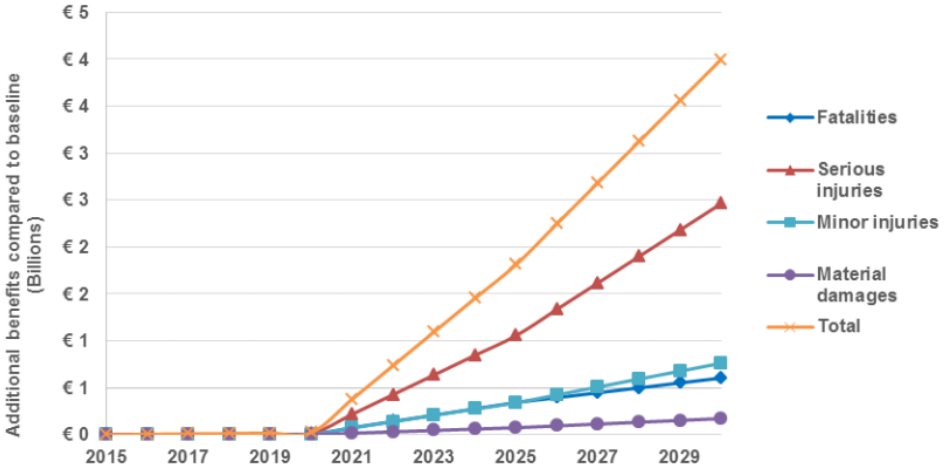


Figure 4 - Safety Benefits / cost reductions from C-ITS [4]

5.3 Environmental impacts

Fuel consumption and CO2 emissions are expected to fall by 1.2% by 2030, equivalent to 1.6 billion € (of which only 0.2 billion € on the emissions side, due to the relatively low unit costs of CO2). Other emissions, such as NOx, CO, VOC and PM, are estimated at +/- 0.5%, resulting in an additional benefit of 33 million € per year by 2030. Although these savings are fairly insignificant when looking at the overall cost analysis and benefits may still have a significant local impact on air quality.

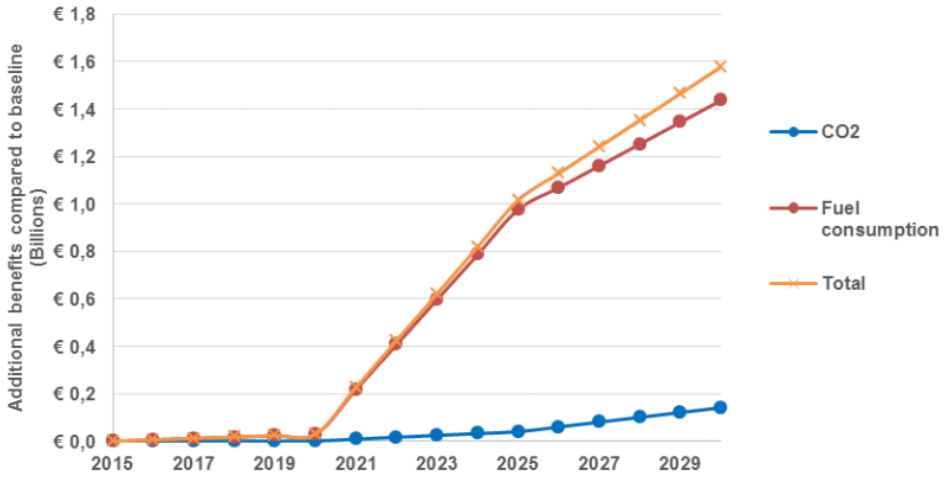


Figure 4 – Environmental Benefits / cost reductions from C-ITS [4]

6. CONCLUSION

Driverless mobility is becoming increasingly important and with deployment of Cooperative Intelligent Transport Systems (C-ITS) on Europe's roads will become even more significant. These new technologies will allow vehicles to 'talk' to the road infrastructure and to other road users and to each other. Vehicles, traffic signs and motorways will be equipped with technology to send standardized messages to all traffic participants around them. [6] This is necessary in dangerous situations and road works to make roads safer, cleaner and more efficient.

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GABRIJELA BUDIMIR ŠOŠKO, Ph.D.[1]
E-mail: gabrijela.budimir.sosko@gmail.com
KREŠIMIR BUNTAK, Ph.D.[2]
E-mail: krbuntak@unin.hr
DAVOR GRGUREVIĆ, Ph.D.[3]
E-mail: davor.grgurevic@gmail.com
[1] Znanstvena riječ d.o.o.,
Ilica 376, 10 000 Zagreb, Croatia
[2] Sveučilište Sjever
Ulica 104. brigade 3, 42000, Varaždin, Croatia
[3] Ministarstvo unutarnjih poslova RH
Ulica grada Vukovara 33, 10 000 Zagreb, Croatia

ANALYSIS OF SUSTAINABLE URBAN MOBILITY SOLUTIONS AS AN IMPERATIVE IN 21ST CENTURY

ABSTRACT

The current trends are showing that number of people living in urban areas are constantly increasing. Although, the urban areas contribute significantly to the economic growth and employment, they are the source of multiple problems, such as air pollution, congestion, noise pollution and safety - mainly caused by transport and traffic. The paper is analysing the current situation and trends related to the sustainable urban mobility issues and it gives a short review of urban mobility situation in Croatia. It was shown that an implementation of sustainable urban mobility solutions has a positive impact on long-term ecological sustainability, satisfaction of basic mobility needs of citizens, and equity of inter- and intra-generational mobility, as well as that this implementation represents an imperative in 21st centuries' urban areas. Beside the method of secondary sources, that included available scientific research, legal documents and other sources, the methods of analysis, synthesis and comparison were also used. The main aim of the paper was to give a scientific overview of the fast growing changes affecting the urban mobility and to warn of the urgency and the necessity of introducing sustainable mobility solutions.

KEY WORDS

urban mobility; sustainable transport; sustainable urban mobility plan.

1. INTRODUCTION

The current trends are showing that number of people living in urban areas constantly increasing. According to the European Commission data [1], in 2010, 73% of the people in Europe lived in urban areas, with the trend of increasing of this percentage to 80% by the year 2050. It is believed that some, more developed countries of the European Union, as Belgium, Denmark and Sweden, will have over 90% of their population living in urban areas by the year 2050. In Croatia, according to the World Bank in 2016, there were 59.28 % of the population lived in urban areas, showing an increasing trend as well [2]. Although, the urban areas contribute significantly to the economic growth and employment, they are the source of multiple problems, as well. These problems are mainly caused by transport and traffic. Namely, the problems are numerous: air pollution, congestion, noise pollution and safety are one among many others. The growth of private car use is not accompanying expansion of public transport networks, which cause reduced mobility of the citizens. There is an urgent need to solve this issues, as shown in the research where 90% of the European citizens declared that traffic situation in that area should be improved [3]. The obvious solution to these issues is the development and the implementation of the sustainable urban mobility solutions. This paper is analysing the urgency and

the necessity of implementation and further development of sustainable urban solutions, as well as giving an overview of the current strategies, policies and practises covering these issues. Also, it includes scientific literature overview of this subject. Hypothesis were set as follows:

H1 The implementation of sustainable urban mobility solutions has a positive impact of long-term ecological sustainability, satisfaction of basic mobility needs of citizens, and equity of inter- and intra-generational mobility.

H2 The implementation of sustainable urban mobility solutions represents an imperative in 21st century urban areas.

Beside the method of secondary sources, that included available scientific research, legal documents and other sources, the methods of analysis, synthesis and comparison were also used.

The aim of the paper is to point out the importance and to give the overview of the fast-growing changes affecting the urban mobility and to warn on the urgency and the necessity of introducing sustainable mobility solutions, as well as to raise awareness on these issues.

2. SUSITANABLE URBANISATION AS A MAIN GLOBAL CHALENGE IN 21ST CENTURY

It should be mentioned that the European Union has recognized sustainable urbanisation as a main global challenge in 21st century and therefore issued the document named "The Sustainable Urban Mobility Plan" [1], consisting of ten principal reasons for implementing it, as shown in Table 1.

Table 1 – Principal reasons for adopting Sustainable urban mobility plan

Number	Principal reasons for adopting Sustainable urban mobility plan
1	Improving quality of life
2	Saving costs and creating economic benefit
3	Contributing to improved health and environment
4	Making mobility seamless and improving access
5	Making more effective use of limited resources
6	Winning public support
7	Preparing better plans
8	Fulfilling legal obligations effectively
9	Using synergies, increasing relevance
10	Moving towards a new mobility culture

Source: [1]

These principal reasons have been chosen since there is strong evidence that the sustainable urban mobility planning increases the quality of life in urban areas [1]. Further, healthier environment is reducing local community costs and therefore attracts new investors, confirming the strong influence of mobility on local economy. There are numerous positive effects on health and environment since it consequently results in better air quality, less noise and more active forms of travelling, such as walking and cycling. Also, it is an excellent tool to create multi-modal door-to-door transport solutions and causes the change of focus from solely road-based infrastructure to the balanced mix of measures including lower cost mobility management measures, ensuring the most cost-effective use of available funds. Similarly, many examples are showing that sustainable urban mobility planning creates a common vision of a new mobility culture that is supported by politicians, the general public and institutions and that provides long-term benefits [1].

However, creating a solution for sustainable urban mobility that is easily accessible, efficient and environmentally friendly is not an easy task since it includes many different factors that are dependent on how urban transport itself develops in the future, and the directions in which it will move based on technological progress, demographic changes, socioeconomic and environmental developments and the effects they will generate.

According to Lima [4] the sustainable development, beside physical and economic questions, contains also the social, environmental, political and cultural issues that should be taken into consideration in transportation planning. There is an instrument developed – The Sustainable Urban Mobility Index, in order to evaluate mobility conditions [5]. This index covers global characteristics as well as specific point for each issue [6].

But, there are also the low-cost measures which can be integrated in practically every urban mobility plan as shown in Figure 1.

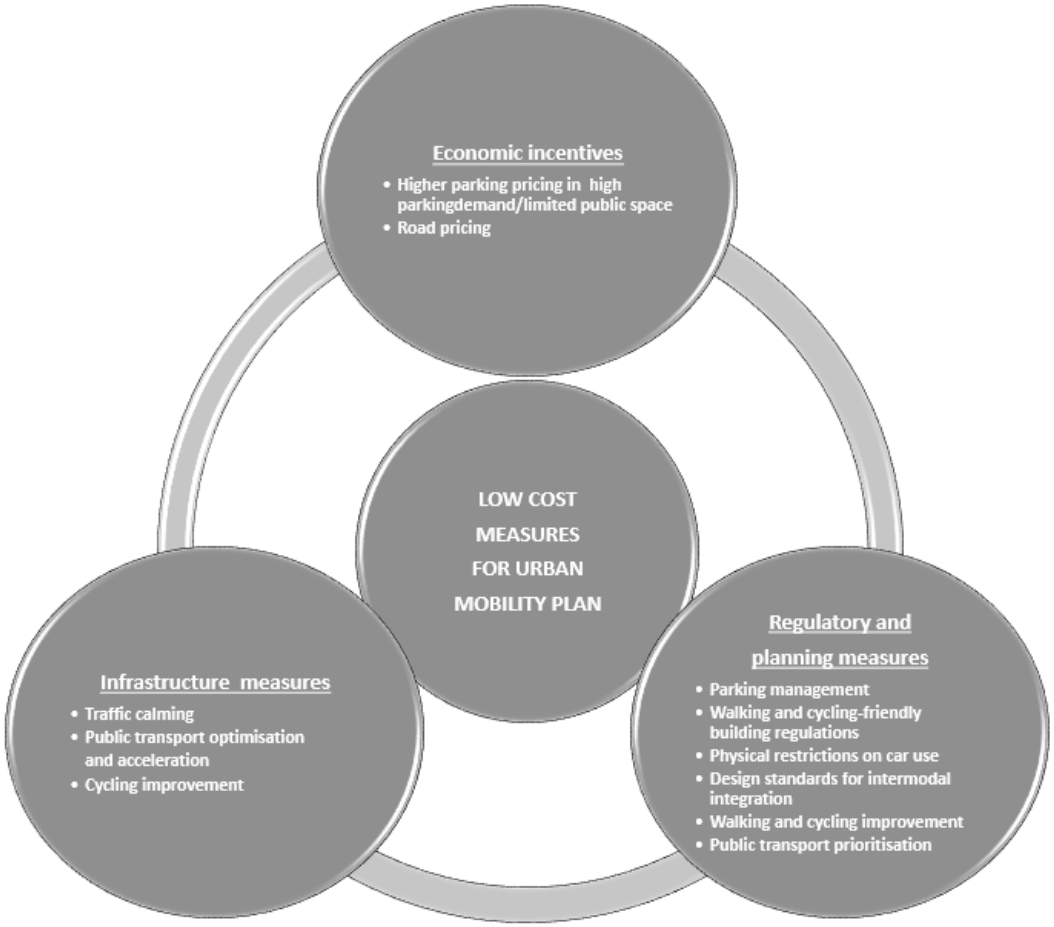


Figure 1 – Low cost measures for urban mobility plan
Source: [7]

There is an interesting example of convincing passengers to use the public transport system for both everyday and leisure time travel, suggested by [8] that included using of smartphones and a database with schedules for all Dutch public transportation systems. In order for mobile applications to affect passenger behavior and changing their travel habits, they should include information such as information about travel, including convenience information, planning, routing, access to shared mobility modes, booking, payment, price comparison of travel alternatives, safety and health advice, and social media applications. Gössling [8] suggested that applications can use the persuasion to support mode change towards “sustainable transport choices”.

3. SUSITANABLE URBAN MOBILITY ISSUES

There are several terms used in literature referring to the sustainable transport as are sustainable mobility, sustainable transportation, sustainable transport systems, and sustainability issues in transport [9], but basically, these terms can be considered as synonyms. Mainly, “sustainable

transport" is a preferred term in the North America, and "sustainable mobility" term prevails in the Europe [10]. Further, the main dimensions of the term "sustainable development" was set by the Brundtland Report [11] thirty two years ago, and it became a type of a standard and the point of reference for a sustainable development [12]. This report includes a broad spectrum of issues related to the sustainable development: political, social, economic and cultural issues, and is often called "broad sustainability." The primary goals of this concept are safeguarding long-term ecological sustainability, satisfying basic human needs, and promoting intergenerational and intergenerational equity [13].

The term "sustainable transport" as an integral part of the sustainable development concept was launched by the European Commission Green Paper on Transport and Environment [14] in 1992. It was characterized as a single disciplinary, focused mainly on environmental issues. However, during the time, the concept was considerably changed by emphasizing an multi-disciplinary approach with a focus on welfare distribution issues, as well as focusing on the leisure-time travel [9], [13], [15]. Nevertheless, an increased number of citizens in urban areas, as well as the developmnet of technology, have made a significant difference in urban transport planning when compared to the traditional planning approaches. The traditional approaches are mainly focused on expanding infrastructure for vehicles, while the sustainable urban mobility planning approaches are focusing on mobility and accessibility for all population groups, as shown in Table 2 [16].

Table 2 - Comparing of the traditional transport planning and the 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
Focus on particular transport modes	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
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: [16]

The European Commission [17] is suggesting adapting three characteristic in achieving sustainable transport:

- the impact of transport activities must not threaten long-term ecological sustainability.
- basic mobility needs must be satisfied (travel to work and other vital private and public services)
- the equity of inter- and intra-generational mobility must be promoted (everyone should have access to a specified minimum level of mobility)

However, translating these characteristics into appropriate sustainable transport indicators and goals is not an easy task and still, there is no consensus among different researchers. So, Holden [9] is focusing on developed countries and suggests the translation and the corresponding challenges with the following indicators for achieving sustainable transport:

- Halving their per capita energy consumption for passenger transport (to 8 kWh per capita per day) in accordance with the long-term ecological sustainability requirement and the inter-generational equity requirement.
- Increasing mobility for their low-mobility groups (to 11 km per capita per day available by public transport) in accordance with the basic transport-needs requirement and the intra-generational equity requirement.

These thresholds set by Holden [9] were calculated taking into consideration the Brundtland Report [11], which states that the 1985 global energy consumption of 9.9 TW is allowed to increase to 14.4 TW by 2030.

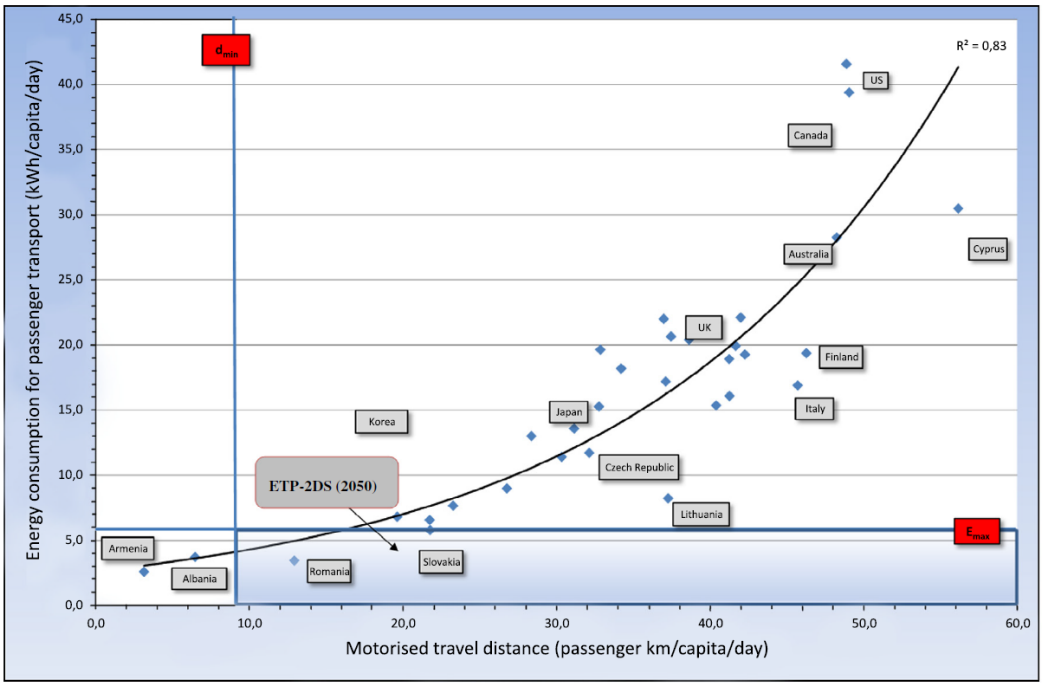


Figure 2 – The sustainable transport space (STS) for daily per capita energy consumption for passenger transport and daily per capita motorised travel distance
Source: [9]

As shown in Figure 2 there is a relation between the daily per capita energy consumption for passenger transport and the daily per capita travel distance by motorised transport, including air transport for selected countries. The lower right quadrant represents sustainable transport areas– areas where energy consumption per capita is below 5.6 kW h/day and travel distances per capita are above 9.2 km/day. The lower left quadrant is showing energy consumtion for the developing countries, however, the graph refers only to the countries that have been processed during the research. It is suggested that these countries should focus their sustainable transport strategy on decreasing per capita motorised travel.The upper right quadrant is showing the most developed countries which exceed the maximum per capita threshold of 5,6 kW h/day and it can be concluded that the mentioned countries should reduce their energy consumption for passenger transport while still satisfying basic transport needs. It is also noticeable that there are significant differences among the most developed countries in this quadrant, and therefore in achieving the sustainable transport, they are facing very different challenges [9].

In achieving sustainable transport, there are three main approaches: efficiency, alteration and reduction approach [9], as shown in Table 3.

Table 3 – Approaches for achieving sustainable transport

Approach	Policy orientation		
	Technology	**Regulation/ Economic instruments**	**Information**
Efficiency	Develop more energy efficient transport technology (e.g., government funding for demonstration programmes).	Regulate the use of more energy-efficient transport technology (e.g., emissions standards for vehicles).	Adapt to the use of more energy-efficient transport technology (e.g., buying smaller and less powerful cars).
Alteration	Develop new technology for more energy-efficient modes of transport (e.g., AGV(i), MAGLEV(ii) trains and Smart Cards(iii)).	Regulate the use of more energy-efficient modes of transport (e.g., lowering fares for public transport).	Adapt to the use of more energy-efficient modes of transport (e.g., increase the use of public and nonmotorised transport).
Reduction	Reduce travel demand through the development of ICT (e.g., attractive forms of mobile conferences and telecommuting).	Reduce travel demand through land-use planning (e.g., dense and concentrated housing development).	Reduce travel demand through increasing positive environmental attitudes (e.g., awareness campaigns).

Source: [9]

By analysing stated approaches and policies, the literature ([19], [20], [21], [22], [9], [23], [10]) points toward developing and implementing new technology, improving public transport, including cycling and walking, increasing the "green" attitude of an individual, promoting sustainable land-use planning, including transport infrastructure, enhancing ICT and deploying market-based instruments (taxes/subsidies), as the ways for achieving the sustainable transport.

The majority of the available research on sustainable passenger transport is focused on everyday travel rather than on sustainable leisure time transport [24], which is understandable since the needs related to these two types of transport are different. However, sustainable leisure time passenger travel should not be neglected since the share of leisure time travel in the total travel share is significant. In the European Union, leisure time travel makes one third of all travels [25], and since Croatia is primarily popular as a tourist destination, the share of leisure time travel in total passenger travel is not negligible. Moreover, it is expected that over the next decades, the number of leisure time travellers will increase, as the share of the older population will be higher and wealthier, with focus on the long distance air travel [26].

Based on the Brundtland Report's low-energy scenario, Holden [9] created seven scenarios trying to answer if the fifteen developed countries of the European Union can achieve the sustainable mobility by the year 2030, assuming the reduction in energy consumption for passenger transport not exceeding 8 kWh daily and that the available travel distance by public transport in 2030 needs to be at least 11 km per capita per day. First four scenarios employed a bottom-up approach, assuming the improvements in specific energy consumption, changes in occupancy rates and annual transport growth rates for each mode. Three scenarios employ a top down approach, so these scenarios per definition comply with the sustainable mobility requirements, and the models results in various combinations of the levels of specific energy consumption, occupancy rates and transport growth rates for all means of transport that would fulfil the sustainable mobility goals. The first scenario called „Business as usual“ (BAU) was used as a benchmark because it shows the effects of the actual pattern if nothing alters it, meaning that the growth in travel distance for all modes follows the same pattern as 1990-2000 and the specific energy consumption for all means of transport declines slowly. The conclusion was that according to this scenario, the European Union will not achieve sustainable mobility goals since it leads to 53% increase of per capita energy consumption for passenger transport and it also does not achieve the goal of public transport. In the second „Efficiency“ scenario, it was assumed that technological efficiency for all means of transport is increased, while growth in travel

distances for all modes is the same as in the BAU scenario. The result was that per capita energy consumption was stabilized at 2002 level, and it does not meet the sustainable mobility's public transport goal. The third scenario „Alteration" assumed the greatly increased use of public transport, while growth in total travel distances and reductions in specific energy consumption for all means of transport are at the BAU scenario level. The effect is not the realistic one, since the average travel distance by public transport in 2030 would be three times greater than today in Austria - the highest in the European Union. Fourth scenario „Reduction" assumed stopping the growth in passenger transport by car and plane, while total travel distances by public transport and specific energy consumption for all means of transport follow the BAU scenario. This scenario results in 25% per capita energy consumption increase while the public transport goal is met. Figure 3 is showing the last three scenarios compared to the BAU scenario [9].

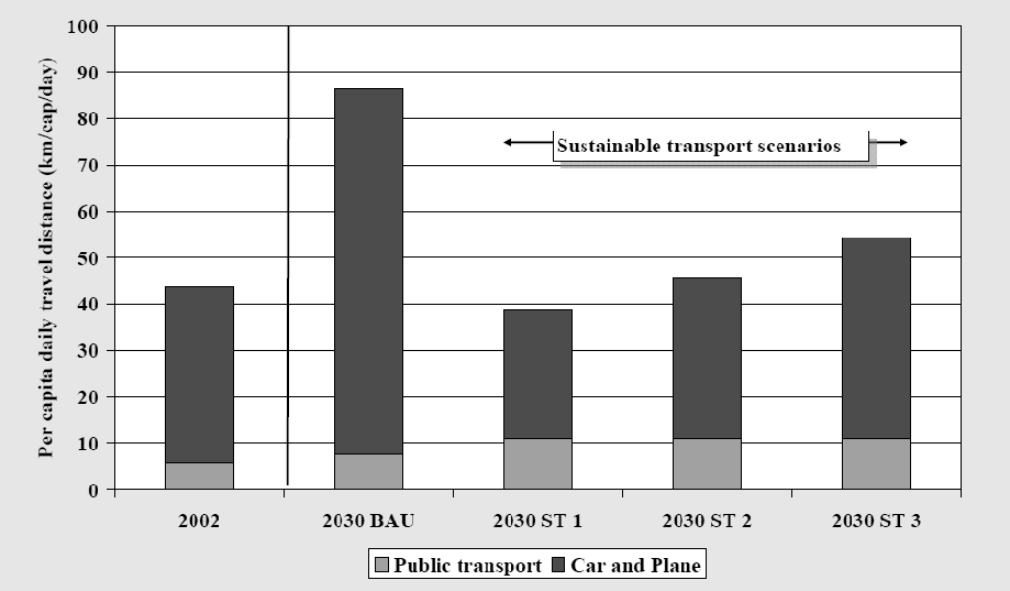


Figure 3 – Four 2030 sustainable passenger transport scenarios for EU-15
Source: [9]

These three combined approaches meet the sustainable mobility goals while demand is growing at least 2.5% per annum related to the travel distance by public transport. Sustainable mobility scenario (SM1) assumed that occupancy rates for all means of transport are increased by 10%, while specific energy consumption for all means of transport are reduced at the same amount as in the BAU scenario. Sustainable mobility scenario 2 (SM2) assumed the same level of increase of occupancy rates for all means of transport, but specific energy consumption for all means of transport is reduced at a level between the BAU and „Efficiency" scenario. The third, sustainable mobility scenario (SM3) also assumed that the occupancy rates for all means of transport is increased by 10% but the specific energy consumption for all means of transport is reduced as in the „Efficiency" scenario [9].

It can be concluded that a solution should be found in combining of technology development, increase in using of public transport, adopting green attitudes, careful land use planning and raising the awareness on travel behaviour of passengers.

Holden also argues [9] that sustainable transport passenger policies as planning more compact cities and investing in public transport infrastructure are directed to everyday travel but without an impact on leisure-time travel, especially on long travelles by car or plane and express concern that they could cause an opposite effect on leisure travel time since consuming the less energy in everyday travel could be compensated with consuming more energy in long leisure time travel. This was confirmed by the study from Andreew et al. [27] that reviewed a hundred studies on the effect of ICTS on

telecommuting, teleshopping and teleleisure. They concluded that there are four major direct effects of ICT on travel:

- substitution - ICT replacing existing travel
- complementarity - ICT generating new travel
- modification - ICT changing travel patterns
- neutrality - ICT having no effect on travel

The most prevalent for telecommuting was substitution and complementarity the most prevalent for teleshopping and teleleisure [27]. These findings could indicate that, although is not possible to make a precise prediction of technological development, that element is certainly a factor that should be taken into some consideration when making sustainable passengers plans for the future.

4. THE SUSTAINABLE URBAN MOBILITY SITUATION IN CROATIA

According to [28], Sustainable Urban Mobility Plans (SUMPs) in Croatia are not legally defined, there are no national guidelines for their preparation and they are not connected to the national funding sources. There are objectives of sustainability and political support for SUMPs, while public participation and technical possibilities for the preparation of SUMPs are limited.

In "Republic of Croatia's transport development strategy 2014-2030" [29], as the general goal was stated to achieve an efficient and sustainable transport system in the territory of the Republic of Croatia. Since the Republic of Croatia accessed the European Union, the strategy [29] contains principles, which are in line with the policies of the European Union, standards and regulations:

- Ensure environmental and social sustainability,
- Ensure safety and security,
- Ensure efficiency,
- Ensure financial sustainability,
- Improve accessibility and social inclusion,
- Improve energy efficiency,
- Improve modal split in favour of public transport, environmental friendly and soft modes (pedestrians and bicycle),
- Increase level of service,
- Ensure quality of service,
- Ensure interoperability of the system.

According to this strategy, the sustainable transportation system is one that:

- „Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations. Is affordable, operates efficiently, offers choice of transport mode and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components and minimises the use of land and the production of noise."

The current situation in the Croatian transportation system, according to the data from 2012 [30], there were 336 registered personal cars per thousand inhabitants, meaning that almost every third citizens in Croatia owns a personal car that is producing the damaging environmental issue. Croatian Agency for Environment suggested that air pollution can be reduced by inducing vehicles with catalytic converter, rejuvenation of vehicles and by using of the high-quality fuel. These measures were proven successful since emissions of polluting substances from road traffic has significantly decreased compared to 1990. Carbon monoxide (CO) emissions has decreased by 70%, nitrogen oxides (NOx) by

22% and lead (Pb) by 94 %, while in the same period, the total number of vehicles has increased by 52.4%. Out of that, 80.4% were personal vehicles, heavy trucks 2.2%, light trucks 7.2% while mopeds and motorcycles by 10.2%. After the initial growth, the consumption of liquefied gas and liquid biofuels in the last two years has increased considerably due to higher gas prices, i.e. reductions in the use of biofuels in the public transport system [30].

Safety and security were set to be the primary concern for the Croatian transport system, as well as creating the environment for safe transport [29]. As measures for improving safety, creation of user rights charters, adaptation of pracitces of safe modes to other modes, establishment of effective internalisation systems for the costs of accidents in each mode were mentioned. It was clearly stated that transport security is the important issue since risks related to transport security exposes the vulnerabilities of the entire transport supply chain.

However, although these are excellent goals, it remains the fact that in period between 2001 and 2010 (Figure 4), Croatia was among the three worst performing EU countries in terms of road safety, having 80 deaths per million inhabitants versus 49 which is the average of the European Union [31].

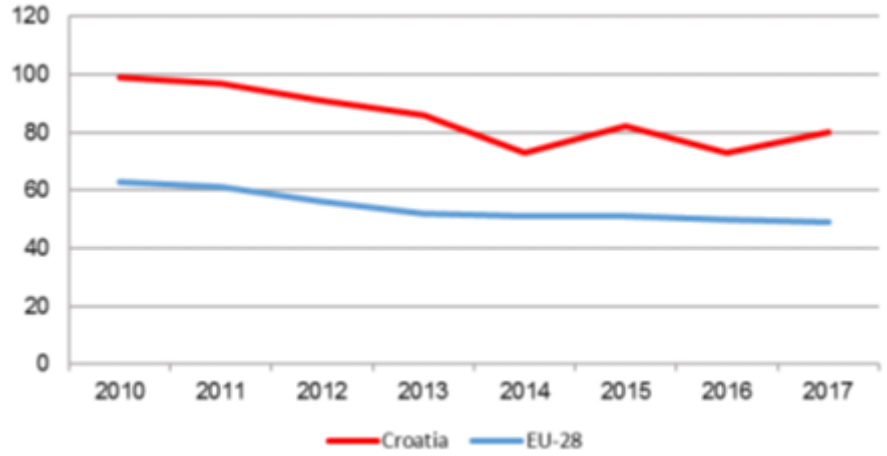


Figure 4 – Road fatalities per million inhabitants
Source: [31]

Other important issues set in the Croatia's transport development strategy 2014-2030 [29] were to insure efficiency of the transport system, including quality of services, enhanced transparency and public involvement, greater integration of transport modes, better-quality services, including adequate conservation systems and higher safety standards in all transport modes.

To conclude with, there is a lot of space for improvement in transportation sector in Croatia, especially bearing in mind the standards and recommendation of the European Union and other strategy documents related to the transport.

4. CONCLUSION

The number of people living in urban areas is increasing. These growing trends are going to continue. In developed countries of the European Union, these numbers are expected to increase by 80% by the year 2050. In Croatia, urban population makes 59,28% of the total population with an increasing trend as well. Urban areas represent a positive economic growth factor, but at the same time, represent a source of numerous problems such as air pollution, congestion, noise pollution and safety. Constant growth in living standards and technology development as a result has a comparatively high growth in the use of personal cars to carry out everyday travel. The problem arises from the fact that this growth is not accompanied by an expansion of the public transport networks, which all cause reduced mobility of citizens, especially in urban area. Therefore, it is not surprising that

90% of the citizens in the European Union stated that the traffic situation should be improved. So, it is clear that an urgent need to solve these issues exists. The European Union is, through different strategies, working papers and measures, as a solution of these issues, encouraging development of sustainable urban mobility solutions. However, the most sustainable transport passenger policies, as the planning more compact cities and investing in public transport infrastructure, are directed towards everyday travel but without an impact on leisure-travel time, especially on long travel by car and plane. It was shown that there is a danger that these measures could cause an opposite effect on leisure-travel time since consuming of the less energy in everyday travel could be compensated with consuming of more energy in leisure-travel at longer distances and of greater duration. Additionally, development of information and communication technologies produced an additional effect on travel, by the emergence of new categories of telecommuting, teleshopping and teleleisure. These trends are changing consumers preferences and the effects of substitution, i.e. replacement of existing travels by information and communication technology solutions, as effects of complementarity and modification appeared. It was shown that the most prevalent for telecommuting was substitution and the complementarity as the most prevalent for teleshopping and teleleisure. These findings are certainly factors that should be taken into consideration when making sustainable passengers plans for the future.

By analysing secondary sources, available scientific research, legal documents, institutional strategies and working papers, as well as different practises, mainly in developed countries and by using the methods of analysis, synthesis and comparison, it was confirmed that implementation of sustainable urban mobility solutions has a positive impact on long-term ecological sustainability, on satisfaction of basic mobility needs of citizens, and on equity of inter- and intra-generational mobility and that implementation of sustainable urban mobility solutions represents an imperative in 21st century urban areas.

Regarding the sustainable urban mobility development in Croatia, it was found that such plans were not legally defined, there were no national guidelines for their preparation and that they are not connected to national funding sources. However, there is a Republic of Croatia's transport development strategy 2014-2030 that set, as the general goal, an achievement of efficient and sustainable transport system in the territory of the Republic of Croatia, but public participation and technical possibilities for the preparation of sustainable urban mobility plans are limited. Although, the safety and security were set to be a primary concern for the Croatian transport system as well as creating the environment for safe transport, it remains the fact that in period between 2001 and 2010, Croatia was placed among the three the worst performing EU countries in terms of road safety, having 80 deaths per million inhabitants versus 49 in the European Union.

The aim of the paper was to point out the importance and to give a scientific overview of fast-growing changes affecting the urban mobility and to warn of the urgency and the necessity of introducing sustainable mobility solutions, as well as to raise awareness of this issues.

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LUCIJA BUKVIĆ, bacc. ing. traff.[1]
Corresponding author
E-mail: lucijabukvic01@gmail.com
JASMINA PAŠAGIĆ ŠKRINJAR, Ph.D.[1]
E-mail: jpasagic@fpz.hr
MARTINA JAKARA, mag. ing. traff. [1]
E-mail: mjakara@fpz.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

POSSIBLE APPLICATION OF ELECTRIC VEHICLES IN ZAGREB CITY LOGISTICS

ABSTRACT

Nowadays there are increased demands and orders for the distribution of goods, especially in urban areas due to constant population growth. Distribution of goods, which is mainly carried out by road transport in urban areas, results in traffic congestion, noise, emissions and harmful traffic generated by delivery vehicles. This paper deals with the topic of new trends in city logistics and distribution of goods in urban areas. New technologies, such as electric vehicles, contribute to the optimization of city logistics. Possible application of electric vehicles in city logistics is shown in the example of the city of Zagreb.

KEY WORDS

City logistics; mobile cabinets; electric vehicles; urban freight transport; city of Zagreb; last mile

1. INTRODUCTION

On a global scale, significant shifts in innovative solutions for decentralization of goods flows can be seen each year. In Europe, more than 50% of road transport, and fuel consumption are contained in urban areas. [1]

Last mile delivery takes up the most time and money in the entire delivery process, according to a study administered by Business Insider, which identifies the costs of last-minute delivery of 53% of the total amount of the process.

Much of the urban logistics take up deliveries up to 5km and at least 25% of those deliveries could be done by bicycle or any other non-motor vehicle. Human driven vehicles, robots or semi-autonomous vehicles should have a significant role at least in the segment of short-term delivery. [2]

The city of Zagreb cannot host large infrastructure projects in the urban center, which would generate large investment costs. Therefore, the focus needs to be shifted to more innovative and cheaper solutions based on maintaining the current infrastructure. Due to the lack of space and high consolidation centers construction costs, combining mobile package boxes with logistics centers on the city margins represents a solution with improving conditions for delivery staff as well.

Package boxes are locked storage units in accessible locations that serve as package collection spots. Mobile boxes pertain to electric vehicles where each box within the vehicle has its own electronic key chosen by users themselves during registration. This way, lockers can be used in different times by different users. For all supply chain subjects, it is vital to decrease the number of deliveries in urban centers, failed deliveries and returns. Package lockers shorten length of the vehicle trip, congestion and energy consumption. According to the research done by the Department of robotics and mechatronics in Krakow, such lockers in Poland can deliver 600 packages per day with length of the trip of 70km. The conventional delivery system delivers 60 packages with 150km. [3]

2. KEY INDICATORS OF THE EFFICIENCY OF PACKAGINGS IN CITY LOGISTICS

2.1 The analysis of the efficiency of packing cabinets in the last mile delivery

According to the *Global B2C*[1] *E-commerce Report 2014,* internet sales have been steadily increasing since 2010 and the growth rate is quite constant over a four-year period with an average value of 23.6% [4]

An increasing number of such purchases results in a larger number of deliveries in urban areas. Comparison of the method of collecting the end-customer's shipment is shown in *Table 1*. A particularly interesting solution is provided by mobile cabinets because they reduce the number of deliveries and improve their consolidation in order to be more independent of deadlines.

Table 1 – Comparison of delivery method

	Classic delivery	**Sort centers/Hubs**	**Electric locker vehicle**
Who covers the last mile?	Delivery company	Delivery company	End user
Presence of user	Yes	No	No
Product type	Various	Packages	Packages
Level of failed deliveries	High	Low (virtual)	Low (virtual)
Time windows	Fix time	Working hours	Depends on user
Time of delivery	Inappropriately	Working hours	24/7
Time of subsequent pick up	None	Working hours	User determines
Waiting for deliverer	Longer	Shorter	No waiting
Investment	Low	Middle	Low/Middle
Delivery expences	High	Middle	Low
Possible operative problems	Failed deliveries, Poor vehicle capacity usage	User collects package	User collects package
Delivery number reduction	No	Yes	Biggest reduction

Source: according to [4] adjusted by the author

2.2 Mobile parcel lockers as a system of last mile delivery

Packaging cabinets are in the traditional way of delivery, and in the form of an electric vehicle (*Figure 1*) parked at certain time intervals, they would reduce the number of deliveries to the home threshold and failed delivery.



Figure 1 – Electrical delivery vehicle with cabinets.
Source: [4]

[1] B2C- bussiness to customer, online shop

On the other hand, only an electric vehicle doesn't let off CO_2 emission during exploitation, which has a positive influence on urban pollution, and does not produce noise, which makes it the best choice for delivery in large city centers.

The vehicle can also receive shipments for sending, and for sending and delivering, a user account previously created on the site of the service provider is required. The system labels data packets from the system, and the user chooses the location of the vehicle and the time interval when offered. The whole process is accompanied by detailed reporting by the service provider via SMS or e-mail. In this way, the user can track the location of his package and collect it as soon as possible. [5]

2.3 The value of packaging cabinets/lockers in practice

Packaging cabinets have already proven to be a useful and innovative solution for any type of city with positive effects for users and online market. One such service provider is *InPost* with 300 package cabinets in countries of Europe, Asia, South America and Australia. Taking into account the growth of this type of sales, current and future generations will reap the benefits. Static/ fixed package cabinets would not be the best solution for the city of Zagreb as there already are 22 service providers with offices which redirect merchandise after failed deliveries. Other issues during static package cabinets setup planning are:

- terrain expenditure
- higher citizens' expenses (52% of citizens frequents shops during package pickups)
- needs to be set up on hubs of collections and deliveries
- terrain commercialization (ads on the cabinets)
- abuse of delivery system [6]

Therefore, an optimal solution for Zagreb would be electric vehicles with installed cabinets due to simple vehicle parking on spaces in proximity of fulfilment hubs. The main characteristics are shown by SWOT analysis in *Table 2*.

Table 2 – SWOT analysis of mobile package cabinets.

STRENGTH	WEAKNESSES
Users can access and pick their packages anytime	Electric mobile lockers are private property and local authorities
Users can track deliveries and be informed via SMS or e-mail	don't have informations on usage purposes
Reducing mileage and number of classic deliveries, emissions, noise and energy consumption	Buyer must walk to the vehicle to collect packages
Low delivery expences	High investment costs
OPPORTUNITTIES	**THREATS**
Efficiency goals for logistic service providers	Online shopping growth is expected so does the number of deliveries
Mobility - it can be used in locations where is the highest concentration of deliveries in real time	Thefts and devastation if there's no security mechanism

Source: according to [6], modified and adjusted by author

3. TESTING OF AN ELECTRIC DELIVERY VEHICLE IN CITY OF ZAGREB

The DPDgroup, as well as DPD Croatia invest into new technologies to achieve a positive impact on areas closely connected with basic activities. Within the social responsibility program *DrivingChangeTM*, DPDgroup Made a commitment to CO_2 neutral delivery of each delivered package, with no additional costs to users. The purpose of the electric vehicle testing is to get acquainted with its performances and gain knowledge on how this type of vehicles works in daily situations in urban centers. For that same reason, the vehicle was tested on deliveries into the city center of Zagreb. The cargo space of the tested vehicle is $8m^3$ and it can transfer up to 600kg. The maximum speed it can achieve is 123km/h, which is more than enough to drive through the city center, as well as the length it can cross on one charge; 100 to 140 km. [7] *Table 3* shows the comparison of delivery into Zagreb city center by classic courier vehicle and the delivery by mobile package cabinets.

Table 3 – Comparison of classic delivery and delivery by electric vehicle.

	Classic delivery	Electric locker vehicle
Daily mileage (in km)	150	100
Daily number of delivered packages	60	400
Annual emissions of CO2	1.22 T	min
Annual energy source consumption	5584.5 l	15000 kWh
Annual energy source costs	55,845 HRK	8,400 HRK
Vehicle purchasing cost	150,000 HRK	216,000 HRK (+ lockers installation cost)

Source: according to [7] and [8], modified by author

By comparison from *Table 3*, we can see the difference in vehicle acquisition price, but for, the return on investment comes already in year 3 of utilization. Zagreb still has a relatively low number of electric vehicles, only 465 including motorbikes, whereas the total number of registered vehicles is over 2 million. For that reason, charging the vehicles on Zagreb's electric charging stations is still free at the moment. Having that in mind, the investment return even sooner.

The most important factor of vehicle efficiency is its placement on important locations in the city. According to *InPost* data, the best locations are close to:

- local *hot-spots* - shops, high inhabitation density, squares between buildings
- shopping centers, supermarkets, stores
- train stations, bus and tram terminals
- business parks

Area Medveščak belongs to central, core part of Zagreb. Surface of it is 10km^2, which calculates to 3.096 inhabitants per square km. Upper town attracts the biggest concentration if people during the day, and because of pedestrian zones coverage, service providers have already turned to new ways of delivery. [10]

Deliveries between 10 pm and before 7 am are charged with penalties for conventional vehicles in this part of the city. This results in reducing traffic congestions and problems of blocked view caused by delivery vehicles.

Traditional borders of Gornji grad (Medveščak) are shown in Figure 2 and Sljeme is on the north side. Polygons P_0 and P_1 are in similar size as slightly bigger parking space (15 m^2). Traditional borders of Gornji grad (Medveščak) are shown in *Figure 2* and Sljeme is on the north side. Polygons P_0 and P_1 are in similar size as slightly bigger parking space (15 m^2).



Figure 2 – Potential locations for placing electric locker vehicles.
Source: [11]

Suggestion for improvement considering the configuration of Zagreb city center is to locate two electric locker vehicles on:

- Britanski trg-Radnički dol – market, bus line terminal, gravity zone for population of west Medveščak and population from Podsljemenska zona.
- intersection at Tkalčićeva street and Tome Mikleušić street, high concentration of population flow through Tkalčićeva street, near Dolac market, business center Kaptol, pedestrian zone.

4. CONCLUSION

Constant growth of online B2C sales results in new demands for optimizing the last mile delivery in central urban areas. Great impact on delivering packages is also visible because of the traffic congestions caused by the delivery services, and mostly failed deliveries and reverse logistics generate more expenses. New technologies became an inevitable way for all the stakeholders in supply chains in finding a more environmentally friendly (greener) way.

So to solve the problem of implementation of electric delivery vehicles with built in package lockers that would improve the failed deliveries problem presents a great idea for the city of Zagreb, so the users can collect their packages in adapted intervals and in nearby locations. The costs of acquiring such vehicles returns in 3 to 5 years, and the level of emissions caused by conventional delivery vehicles is reduced by at least 20 percent per delivery. Due to environmentally friendly operating, the vehicles can enter the urban centers at any time as they do not produce noise and emissions so there are no penalties either. By placing the vehicles in two hotspots on Donjo Grad area, where there is a large concentration of pedestrians, there is asunstantial decrease in delivery path to delivery personnel and utilizers. The downsides of this type of delivery are possible theft of inventory or vehicle devastation as well as too small storage space in the vehicle for delivery of larger amounts of goods (over one pallette). In parallel to the economic sector, inovators have the opportunity to integrate electric vehicles into city logistics and adjust with the society and the ecological initiatives. That way,the knowledge of the economic sector should improve and the new findings can be applied to the existing infrastructure and consolidation hubs. Transformed models of city administration can progressively build trust among the citizens and Create new solutions for city logistics.

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CEM CETEK, Ph.D.[1]
Corresponding author
E-mail: ccetek@eskisehir.edu.tr
BILJANA JURIČIĆ, Ph.D.[2]
E-mail:bjuricic@fpz.hr
THOMAS FEUERLE, Ph.D.[3]
E-mail: t.feuerle@tu-braunschweig.de
TOMISLAV RADIŠIĆ, Ph.D.[2]
E-mail:bjuricic@fpz.hr
[1] Faculty of Aeronautics and Astronuatics
Eskisehir Technical University
Iki Eylul Kampusu
26555 Tepebasi, Eskisehir, Turkey
[2] Faculty of Transport and Traffic Science
University of Zagreb,
Vukelićeva 4, 10000 Zagreb, Croatia
[3] Institute of Flight Guidance
Technische Universität Braunschweig
Hermann-Blenk-Str. 27, 38108 Braunschweig, Germany

DEVELOPMENT OF COMMON ATC SIMULATION TRAINING ASSESSMENT CRITERIA BASED ON FUTURE PAN EUROPEAN SINGLE-SKY TARGETS (ATCOSIMA): A PROJECT OVERVIEW

ABSTRACT

This study aims to provide an overview of the ongoing 'Development of Common ATC Simulation Training Assessment Criteria Based on Future Pan European Single-Sky Targets (ATCOSIMA) project which primarily aims to develop common assessment criteria for simulation training courses within the ATCo basic training in order to improve students' competencies regarding working effectively and in harmony within the integrated Pan-European air traffic system; improve metrics and scoring tools for the evaluations of students according to SESAR's future targets and provide guidelines and recommended practices for enhanced ATCo training across the Europe. The project proposes an innovative approach to measure the performance of ATCo trainees in radar approach simulations based on integrated ATC radar and flight cockpit simulations. General methodology, real-time simulation and data collection processes and contributions of the project will be discussed.

KEY WORDS

Air Traffic Control; Radar Control Simulation Training; Human-in-the Loop Simulations; Fight Cockpit Simulations; Assessment Criteria.

1. INTRODUCTION

European Airspace accommodates one of the densest air traffic volumes in the world. The total of the flights reached over 11 million within the EUROCONTROL Network Manager (NM) Area in 2018 [1]. This traffic volume is expected to be multiplied by 1.2 to 1.8 by 2035 according to the long-term forecasts done by EUROCONTROL [2]. European Airspace, on the other hand, has been managed by numerous Air Navigation Service Providers (ANSPs) as presented in Figure 1 [3]. This fragmented structure leads to deficiencies in air traffic flow and capacity management. In order to eliminate these drawbacks and handle the ever-increasing air traffic safely, efficiently and economically, European Union (EU) launched Single European Sky (SES) initiative which aims to organize European Airspace

according to air traffic flows rather than national boundaries [4]. While SES provides a legislative framework towards integrated airspace and air traffic management (ATM) across the Europe, it is supported by Single European Sky ATM Research (SESAR) Joint Undertaking focusing on the technological dimensions of integrated European ATM system through coordinating and conducting innovative research and development efforts [5].

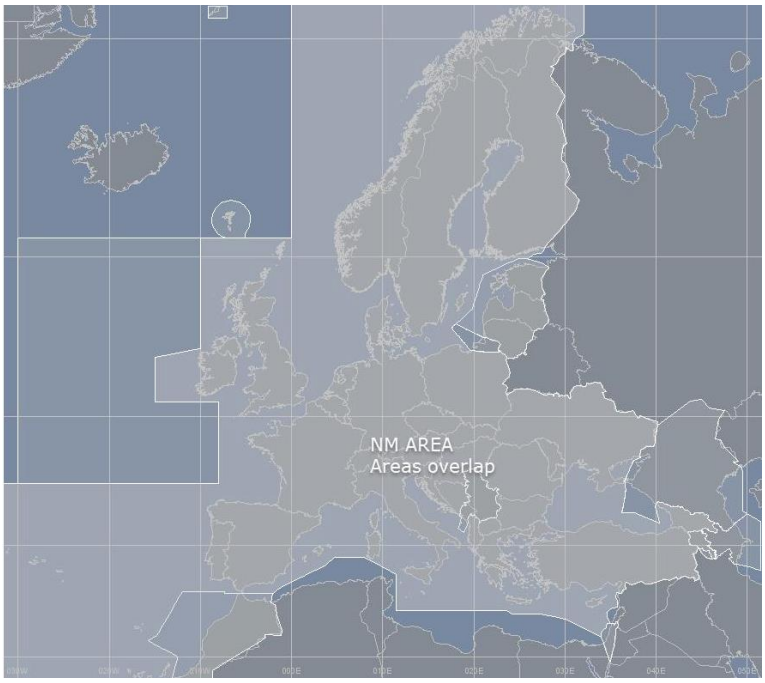


Figure 1 – EUROCONTROL Network Manager Area Boundaries
Source: [3]

Integration towards a Pan-European Air Traffic Management (ATM) requires not only adaptation of common legislative framework and technological infrastructure but also standardized air traffic controller training and assessment which support its safety, efficiency and economic targets for sustainable growth of future operations.

Air Traffic Controllers (ATCo's) are responsible for maintaining safe, orderly and expeditious air traffic flow within the airspace under their jurisdiction according to national and international regulations. While complying with these duties, they are in charge of planning, monitoring, controlling, coordination, communication, aircraft conflict detection and resolution tasks. Due to these complex and specialized requirements, air traffic control is considered as one of the most stressful professions in the world [6].

Although the nature of their role switches dramatically from a labour-intensive one to a more technology-intensive one with increasing level of automation, they will remain as the key component of this integrated ATM system [7]. ATCo candidates should go through a combination of intensive theoretical and practical training to acquire the required competencies. ATCo training consists of three phases: initial, unit and continuation training. Initial training includes basic training and generic rating training stages to prepare ATCo candidates for next and more specific training stages at operational ATC facilities. Basic training stage in the initial phase has a special importance because it imparts fundamental knowledge through theoretical classes and develops the required skills through practical classes using synthetic training devices referred as to Air Traffic Control (ATC) simulators [8].

Despite the main elements of course, content and methods to be used in the basic training are defined within EUROCONTROL Common Core Content [9] and EU REG 2015/340 document [10] regarding licensing and certification of ATCo's, similar to ATM, there is a diversity in training and

assessment processes of basic training across the Europe. These processes differ not only according to the specific approaches and practices adopted but also according to the study mode by each country. While some countries chose to provide basic training as a form of vocational training courses delivered by Civil Aviation Authorities (CAAs) or ANSPs, the other countries offer it as different academic degree programs in their higher education institutions [6]. All these trainings can be varied in terms of training hours, frequencies and percent shares, number of exercises, depth and breadth of theoretical and practical parts. Besides, there is no commonly agreed framework for assessment criteria especially for the practical parts of ATCo basic training. Although EU and EUROCONTROL documents state a set of general performance objectives for the training, they have two important shortcomings: neither they define any standard metrics and scoring for the assessment process nor they include SESAR's targets regarding efficiency and economics of traffic flow.

The Air Traffic Management (ATM) systems have been increasingly shifting towards automation driven by the technological advances in communication-navigation-surveillance (CNS) systems. Although numerous researches have been conducted regarding human factors issues to investigate impacts of automation and resultant paradigm shift on air traffic controllers [11], there are not many studies in the literature on how the training and assessment of future ATCos are to be performed especially for the simulation courses in the basic training stage. Previous studies proposed some basic principles for the assessment of simulation courses such as evaluations of skills regarding air traffic separation, control judgement, implementation of methods and procedures, equipment usage, communication and coordination [12]. The evaluations of these skills, therefore, are performed based on the safety and controller work-load precepts such as number and duration of airborne conflicts, occupancy, number and duration of ground-to-air communications etc. FAA also conducted several research projects for the performance measurement of ATCo candidates based on similar metrics such as over-the-shoulder (OTS) rating scale, count of mistake and counts of actions that would be required to move aircraft from the sector at the end of the scenario [13].

Several projects addressed requirements and guidelines for the initial training of future ATCo candidates according to change in the task due to technological advancements in ATM such as 'CAST: Consequences of future ATM systems for air traffic controller selection and training' [14]; 'BENT-PAC: Build and evaluate a new training path for air traffic controllers'[15]; and 'A new evaluation system for the on-going assessment of initial training in technologically developed activities; the case of air-traffic control' [16]. Although these projects emphasized new skills and competencies of ATCOs for the future ATM environment such as collaborative decision making, cooperative work and automation failure recovery, future competencies regarding efficiency and economics were not addressed for the integrated airspace and air traffic management. These projects were active during 1990s and the results obtained from these studies are mostly obsolete since the ATM system and ATCo tasks have changed drastically during the years.

Various studies on ATC simulation training development issues have been conducted recently to address the current and future requirements of ATM system. Updegrove and Jafer [17, 18] reviewed the current ATC training techniques and made recommendations regarding the inclusion of instructor supper technologies such as recording and playback capabilities and intelligent tutoring systems to expediate adaptation of trainees to more complex traffic scenarios. Coyne et al [19] evaluated perception of students on the use of ATC simulations to provide feedback to FAA authorized Air Traffic Collegiate Training Initiative (AC-CTI) Programs. Chhaya et al (2018) [20] proposed a scenario exploration technology platform to allow trainees and instructors to exercise wide range of simulation scenarios. Falkland and Wiggins (2019) [21] examined the role of cross-task cue utilization in the situational awareness such that perception, comprehension and prediction skills of students for initial stages of ATC simulation training. Bernhardt et al (2019) [22] studied workload and engagement metrics of ATCo students during radar approach simulations across different scenario difficulties and experience levels using EEG and pupil diameter measurements. Although these studies provided important insights in terms of human factors, ergonomics, learning technologies and curriculum

design, development ATC training assessment in parallel to the future targets regarding efficiency and economics is still an untouched issue.

This study aims to provide an overview of the ongoing 'Development of Common ATC Simulation Training Assessment Criteria Based on Future Pan European Single-Sky Targets (ATCOSIMA) project funded by the Erasmus+ Program of the European Union within the KA2 Cooperation Innovation and the Exchange of Good Practices/KA203 Strategic Partnership for Higher Education. The project proposes an innovative approach to measure the performance of ATCo trainees in radar approach simulations based on integrated ATC radar and flight cockpit simulations.

The development of the common assessment criteria can shorten adaption times of new ATCos to operational environment, reduce times and costs of advanced ATCo training at operational ATC facilities and improve the overall quality of air traffic services for the airspace users in Europe. It can also increase the transparency and recognition of the skills, qualifications and competencies to facilitate learning, employment opportunities and labour mobility of ATCo candidates across Europe. Furthermore, the development of these criteria can improve the level of coordination and harmony between ATCo's trained in different countries. Therefore, they become more competent to work in the integrated Pan-European air traffic system of the future. Besides, outcomes of the project will enhance their skills required by the targeted integrated European ATM such that effective communication with pilots, recognition of pilot intentions, effective use of airspace and flight efficiency. The outcomes of the project can improve overall quality of ATCo training in the higher education across Europe through the promotion of common awareness of aviation safety and efficient and economic air traffic flow management concepts of future operations. The project offers increased cross-border cooperation between higher education institutions, ANSPs and vocational training organizations involved with basic ATCo training in Europe. The outcomes can lead to possible policy revisions and improvements in the international reference documents such as EU REG 2015/340 and provide an important step to the standardization of the ATC simulation training in the transition to future Pan-European Single Sky ATM. Therefore, they will support to achieve its operational targets such that safe, efficient and economic management of an integrated airspace for sustainable growth of air transportation.

2. PROJECT DESCRIPTION AND GENERAL METHODOLOGY

The primary objective of ATCOSIMA is to develop common assessment criteria for simulation training courses within the ATCo basic training in order to improve students' competencies regarding working effectively and in harmony within the integrated Pan-European air traffic system; improve metrics and scoring tools for the evaluations of students according to SESAR's future targets and provide guidelines and recommended practices for enhanced ATCo training across the Europe. The project has been conducted by three higher education institutions including Faculty of Aeronautics and Astronautics at Eskisehir Technical University (ESTU), Faculty of Transport and Traffic Science at University of Zagreb (ZFOT) and Institute of Flight Guidance at Technische Universität Braunschweig (TUBS).

ATCOSIMA will be the first study which considers ATCo-Pilot interactions and reflects the performance metrics related with the needs of airspace users in order to define assessment criteria and training guidelines for radar simulation courses within the basic ATCo training. In order to reach these outcomes, the project team choses an alternative approach based on flight cockpit and integrated ATC- flight cockpit simulations. These simulations will be used to evaluate the impacts of ATCo's instructions on pilot workload, voice communication, flight economics and efficient use of airspace. These results will support development of common quantitative assessment criteria and training guidelines for ATCo training. In order to meet this objective and its related targets, the project proposes an innovative approach to measure the performance of ATCo trainees in radar simulations based on flight cockpit and integrated ATC and flight cockpit simulations. Instructions of ATCo trainees

will be tested in terms of airspace occupancy, service times, aircraft fuel consumption, pilot workload and readability and implementability of ATCo instructions by pilot.

The general methodology of the project is presented in Figure 2. Implementation of this methodology includes two essential parts: a baseline analysis to evaluate performance of ATC trainees using current assessment criteria and training techniques and development and testing of new assessment criteria. Both parts require a close transnational collaboration between the partners providing ATCo training and conducting high-end ATM research. Each part consists of a set of planning, preparation and analysis task represented by blue blocks, real time (human-in-the loop) simulations to be performed at ATC Radar and integrated ATC Radar and Flight cockpit Simulator setups represented by yellow blocks, and outputs represented by red blocks. Outputs include results of planning and preparation tasks and analysis of collected and post-processed data and they will be the input for the parallel and subsequent tasks.

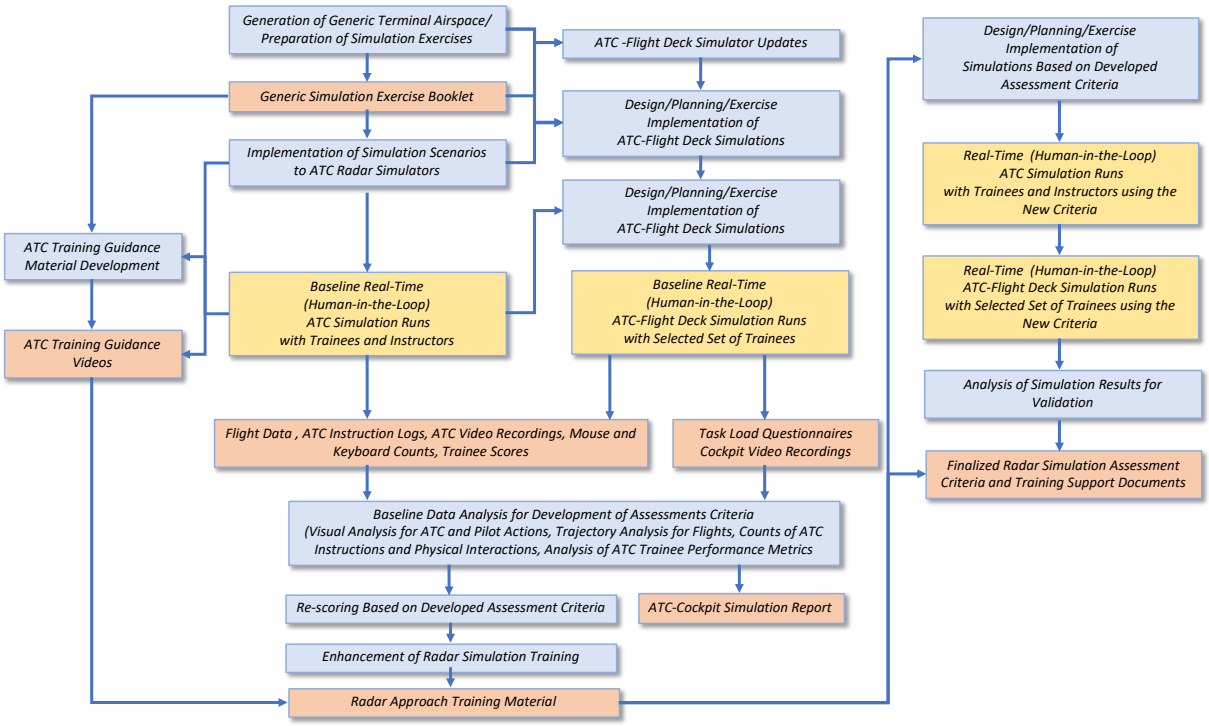


Figure 2 –General Methodology: Blue Blocks Represent Preparation and Analysis tasks, Yellow Blocks Represent Human-in-the Loop Simulations and Red Blocks Represent Outputs.

Planning, designing, preparation and execution of real-time simulations have mainly been carried out by ESTU and ZFOT. Both partners have been providing ATCo training at higher education level and have the necessary expertise and capabilities in ATC radar simulation training and assessment. Real-time simulations have been carried out parallel with two different trainee groups both in ESTU and ZFOT. Therefore, a common framework for ATC training and assessment can be investigated using different training approaches and cultural background. The trainees are selected among the students of air traffic control programs of ESTU and ZFOT. They are required to be familiar with ATC radar control techniques, phraseology and graphical user interface (GUI) and functions of the radar simulator. Therefore, students who took and succeeded radar control theory and simulation courses are selected as participants of ATC students. Gender equality is also ensured during the selections. The successful students in ATC radar simulations are selected to participate integrated ATC-Flight cockpit Simulations at TUBS.

Both ESTU and ZFOT have been using the MicroNav BEST ATC radar simulators. This will provide two advantages for the project. First, design, planning, execution and data extraction processes of the simulations will be done easily in such a compatible simulation environment and second, comparison of simulation results will be more accurate in the post-simulation analyses. In order to further analyse the correlation of assessment criteria and flight efficiency, integrated ATC radar and flight cockpit simulations planned to be carried out at ATC-Flight cockpit simulators of TUBS. Flight cockpit simulator is a fix-based simulator containing a full replica mock-up of an Airbus A320 cockpit. It is part of TUB's simulation environment providing a realistic platform for research activities in terms of both airborne and ground operations. The computational units of the simulator consist of commercial off-the-shelf computers. The software modules are primarily based on commercially licensed programs and additional applications developed by research engineers of the institute. The specific architecture permits modification of individual components and is therefore particularly suitable for the execution of scientific studies. At the end of the project, the assessment criteria document and radar approach training guideline will be created as the output of the project according to the analyses obtained through the work packages. Besides, the new supplementary training guidelines will also be tested and validated in integrated ATC-Flight cockpit simulations. Since studying impacts of ATCo instructions on pilot workload is a novel approach in the field, its findings will be published in an academic journal. The simulation analyses obtained during the project will be shared on the project website. At the end of the project, radar simulation assessment criteria document and training guidance document will be published and shared with all stakeholders.

3. SIMULATIONS AND DATA COLLECTION

Vast amount of data is planned to be collected from ATC radar simulations and integrated ATC-Flight cockpit simulations for both the baseline and new criteria testing studies. In order to execute these simulations, an airspace model has been developed based on Frankfurt TMA to be used for generic exercises in ATC radar and integrated ATC-Flight cockpit simulations (Figure 3). Frankfurt TMA has generic characteristics allowing quick and easy adaptation of ATCo trainees during basic training such as a convex airspace boundary with a moderate number of entry points (fixes), low Minimum Vectoring Altitude (MRVA) allowing continuous descent approaches (CDA) and absence of prohibited and restricted areas. These characteristics also allow candidates perform sequencing of arrival and departures, implement radar vectoring techniques and develop skills for planning and execution of efficient air traffic flow within the TMAs. Frankfurt TMA can be considered as a broad airspace in which the minimum and maximum distances between its entry points are 82 NM and 146 NM, respectively. Therefore, trainees have a relatively long planning and execution time for vectoring aircraft to ILS course of the runway during their approach and landing sequences. For basic training, this relatively relaxed time window helps trainees detect aircraft conflicts and develop appropriate resolutions for them during the simulation exercises. Furthermore, this issue allows instructors convey critical pedagogical information to trainees and explain to them necessary tasks to be performed during the exercises.

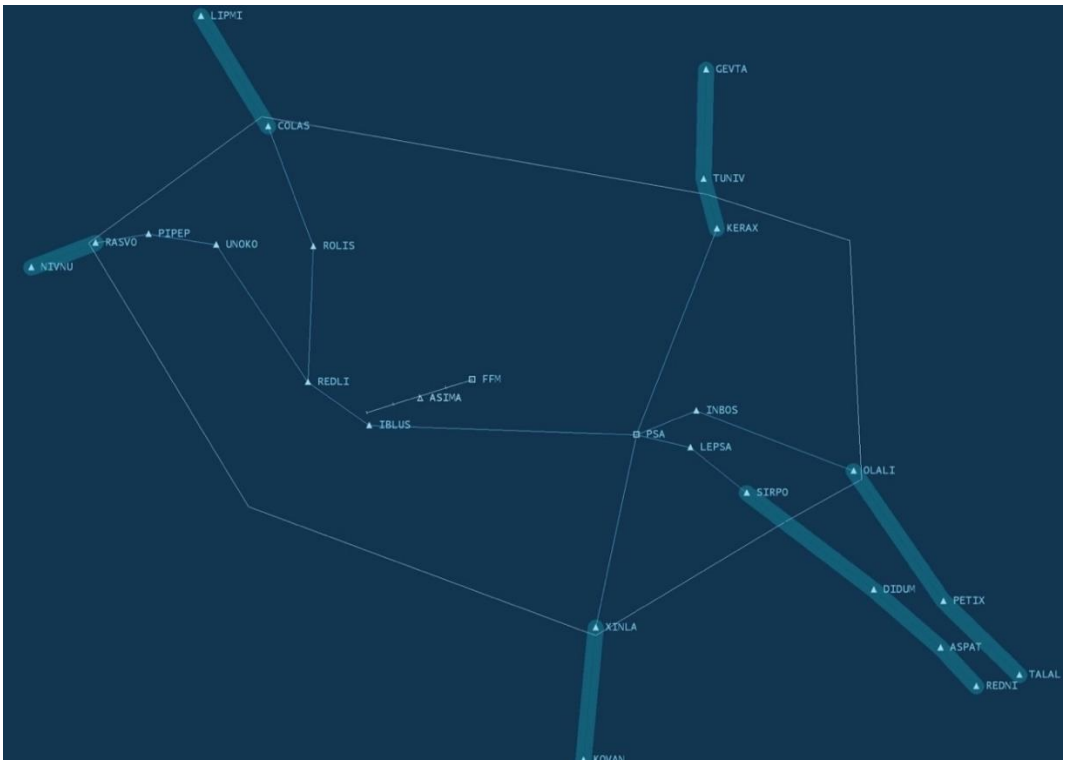


Figure 3 – Plan view of Frankfurt Terminal Airspace with its fixes and routes in ATC Radar Screen

In Frankfurt TMA, there are six different instrument standard arrival routes (STARs) passing through six different entry points, namely XINLA in the south, SIPRO and OLALI in the southeast, KERAX in the northeast, COLAS in the northwest and RASVO in the west (Figure 3). All arriving flights in the exercises are planned to fly along these routes composed of a chain of flight segments between fixes, geographical positions determined by reference to one or more navigational aids or by other navigational devices or techniques. Trainees are expected to direct each arriving flight from the TMA entry point to the ILS course along its route using radar vectoring techniques. Trainees should ensure that aircraft are established on ILS course before they reach to ASIMA, aircraft hand-off point from the approach control to the aerodrome control unit. ASIMA point is on ILS course and located 10 NM from FFM, the position of VOR at Frankfurt Airport. Transition altitude is selected as 5000 ft for all arriving aircraft within the TMA.

Location of Frankfurt Airport is indicated by FFM VOR point (Table 1). Frankfurt Airport has four runways in use, namely 07R/25L (runway south), 07C/25C (runway north), 07L/25R (runway northwest) and 18/36 (runway west). But in the exercises, it is assumed that 07C/25C is active only and both arrival and departures operations take place at runway 07 direction. This single-runway configuration is not only one of the most common and therefore generic features among the existing airports but also appropriate for the instruction and assessment of radar vectoring techniques to trainees in basic ATC training.

Although the TMA entry and exit points are different in the existing Frankfurt TMA, they are assumed as the same points (such that XINLA, SIRPO, OLALI, RASVO, COLAS and KERAX) in the simulated TMA model used in the exercises for convenience in training in terms of reduced complexity and increased generic-ness of the airspace. Departing flights fly 10 NM from FFM VOR point and then take a direct route planned TMA exit point. The flights are handed off to the relevant en route radar control unit (Langen North or Langen South) when they climb to FL250. All aircraft flying within the TMA should be separated at least 5 NM horizontally and 1000 ft vertically including final approach course.

The existing MRVA limits do not prevent continuous descent of arriving aircraft within the TMA, therefore they provide trainees to practice efficient and environment friendly continuous descent approach (CDA) procedures during the exercises and enhance their skills and awareness regarding flight efficiency issues in ATC operations. While the highest MRVA limit is 5000 ft near the TMA entry points, the highest MRVA limit around the ILS course is no higher than 4000 ft. As a result, aircraft can be descended from the entry points to ILS course without the necessity of any level offs or climbs during the exercises. In order to run ATC radar simulation, ten exercises were prepared for radar approach control simulation training and assessment with increasing different level of complexity and difficulty as presented in Table 1. Difficulty levels of exercises are depend on not only number of aircraft in the exercise but also a set of traffic complexity metrics such that operation mix of departure and arrivals, initial separation between successive departures, number of conflicts between arrivals and departures, and initial distances of arrivals from the ILS course .While the first exercises are designed to familiarize trainees with the TMA and potential conflict points and allow them to use basic radar vectoring techniques, the last exercises require advanced decision-making skills regarding effective and timely use of vectoring, airspeed adjustments and flight level change for conflict resolution and arrival sequencing.

A single aircraft type (i.e. Airbus A320) has been simulated in all exercises. Airbus A320, narrow-medium body twin engine jet aircraft, is on the most commonly used aircraft type with a 15.8% share in the European total traffic [23]. Aircraft performance data used in simulation are based on Base of Aircraft Data (BADA) [24] and cover airspeed, rate of climb (ROC) and rate of descend (ROD) values defined for different flight levels. For the baseline analysis, these 10 ATC radar simulation exercises were run with 19 trainees (14 from ZFOT and 5 from ESTU) under the supervision of ATC instructors. ATC radar simulation circuit and data to be collected is presented in Figure 4. The circuit consist of one ATC workstation for ATC trainee and several pseudo-pilot workstations for pseudo-pilots controlling arriving and departing aircraft within the TMA during the exercises. All stations are connected to the system administrator (sysman) computer in which all airspace and air traffic data and communication configurations are stored as inputs. During the exercises, sysman records exercise replay files and simulation logs. These data provide inputs for assessments, keeping ATCo instructions and air flight path information. Video screen captures and mouse-keyboard actions of trainees are also collected to evaluate task load and occupancy of trainees. Trainees were assessed based on the current assessment criteria adopted by ESTU and ZFOT. ATC instructors performed the assessment using video screen captures and exercise replay files.

Table 1 – Radar Approach Control Exercises to be run in ATC Simulations

	Number of Aircraft		**Exercise Characteristics**	
Exercise Number	**Arrival**	**Departure**	**Duration (min: sec)**	**Difficulty Level**
1	5	0	23:30	1
2	6	2	25:30	2
3	6	3	24:30	3
4	6	4	26:00	4
5	7	3	27:00	4
6	7	4	27:30	6
7	8	3	28:00	8
8	8	4	30:00	9
9	9	3	31:00	9
10	9	4	30:00	8

ATC radar simulations were done between the period of February-April 2018 at ESTU and ZFOT. According to the relevant criteria (assessment achievement, gender, age), 5 of 14 ZFOT students were selected according to go for TUBS ATC- Flight cockpit simulations. ESTU could not perform any selection because of the number of eligible trainees for the ATC simulation runs.

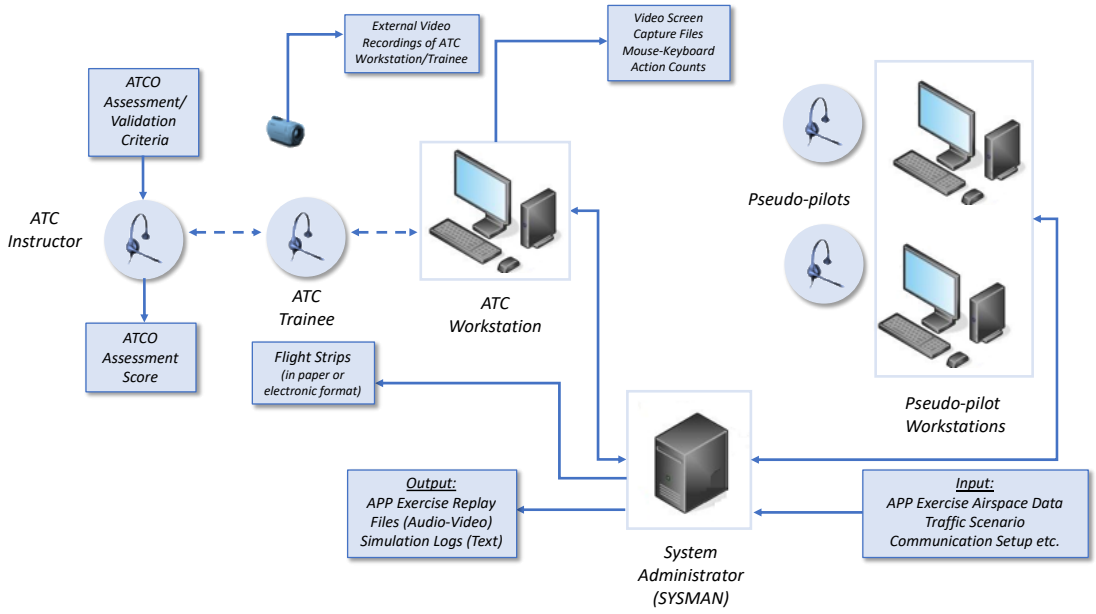


Figure 4 – ATC Radar Simulation Circuit and Data to be Collected

Integrated ATC-Cockpit Simulations were done in June 2018 at TUBS. Ten trainees participated the simulation runs and the exercise 9 was rerun in the integrated ATC-Flight cockpit simulator circuit presented in Figure 5. In these simulation runs, 8 of the arriving and 3 of the departing aircraft were controlled by pseudo-pilots while 1 arriving aircraft was controlled by the pilot in the A320 flight cockpit simulator. ATC workstations were updated by TUBS teams in order to provide a similar GUI and system functions to trainees. Flight cockpit simulation logs including detailed flight trajectory data were collected for the estimations of flight efficiency in terms of flight time, distance flown and fuel consumed. Pilots actions were also recorded using a video camera in the cockpit in order to determine task load and occupancy of the pilot through visual analysis. Simulation logs of the aircraft controlled by pseudo-pilots were collected as well to estimate flight efficiency of other aircraft. Communication logs were acquired to analyze ATCo instructions along with simulation logs. Video screen capture files and mouse-keyboard action counts were also extracted from ATC workstations to be used for assessment and task-load/occupancy analysis of trainees. After each simulation both the pilot and trainees were administered NASA Task Load Survey (NASA-TLX) [25] in electronic form to obtain further data for their task-load analysis.

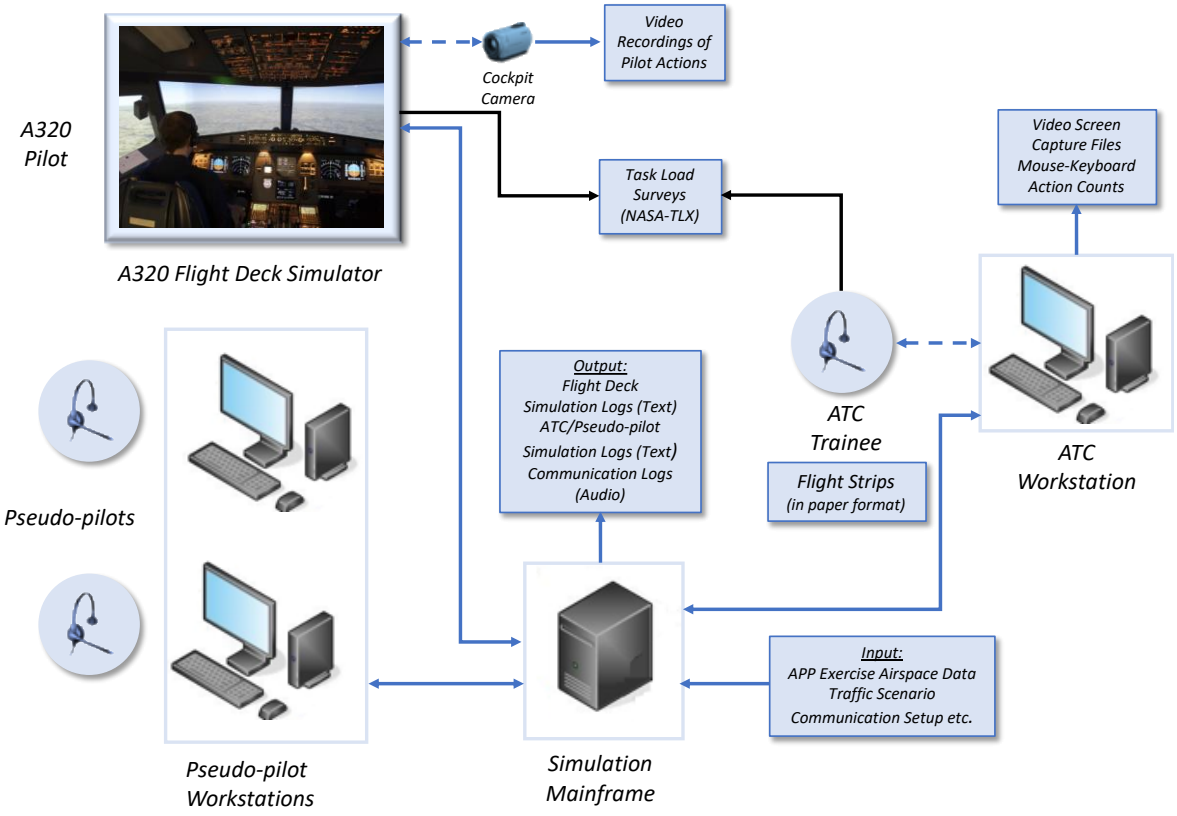


Figure 5 – Integrated ATC Radar-Flight cockpit Simulation Circuit and Data to be Collected

4. CONCLUSION

The baseline analysis tasks of ATCOSIMA have been completed and Generic Simulation Exercise Booklet including scenario details as well as simulation files and setups for ATC and integrated ATC-Flight cockpit Simulations were prepared. In addition to these intellectual outcomes, baseline assessment validation criteria were adopted and instructive ATC training guidance videos were produced in order to be used as the inputs of the next steps of the projects. A vast amount of data set was also collected for the further analysis regarding ATCo performance, flight efficiency and pilot task load and acceptance. These outcomes will not only support the development of new ATC radar simulation assessment criteria but also provide a framework and database of other studies to be done in the future. Although the project primarily targets the instructors and students of ATCo basic training programs in higher education institutions, its outcomes will provide feedback and recommendations for the revision of reference documents. Therefore, the results can be reached and used by all ANSPs, Civil Aviation Authorities and vocational ATCo training organizations in Europe.

ACKNOWLEDGEMENTS

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OLJA COKORILO, B.Sc./M.Sc./Ph.D.[1]
E-mail: o.cokorilo@sf.bg.ac.rs
LIDIJA TOMIC, B.Sc.[1]
E-mail: lidijatomic11@gmail.com
[1] University of Belgrade
Faculty of Transport and Traffic Engineering
Vojvode Stepe 305, 11000 Belgrade, Serbia

CORSIA- CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION: CHALLENGE AND PRACTICE

ABSTRACT

The objective of this research is to analyze aviation environmental issues based on contemporary market related measures. In order to respond to the pressures of international aviation authorities and organizations, the aviation industry has developed different operational, technological and market-based measures. Therefore, this paper is focused on the last developed ICAO market measure, CORSIA (Carbon Offsetting and Reduce Scheme for International Aviation), a scheme for reducing and neutralizing carbon growth in international aviation. The paper reflects actual challenges and practical requirements necessary for adequate implementation and aviation community positive reflection. The ultimate purpose is to provide the importance for investigating new measures for CO_2 reduction during the aircraft operations.

KEY WORDS

aviation; CORSIA; environmental protection; aircraft; operations;

1. INTRODUCTION

With the rapid development of air traffic, and consequently by the increase in emissions, the aviation industry has become exposed to pressure from the international community due to the negative environmental impacts, but also with great challenges in reducing the adverse impacts arising from aircraft operations. Additionally, fuel consumption directly increase CO_2 whereas statistics show that the aviation industry is responsible for about 2-3% of generated CO_2 in the atmosphere and about 12% of produced CO_2 compound to the entire transport industry [1].

Emissions from combustion of fossil fuels are accumulated in the atmosphere and can stay there for hundreds to thousands of years, and the impact of airborne emissions (especially carbon dioxide (CO_2)) is highly important for climate change.

In order to respond to the pressures of international aviation authorities and organizations, the aviation industry has developed different operational, technological and market-based measures. Therefore, this paper is focused on the last developed ICAO market measure, CORSIA (Carbon Offsetting and Reduce Scheme for International Aviation), a scheme for reducing and neutralizing carbon growth in international aviation.

2. AIRCRAFT OPERATIONS – EMISSIONS

The main pollutants emitted by aircraft engines during the aircraft operations are: carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), and soot (*Figure 1*). It could be shown that the largest amount of harmful gases produced by aircraft engine is CO_2 (with total amount of 8500kg according to the conditions described in Figure 1.) [2].

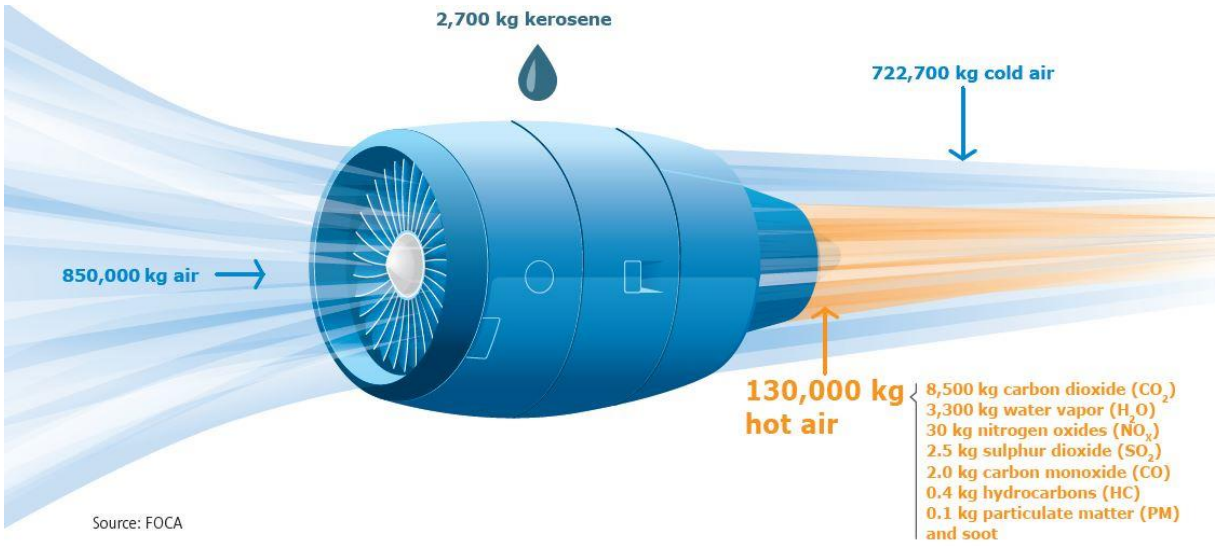


Figure 1 – Emissions from a Typical Two-engine Jet Aircraft During 1-hour Flight with 150 Passengers
Source: [2]

As air traffic began to develop rapidly in the 1950s, gas emissions were becoming more and more common. For this reason, programs for reducing emissions of gases are continuously being developed. For illustration, in 2016, 815 million tons of CO_2 was produced globally in aircraft operations around the world [3]. Also, statistics show that air traffic in Europe represents 20% of the world's CO_2 emissions from air traffic.

Considering the fact that every kilogram of fuel burns produces 3.16kg of CO_2 emissions, CO_2 emissions from aircraft are directly related to the fuel efficiency of the aircraft. The standards used for measuring CO_2 emissions measure average burnt fuel (kg) per unit range (km) along the cruise phase (*Figure 2*). Those three selected points represent the range of aircraft weights in everyday operations (since the largest amount of CO_2 is emitted during the cruising phase).

In order to capture a wide range of different types of aircraft, the standard also takes into account aircraft performance and capabilities to allow fair and direct comparison of different types of aircraft. This adjustment is done through a factor that calculates differences in aircraft sizes.

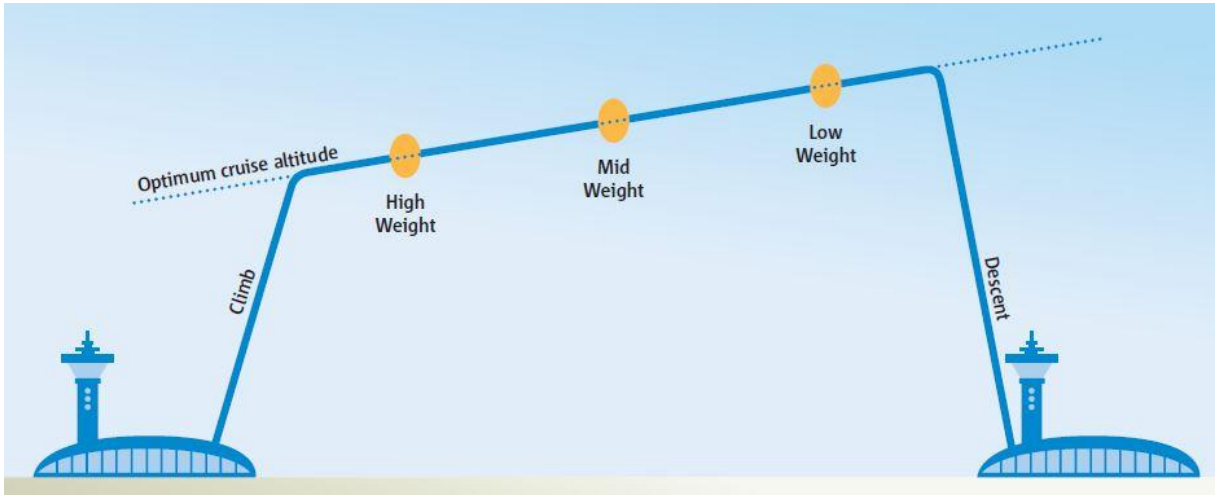


Figure 2 – Illustrative Example of the CO_2 Cruise Measurement Points
Source: [2]

2.1 Setting up the Aviation Environmental Protection Main Goals

It should be noted that the aviation sector is not fully comparable with other economy sectors, since it is complex to achieve a reduction in emissions in aviation. This is partly due to the relatively long aircraft life span, whereas, the period of exploitation of aircraft is usually 25 years or even longer. Various systems and schemes allow the compensation of aviation emissions through reductions that are easier to achieve in other transport sectors. However, aviation will have to make a significant reduction in emissions in the years to come [2].

The ICAO has denounced two global objectives pursued by the international aviation community and they relate to:

- An annual reduction in fuel consumption from 2% to 2050.
- Neutral growth of CO_2 emissions from 2020 (CNG 2020).

There are various measures by which the stated ICAO objectives can be achieved, and the ICAO sets out the following measures as a proposal:

- Improving standards and technologies applied in aviation.
- Improving the air traffic management system.
- The use of bio-fuels in aviation.
- CORSIA - Carbon offsetting and reduction scheme for international aviation.

The (*Figure 3*) shows CO2 emission trends to be achieved by 2050 regarding actual state of the art in aviation sector.

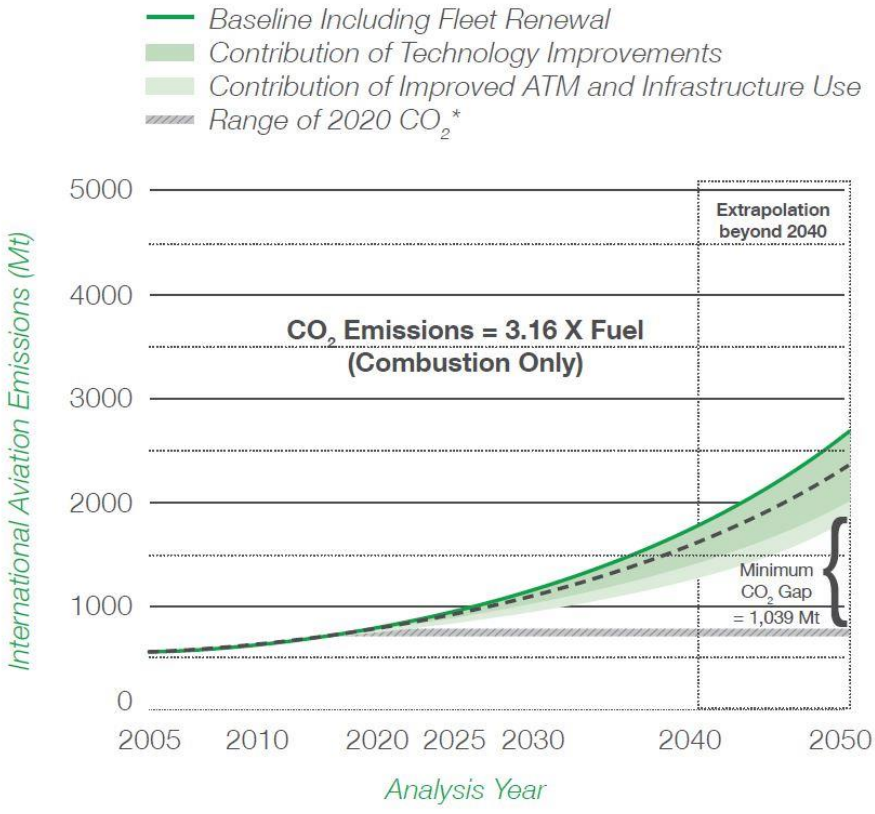


Figure 3 – CO_2 emissions trends from international aviation (2005-2050)
Source: [4]

The last mentioned measure, CORSIA, is the subject of this paper, and in the following chapters, a more detailed description of the concept, its goal, and the implementation plan is given.

3. CORSIA PROJECT: IMPLEMENTATION AND TIME FRAMEWORK

As mentioned above, there are numerous measures to reduce CO_2 emissions, which can be divided into four groups: operational, infrastructural, technological and market oriented measures. The CORSIA project belongs to a group of market measures that are an instrument designed to deal with the aviation's climate impact, above the level that operational and technological measures or sustainable aviation fuel can achieve [5].

For the long term forecast, all aircraft operators that produce an annual CO_2 emissions, on international flights of more than 10,000 tones with aircraft with a MTOM greater than 5,700 kg, whether or not their country is in the accession stages CORSIA or not, will be required to monitor, verify and report their CO_2 emissions during year 2019 and 2020. Humanitarian flights, flights for medical purposes and fire extinguishing operations are exempt. The average annual CO_2 emissions during that period will be the basis for a neutral carbon increase from 2020. From 2020, the aviation sector will have to neutralize its international CO_2 emissions above this level [2].

The (*Figure 4*) shows the map with ICAO members expected to participate in the CORSIA project, which also marks the countries that have already joined the project on a voluntary basis.

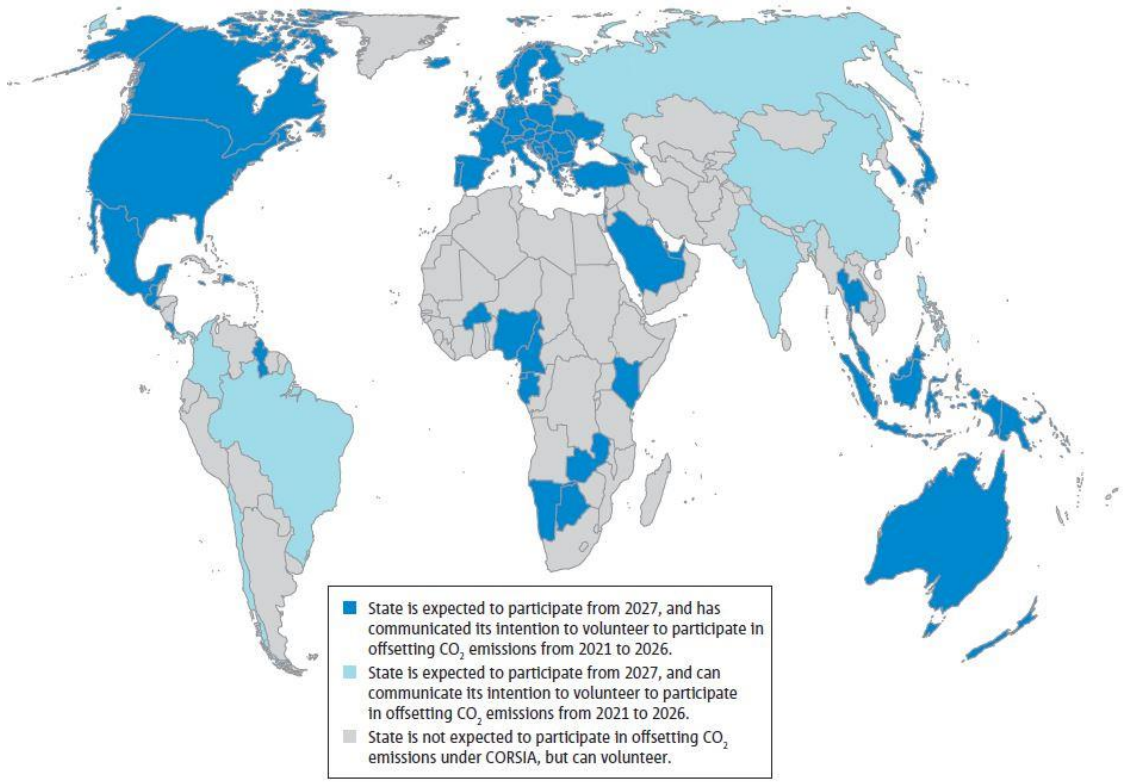


Figure 4 – ICAO Member States Expected to join CORSIA in the Various Phases
Source: [2]

The CORSIA project is a global scheme. As a final result, CORSIA is projected to reduce CO_2 emissions around 2.5 billion tones between 2021 and 2035, which is an annual average of 164 million tones of CO_2. This represents an investment of approximately $ 40 billion in climate projects (assuming the price of carbon will increase from $ 8 in 2021 to $ 20 in 2035) [6].

CORSIA includes three phases of implementation: pilot phase (2021-2023), first phase (2024-2026) and second phase (2027-2035). These phases are explained in the next chapter.

4. CORSIA: IMPLEMENTATION PHASES

In order to include different circumstances and the different capabilities of countries, CORSIA will be implemented in three phases (Figure 5) [6]:

I. PILOT PHASE - From 2021 to 2023 only flights between countries that volunteer in the first stages of the project will be subject to neutral CO_2 growth measures.

II. FIRST PHASE - From 2024 to 2026 all international flights will be subject to neutralization measures, except flights to and from third countries. An exception will be if these countries decide to participate on a voluntary basis.

III. SECOND PHASE - From 2027 to 2035, all air carriers are obliged to monitor and publish emission data recorded on all international flights, including third countries.

In the (*Figure 5*) and (*Figure 6*), an illustration of the implementation of the above phases is given. [5]. In practice, the cases presented can also be found under the heading "Route-based CORSIA approach", or this is an approach that shows which routes are subject to the implementation of CORSIA, depending on whether the countries between which flights are performed are connected to the CORSIA project.



Figure 5 – Implementation of CORSIA in the Pilot and the First Phase
Source: [5]

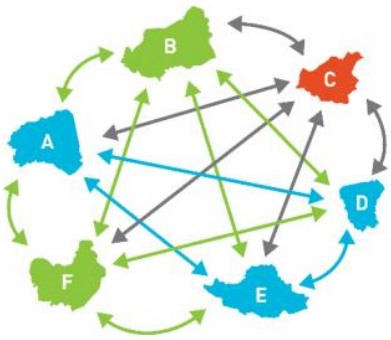


Figure 6 – Implementation of CORSIA in the Second Phase
Source: [5]

(*Table 1*) shows the CORSIA implementation plan and the check list for the countries participating in this project in order to fulfill the planned commitments for the implementation of the project [8].

Table 1 – Checklist for Countries Participating in the CORSIA Project

2018: Recommended Preparatory Actions	**Timeline**
Designate a focal point for CORSIA implementation	February
Participate in ICAO's CORSIA training and capacity building	March/April
Coordinate necessary actions with focal points of aeroplane operators attributed to your State	May/June
Approve the aeroplane operator's Emissions Monitoring Plan	30 November
Send a list of aeroplane operators attributed to your State to ICAO	30 November
Establish necessary national regulatory framework	December
Obtain and use the ICAO document entitled "CORSIA Aeroplane Operator to State Attributions"	31 December
2019-2020: The Main Planned Actions	
Approve the aeroplane operator's Emissions Monitoring Plan	30 April 2019

2018: Recommended Preparatory Actions	**Timeline**
Submit lists of aeroplane operators attributed to your State and verification bodies accredited in your State to ICAO	30 April 2019
Obtain and use ICAO document entitled "CORSIA Aeroplane Operator to State Attributions"	31 May 2019
Conduct an order of magnitude check of the aeroplane operator's verified 2019 Emissions Report	1 June - 31 August 2020
Notify ICAO of your State's participation in CORSIA offsetting in year 2021	30 June 2020
Notify ICAO which option your State has selected for calculating the aeroplane operator's offsetting requirements during the 2021-2023 period	30 June 2020
Obtain and use the ICAO document entitled "CORSIA States for Chapter 3 State Pairs"	1 August 2020
Submit 2019 CO2 emissions data to ICAO	31 August 2020
Submit updates to the list of aeroplane operators attributed to your State and updates to the verification bodies accredited in your State to ICAO	30 November 2020
Obtain and use the ICAO document entitled "CORSIA Aeroplane Operator to State Attributions"	31 December 2020

Source: [8]

5. CORSIA IN PRACTICE

Each international flight within CORSIA is attributed to the aircraft operator, and every aircraft operator is assigned to the State to which the Emission Monitoring Plan is required. Aircraft operators monitor, verify and report on fuel consumption in accordance with an approved plan, while their annual emissions neutralization requirements are calculated by the state. Emission monitoring applies to all flights, including those that are not subject to neutralization requirements. Requests for neutralization are calculated according to a dynamic approach in order to take into account the growth in the aviation sector and the growth in the number of individual airline operators [2].

5.1 Application of the CORSIA Concept to Airlines

Where operators monitor actual fuel use, they may select one of five fuel monitoring methods. Different methods may be used for different airplane types, but the same method must be used for all airplanes of the same type. The five monitoring methods are [5]:

- Method A, which is based on measurements after the completion of fuel uplifts (for the flight under consideration and for the subsequent flight) and the fuel uplift for the subsequent flight.
- Method B, which is based on measurements at block-on times (preceding flight and flight under consideration) and the fuel uplift for the flight considered.
- Block-off / block-on, which is based on the fuel consumed between block-off and block-on;
- Fuel uplift, which is based on the fuel uplift before each flight.
- Block-hours, which applies the average fuel burn ratio by aeroplane type and during the reporting year in question to the block hours of each flight.

The (*Figure 7*) below provides an overview of the data points and formulas for each method. The figures indicated in the chart are illustrative and are not indicative of any quantitative differences which would be observed using real-life measurements.

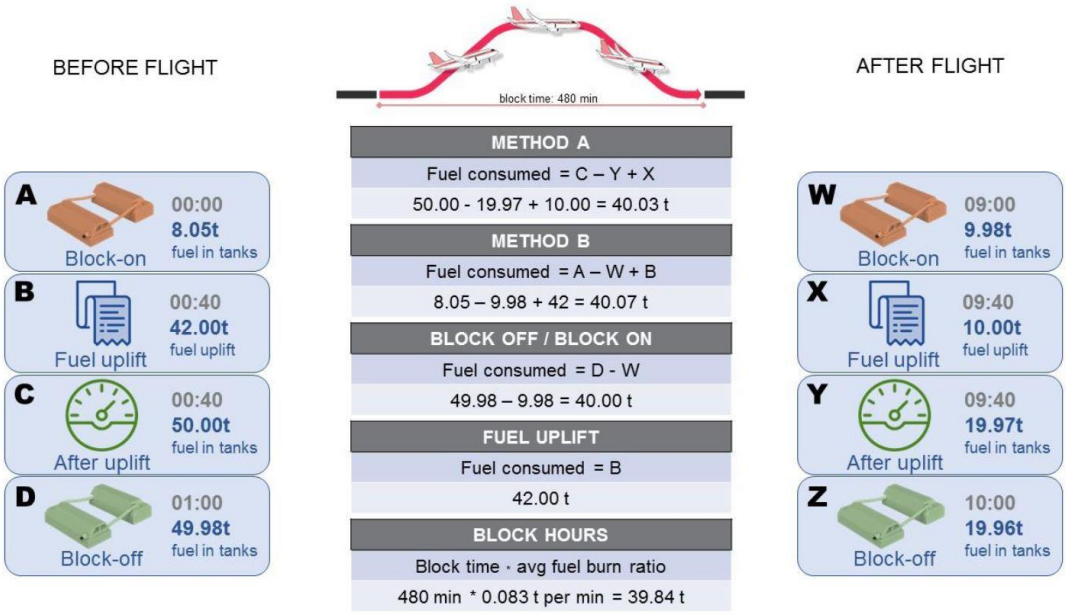


Figure 7 – Implementation of CORSIA in the Second Phase
Source: [5]

Operators eligible for simplified monitoring are not required to monitor actual fuel use but have the possibility to calculate their emissions using the ICAO CORSIA CO_2 Estimation and Reporting Tool (CERT), an estimation tool developed in ICAO. The CERT applies CO_2 Estimation Models (CEMs) to estimate the emissions of a flight on the basis of great circle distance or block time for a given aircraft type [9].

5.2 The Importance of CORSIA for Airlines

Fuel is one of the most important items in the cost of airline companies. In 2017, on average, fuel was 21.4% of the total operating costs of the airline. CO_2 emissions are directly related to fuel consumption: by average, each aircraft emits 3.16kg CO_2 for each kilogram of fuel consumption. This fact creates a very powerful financial management tool to reduce fuel consumption and emissions. The concept of neutralization and the concept of "carbon markets" (EU Emissions Trading System - EU ETS) are fundamental components of global, regional and national emission reduction policies. Neutralization is more effective than the payment of certain taxes / fees, as carbon fees only require companies to pay for their emissions, without any warranty that the payment of fees for them will lead to any reduction in emissions.

Costs incurred by CORSIA to air carriers are not insignificant, but are acceptable to air carriers, especially in comparison with the costs that would have been incurred if each country introduced national measures to prevent the increase in emissions. Regarding new airlines, they will be exempted from CORSIA's first three years of operation or until annual emissions do not exceed 0.1% of total emissions at the 2020 level.

6. CORSIA: ECOLOGICAL INTEGRITY

In order to ensure the ecological integrity of CORSIA, the ICAO Assembly has adopted a set of measures that will contribute to the promotion of the CORSIA project. The Assembly's decision was made by the Technical Advisory Body, which will determine the way in which neutralization measures lead to a reduction in CO_2 emissions. The criteria to be used are based on principles commonly applied within existing emission trading mechanisms and well-accepted carbon neutralization standards.

Neutralization must be a measure which leads to a permanent reduction in CO_2 levels and may not be of a reciprocal character [7].

7. CONCLUSION

International cooperation, including addressing environmental issues, is crucial for a sector such as aviation. Consequently, by the Chicago Convention, States committed themselves to cooperating in securing the highest degree of uniformity of regulations and to harmonize their national regulations with international standards and recommended practices.

In accordance with the facts stated in the paper, there is a need to involve as many countries as possible to the reduction and neutralization emissions scheme within international aviation standards. Using CORSIA, as one of the latest market measures made by ICAO with the goal of helping to solve the problem of annual CO_2 emissions and helping the aviation industry achieve goals in terms of reducing emissions would benefit in the short and long term period. Other actual measures, based on operational measures or infrastructure measures [10] are not seen as sustainable tool in the long term period.

Implementation of CORSIA will allow to reduce emissions without introducing additional costs for airlines and civil aviation authorities, and in the future it will also lead to the abolition of existing emission fees and/or taxes.

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DOMINIK CVETEK, M.Sc.[1]
E-mail: dcvetek@fpz.hr
VEDRAN BOJIĆ, B.Sc.[1]
E-mail: 0135226803@fpz.hr
NIKO JELUŠIĆ, Ph.D.[1]
E-mail: njelusic@fpz.hr
MARIO MUŠTRA, Ph.D.[1]
E-mail: mmustra@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

INITIAL BLUETOOTH PROBE VEHICLE PENETRATION RATE ANALYSIS: A CASE STUDY IN THE CITY OF ZAGREB

ABSTRACT

The most of Intelligent Transport System applications rely on various traffic flow data collection technologies. Bluetooth is widely used standard for wireless short-range communication. It is not dedicated for traffic data collection, but Bluetooth devices located in vehicles make them act as detectable probes in traffic flow. That allows collecting of very desirable traffic flow data such as travel times and constructing origin-destination matrices. The Bluetooth probe penetration rate analysis is the first and necessary step for assessment of Bluetooth as traffic flow data collection technology in the area of interest. In this paper we bring field measurement, raw data processing, and filtering with robust filters for detecting outliers in vehicle detection using Bluetooth signal as a marker. In accordance with the reviewed literature, obtained results show that Bluetooth probe penetration rate in the City of Zagreb is sufficient for some ITS applications, and it is stable throughout the week.

KEY WORDS

Intelligent transportation system; Bluetooth technology; Bluetooth vehicle probe; traffic flow data; Bluetooth penetration rate; Vehicle detection;

1. INTRODUCTION

Traffic flow data collection technologies are essential for Intelligent Transportation Systems (ITS) applications. Some of them, which include Bluetooth, can provide very desirable traffic data such as travel time and Origin-Destination (O-D) matrix. Bluetooth (BT) is trademark for short range radio communication standard designed for exchanging data between electronic devices which are frequently and widely used in everyday life. BT based detectors can record unique identifiers of BT devices, Media Access Control (MAC)-addresses. Quality of traffic information derived from collected data by BT detectors depends on number and density of BT probes in traffic flow. BT probe is a vehicle which contains at least one detectable BT device. Therefore, measuring BT probe detection rate in overall flow is a necessary step for assessing the applicability of BT detectors in the area of interest.

Today, data collection technologies for traffic management applications can be sorted in three groups: point sensors, point-to-point sensors and area wide sensors. Technologies which provide vehicle detection at multiple locations as they traverse the network belong to the point-to-point sensors and these are: Automated Vehicle Identification (AVI) Systems, Vehicle identification without driver "cooperation" which include Wi-Fi and BT, and Automatic License plate recognition (ALPR) (1). The application of BT for traffic data collection has some obvious advantages: BT detectors have low cost components, number of BT-enabled devices is increasing, poor weather does not influence

detector's performance, and this identification principle is far more acceptable in privacy issue then ALPR.

There are number of papers about BT technology application in traffic which show that BT as a traffic data collection technology has been subject of research in the past decade and still remains topicality. The most frequent papers about BT application in traffic deal with travel time estimation and analyzing its accuracy and reliability, for example (2–5). Some papers extend this topic with application in traffic management or with providing data other than travel time. Authors in (6) deals with BT-based travel time for automatic incident detection. (7) presents integration of BT MAC Scanners data and inductive loop data to obtain travel time and density estimation on urban network. (8) used network of BT Low Energy devices and the received signal strength indicator to detect and classify vehicles by their type: personal car, semi-truck and truck.

Because of BT communication establishment procedure and other factors like signal strength, distance, used antennas and speed of the vehicle in the detection area, not every BT device will be detected by a BT detector. In (4), an experiment was described in which BT devices in vehicles are detected only 80% of the time while passing the BT detector. Quality of information derived from BT data depends on penetration of BT probes in overall flow. In (9) it is concluded that penetration rate should be at least 3% of total vehicle volume and minimum of 20 days of data collection for estimation travel time gives reliable results. Some studies concluded that the minimum percentage of BT penetration rate should be at least 5% (10). Authors in (11) proposed a detection probability model for moving Bluetooth devices. Empirical measurement of BT probe penetration rate is reported in a few studies (12–14). Authors in (12) reported the average rate of 4.5%, in (13) of 29%, and in (14) between a minimum of 4.3% and a maximum of 6.9%. However, the literature is not rich with papers giving precise data about the BT probe penetration rate.

The main objective of this work is to determine the BT penetration rate in overall flow. The rest of this paper is structured as follows. In Section 2 BT standard, test site and used measuring equipment are described. Also, presents proposed filters for outliers. Section 3 combines the case study results and discussion. The final section concludes the case study.

2. METHODOLOGY

Bluetooth standard

BT stands for technology with short-range communication, low-cost components, and low energy consumption. It is convenient for machine-to-machine applications, mobile, voice or stereo handsets, wireless controllers or human interface devices, etc. Bluetooth standard has been constantly evolving since 1994. The last version of Bluetooth is v5.1, presented on 21st January 2019 (15). However, previous versions are still widely used. The commonly used BT versions: Bluetooth v.1.x support data rates up to 1 Mbps, Bluetooth v2.1 + EDR introduced enhanced data rate (EDR) up to 3 Mbps, Bluetooth v3.0+HS 24 Mbps speed rate and Bluetooth v4.0 and Bluetooth Low Energy (15) (16). BT connection between two devices is a multi-step process and those steps are the inquiry, paging or connecting, and connection. It uses the same 2.4-GHz ISM frequency band as RF protocols ZigBee and Wi-Fi (17). The vehicle detection system (VDS) is possible because the BT device has a unique 48-bit address. Usually it is shown in form of a 12-digit hexadecimal value. The half (24 bits) of the address refer to the organization unique identifier (OUI), which identifies the manufacturer. The lower 24-bits are a unique part of the address. Also, important part of BT detection system is its detection range. BT devices are separated into three groups by their power class and range. Class 1 with 100 mW output power and 100 meters range, Class 2 with 2.5 mW output power and 10 meters range, and Class 3 with 1 mW output power and 10 centimeters range (16).

Bluetooth detector

The BT data collection system consists of a BT detector or scanner, a host computer (for gathering and analysing data) and communication, an antenna, power supply, casing, and equipment for mounting. BT is mounted mainly on lighting poles next to roads and it detects passing BT devices, collects data and stores them for future use. Detectors constantly scan the surrounding area in search of an active BT device. Successfully detection means that a device is identified with a unique MAC address. Besides the MAC address, BT detectors receive further information such as a time stamp, name of the device, class, and the strength of the received signal.

The high resolution and time-stamped data can be provided by BT probes to derive traffic metrics such as travel time, O-D matrix, and speed (18). For calculating these measures, two or more BT detectors are required, but there are traffic data that can be provided with only one BT detector.

Number of Hits (N_{Hits}) is the number of times (k) a device or vehicle identified by a unique MAC address is detected in a single detection zone. It is obvious that vehicles or devices are detected more often if they stay longer in the detection zone, based on the fundamentals of the BT detection process (19, 20).

$$N_{Hits} = \sum_{i=1}^{k} MAC_address_i \ [hits] \tag{1}$$

BT Dwell Time (dwT) is a single detector measurement that is computed from the timestamps of a device entering the detection zone of a detector (first detection) and exiting it (last detection) (19).

$$dwT = Time\ of\ Last\ Hit - Time\ of\ First\ Hit\ [s] \tag{2}$$

Number of Hits and Dwell Time is a surrogate measure for loop detector occupancy. For example, the greater the dwell time, the longer a vehicle “occupies” the detection zone. As it is possible for a device or vehicle to be detected multiple times at a single detection zone, there are several ways to define BT travel time. The difference between the time of detection first – first, first – last, last – last, last – first, average – last, and average – first.

Average BT travel time (TT_{BT}) between nodes A and B during the period P, where n is the number of observations during the period P (21).

$$TT_{BT}(P) = \frac{\sum_i^{n_P}\left(t_{i,B} - t_{i,A}\right)}{n_P} \ [s] \tag{3}$$

Data collection and filtering

The result of BT observations are mostly heterogeneous datasets collected from various personal devices used by commuters. (22) used three cluster analysis methods K-means (KM), fuzzy c-means (FCM), and partitioning around medoids (PAM) to automatically classify different travel modes from MAC addresses collected from moving entities. In this paper the goal is to detect only vehicles with BT devices. So, we choose the test site where other modes of transportation are rare. The main idea to classify BT device as “vehicles” relies on recorded BT Dwell Time and Number of Hits. If the BT Dwell Time is reasonable in duration and has a reasonable Number of hits than that device is considered to be a “vehicle”. All others are considered as outliers. Detection of outliers is an essential part of data analysis. Outliers may cause a negative effect on data analysis, such as Analysis of variance (ANOVA) and regression, based on distribution of assumptions, or may provide useful information about data when an unusual response to a given study is discovered. Some methods are sensitive to extreme values, and others are resistant to extreme values, like Tukey’s and Median rule method (23), used as

methods for filtering the outliers. In the section 3 results of these two methods are compared regard to detection rates of BT vehicles.

Bluetooth probe dataset

An example of recorded BT probe dataset is shown in Table 1. Each row in dataset contains columns presenting timestamp in Unix Timestamp format, MAC address, the first part of MAC address, device type in hexadecimal form, and Received Signal Strength Indicator (RSSI). RSSI is measure of signal strength or received signal power in dBm.

Table 1 – Row example in dataset

TIMESTAMP	***MAC_ADDRESS***	***FIRST_MAC***	***DEVICE_TYPE***	***RSSI (dBm)***
1552565883	*48:a9:d2:ef:9c:98*	*48:a9:d2*	*340408*	*-84*

BT detector scans the space and if the device is retained in the detection zone for more than 10 seconds, the same MAC address will be recorded. The number of hits is a measure that points to several rows with equal MAC addresses. This leads to a logical conclusion that if devices pass faster through the detection zone, they will have less amount of the number of hits and vice versa (18).

Filtering methods

Tukey's method is applicable to skewed or non-mound shaped data (24). This paper proposes Tukey's method or Interquartile range (IQR) method for filtering BT probe dataset.

In cases when a dataset has outliers or extreme values for describing a dataset by a typical value, the median is used in opposition to the mean. Variability should be summarized by a statistic measure called the interquartile range. The interquartile range is the difference between the first and the third quartile.

The first quartile denoted as $Q1$, represents the value in the dataset that holds 25% of the values below it. The third quartile denoted as $Q3$, represents the value in the dataset that holds 25% of the values above it.

The interquartile range is defined as follows:

$$IQR = Q3 - Q1 \tag{4}$$

Tukey fences filtered data outside the following range:

$$[Q1 - k \cdot IQR, \quad Q3 + k \cdot IQR] \tag{5}$$

for some non-negative constant k.

Tukey proposed this test, where $k = 1.5$ indicates a less skewed distribution, which is called an inner fence, and where $k = 3$ which indicates data with outliers far out, called an outer fence (24).

The median is a robust estimator of population. It is an 50% breakdown point. The values that are located exactly in the centre of the population when the data is arranged in order (23).

$$Q2 = \begin{cases} \left\{\frac{(n+1)}{2}\right\} th\ value, & if\ n\ is\ odd\ number \\ \frac{\left[\left\{\frac{n}{2}\right\} th\ value + \left\{\frac{n}{2}+1\right\} th\ value\right]}{2}, & if\ n\ is\ an\ even\ number \end{cases} \tag{6}$$

The Median rule *filtered data outside the range*:

$$[-Q2 - 2.3 * IQR, \qquad Q2 + 2.3 * IQR\ ] \tag{7}$$

Measuring equipment and test site

Measuring equipment used in this case study includes BT traffic detector and radar traffic detector. Radar detector is used as ground truth technology for counting the total number of vehicles and measuring their speed. For the power supply we used a solar-powered system independent of outside power source. Photovoltaics system contains a solar panel, battery, and charge controller.

Frequency Modulated Continuous Wave Radar (FMCW) used for overall flow measurement was Huston SpeedLane, working in 24 GHz K-band. This radar is specifically designed for portable or permanent traffic data measurement and collection (25).

The DeepBlue Sensor v2t R-Model by trafficnow® is used as a BT detector. It detects all BT versions in more than 500-meter range with -104 dB receive sensitivity. It is suitable for usage in large urban metropolitan area or at intersections (26). In this paper, the BT detector is used as a point detector on a road segment.

In this experiment we used a flat patch range extender antenna L-com model RE09P with the gain of 8 dBi. It is suitable for both indoor and outdoor applications in the 2.4 GHz ISM band, including IEEE 802.11b and 802.11g, BT and for public wireless hotspot applications (27). (*Figure 1*) shows antenna gain (radiation) pattern.

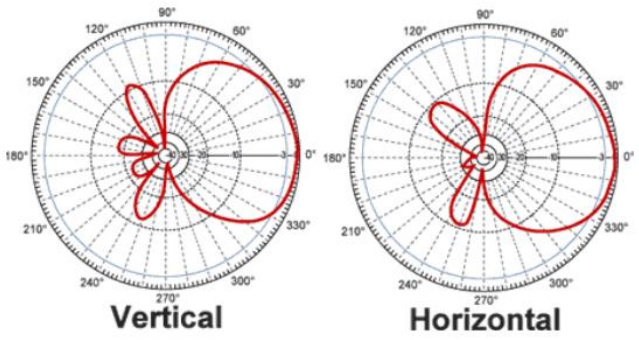


Figure 1 – Antenna gain patterns
Source: (27)

Measurement of BT probe data was done in Zagreb near the underpass - Miramarska street. All equipment was mounted on the concrete pole. Figure 2 shows the exact location of radar and BT detector in Miramarska street.

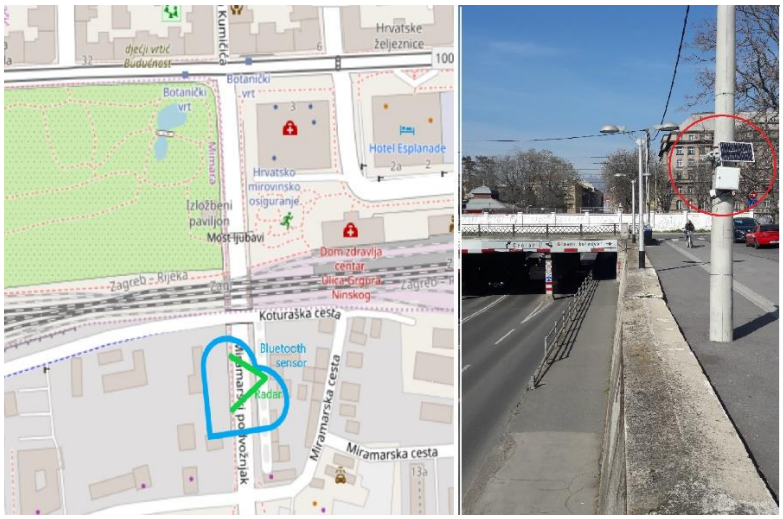


Figure 2 – The location of radar and BT detector

3. RESULTS AND DISCUSSION

BT detector collected 84,767 records between 14th and 15th and between 22nd and 25th March 2019. From 14th March in 15:00 h to 15th March in 15:00 h 4,167 unique MAC addresses, referring to unique devices were recorded and 4,763 from 23rd March in 00:00 h to 26th March in 00:00 h. The observed dataset is used to compare the BT vehicle penetration rate on working and non-working days. Figure 3 shows behaviour of the traffic from 14th March in 15:00 h to 15th March in 15:00 h. *Y*-axis shows that only few devices were detected with large amounts of hits and all three days show a very similar distribution of the number of hits.

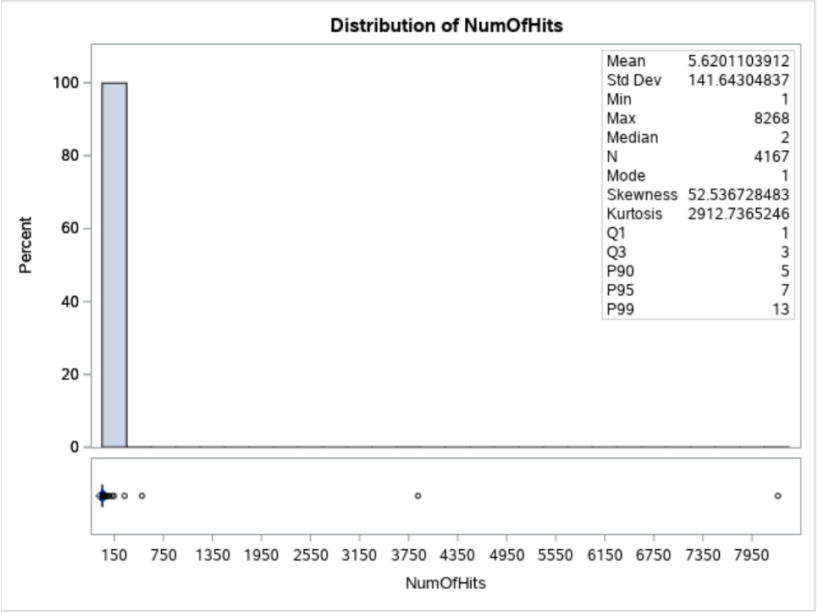


Figure 3 – Frequency of number of hits in observed population

Figure 4 shows distribution when obvious outliers presented by a large value of number of hits are discarded. From frequency distribution in Figure 4, it is evident that most devices have small values of the number of hits.

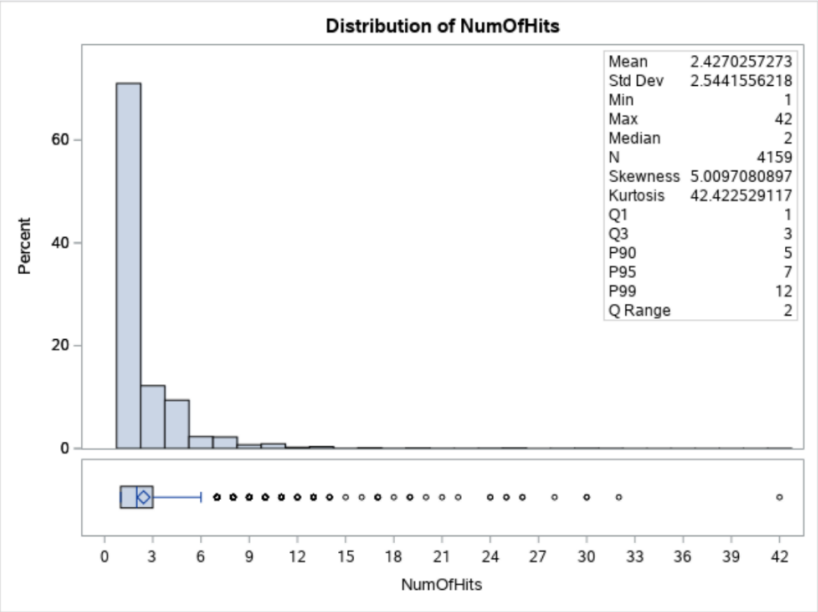


Figure 4 – Distribution of Number of Hits without "tail" values

Collected data show that there is a large dispersion and that points to a premise we are dealing with a heterogeneous set of data. In order to separate vehicles from all recorded BT probe data, filtering was done using the Tukey's method and the Median Rule method.

Table 2 shows data from the Radar detector from Thursday to Friday (24-hour period), Saturday and Sunday.

Table 2 – Radar vehicle data collection

Days	from Thursday to Friday	Saturday	Sunday
Number of vehicles (*N*)	32,379	23,874	17,207

For the weekend period, there is an expected fall in the number of vehicles, but the percentage of vehicles equipped with BT devices remains roughly the same. Figures 5-7 show the comparison between the actual vehicle count measured by the radar detector and the BT share in the actual vehicle count. The BT share for all three days is firstly filtered using the Tukey's method. In Figures 5-7) Blue line (lower line) shows filtered data by the Tukey's method and *k*=1.5.

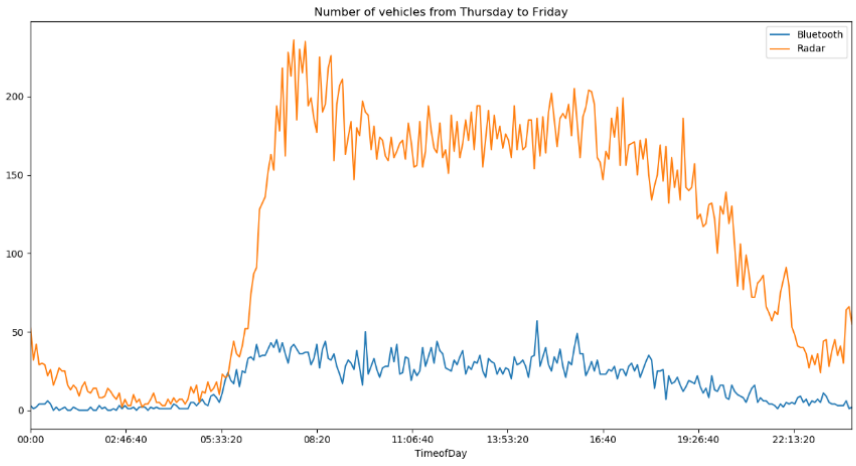


Figure 5 – Radar and BT counts in 5-minute intervals for Thursday and Friday

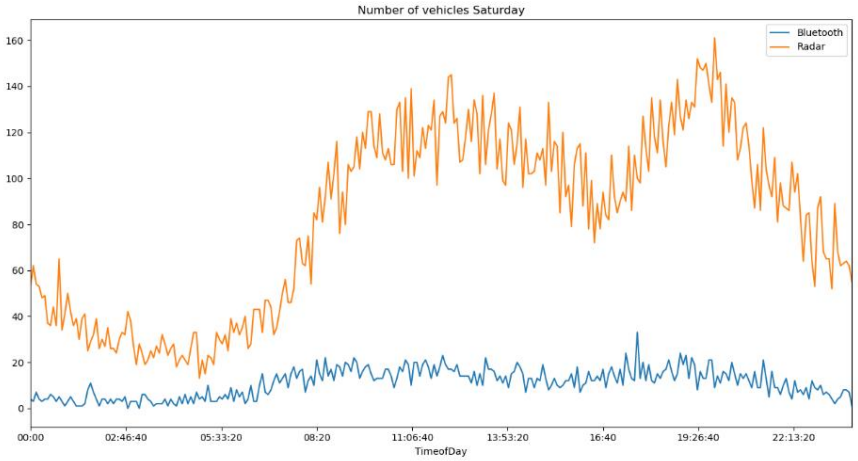


Figure 6 – Radar and BT counts in 5-minute intervals for Saturday

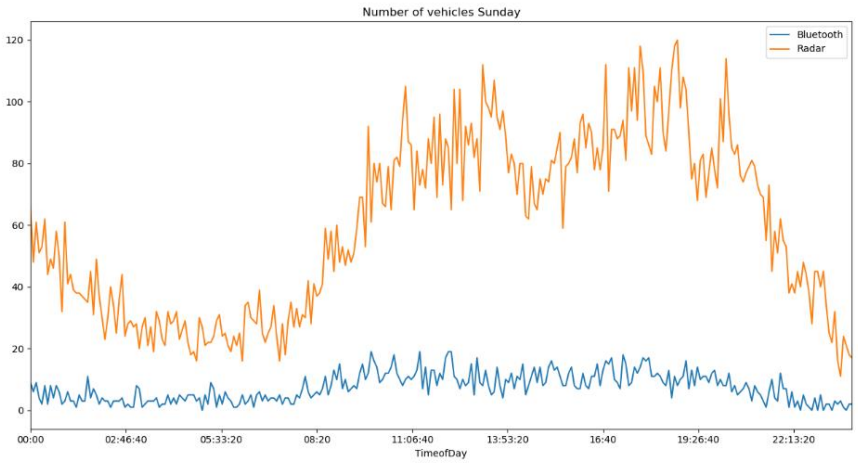


Figure 7 – Radar and BT counts in 5-minute intervals for Sunday

The Tukey's and the Median rule method were applied to data, and the percentage of the vehicles equipped with a BT device is presented in Table 3. The Median rule and the Tukey's fences have the same results for k=1.5. Tukey's method for k=3 against k=1.5 and Median rule have the same difference in percentage, 0.77% (which is for absolute value 183 vehicles for Saturday and 132 vehicles for Sunday). For Thursday to Friday this difference is 0.31% and in absolute value the difference is 97vehicles.

Table 3 – Percentage of vehicles in actual vehicle count

Filtering method	Thursday and Friday	Saturday	Sunday
Tukey's method k=1.5	12.19 %	10.43%	10.00%
Median rule	12.19 %	10.43%	10.00%
Tukey's method k =3	12.5%	11.2%	10.77%

By applying these two methods the percentage of the vehicles equipped with BT devices is in the range between 10% and 12.19%. It can be concluded that BT penetration rate over the time is stable.

The methods used in this paper filters static BT devices, i.e. those with a far greater value of the number of hits, than the rest of the observed population. However, this is not efficient if the measured percentage of BT devices has a large share of cyclists or pedestrians. The number of hits for each MAC address during the observed period is calculated cumulative. This means that the vehicles passing more

than once through the road segment have a higher value of the number of hits. This can cause, for example, that the vehicle which passes several times through the detection zone has the same number of hits as the pedestrian that passes through the detection zone once.

However, the Tukey's method for k=1.5 and the Median rule have discarded all consecutive detections of the same devices with the number of hits above 6. This means that devices that have been retained in the detection zone for more than one minute have not been considered in the detection of vehicles equipped with BT devices. it is possible that vehicles that were in congestion were thrown out by this rule. In order to obtain a more accurate estimation of the percentage of vehicles equipped with BT devices, the number of hits should be calculated within intervals and separated by different vehicle routes. It is necessary to find patterns of pedestrian and bicycle behavior to extract these devices from the total number of detected BT devices. To achieve this goal, two or more BT detectors can be used, and cluster analysis methods can be applied to more precisely determine the mode of transport detected from BT detectors.

4. CONCLUSION

Traffic data collection based on BT technology has some notable features: possibility of measuring very desirable traffic parameters such as travel time and O-D matrices, increasing rate of Bluetooth devices in vehicles, more affordable assembly components of Bluetooth traffic detectors and easy mounting of Bluetooth traffic detectors. This makes Bluetooth technology an attractive complementary source of traffic data. Field experiment and data analysis show that the penetration rate of BT probe vehicles is in the range between 10% and 12.19%, and it is stable over the time. This statement is justified because robust filtering of outliers was used. For further analysis, pedestrian and bicycle patterns should be taken into consideration as well as cases of usage of multiple BT devices per vehicle. Results of the case study in the city of Zagreb (Croatia), shows that Bluetooth technology can be considered as an acceptable technology for automatic data collection.

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ANA DLESK, dipl.ing.[1]
E-mail: ana. dlesk@croatiaairlines.hr
DINO KUČIĆ, dipl.ing. [1]
E-mail: dino.kucic@croatiaairlines.hr
F/O DANIJEL PULJEK, dipl.ing.[1]
E-mail: danijel.puljek@croatiaairlines.hr
[1] Croatia Airlines
Bani 75b, Buzin, 10010 Zagreb, Croatia

AN AIRLINE VIEW OF NAVIGATIONAL AND ECOLOGICAL TRENDS

ABSTRACT

Croatia Airlines as a national air carrier boldly goes into future endeavours which are wider than its primary goal – economical commercial aviation. By keeping the pace with new navigational, surveillance, organisational and environmental standards, the company is growing further aware that sustainable development has no alternative in aviation. With this paper, the implementation of the WAAS (Wide Area Augmentation System) equipment on Croatia Airlines Dash8 fleet will be presented. Also, the overall effect on the environment will be shown to present synergy of technical improvements and sustainability through trends with practical examples.

KEY WORDS

Croatia Airlines; aviation; future; CNS; CPDLC; ADS-B; environment; sustainability

1. INTRODUCTION

Over the years, aviation is experiencing number of different changes and facing with a rapid growth of new technologies and innovations, that have and shall have influence on all. The reasons for these changes, like in all other fields, are not just related to the technology, but also related to the society, environment, economy and politics.

Although the aviation industry was/is growing constantly over the years, the increased growth for airlines and ATSs (Air Traffic Services) started in 2012 with introduction of the (new) ICAO plan (ICAO plan 2012), that brought new identifiers used for ATC (Air Traffic Control) planning and common rules/standards applicable to the airlines and ATSs world-wide. 2012 brought so called PBN (Performance Based Navigation) concept whose aim was to ensure global standardisation of area navigation systems.

Quote - source [1]:
"Performance-based navigation. Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.
Note: Performance requirements are expressed in navigation specifications in terms of accuracy, integrity, continuity and functionality needed for the proposed operation in the context of a particular airspace concept.

A navigation specification is either an RNP specification or an RNAV (Area Navigation) specification. An RNP (Required Navigational Performance) specification includes a requirement for on-board performance monitoring and alerting, while an RNAV specification does not."

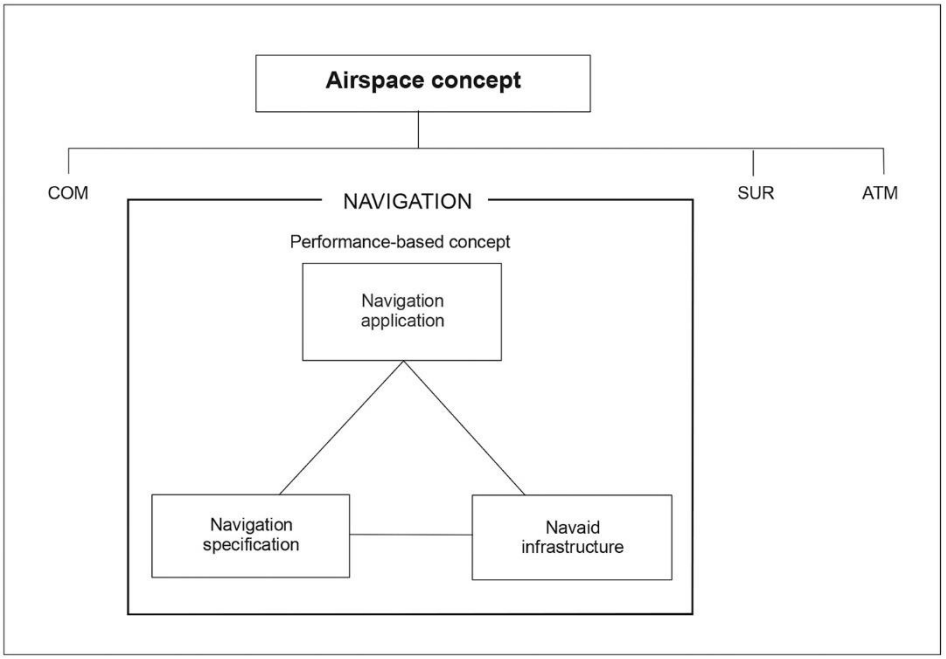


Figure 1 – PBN concept
Source: [1]

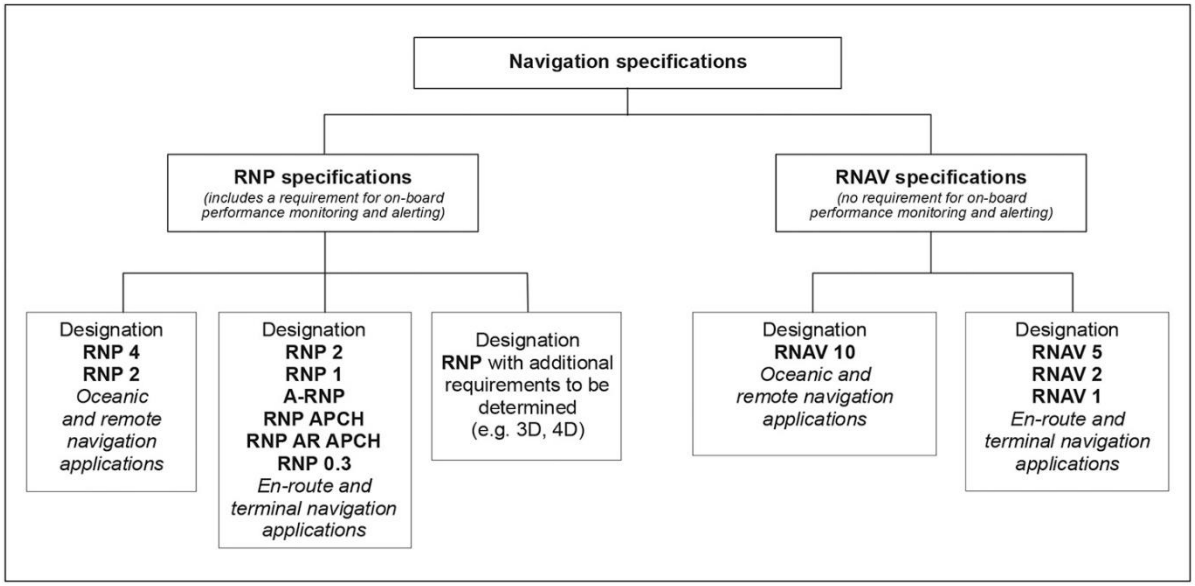


Figure 2 – Navigation specification designations
Source: [1]

The strategic objectives for the PBN concept and all current or future (related) changes, were safety, capacity, efficiency, environment & access.

Parallel with world-wide initiative of PBN concept implementation, starting from 2009, Europe was/is preparing for initiative, Single European Sky and so-called FRA (Free Route Airspace). FRA concept in Europe is a step-by-step process whose aim is to enhance European en-route airspace design. It brings benefits to airspace users such as improved flight plan efficiency (shorter routes and reduced flight time), reduced CO2 emissions and fuel waste.

New technologies and procedures obligated, in 2018, airlines operating flights in the North Atlantic (NAT) airspace to implement concept aligned with the PBN, concept for communication and

surveillance performance, called Performance Based Communication and Surveillance (PBCS). The aim of this concept is to have real time alerts with included post-implementation monitoring programmes.

Quote - source [2]:
"There are some differences between the PBCS concept and PBN concept:

- the PBCS concept applies RCP and RSP, which allocate criteria to ATS provision, including communication services, aircraft capability, and the aircraft operator; whereas the PBN concept applies RNP/RNAV specifications, which allocate criteria only to the aircraft capability and the aircraft operator; and
- the PBCS concept includes post-implementation monitoring programmes, on a local and regional basis, with global exchange of information; whereas the PBN concept includes real time monitoring and alerting functionality in the aircraft capability."

Note: RCP - Required Communication Performance
RSP - Required Surveillance Performance

PBN and PBCS concepts are known under joint name CNS concept (Communication, Navigation and Surveillance concept):

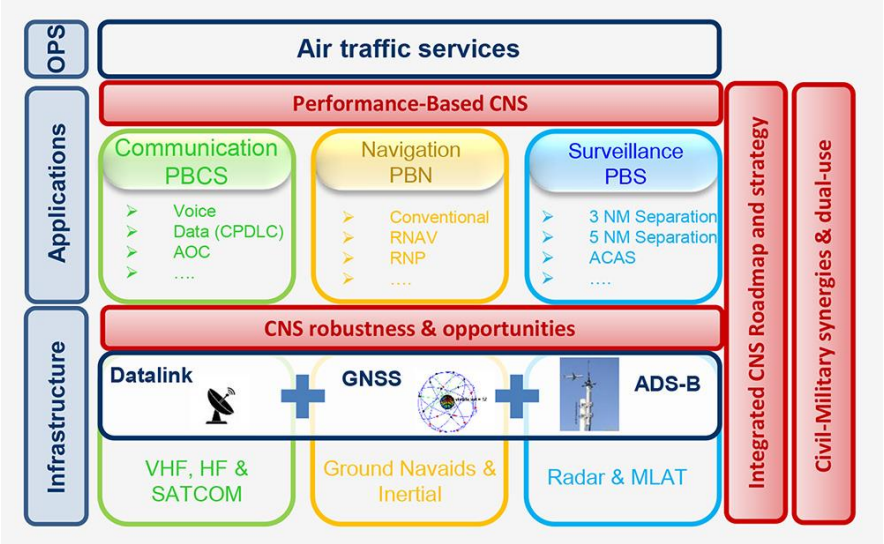


Figure 3 – Integrated CNS concept
Source: [5]

Since 90's, industry is developing and improving an application/method called, Controller-Pilot Data Link Communication (CPDLC), a method for communication between controller and pilots using data link for ATC (Air Traffic Control) communication. CPDLC is a two-way data-link system used for non-urgent strategic messages with aim to speed up air-ground communication by replacing voice communication. It should be used for (ATC) clearances, information and requested messages. For that reason, a Data Link Service Implementing Rule (DLS-IR) in Europe was adopted in 2009. and it is applicable (but not obligatory yet) to airlines operating above FL285 (Flight Level of 28 500 feet).

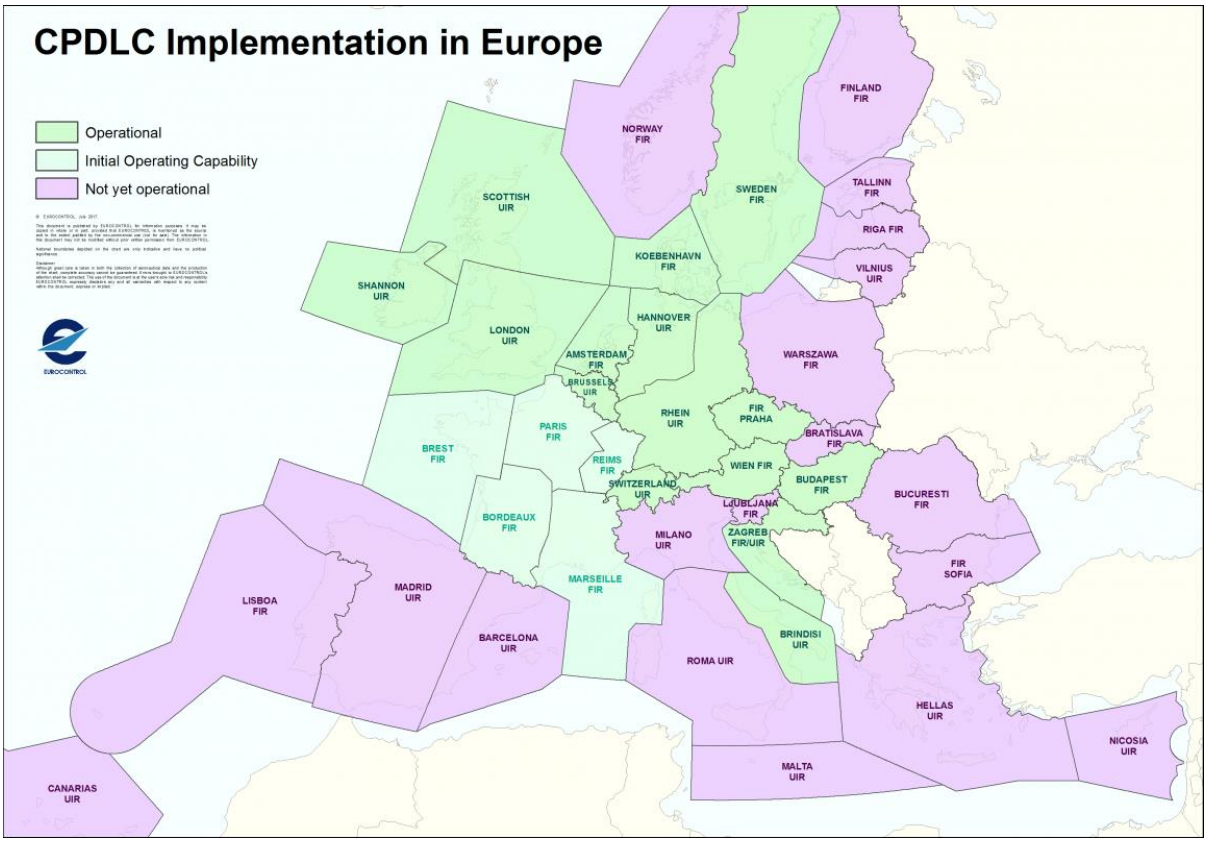


Figure 4 – CPDLC Implementation in Europe
Source: [6]

All mentioned leads us to something simply called 2020. 2020 standard is actually year that mandates compliance with ADS-B out (Automatic Dependent Surveillance-Broadcast) and CPDLC use. ADS-B out mandate in Europe, in this moment, applies to aircraft with a maximum certified take-off mass exceeding 5700 kg or a maximum cruise true airspeed greater than 250 knots, but EC regulation allows local aviation authorities to extend requirement to a wider aircraft. ADS-B out is one of the NextGen programs, a surveillance technology that allows determination of an aircraft position via satellite navigation, aiming to replace traditional radar and ground-based navigational aids with ADS-B receivers (antennas).

Automatic - it is always ON and requires no operator intervention
Dependent - it depends on an accurate GNSS (SBAS) signal for position data
Note: GNSS - Global Navigational Satellite System
SBAS - Satellite Based Augmentation System
Surveillance - it provides „radar like“ surveillance services
Broadcast - it continuously broadcasts aircraft position and other data to any aircraft or ground station equipped to receive ADS-B.

ADS-B should enhance situational awareness for both, controllers and pilots, and it should allow more efficient flight profiles (more direct routing and reduce separation minima).

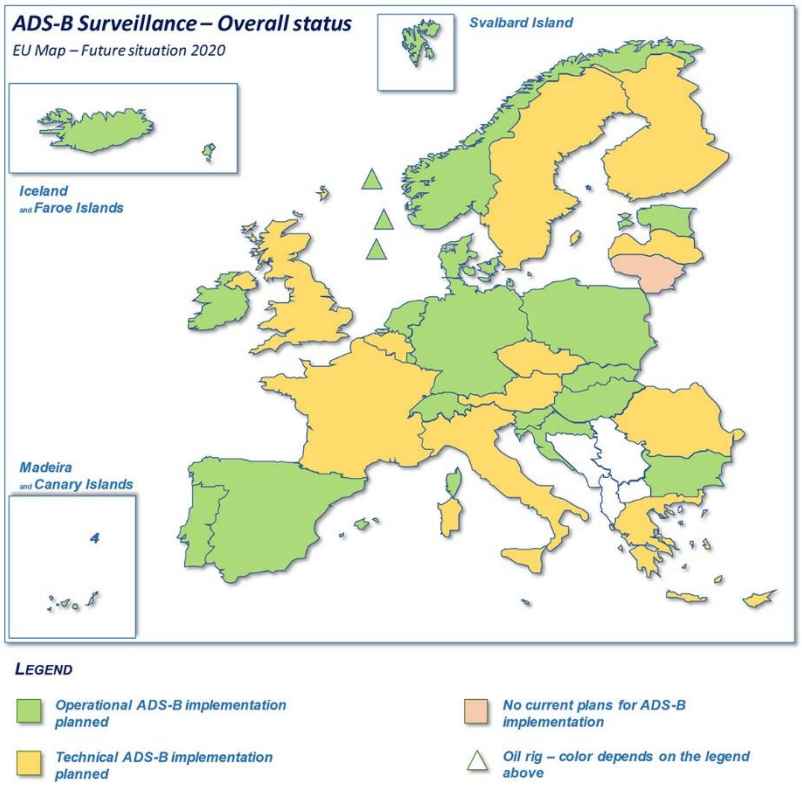


Figure 5 – ADS-B surveillance - future situation
Source: [10]

In addition, to the ADS-B closely related term is multilateration (MLAT). MLAT is a surveillance technique based on the time difference of a radio signal arrival at a number of geographically remote stations at known times, used in airport areas.

Except all this known, defined changes, there are further plans for other PBN improvements and additional changes to the ICAO plan(s). In the „spirit" of all these changes, ICAO has developed so called The 2016-2030 Global Air Navigation Plan (quote - source [11]): "It identifies all potential performance improvements available today, details the next generation of ground and avionics technologies that will be deployed worldwide, and provides the investment certainty needed for States and Industry to make strategic decisions for their individual planning purposes."

There are also projects dealing with environmental aspects, like developing engines with greater fuel efficiency, engines using mixtures of alternative fuels and engines having reduced noise level.
To improve aviation meteorological predictions, researchers and scientists are constantly developing and implementing new technologies (technologies that should result in more accurate predictions well in advance).

2. CROATIA AIRLINES VIEW OR WHERE CROATIA AIRLINES STANDS

Croatia Airlines strategic goal is to fulfil more than requirements are, in all aspects of commercial aviation business. Due to that, to follow all requirements and new trends in navigation and surveillance is one of the primary tasks for Croatia Airlines. Dedicated to Croatia Airlines core business, passengers and cargo transport, it primarily recognised the need to organize new task groups consisted of highly specialised professionals from different organisation divisions in the company. Engineers, navigational engineers, technicians, pilots, financial officers and others, are members of small teams dedicated to certain task. Dispersion of tasks has been done during last few years with present result of parallel dealing with upgrade of SBAS capable navigational equipment on Dash 8-Q400 fleet, upgrade of both our fleets, Airbus and Dash 8-Q400 fleet, with ADS-B out capable transponders, implementation of

CPDLC on Airbus fleet, upgrade of Dash 8-Q400 fleet with modern mQAR (micro Quick Access Recorder) devices etc.

Along with intensive fleet technical upgrades, Croatia Airlines actively supports local Universities and participates in different aviation related local projects. Together with Faculty of Transport and Traffic Sciences it is taking part in the European project, KAAT (Knowledge Alliance in Air Transport), through which Croatia Airlines share its commercial aviation knowledge and challenges with colleagues from academic part of aviation.

Technical aspects of Croatia Airlines fleets transition towards modern navigation trends and needs are wide. Croatia Airlines fleet consisted of 2 Airbus 320, 4 Airbus 319 and 6 Bombardier DASH 8-Q400 aircraft different in age, equipment technical level and company idea of fleet usage. Due to mentioned constraints, in Croatia Airlines Technical department, the company is developing its yearly maintenance plans, to align Croatia Airlines normal maintenance tasks, such intensive checks, with upgrade of the equipment. It was important for Croatia Airlines in regard of aircraft operational and maintenance planning, with idea to achieve maximum upgrade level in shortest possible time for one aircraft.



Figure 6 – One of DASH 8-Q400 during SBAS navigational retrofit
Source: Croatia Airlines archive

After developing initial plans, Croatia Airlines submitted proposals for EU funding, in front of the European Innovation and Networks Executive Agency (INEA), for aircraft equipment upgrade in relation with goals set by Connecting Europe Facility (CEF) and its aviation dedicated subpart Single European Sky ATM Research (SESAR) program. Croatia Airlines upgrade plans, divided into two project proposals, were recognised as eligible in term of new European ATM goals, so today Croatia Airlines is successfully performing two projects: „Croatia Airlines joining EGNOS family“ based on regional Dash 8-Q400 fleet upgrade for RNP Approaches capability down to LPV (Localiser performance with vertical guidance) and „ADS-B implementation“ based on upgrade of both fleets to technically meet ADS-B mandate before timeframe set to 2020.

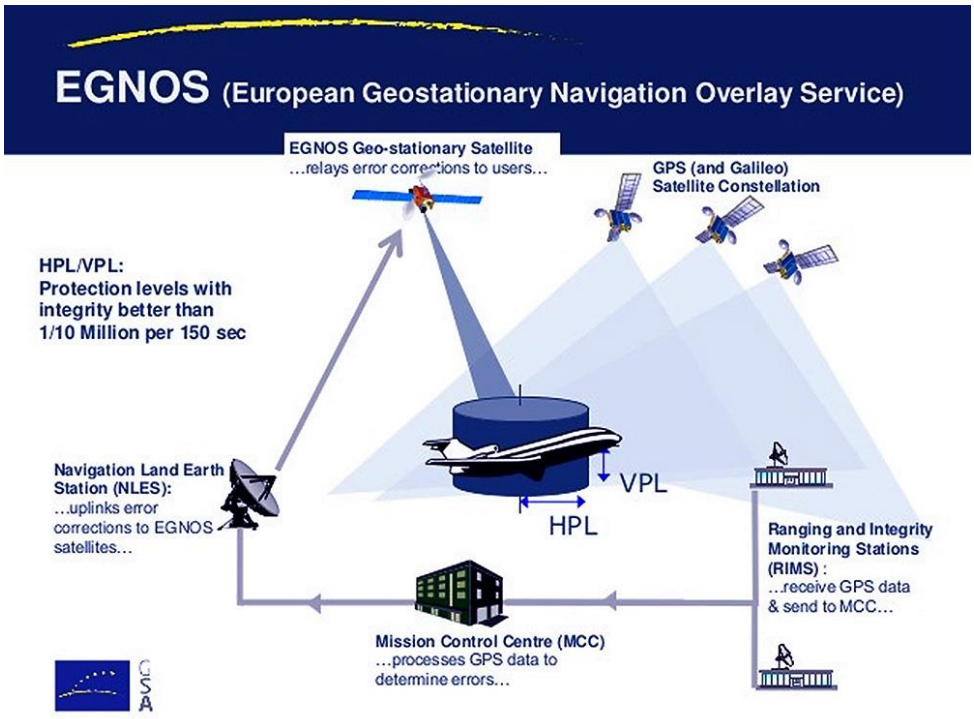


Figure 7 – EGNOS operational principle
Source: ©GSA, ©European GNSS Agency

In efforts to achieve technically demanding prerequisites for RNP APCH (Required Navigation Performance approach) with LPV minima, Croatia Airlines decided to upgrade its Dash 8-Q400 fleet with the most modern Flight Management Systems (FMS) that have integrated Satellite Based Augmentation System (SBAS) receivers capable to receive EGNOS signal. European Geostationary Navigation Overlay System (EGNOS) is addition to Galileo constellation, that together with any GNSS signal provides additional navigational accuracy important for RNP approaches.

In the second project, aircraft already equipped with SBAS capable receivers, are equipped with ADS-B capable transponders and upgrade was completed. After this navigational retrofit, Croatia Airlines Dash 8-Q400 became capable to fly most of actual and planned PBN navigation specifications in at least next decade.

In parallel, all the other aspects are covered and whole flight operations related documentation has been revised, updated or created in accordance to EASA regulations, to cover new elements in term of crew training, aircraft handling, renewing of issued documents etc. With the coordinated approach, all operational aspects have been covered besides to the technical part of the upgrades, to achieve main goal of the activities – operational usage of the new equipment on European sky.

According to the present state of all ongoing actions and tactical company plans set up to 2020, Croatia Airlines expect to reach ADS-B mandate well before deadline. Also, Croatia Airlines is expecting to obtain operational approval for navigation specification RNP APCH with LPV minima for Dash 8-Q400 fleet to the end of 2019, with further navigation specifications adoption plan already set for 2021 including RNP AR APCH (Required Navigation Performance Authorization Required approach), RNP 1 and 2 etc.

3. ENVIRONMENTAL ASPECTS IN THE WORLD AND CROATIA AIRLINES

The new Environmental Era of aviation in Croatia Airlines started during 2008 which was critical due to global circumstances (the recession in the aftermath of 9/11 and SARS). Simultaneously, fuel prices raised almost uncontrollably causing airliners to act swiftly in the effort to mitigate negative trends with industry wide efforts supported by IATA and Star Alliance. Establishing fuel assessment teams, working groups, "Pillar policies" and strategies resulted in fuel consumption reduction on a larger scale. Volatility of Fuel price is best shown on Figure 8 with analysis made by IATA.

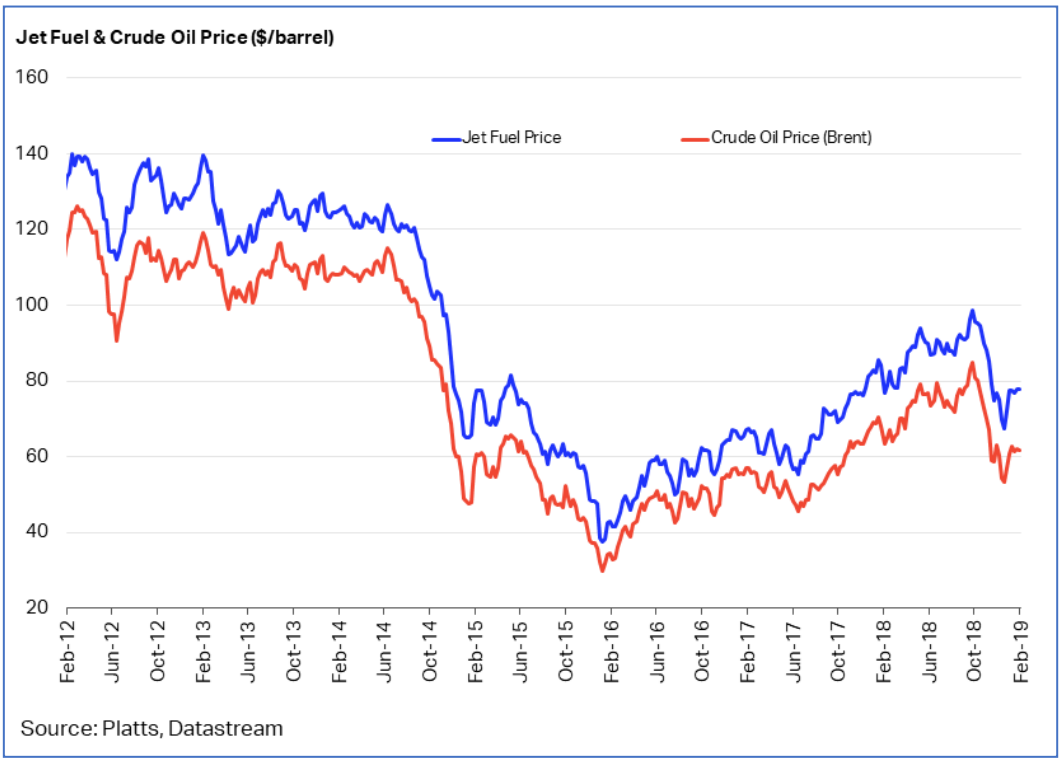


Figure 8 – IATA Jet Fuel price monitor
Source: [12]

Also, global warming issue became one of the main points of awareness and focus. The EU, as the leader in climate action, acted enforcing the EU ETS on aviation operators from 2010. The full implementation of the Directive 2003/87/EU brought almost worldwide trade war affecting Boeing and Airbus orders, causing countries to legally ban their operator's contribution in the EU ETS, and threats to blacklist operators from EU airspace.

Tensions declined when EU ruled „reduced scope" of the system even if that meant that the EU operators are in disadvantage on the market. The emissions trading started in 2012 with emissions prices fluctuating from 2 EUR/t up to 5 EUR/t until the spring 2018. From summer of 2018, this price increased dramatically to peaks of 25 EUR/t, so the year 2018 can be considered as the „Emissions Peak" year reminding of fuel in 2008 as shown on Figure 9 with Croatia Airlines internal analysis of EUA Emissions units.

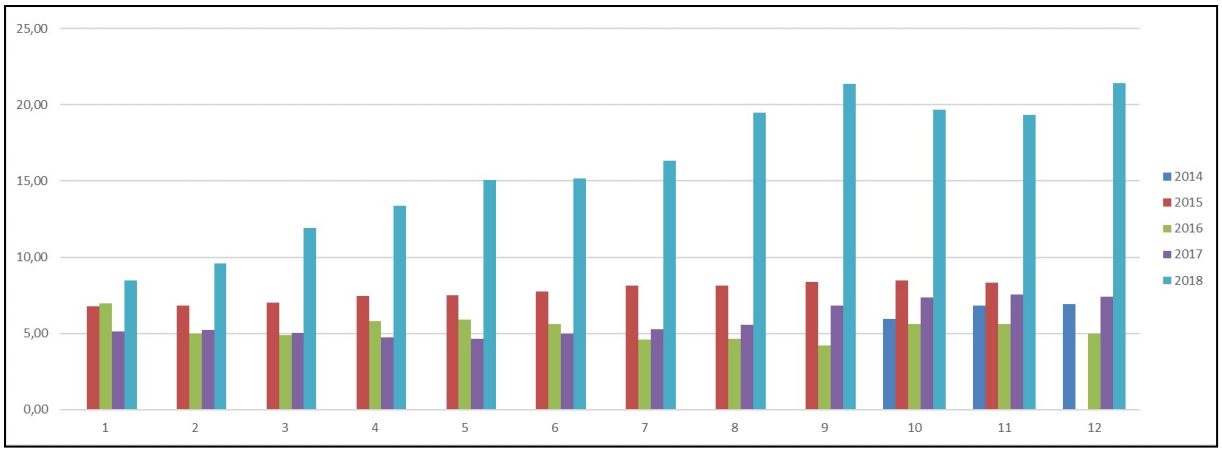


Figure 9 – EUA Emissions units per month and year
Source: Croatia Airlines internal analysis

In the same period, fuel prices were declining, and even fall below all expectation but mostly were stabile (with slight rise) comparing to the 2008.

Transition of 2018-2019 was very significant because in the efforts to make emissions system global ICAO stepped up and revised Annex 16 enforcing CORSIA system for all international flights for countries in voluntary phase form 2019 (most countries and the EU) and for all the rest countries from 2021 creating parallelly a market for this global market measures first time in aviation history. For Croatia Airlines this means continuation of emissions reduction efforts.

Looking into current short- and long-term trends, it can be seen the demand is increasing rapidly which is good for the industry and not so god for the environment. Sustainable development is the joint answer where the measures should achieve just that-sustainable development. These measures basically are technological and technical.

Technological measures can be found in examples of flexible and better use of airspace, use of remote tower technology and better data flow between ANSPs (Air Navigation Service Provider) and joining individual ANSP into „bigger units/areas “. Big trend is waste reduction (up to “zero waste” concept) where significant example is the EU removing single use plastics etc. On board of Croatia Airlines just a 15gr/2dl water cup can make 15 tons of plastic waste on a million passengers for next 150 years, creating dangerous “Rule of Thumb”. From 2019, Croatia Airlines decided to remove most plastics from Catering services.

By taking a look at on main environmental aspects of an airline it is clear that beside emissions and waste, noise is an important factor. Croatia Airlines Dash8 Q400 fleet is equipped with ANVS system (Active Noise Vibration and suppression System) which reduces noise by countering primary noise of the engines thus reducing noise footprint of the aircraft. Together with company’s Airbus fleet it shares ICAO Annex 16 Chapter IV compliance. Additionally, during the Winter of 2018/2019 the company invested in modification of the Airbus fleet by installing “wake vortex” generators, silencing the take-off and landing operations by an average of 9dB.

Currently a lot of airlines are developing new flight procedures as well as certain upgrades such as mentioned in this text to upgrade the potential of current fleet thus avoiding prompt fleet replacement.

Biggest technical measures are achieved already with new “Leap” engines technology shown in Figure 10. Leap engines are basically geared engines working similar as cars with gear shifting using engine power, thus fuel, in more precise manner according to flight requirements.



Figure 10 – Leap Fan on Safran stand at Paris Air Show 2017
Source: [13]

To clearly show what is basically difference in consumption between three „generations" of aircraft, Croatia Airlines fleet can be compared through history and future from 1990-2022. Starting with Boeing 737-400, continuing with A320ceo and A320 neo (on order) of similar passenger capacity, dramatic improvement in fuel efficiency is shown on Figures 11 and 12. On a sector of 100 Nm, using Eurocontrol Small Emitters Tool the CO2 toll is very different.

ICAO Aircraft Type Designator	City pair flown distance	Nb of flights	Add 95km(51NM)	Estimated Fuel (Kg)	Estimated CO2 (Kg)
B734	100	1	Y	1.688	5.317
A320	100	1	Y	1.743	5.490
A20N	100	1	Y	914	2.879

Figure 11 – Boeing 737-400/Airbus A320 ceo/Airbus A320 neo comparation
Source: [14]

Between oldest and newest airframe on 100 Nm the difference is shown in 2 438 kgs of CO2 or over 50% significantly reducing Emissions footprint of the air travel.

Even in turboprop technology such comparation can be made with comparing Croatia Airlines ATR-42 300 aircraft (42 seats) with bigger Dash-8 Q400 (76 seat configuration) where bigger and newer aircraft has better performance stating, „newer is better".

ICAO Aircraft Type Designator	City pair flown distance	Nb of flights	Add 95km(51NM)	Estimated Fuel (Kg)	Estimated CO2 (Kg)
AT42	100	1	Y	725	2.284
DH8D	100	1	Y	702	2.211

Figure 12 – ATR42 and Dash8 Turboprop comparation
Source: [14]

Next step is wider usage of bio-fuels which can reduce emissions footprint additionally for about another 50% enabling aviation achieving the goal of sustainable development. Currently only big airlines, such as Lufthansa, managed to implement bio-fuels on a series of flights with good results. But the project itself did not continue due to high prices of bio-fuel usage (not technical issues) and availability of the fuel on wider area. Scandinavian countries are at far most concerning efforts of bio-fuels introduction in everyday aviation life, so it is expected they will lead the way and the efforts will expand further. Risk of such development is, off course, the price of the fossil fuel and the price of emissions units, but we must not forget the main reason, and that is environmental protection.

The step after that, projected in 2040. is the wide usage of electric power using the 2000s battery technology "boom" combined with cheap renewable energy production and making energy storage space safe for aviation usage. The basic problem is how to store energy for propulsion of main aircraft type (such as Boeing 737 or Airbus A320) with MTOW of approximately 75 tonnes.

4. CONCLUSION

As aviation changes to adapt to the changing world, even small companies, like Croatia Airlines, may grow with those changes and help to have improved, safer and greener aviation.

All the changes the company had to or decide to do will help to achieve mentioned goals. Having internal projects or participation in different (external) projects, like KAAT project, will contribute to the future of aviation.

With fuel and emissions monitoring, through the years, a baseline for Croatia Airlines fleet has been established giving the values of the operations with attributes. This will enable the company to fully measure the effects when LPV operations will be certified and will start, during the year 2019. These effects will not only affect flight time, quantity and the effects of disruption reduction but also from the environmental point of view reduction in fuel consumption, thus emissions, and noise exposure. The values of overall environmental impact can be found in company non-financial yearly statements starting from 2018. The effects of mentioned navigational upgrades will enable new analysis which will further on open room for new innovations in operations of Croatia Airlines.

Like all industries around the world, airlines need to find the best way to follow the trend and to be sustainable on the market.

Sustainable development has no alternative in aviation because climate changes will not only affect economic ability for general population to become airline passengers, but also physically endanger normal operation of airlines due to weather extremes.

As a summary it is quite clear to say that aviation is leading the way towards sustainability with technological/technical upgrades and involving academic society in forming new projects and programmes creating experts for new aviation era with full support and participation of Croatia Airlines.

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MIROSLAV DRLJAČA, Ph.D.[1]
IAQ-Associate Academician
E-mail: mdrljaca@zagreb-airport.hr
[1] Zagreb Airport, Ltd., Zagreb, Croatia &
University North, Varaždin-Koprivnica, Croatia

REVERSIBLE SUPPLY CHAIN IN AGRICULTURAL PRODUCTION

ABSTRACT

The Supply Chain (SC) represents the flow of goods, services and information from raw material suppliers, manufacturers, distributors, retailers to the end-customers. The flow of goods, services and information enables transportation. Small producers, especially family farms, have recently opted to avoid intermediaries in transporting and distributing the products to the end-customer. The reason is to increase the quality of their products and competitiveness by eliminating the costs of intermediaries in transport and distribution. This is achieved by merging and shortening the SC. The market situation requires further optimization by producers due to lack of labour force and the need to increase competitiveness and leads to the emergence of a Reversible Supply Chain (RVSC) phenomenon which differs from the reverse SC. There is a problem in how the end-customer comes to the consumable product, since the producer is unable to provide distribution directly or through the intermediary. Explanation of how to solve this problem by modelling a brand new SC in which there is no classical distribution is the fundamental goal of this work. In the paper, the author, by applying scientific methods, researches the genesis of RVSC as a main output of this research.

KEY WORDS

supply chain; reversible supply chain; logistics;

1. INTRODUCTION

The SC definition is complex. 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.

The Act on the prohibition of unfair trading practices in the business-to-business food supply chain (Official Gazette 117/17) states that the SC „ … encompasses all participants in production, processing and trade..., as follows: producers, ..., wholesalers and retailers." [1] Further on, „ ... 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]

The supply chain can be considered a network of structures, distribution, transforming of procured materials into semi-products or final products for customer. [3]

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". [4]

For the purpose of delivering the product without losing its characteristics, which would mean a fall in quality for the customer, producers, in particular small family farms, producers of agricultural food products, will restructure the SC by shortening methods, in order to avoid intermediaries on the way from production to customer and that is, increasing the price of their products and other, reducing the

time of SC cycle. The shortening the SC maintains the steady quality of agricultural food products from the moment of production until delivery to the customer, reduces SC cycle costs and increases product competitiveness on the market.

In the circumstances of lack of labour force and the efforts of producers to sell goods while maintaining competitiveness, there is a RVSC phenomenon established, especially in small family farms producing fruit, vegetables and other domestic products.

This is a phenomenon when the producer doesn't distribute the products through the distributor or directly, but the end-customer comes to the producer and picks up the products (fruit, vegetables, etc.). It is much more different phenomenon then reverse logistic which basically means any process or management after the delivery of the product. Here is the absence of a classical distribution where the distributor or producer deliver the product to the end-customer.

For a RVSC it is characteristic that it does not apply to parts of the process after the delivery but that the classic distribution is actually made in such a way that the end-customer comes to the producer and takes over the product itself. RVSC is not the case if the product is defective and the customer would return the product. RVSC is also not the case when the producing company would have to organize shipping of the defective product, testing the product, dismantling, repairing, recycling or disposing the product. RVSC is not the same as reverse SC. RVSC is not the situation such as reverse supply chain when the product would travel in reverse through the supply chain network in order to retain any use from the defective product.

However, it may be concluded that the SC is a flow of goods, services and information from suppliers, through transport, producers, distributors, and retailers to the end-customer. In the same time, it can also be concluded that the SC is a complex system of integration of suppliers, producers, distributors and traders for the purpose of production and distribution of goods/services in the right quantities, in the right place and at the right time, all with the aim to balance supply and demand.

2. METHODS

The research question in this paper is the functioning of the RVSC phenomenon which differs from the classical SC in the distribution and delivery segment. Therefore, in RVSC concept producer doesn't distribute its product to the end-customer through the intermediary either directly. Distributions actually don't exist in the classical sense. The end-customer comes to the producers and collects agricultural products, pays them and takes them for consumption.

In researching this phenomenon, the author approaches the research of the context that caused the RVSP phenomenon, which is the economic situation characterized by the presence of large shopping centres on the market that set the conditions for small agricultural producers, the lack of workforce in agriculture especially at the time of harvesting fruit and vegetables and the need for a small producers to be competitive, and this can only become SC optimization.

In the paper, the author has applied general and special scientific methods of cognition. The real dialectical-materialistic method as a general philosophical method of cognition was applied to reach an objective understanding of the RVSC phenomenon based on practical human activity, i.e. the objective reality present in the agricultural production of small family farms.

From the general scientific methods of cognition used the method of system theory is applied to understanding the context and its impact on the small family farms in agriculture as part of the economic system of the region and the state, too.

The modelling method was applied to RVSC design, which is specific to RVSC's traditional approach and a sustainable model that represents a modern approach.

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

The comparative method was applied in the research and comparison of SC, Short Supply Chain (SHSC) and RVSC, as well as in comparison and observation of the essential differences between the model representing the traditional SC approach and the model of Sustainable Supply Chain (SSC) or modern approach.

Of the special scientific methods of cognition an analytical-synthetic method was used in the research of RVSC evolution from SC, through SHSC, as well as the transformation of the traditional SC model to the SSC model.

The deduction method was applied when deciding on the impact of the context that represents the economic environment in which a small family farm agricultural producer operates, his mode of operation and the need to innovate the SC to create preconditions for survival on the market. Some other methods have been partially used.

3. TRADITIONAL APPROACH

Researching the traditional SC concept has been established, the conclusion is that it doesn't present a realistic situation with regard to the requirements of today's modern time as well as the future. Businesses need to be implemented today by applying certain principles: quality, sustainable development, social responsibility, processes optimization, cost optimization, competitiveness, products lifecycle review. In this respect, it should be noted that the traditional SC approach doesn't present realistic needs for business in todays and future times.

There was a need for a transition from traditional to SSC as a modern approach, respecting the above mentioned principles of modern business and the requirements and respect of the principle of the circular economy. In the literature, the traditional approach to SC as a one-way direction process is still massively illustrated, which certainly needs to be changed as it doesn't meet the needs of modern business and the world.

Optimization of logistic costs is actually a simultaneous optimization of SC. It is imperative that small producers, shortening SC and taking SC parts on their own, shortened the way of procurement and production to the end-customers and thus optimized their logistical costs. However, there is no end to the process of optimizing logistical costs and the SC, too.

Due to the lack of labour force and the inability to increase wages, and the need for agricultural and fruit products to be delivered to final consumers in a short time, there is a RVSC phenomenon that is characterized by the fact that the end-customer comes to the producer and collects the products themselves. This concept is upgraded to SHSC and allows producers to place product placement and maintain competitiveness.

3.1 Supply Chain – traditional approach

Traditional approach to the SC begins with procurement of raw materials needed for production of products or ensuring prerequisites for provision of services. Finished products are stored until the time of distribution, and then distributed, most often through a widespread retail network, to a big number of customers. Customers are usually end users or consumers of these products. Products are in most cases placed in packaging made of various materials: cardboard or paper, glass, plastics, metal and the like. This packaging has traditionally been transformed to waste and disposed of after consumption, most often in the environment. [5]

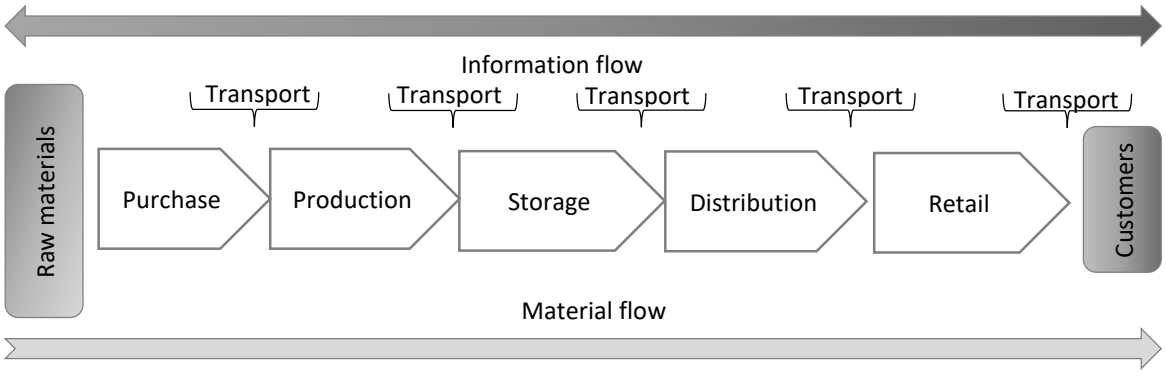


Figure 1 – Traditional approach to the Supply Chain
Source: Author.

It is obviously one-way movement (Figure 1) of materials and goods, from raw materials required for production, through production of final products, storage, distribution, delivery to customers and consumption and disposal of waste in the environment. [6, 7]

3.2 Short Supply Chain - traditional approach

Despite the traditional approach to the SC, which is characterized by a one-way flow material, given the number of participants, some of whom are in the role of intermediaries that charge their services, the SC also implies certain logistic costs.

The total logistical costs consist of the costs of all the activities carried out in order to model, direct, control and control the flow of materials and goods, energy and information. These costs are: manipulation, transportation, warehousing, inventory management and associated management costs of SC. They are used as an indicator of SC's performance, but also of the entire logistic systems.

The share of logistical costs in total costs differs from company to company, depending on the underlying activity, with a larger share in retail organizations than in manufacturing. This was due to the development of logistics.

In the structure of the company's total cost of business, logistics costs account for 15% to 25%, while on average they account for about 8% of total corporate income. The share of logistics services in Gross Domestic Product (GDP) in heavily developed countries (Germany, France), has increased by about 10-15% over the last twenty years. [8]

By implementing the strategic determinants of modern logistics, the benefit that is generated is increased through the time dynamics, and the overall SC costs fall for the implementation of rationalization. In the optimum of total cost and benefits within SC, there is an extra profit that can be used to improve the quality of SC in subsequent cycles. This is actually the goal of logistics.

Each of these strategic determinants has an impact on SC optimization. SC optimization can be achieved, on the one hand, by quality and on the other, by optimizing costs. SC optimization is actually a function of cost optimization. There is no clear and simple definition of "local food products" or SHSC 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 producer, the distributor, the retailer to the end-customer, whereby the producer 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 (Figure

2). In the EU, SHSC is mainly used in the production of agricultural food products on small and medium-sized family farms. The main goal is logistic costs optimization.

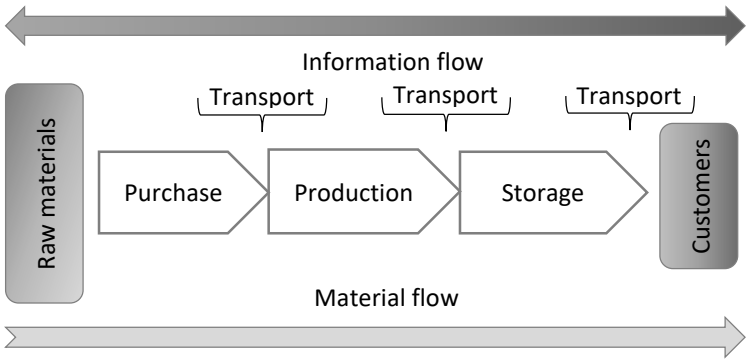


Figure 2 – Traditional approach to the Short Supply Chain
Source: Author.

What's SC is shorter, it's easier to keep and emphasize the authenticity and genuineness of food products. Despite the broad understanding of local food networks and SHSC, there is no single definition applicable in all EU Member States.

4. REVERSIBLE SUPPLY CHAIN

Local food SC are often considered to be relatively sustainable partly because they support 'mixed' and organic farming and reduce emissions and externalities created by long-distance transport and high 'food miles'. [9, 10] Local food SC are also valued for their capacity to generate rural enterprise and regenerate rural communities, break agribusiness monopolies and create spiritual links between man and nature. [11]

The food production and distribution are one of the key conditions for functioning of the agribusiness. The way and principles of food movement from the farmer to consumer are determined by agribusiness links that form the food chain. [11] But, over the last few years, many countries, particularly those in transition, face at least two problems: 1) emigration of young educated labour force into more developed countries and 2) the fact that small producers, especially agricultural products, can't compete with large shopping centres.

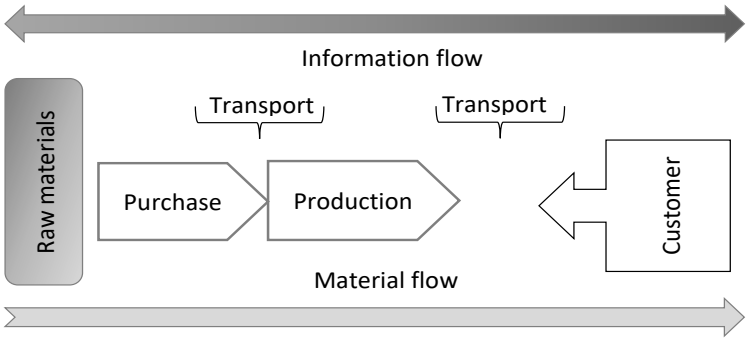


Figure 3 – Traditional approach to the Reversible Supply Chain
Source: Author.

This has resulted, on the one hand, by the lack of labour force for agricultural works especially in the period when fruit and vegetables mature and need to be harvested in the short term.

On the other hand, large shopping centres dominate the market. Small producers operate under their domination and their conditions. In those circumstances, they do not have possibility to increase wages to provide enough workers over the period when fruits and vegetables are mature.

To solve this problem, there was a need for innovation in SHSC. Innovation is that the manufacturer doesn't distribute the products to the final customer, but the end-customer comes to the manufacturer, and on the spot he picks up and pays the products he wants to buy. So, it was in the segment of distribution to reversible movement (Figure 3). The producer no longer goes to the customer with his products, but the end-customer comes to the manufacturer's products. In this way the products are of high quality to the end-customer, and the producer optimizes their logistics costs and remains competitive.

Transparent reporting of logistics costs and the related accounting of their cost drivers present a significant factor for the successful management of material flows and the related logistics activities in production companies. [12] The RVSC stems from the later shortening of the SHSC.

In RVSC streams information and product flows are not changed. Information is also exchanged among all RSC participants in both directions. The product flows from the supply of raw materials, through the producer, to the end-customer, with the difference that the end-customer comes to the products and often pick up them.

Food industry is the first in European Community for revenues, with more than 8 million of employee. Logistics and supply chain management play a crucial role in food industry. [13]

For example, even 70 percent of vegetables are produced in continental Croatia, and fruits, especially citrus fruit, dominate in the area of coastal Croatia. According to data from Croatian Chamber of Economy, as many as 72.5 percent of Croatian consumers eat fruits and vegetables every day. This is more than the average in the EU countries where this figure is about 65.5 percent. It is interesting to note that 3.3 percent of average annual household expenditure stands out for vegetables and 1.9 percent for fruit. The latest data from last year show that residents of Croatia use 29.5 percent of their income on food. In the EU, that average is 12.4 percent. [14]

Thanks to the lack of a sustainable development strategy in Croatia, the lack of workforce, high taxes and other giving to the state, but also the high potential in agricultural products production, RVSC as the SHSC model will certainly develop, as it enables the small producer to be competitive.

4.1 Sustainable Supply Chain as a modern approach

SSC or modern approach to SC is not a one-way phenomenon. It doesn't end with waste disposal in the environment after each SC cycle. What distinguishes it from the traditional approach (Figure 4) is a feedback.

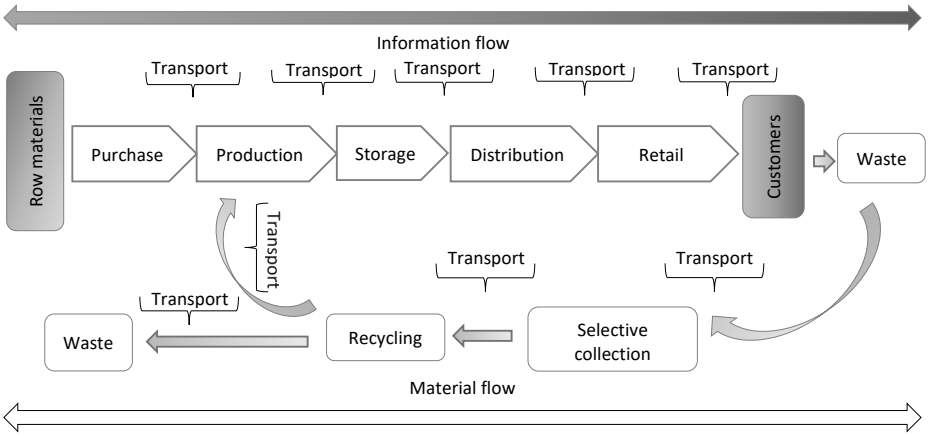


Figure 4 – Sustainable Supply Chain as a modern approach
Source: [5]

The traditional SC approach doesn't take into account the Life Cycle (LC) of the product. Acceptance of the concept of the product LC is now also necessary with the optimization of cost considerations and involves abandoning the traditional SC approach and accepting the SSC or the modern concept of SC in keeping with circular economy principles. [6]

"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." [5]

4.2 Sustainable Short Supply Chain as a modern approach

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. [15]

Local food production systems and SHSCs are continuously developing without too much impacts in the EU for many years now - most are locally driven as a result of the immediate needs of an individual farm, place or community. The producer is seeking to improve its competitiveness through optimization of logistics. But, in these circumstances they should apply the strategy of modern approach to the SHSC (Figure 5).

Approximately 4% of Flanders producers work in SHSC. About 1% of all food products in Finland are delivered through SHSC. In 2005 more than 16% of French peasants made direct sales of their products. Almost 3% of Denmark's producers have more than 1,200 people, dealing with direct sales. [16]

This concept is also applied in other 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 SHSC. 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. [16]

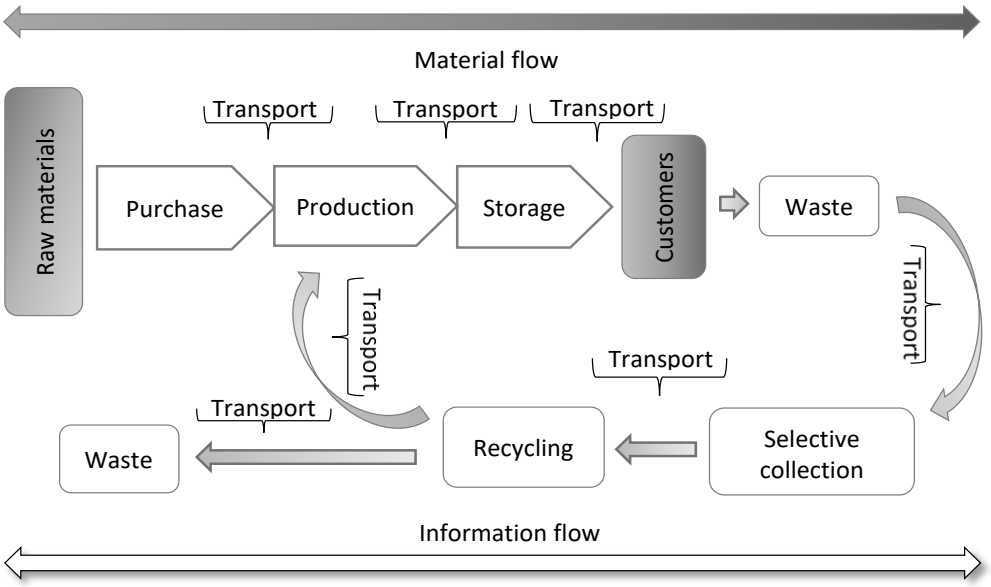


Figure 5 – Sustainable Short Supply Chain as a modern approach
Source: Author.

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 the transition from traditional to the SSC or modern SC concept and thus contribute to environmental conservation and contributions and development of the local economy. Over the past period, the EU has adopted more laws regulating public procurement and food safety.

4.3 Sustainable Reversible Supply Chain as a modern approach

RVSC is also in transition to SSC or modern approach (Figure 6) since it is a requirement of modern business and modern times.

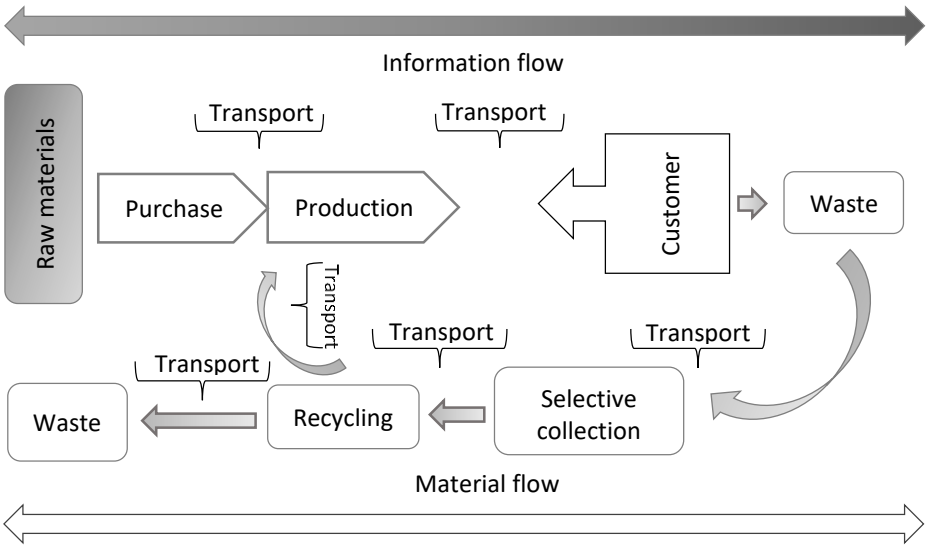


Figure 6 – Sustainable Reversible Supply Chain as a modern approach
Source: Author.

The producer and the end-consumer are involved, because the environmental problem is not an individual problem, but every individual (the producer, the end-consumer) has the responsibility for environmental protection and should make a contribution within the system that operates in a particular area. [6]

5. CONCLUSION

SC is further defined in the literature as a one-way flow of goods from the supply of raw materials through production, storage and distribution to the final consumer. This traditional approach can't meet the needs of modern business and modern societies, both from the standpoint of profitability and from the standpoint of ecology, sustainable development and social responsibility. Therefore, the transition and transformation of traditional approach to the SC is a necessity in the SSC as a modern approach, for which there is a characteristic retreat after product consumption. This transition and transformation are based on the principles of the circular economy.

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, 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. This reduces up to 60% of total logistics costs since SC eliminates intermediaries in the storage, transportation, wholesale, retail and sales phases. The SHSC is applied to the EU, which has made the institutional framework that has allowed them to develop many years ago.

The strategic guidelines underlying this concept are: quality, life cycle, process and cost optimization and competitiveness.

The problem researched in this paper is SC and the need for its transformation due to context change. By researching the SC in the context of market demands and modern societies, the SC transformation necessitated from the traditional to the SSC as a modern approach. Also, as a result of changes in market circumstances, it has been demonstrated that small producers, especially of agricultural products need to work on innovations of SC to remain competitive on the market. The result of these innovations is the SHSC, as the first step in logistical cost optimization and SC, too. Due to the further streamlining of the market context, there was further innovation and the RVSC model was established. This model enables small manufacturers to remain competitive and continue to operate on the market.

The result of the research presented in this paper is the flexible SC model that adapts to the context, applicable in all economies to optimize logistical costs and SC cost, too and business 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 should aim to optimize the SC from the point of view of small agricultural producers in order to increase their competitiveness, survive on the market, contribute to reducing unemployment, producing healthy food and thus contributing to the development of the entire economy.

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MARIO FIOLIĆ, mag. eng. traff.[1]
E-mail: mario.fiolic@fpz.hr
MARIJA FERKO, mag. eng. traff.[2]
E-mail: marija.ferko@smartview.hr
MARKO RUŽIĆ, mag. eng. traff.[1]
E-mail: marko.ruzic@fpz.hr
HELENA DIJANIĆ, mag. eng. traff.[1]
E-mail: helena.dijanic@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10 000 Zagreb, Croatia
[2] Smart View d.o.o.
Stolačka 14a, 10 000 Zagreb, Croatia

REVIEW – DRIVING SIMULATOR AS A TOOL TO IMPROVE TRAFFIC SAFETY

ABSTRACT

The invention and production of the driving simulator in the past was primarily aimed at visual improvement of video games and creation of realistic representation of reality. By improving technical features of the simulator, it was possible to use it for research purposes in the industry as well as in driving schools to train potential candidates for obtaining a driving license. At the same time, driving simulator proved to be an efficient tool for collecting and obtaining driver behavior data in demanding and common traffic situations and in various weather conditions. Plans for reconstruction of existing roads and the new ones with a view to preserving traffic safety can be made by analyzing the data of the tests carried out in a safe environment. The purpose of this paper is to provide a detailed insight into conducted studies involving the usage of a simulator as an effective tool for drivers. In that regard it is possible to get a fundamental driver behavior pattern for all traffic situations by getting insight into studies which measured driver behavior at different speeds and under influence of alcohol.

KEY WORDS

driving simulator; road safety; driver behavior; attention

1. INTRODUCTION

Road safety is determined by the interaction of driver, vehicle and environment, respectively road, traffic and incident factors. A driver's actions during his participation in traffic directly and indirectly affect its own, but also the safety of all participants. Moreover, it can be said that he is the most important factor in traffic safety. There are great differences in driver behavior in different situations, primarily depending on the level of education, health, age, morale and experience. It is believed that driver is guilty of more than 90 % of traffic accidents, and the cause of the remaining traffic accidents are other traffic factors [1]. This is also confirmed by the statistical data from the Survey of safety indicators, which the Ministry of the Interior of the Republic of Croatia publishes every year. Statistical data [2] point out that 95.07 % of traffic accidents, which occurred on the state roads in the Republic of Croatia in 2017, are caused only by the driver's fault.

There are many strategies which increase road safety in the world today. One of the methods is the use of a driving simulator, which represent an effective mean of research for researching driving behavior in various situations. The driving simulator provides an interactive road traffic reconstruction that includes the road, traffic participants, landscape and traffic signaling. On the driving simulator, it is possible to set up numerous and preprogrammed scenarios with different weather conditions

including wet, icy or snow road. Also, it is possible to monitor attentiveness and driver behavior, i.e. the way driver perceives traffic signaling within simulated environment. The driving simulator is thus an easier and safer way of conducting research than the one that needs to be conducted directly on the road. Consequently, by using driving simulator it is possible to detect differences in driving behavior affected by various factors that reduce its cognitive abilities (alcohol, disease or disability).

In the recent years there has been an increase in the number of studies that are based on the utility of the driving simulator. For this reason, this paper will show the ones that study driver behavior on the simulator at different speeds and the effect of alcohol on its performance. Also, in this paper it will be presented which indicators mostly affect drivers skills, which drivers causes traffic accidents and to what extent. To gain these answers, the driving speed, driving simulator, trained drivers and driving under influence of alcohol were just one of the main key words that were used for searching available studies in Scopus and Web of Science databases.

2. THE EFFECTIVENESS OF DRIVING SIMULATOR APPLICATION FOR DRIVER'S TRAINING IN IMPROVING TRAFFIC SAFETY

Because of their inexperience, young drivers are frequent participants in traffic accidents [3]. According to statistics conducted in 2017 in the Republic of Croatia, 11 % of all traffic accidents were caused by young drivers [2]. Considering that they make a total of 8 % of the driving population in road traffic, the percentage of traffic accidents that they cause is relatively large [2]. With the aim of reducing such scenarios, the use of the driving simulator has been introduced as an acceptable tool for training future drivers, as well as those with less driving experience. Getting to know the driver with unpredictable road hazards, the unwanted consequences can be prevented in real life. Based on tests and simulator exercises, inexperienced drivers can be better prepared and thoughtful in anticipation of unexpected situations which they will encounter on the road. Accordingly, below are presented studies that examine the behavior of all and especially inexperienced drivers. In addition, it will be presented how simulator training increases safety in actual traffic conditions.

Hirsch and Bellavance claim that one driving simulator hour can replace one on-road hour for up to 50 % of the 15 hours of mandatory on-road lessons. In their paper [4] they report that a long-term, naturalistic, prospective-cohort transfer of training study was conducted in commercial driving schools in Quebec, Canada, to test the effects on driver performance and behavior of integrating driving simulator-based training into the driver education program. Four driving schools provided a convenience sample of 1 120 learner drivers (average age 17.7 and 52.7 % female) between 2010 and 2014. Of the study sample, 95 % received 1 to 4 hours of driving simulator-based training. Those in the comparison group were all new, young Quebec drivers who had completed the mandatory driver education program in the same period.

Authors in [4] report on the association between driving simulator-based training and government driving records for 2 years after licensing. The driving simulator-based training group recorded lower infraction rates and, controlling for vehicle ownership and age, comparable crash rates. Overall, these results show that the substitution of relatively few hours of driving simulator-based training for on-road training is associated with reduced infractions and has no apparent influence on crashes in the first 2 years of unsupervised driving after licensing.

On the other hand, authors in [5] used a risk event simulation to study how enabled drivers with different levels of driving experience receive situation awareness training. X Ou et al. in their study concluded that novice and experienced drivers have different levels of road risk perception because it is more difficult for them to perceive the potential road risks.

They came up to that conclusion by dividing participants into three groups. First, group A contained 24 novices without driving licenses who had no experience in vehicle operations and road knowledge. Second, group B contained 24 novices, who had drivers' licenses and driving skills of a basic level.

Ultimately, third group C contained 17 veterans with driving license who had proficient driving skills due to rich driving experience and possessed a certain degree of experience in response to emergencies. The participants were aged between 18 and 24 years old and they had no traffic accident records previously. In the study it was used the car simulation platform PreScan to produce the semi-real traffic environment for the risk perception education, which enabled trained drivers to observe the potential road risks in the simulation process. The risk perception time and reaction time for all training were recorded to determine whether the decision-making was correct. After conducted study, the results showed that the reaction time of the subjects in all groups, in response to the risks, was all reduced. The results pointed out that, prior to the training, that only 14 (23 %) of the subjects of the three groups could perceive the potential risks in a blind spot, where 13 out of them were from group C consisting of slightly experienced drivers. Posterior to the training, the number of subjects of the three groups successfully recognizing the influence before the occurrence of the risks and responding appropriately increased significantly. 17 subjects from group A, 23 from group A, and 17 subjects from group C, respectively, could perceive and respond to the situations.

Authors in [5] concluded that the reliability and validity analysis results indicated that the simulator-based risk training could significantly enhance the learning of road risk perceptions for drivers. Driving simulator experiments have demonstrated that the system can be used as an effective method to aid new and young drivers. The same benefits of driving simulator have been confirmed in numerous studies, out of which [6,7,8] are just a few.

3. DRIVING BEHAVIOUR AND SPEED PERCEPTION

The driver behavior on a simulator can be identified with his behavior in realistic road situations, since the driving simulator is a quality instrument that can simulate typical traffic situations. Testing and observing driver's habits, knowledge and experience can be demonstrated by a simple test which examinees mentioned through the previously defined scenario. Since inexperienced drivers usually overlook their capabilities, they often drive faster than traffic conditions allow it [9]. On the other hand, experienced drivers think that they have enough knowledge and experience so that they can ignore traffic signaling set. As a result, both categories of drivers use their subjective speed impression for driving in many traffic situations. In order to confirm or deny previously presented facts, various studies have been carried out to consider driver behavior.

Casucci et al. researched driver behavior and driving speed in various situations by creating different events. Participants were, depending on their driving experience, divided into three groups: novice drivers, average drivers and professional drivers so that a large degree of variability was covered. After conducted simulation and statistical analysis, Casucci et al. did not find significant differences in breaking behavior between drivers with different levels of experience, but they found that the overall sequence is completed in a much shorter period by the aggressive drivers than by the prudent drivers. Also, the cruising speed of the aggressive drivers was much higher (high above the legal speed limit) than the one of the prudent drivers [10].

In addition to previous, Michaels et al. researched which drivers of different age groups (from 18 to 86 years) naturally self-select their driving speeds. They found out that in the absence of external pressure all participants drove faster while older adult participants drove significantly slower than younger and experienced adult participants. Accordingly, younger participants were more likely to experience near crashes than older. Statistical analyses also revealed that inexperienced and experienced young drivers drove faster than older drivers. Although the statistical analyses were designed to control driving speed, the slower driving speed exhibited by older participants was well-documented and explain the trend toward an association between younger age and higher near crash risk. Inexperienced drivers tended to drive faster compared to experienced drivers in that scenario. This tendency is consistent with previous findings showing that inexperienced and younger drivers take more risk while driving by speeding [11].

The various speed profiles showed that without speed control, drivers are susceptible to poor speed adaptation. It is common situation that drivers do not decelerate to the speed limit of the villages (48 km/h) as they pass the new speed limit, although the advisory system does encourage drivers to reduce their speed. This fact was confirmed in the study of The University of Leeds [12] where scenarios were designed to test speed control of advisory system against a baseline control (no system). A total of 60 participants took part in the experiment and they were asked to drive on six sections of road network with different features regarding road types and speed. The results confirmed that drivers who were not speed-controlled had only reduced their speed by approximately 15 km/h (as opposed to the appropriate reduction of approximately 35 km/h).

Another study showed the difference between speed perception and actual speed [13]. The first part was assessed based on the speed perception observations from forty volunteers that participated in the study. Speed estimations for four different requested speeds (50, 70, 80 and 100 km/h) were recorded under two conditions, when speedometer was hidden, and revealed. In the second part, the comparison of actual speed observations from field and simulator was done. The subjective validity of the simulator setting was assessed through a questionnaire. Results from both experiments showed correspondence of the driving behavior between the simulator and real-world. In general, the profiles for estimated speed and actual speed followed a significantly similar tendency and indicated relative validity in both experiments. Furthermore, external absolute validity for speed perception was established on all the requested speeds with speedometer hidden while only for the requested speed of 80 km/h with speedometer revealed. Participants' evaluation of the quality and performance of the driving simulator supported the subjective validity of the simulator setting. In the end it was concluded that the fixed-base driving simulator used in this study can be considered as a useful tool for research on actual speed and speed perception [13].

Besides numerous studies with the goal of using driving simulator for improving traffic safety, in [14] author examines the effects of calming measures near road regarding distance (along the road) and time (under repeated exposure during five consecutive days). For the purpose of doctoral dissertation, Ariën performed five driving simulator studies, and one of these studies measured the impact of digital information displays on speeding behavior at 70 km/h-to-50 km/h transition zones. Sixty-six participants completed an 18.9 km trip during which they passed four conditions (baseline with no display, Smiley, "You are speeding! / Thank you" or "Speed enforcement"). Results of this study showed that "Speed enforcement" message was found to be most effective in reducing speed (speed reduction up to 3.2 km/h). Besides that, Smiley and "Too fast" messages also reduced speed compared to baseline. These results imply that a message related to speed enforcement was considered most effective in reducing speed in speed transition zones.

Despite the fact that various external factors affect speed perception and that inexperienced drivers perceive traffic situations different from the experienced one, driving simulator in that way can be used as an effective tool for testing their performance and better understanding their actions taken.

4. THE INFLUENCE OF ALCOHOL ON DRIVING SKILLS

It is commonly known that alcohol impairs driving skills by causing impaired vision, reduced reaction times, concentration and vigilance, difficulty in understanding sensory information, failure to obey road rules and over-confidence which may lead to risk taking. Knowing that, driving under the influence of alcohol is not only dangerous for driver but also for other traffic participants. The reason for the overestimation of driving abilities lies in a fact that under the influence of alcohol, drivers incorrectly assess speed, distance and the width of the road, and they also neglect the presence of other traffic participants [15]. The reaction time under the influence of alcohol is prolonged or it is delayed, so it takes more time to evaluate the characteristic situation and to identify dangers. The sequence of actions and procedures during driving can be disturbed, while the coordination of a person's alcohol-induced movement becomes questionable. Even though alcohol affects driver's ability, it doesn't affect

everyone equally. In that case, women usually have a slightly higher blood alcohol concentration than men for the same amount of alcohol taken. However, a person's gender has a fairly negligible effect compared to other factors, such as weight, rate of alcohol absorption, fatigue, medication, age and the state of health. The above has been explored in several studies that are presented below.

The authors' hypothesis in [16] was that the subjective assessment of the traffic situation and the adaptation of behavior under the influence of alcohol plays a major role in accident causation. In order to examine their hypothesis, they conducted two driving simulator experiments at a target blood alcohol content of 0.5 g/l. Experiment 1 included two comparing groups of subjects – alcohol vs. placebo. In this experiment 48 participants were included. Experiment 2 included comparing three groups of subjects – sober, placebo and alcohol and in this experiment, there were 63 participants. The first scenario was a seemingly easy traffic situation and was supposed to lead to a relaxed driving behavior under alcohol. The second scenario involved a complex intersection situation where especially drivers under the influence of alcohol should try to concentrate and compensate their experienced alcohol effects. In all scenarios, a critical object appeared suddenly, and the driver had to react fast in order to prevent an (simulated) accident. Overall, the results support the hypothesis, i.e. accidents were more frequent for alcohol drivers as compared to sober drivers in the easy scenario, but not the complex one. The initial speed of the driver when entering the scenario seems to play a major role in the accident causation. Drivers under the influence of alcohol seem to lower their speed in complex scenarios, possibly to thus counteract alcohol effects. In seemingly easy scenarios this does not seem necessary for them, so they have been driving faster.

In addition, the authors in [17] agree with the previous hypothesis and claim that alcohol is recognized as one major factor of driving impairment and a linear relationship has been demonstrated between blood alcohol concentration and crash risk, notably for young drivers. The aim of their work was to evaluate the combined effect of these major factors of accident and, more particularly, to examine alcohol effect on driving performance as a function of experience, effort and alertness. The main hypothesis was that, with alcohol, during long and monotonous driving task, driving impairment is higher for young novice drivers than for young experienced drivers. A secondary hypothesis was that, in this case, an increase of effort due to lack of experience, decreases alertness. Experimental protocol included fifteen young novice drivers (18-year-old, less than two months of driving license) and 15 young experienced drivers (21-year-old, 3 years of driving license) who participated in three simulated driving sessions in which blood alcohol concentrations were randomly manipulated (0.0, 0.2 and 0.5 g/l). An increase of subjective alertness produced a speed increase with 0.2 g/l. For example, when participants estimated to be alert, they increased their speed in the driving sessions without alcohol and with a very low dose of alcohol. On the contrary, an increase of effort produced speed decrease in the driving sessions without alcohol and with blood alcohol concentration of 0.2 g/l while speed increase with blood alcohol concentration of 0.5 g/l. This implies that effort and alertness have also separated effects on driving parameters. Results showed that speed and speed variation rise higher with blood alcohol concentration of 0.5 g/l than with the other two conditions. Alcohol could thus have a de-inhibited effect on drivers' speed but imply a low stability of speed. Moreover, with 0.5 g/l of alcohol, speed variation increased with the effort. Conversely, with blood alcohol concentration of 0.2 g/l, an effort increase was linked to speed variation decrease. This signifies that, with 0.5 g/l of alcohol, an increase of effort is not sufficient to maintain good longitudinal performance. All the results obtained with blood alcohol concentration of 0.5 g/l thus converge and indicate an increase of risky driving whatever the level of driving experience. In the theoretical field of mental workload, it is also known that the overload threshold is reached earlier for novice drivers than for more experienced drivers. It thus seems that alcohol degrades driving performance, especially when the effort is high, alertness is low, and drivers lack experience e.g. in long monotonous drive at a period of low alertness [17].

In addition to above mentioned, the authors in [18] found a strong relationship between duration of driving and fatigue, especially in young drivers. They conducted their research on driving simulator

from 8:00 am until 8:00 pm during three-peek vacation weekends in the summer. Drivers were asked to drive in a long-distance journey and to complete questionnaires about their habitual total sleep time, sleep latency, sleep quality and sleepiness. A second questionnaire explored the duration of driving, the number and duration of stops and the number of changes of drivers during the journey. All group of drivers had to drive a minimum of 10 000 km/year and have at least 2 years of driving experience. The participants were required to keep the car central between the two sides of the road on the screen and to monitor four digits located at the sides of computer screen. After the conducted test on driving simulator, the results showed that fatigue affects long-distance drivers in a way that they have a harder time to maintain a perfect angle in curves which can be explained by the fact that this procedure requires good coordination. Long duration of driving was associated with sleep restriction and cumulative factors which effects of sleep deprivation. The similar thesis was obtained in [19] where authors researched driver's performance under different road geometries in a sober state, with three levels of alcohol consumption, and under fatigued conditions using a driving simulator.

A conducted simulation studies proved that driving speed, lane position, accident rate, and mostly alcohol consumption can be affected by roadway geometries. Ultimately, it is reasonable to assume that different conditions, as well as, the influence of fatigue and alcohol affect an overall traffic safety.

5. CONCLUSION

The modern development of technology has enabled the creation of a driving simulator as an effective tool for researching drivers' skills. Even though his purpose was different in the past, today it is used for assuring traffic safety by transferring the actual traffic events in safe and virtual environment.

Assuming that road safety is the starting point for overall road safety, numerous studies have been carried out to decrease traffic accidents and their serious consequences. For this reason, it was created the idea of using driving simulator to test driver behavior in simulated conditions.

Since the data from 2017 in the Republic of Croatia indicate that for 95.07 % of traffic accidents are caused by drivers, a basic question has been raised as what kind of driver behavior leads to accidents. The base of numerous studies, which used the driving simulator to study its behavior, showed that there was non-compliance with traffic restrictions and regulations, and that drivers were usually driving at higher speeds than those allowed. Based on the analysis of the conducted studies, regarding speed as one of the main elements which leads to traffic accidents, it was concluded that aggressive drivers did not respect the speed limit set. On the other hand, young drivers drove faster and thereby more risked their own and other people's safety. Further, the studies have confirmed that if the speed indicator is hidden the drivers cannot get the real impression how speed really changes, and they usually drive much faster the road conditions allow.

Although it is known that exhaustion, fatigue and drowsiness affect the driver, many studies have focused their research on alcohol effects since the combination of alcohol and fatigue causes drastic unwanted consequences. In this respect, the studies performed confirmed that the presence of alcohol while driving reduces the driver's performance, which is particularly evident in complex traffic situations at low wakefulness. Drivers who consumed alcohol, while driving on a simulator in complex scenarios, slowed down driving to conceal and reduce the impact of alcohol on their performance. However, simple scenarios for respondents were not a problem, and in these situations, they did not slow down and adjusted their driving to the real limit.

According to the above-mentioned, it was confirmed that in simple traffic situations, due to human negligence and the wrong subjective impression, traffic accidents with severe consequences arise. According to all the above, there is a need for continuous monitoring of driver behavior in traffic. By

conducting tests and creating simulated traffic situations in a safe environment, it is easy to work on improving the overall traffic safety.

Driving simulator is a tool which simulates various driving environments, and its possibilities grow thanks to the technology development. Using this tool, it is possible to study driver behavior in simplified or less simplified environment in a safe way with relatively low costs. Based on the obtained knowledge by reviewing the literature, future research can be focused on studying driver behavior in low visibility and in bad weather conditions when there is large risk of incidents in traffic. In such conditions, the impact of traffic signaling quality could be tested to evaluate its importance and the impact on traffic safety. Other researches carried on driving simulator can be focused on pedestrian visibility during night, dusk and dawn when there is a need for drivers' eye adaptation. Also, studying and comparing driver behavior of different age groups is possible. Such and similar researches can help to evaluate driver behavior due to different scenario, different circumstances and groups of drivers and thus and improve overall traffic safety. The main advantage is repeatability of exactly the same scenario for certain experiment, which is taking place in a controlled environment, by which one can get data that can be compared afterwards. The results gained in such researches could then be used not only in scientific purpose, but also by road authorities to form suitable road infrastructure, manage the traffic flow in better way or optimize the traffic flow.

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MARIO FIOLIĆ, mag. eng. traff.[1]
E-mail: mario.fiolic@fpz.hr
ANA STAŽNIK, mag. eng. traff.[2]
E-mail: ana.staznik@smartview.hr
IGOR HABUZIN, mag. eng. traff.[2]
E-mail: igor.habuzin@smartview.hr
STIPICA ŠARČEVIĆ, mag. geogr.[1]
E-mail: stipica.sarcevic@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] Smart View d.o.o.
Stolačka 14a, 10000 Zagreb, Croatia

AUTOMATIC DETECTION AND IDENTIFICATION OF TRAFFIC SIGNS: A REVIEW OF EXISTING SOLUTIONS

ABSTRACT

The technology development in dynamic transport system brings changes which are visible in the transport infrastructure. Quality management and maintenance of transport infrastructure and traffic signs are one of key elements that enable safe traffic and protection of all traffic participants. By creating a modern database of traffic signs, it is possible to quickly and easily get an insight into the current state of the roads. Also, it is possible to see where are placed damaged and stolen traffic signs or where is the construction of a new road or the reconstruction of existing one planned, and after all if there is a need to restore existing signs. With a comprehensive traffic database with updated real-time data, it is possible to continuously monitor changes on roads and thus establish communication between road users and traffic participants. The aim of this article is to analyze existing technologies for marking traffic signs to update and create a functional database of road data. Based on a comparative analysis of the technical characteristics of the most commonly used methods for traffic sign detection and identification (video and photo, barcode and RFID technology), the basic advantages, disadvantages and potential for application for the purpose of database update of each method will be identified.

KEYWORDS

Traffic sign; detection and recognition systems; RFID; barcode; video stream image extraction

1. INTRODUCTION

Nowadays, roads must be marked with prescribed traffic signs so that traffic participants are timely informed about the state of the road or part of road in front of them. Participants must have knowledge of the restrictions, prohibitions, and obligations that need to be held in traffic and eventually to get all the necessary information for safe and unobstructed traffic flow.

Since traffic signs are the basic mean of communication between the road authorities and road users, improper installation and maintenance affect the driver's perception process. Consequently, it affects the quality of transmitted messages, which directly affects both driver response and overall traffic safety.

A systematic and efficient traffic signs system that has been introduced into a high-quality database can provide insight into the current road conditions. That type of database can be of great use if a traffic accident occurs. Afterward, the disputed question arises as to whether the participants were

timely notified of a dangerous situation on that part of the road. A quality database of traffic signs in a simple and fast way can be used to create plans for the road reconstruction or building new roads. By using such approach and statistical reports, changes in traffic infrastructure can be tracked.

Traffic sign database update, depending on the purpose, can be done in two ways. With traffic infrastructure changes (reconstruction of an existing road or construction of new ones), the update is carried out depending on the project that changes. The other way of updating the traffic sign database implies daily monitoring of traffic signs, tracking their location and possible changes registered by the road control service. Road patrol is carried out primarily to preserve the safety of all participants in the traffic and to carry out activities to protect the public road. Everyday insight into the traffic sign database would facilitate the work for the road patrol service itself. Because of that, road control could base on a visual problem detection and the entered data would inform the authorities to take all the necessary troubleshooting steps. Without a database of traffic signs, it is very difficult to detect the changes that occur. For example, if a certain traffic sign is not in place or a new traffic sign is placed at a new location, it is necessary to establish an automated or semi-automated traffic identification system.

By developing technologies, new methods are used to update the road database. Some of them are methods of detecting and recognizing traffic signs from video and photo, marking and identification methods of traffic signs via barcodes and radio frequency identification (RFID) methods. These methods have been most commonly used in the available scientific literature, and this article will outline the principle of work and the possibilities of each one.

Based on all the above, this article will present an analysis of existing technologies with the aim of updating and creating a functional road database. Accordingly, a thorough comparative analysis will attempt to identify the advantages and disadvantages of existing technological solutions. The obtained analysis will show the types and technical characteristics of the sign marking system and the features of the traffic sign readout system. This analysis could assist the authorities in selecting the optimal on-field signaling system for updating the road sign database.

2. EXISTING TECHNOLOGICAL SOLUTIONS FOR DETECTING AND IDENTIFYING TRAFFIC SIGNS

After inspecting existing trends related to data collection and marking of traffic signs, three basic methods have been considered. These methods are:

- Recognition and detection of traffic signs from video and photo
- The method of marking and identifying traffic signs via barcode
- Radio Frequency Identification Method.

2.1 Detection and recognition of traffic signs from video and photo

One of the earliest approaches to the detection of traffic signs was developed in [1] where cameras, placed on the vehicle roof, were used for data collection purpose. The resulting images were then segmented using pixel values as the basis.

The used algorithm is based on the basic three steps (Figure 1) where the first step involves the color segmentation algorithm applied to the image. As a result of the segmentation, the pixels of the image are indicated in red, blue, yellow, white and black respectively. The next step involves a symbolic description based on the segmented image color using an algorithm for rapid logical connectivity analysis (CCC). The regions of interest are determined based on color combinations that are characteristic for traffic signs. Finally, the regions of interest serve as a hypothesis which needs to be tested, and for this purpose, a classifier, based on a pictogram, is used to determine the identity of the traffic sign.

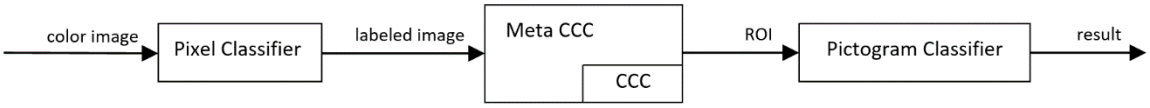


Figure 1 – System Overview
Source: [1]

Authors in [2] develop a data collection system based on eight cameras placed on the roof of a vehicle that captures the environment at every meter. Each clip considers only those signs that are within a distance of at least 50 meters. The first step is to analyze each image separately to reduce the number of false values. Together with the sign recognition, it performs the localization in the 3D space. Since thousands of images are concerned, the approach tries to get out of processing as many background elements as possible and focus processing on only those elements that remain.

Segmentation of traffic signs from the image using the automatic statistical data collection method was developed in [3]. The system covers a range of chromatic and achromatic signs and is based on the three basic steps. Those steps comprise the segmentation of chromatic and achromatic signs using the HSI color field and the "Machine Learning" technique, based on supportive vector statistical analysis systems, additional processing (how it would expel regions of zero interest, link signs that are separated and achieve the connection between signs on the same carrier) and classification of the sign shape using Furier's descriptors and gradually recognize shapes using machine learning techniques. This approach achieves an accuracy of 97 % with a false detection rate of about 3-4 %.

One of the possible uses of traffic sign recognition is in the Driver Support System (DSS), which has been the goal of many previous kinds of researches. DSS systems can detect and recognize the traffic sign in real time and thus help improve traffic flow and overall road traffic safety.

As the existing technologies for recognizing and classifying traffic signs from videos and photos are not primarily developed for the purpose of creating and updating the database, their application is limited. Because of that, there are several problems and difficulties in identifying signs that may have an impact on the accuracy of the database. Traffic signs, except in complex surroundings, can also be found in different unfavorable conditions, such as disoriented signs or damaged signs etc. (Figure 2). Their detection and recognition can face the following problems:

- The color of the signs fades with time due to long exposure to sunlight and reaction of the color and air, making it difficult to recognize and classify the sign
- Poor visibility of traffic signs caused by bad weather such as fog, rain, clouds and snow
- Color information is sensitive to light conditions such as shadows, clouds and sun, which may affect color lighting (daylight), the geometry of illumination and the geometry of traffic signs
- Presence of various obstacles such as trees, buildings, vehicles, and pedestrians, or even signs that hijack other signs
- Disoriented or misplaced signs and damaged signs
- Problems with driving at different speeds and on different traffic surfaces can make traffic signs blur because of uneven terrain
- A problem that occurs at dawn or dusk. At that time, Sunlight is repelled by traffic signs, and together with the light from the headlamps of the vehicle traffic signs are difficult to be spotted
- Different countries use different colors for certain characters and different pictograms.



Figure 2 – Examples of signs that can cause possible problems for detection and recognition
Source: [4]

From the mentioned problems, it is assumed that for the accuracy of the method, the quality of the color segmentation of signs, insensitivity of the signs to brightness change, retention of the same geometric shape and the clarity and permanence of the pictograms and inscriptions are extremely important.

2.2 Marking and identification of traffic signs using barcode technology

The principle of barcode technology is that traffic data such as sign code, retroreflecting material, manufacturer, year of manufacture, mode set and other are encoded on 1D or 2D barcodes. After encoding, the barcodes are placed on the back of the traffic sign. Also, the traffic sign data is entered into database, and each sign is added with a specific code name. For updating the database, the signs are periodically read by the barcode reader in a way that the operator sets the reader at the barcode tag and reads its code or data.

An example of using 2D barcodes can be found in Estonia, where they used technology for fast-reading QR codes to maintain the traffic sign database. As a part of the "Smart Road" project, they marked all traffic signs along the roads in Estonia with QR barcodes. Codes contained key data related to sign, such as traffic sign code, manufacturer, year of manufacture, type of reflective material, etc. [10]. The system structure is shown in Figure 3.

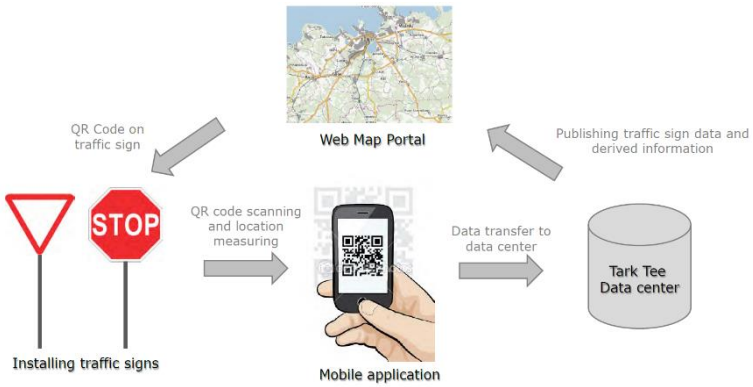


Figure 3 – Database maintenance of traffic signs by using QR codes in Estonia
Source: [5]

As stated in [10], the advantages of QR codes in relation to other 2D barcodes are reflected in higher readings speed, greater reliability, and better accuracy when reading, readability from any direction, including a greater capacity for data storage and errors correction. They used a mobile phone application for the reading of the QR codes. The application automatically sends the GPS coordinates to the database servers.

One problem associated with barcode marking is the life of the barcode itself. Since traffic signs are exposed to external influences such as sunlight, snow, rain, dirt, etc., the barcode tags must be made of special materials to withstand the expected lifespan of the traffic sign. It has been discovered that for long-lasting barcodes, the most suitable application is anodized aluminum. Also, the best way of placing barcodes is beneath the anode surface, protecting the tag from external influences [6].

In addition to the requirements associated with the creation of barcode itself, a significant drawback is manifested in the fact that for reading each sign or to update a database, it is necessary to approach each traffic sign and check it manually. Considering that there are numerous traffic signs on the roads, it can be concluded that updating the database using this technology will be considerably slower. Also, because the reader must touch the barcode or be close to it, the road patrol workers will have to stop the vehicle and read the barcode. That can potentially compromise traffic safety on the roads.

2.3 Radio frequency identification method

RFID – Radio Frequency Identification is the name for a set of technologies that uses radio waves to identify objects. It is based on the creation of electromagnetic waves in transmitters and their detection on a remote receiver. There are several methods of identifying objects. The most common method is to store the identification serial number or some other information on a microchip that together with the antenna makes the RFID transponder. The transponder communicates with the reader via a radio signal, one-way or two-way. It connects the reader to a computer or network on which the database is located. The simple identification code stored on the transponder is related to the information on the tagged product. RFID systems have a wide variety of use which makes them compatible for different applications, which with time and technological progress are growing faster. Incorporating an RFID transponder into literally everything that surrounds people, from underwear, cars, trains, pets, even to people, promises several benefits and new possibilities for a lighter and more efficient performance of all everyday tasks. However, the flexibility and opacity of the RFID system do not only allow numerous applications, but it also open the door to various possibilities.

The operating principle of the system for automatic identification of traffic signs and updating their database is based on passive RFID technology. It is based on passive transponders that contain all the information related to a particular sign such as type and code, shape and dimension of the sign, the way of setup, the height of the sign and the distance from the edge of the roadway, the setup date, the manufacturer's information and the class of retroreflecting material etc.

The RFID system comprises of RFID transponders, RFID readers (controllers) and computers. The antenna is an integral part of the system; however, the antennas are usually integrated into readers and transponders in practical applications. There are also applications of physically isolated antennas and antennas connected with a cable to the parts of the system [7]. Most transponders have at least one integrated circuit, often a silicon chip. The silicon chip contains the transponder and logic identification is needed to navigate the communication protocol between transponders and readers. Readers can have a separate user interface, but in most cases are connected to a computer. The computer transfers control over the reader to the user and displays and stores the obtained data [8].

One of the first test researches related to identifying traffic signs through RFID technology was conducted in [9]. For the purpose of the research, they used passive transponders. The range of transponders was 40 cm. The antennas were mounted on a car 15 cm above the asphalt. For each traffic sign, there were three labels spaced 30 cm apart: Mark 0 - Preliminary Mark, Mark 1 - Initial

Marker and Mark 2 - Final Mark. A total of 57 RFID tags were placed on 19 locations within 0,6 mm thick acrylic housings. The vehicle with reading equipment was moving at a speed of about 20 km/h. Although this was only a test with very limited equipment, the research has shown the potential of RFID technology for traffic signs marking and traffic sign identification. Schematic representation of system logic is shown in Figure 3.

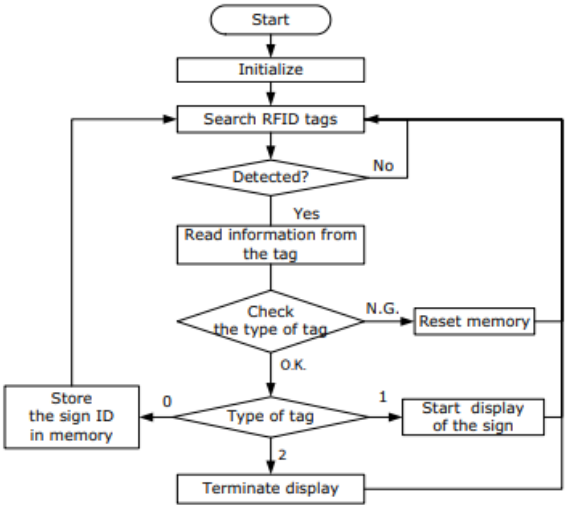


Figure 3 – Flowchart of the signing system
Source: [9]

The system consists of an RFID reader installed on a moving vehicle that continuously reads the passive RFID transponders in the receiving area. A sufficiently large reading range (about 7 m) is necessary to traversal of all traffic signs. A reading range large enough ensures the accuracy of the base update. Transponders are placed in the vertical part of the sign, and the traffic sign information is written in its Electronic Product Code. When the vehicle passes near the sign, the reader reads the signal or transponder data and processes them in real time or stores for later processing [10].

The benefits of RFID technology are that the database can be updated without the need for a sign to be physically read or verified. This could shorten the time needed for traffic signs checkout, reduce maintenance costs and make less traffic disturbance while updating.

One of the potential problems of this technology are external elements. External elements can affect the change of the magnetic field, affecting the quality of the wireless connection. They can affect the accuracy of reading out the transponder. Some of the elements that can affect the quality of connection are metals or humidity, and it has been experimentally proved that the transponder working capacity drops when close to those elements [11]. In order to use passive RFID technology in the environment, where moisture and metals are present, special transponders (Patch-antenna-based) are developed. Such transponders use special antennas attached to the metal surface. It consists of an inner micro-strip, dielectric element between an internal antenna and a metal surface that acts as a sphere that reflects an electromagnetic field [11].

Apart from metals and moisture, the problem with wireless RFID technology is the possibility of signal weakening when the signal is received by multiple channels (unbalanced signal) which affect the speed limitation.

3.1 COMPARISON OF EXISTING TECHNOLOGICAL SOLUTIONS FOR DETECTION AND AUTOMATIZED IDENTIFICATION OF TRAFFIC SIGNS

An overview of the existing technological solutions, for marking and identifying traffic signs for the purpose of updating the road database, identified the main disadvantages of each of these methods, which are explained below.

Disadvantages of using the detection and identification method of traffic signs from video and photo include high technology prices which are needed for system integration. It is necessary to invest larger amounts of money as initial capital so that frequent measurements can be set for more than one vehicle, respectively with favorable technology. Also, for this method it is desirable to have large amount of processing data since the image file requires large amounts of storage space. That directly refers to the investment in, previously mentioned high pricing technology. Shadowing of traffic signs can represent another disadvantage in video and photo method for identification of traffic signs. During driving it can appear that sign is shadowed due to pedestrians and other vehicles passing, vegetation or improperly placed commercials which can hide installed signs. Advertisements or roofs, and recent facades can give false positive returns in a way that system replace sign with objects of the same or similar color as traffic sign, which can result in a waste of data processing. Another disadvantage is similarity between traffic signs. Due to system design, similar signs can be identified as being the same. That further complicates the process of keeping the registry for the need for constant and frequent verification by experts. Also, there is a problem if the system is used in more than one country. Then, there would be a need for additional analysis and upgrading of the system for each case. Considering weather conditions, there is also one disadvantage. Due to the field efficiency of the system (time-consuming), it is not possible to control the time element with great certainty, especially in winter conditions. Moreover, an excessive exposure and retroreflection, due to the occurrence of multiple light sources, can disable the work with the required algorithm and cause many misaligned elements to appear. In the end, during detection and identification of traffic signs by video and photo method, sign distortion (2D or 3D) can be caused. The sign position can vary from mild conciseness to vertical and horizontal distortions of a significant degree and can make it difficult or completely impossible to detect and recognize a sign.

Compared to video and photo method for detection and automatized identification of traffic signs, barcode technology has less disadvantages. First and the main disadvantage is the duration of the bar code itself. Since signs are exposed to external influences such as sun, snow, rain and dirt, barcode tags must be specially designed to withstand the expected lifespan of the traffic sign. Second disadvantage includes physical reading of traffic signs in order to update the database. That would mean that in the absence of significant technology, the method can not be conducted. Ultimately, due to the physical contact between the reader and the barcode, the road patrol workers will have to temporarily stop the vehicle on the pavement and move around the road, thereby posing a potential threat to traffic safety.

RFID disadvantages include susceptibility to physical damage, interference with service denial (interfering with radio signals), counterfeiting, eavesdropping, and unauthorized communication analysis. Also, metal materials reduce the ability to read RFID transponders because metal surfaces interfere with antennas by preventing the antenna from absorbing enough power supply. Because of these characteristics, metals are not suitable for setting up an RFID system, but they can work if the antennas have specific settings. Like metals, liquid surfaces are also not the most suitable for setting up an RFID system. Water, shampoos, liquid solutions are substances that absorb radio frequencies. All absorbed waves result in a reduction in the power of the original signal, or a reduction in the potential energy that the RFID transponder can use. And the last disadvantage includes security. Data protection, especially in passive transponders, is largely compromised. The simplicity of the construction and the subordinate efficiency system leaves room for unauthorized access.

The summary of the main advantages and disadvantages is presented in Table 1.

Table 1 – The advantages and disadvantages of technological solutions for marking and automated identification of traffic signs

	Video and photo	Barcode	RFID
Advantages	• Automatic sign detection during driving	• Affordable price • The ability to store key data for the traffic sign • Readability from all directions • Large storage capacity • Better error corrections	• Automatic identification of the signs and update of the base • Large storage capacity • Long-term cost-effectiveness
Disadvantages	• High pricing technology • A large amount of processing data • Shadowing of a traffic sign • A similarity between traffic signs • No standardization of signs • Inability to store and read sign-related data • Weather conditions • Sign distortion, 2D or 3D • Excessive retroreflection	• Need for a physical reading of the sign • Security risk for the road patrol workers • Duration of the barcode	• Higher initial cost compared to the barcode • Metal impact on the accuracy • Fluid and moisture impact • Sensitivity to physical damage • Hack-security issues

4. CONCLUSION

Traffic signs represent a significant part of the road transport infrastructure. They provide important information to participants, necessary for their safe and comfortable use of the traffic network. For high-quality warning and notification of traffic participants in all situations, traffic signs must be technically correct and meet the prescribed standards. They must meet standards that are not just about the way of setup and visibility, or the intensity of retroreflection, but also for continuous maintenance. Optimized maintenance leads to a better road traffic network and contributes to the increase in overall traffic safety. In addition to this, the goal of an optimized road infrastructure maintenance is cost optimization.

This paper analyzes the existing technological solutions for marking and automated identification of traffic signs. First, the method of detecting and recognizing traffic signs from video and photo was analyzed. Since video and photo technology is based on visual sign recognition, with many advantages, the main drawback is the inability to apply it under certain conditions. If the sign is shielded, damaged or faded, the technology has certain problems with accurately detecting and identifying the traffic sign.

On the other hand, barcode technology has a relatively simple operating principle. The main disadvantage is that each sign needs to be physically read, which significantly slows down the database update. The use of barcode technology, due to the above-mentioned shortage, can potentially endanger traffic safety on the roads. It can also pose a potential risk to persons who read the signs. According to all the above, the assumption about the automatic identification and updating of the traffic signs database is eliminated, and thus the efficiency of the application of the barcode technology.

The RFID technology is a simple structure, yet complex enough to perform advanced and demanding functions. With all the advantages and disadvantages, it represents an efficient, easy and flexible way for an automatic update of the traffic sign database. The benefits of RFID system can be many and are primarily reflect in cost reduction and optimization and functional infrastructure maintenance, optimization of maintenance schedules and maintaining the constant quality of traffic signs.

Based on the studied technologies, it can be concluded that it is possible to develop a functional and usable system for automated traffic sign recognition and database update. However, further

system research and testing, as well as the development of software support, are required to establish a fully functional system.

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MAJA FURDI, mag.ing.traff. [1]
E-mail: maja.furdi7@gmail.com
RATKO STANKOVIĆ, Ph.D.[2]
Corresponding author
E-mail: ratko.stankovic@fpz.hr:
JASMINA PAŠAGIĆ ŠKRINJAR, Ph.D.[2]
E-mail: j.pasagic@fpz.hr
[1] Zrinska ulica 15, 40317 Podturen
[2] Sveučilište u Zagrebu, Fakultet prometnih znanosti
Vukelićeva 4, 10000 Zagreb, Hrvatska

IMPROVING EFFICIENCY OF THE PARCEL DISTRIBUTION BY DYNAMIC REGIONALIZATION

ABSTRACT

This paper outlines findings of the case study on the courier company which distributes parcels on the territory of the Republic of Croatia. The work performance indicators which are analysed show inconsistency of the workload in the last mile delivery, as the result of the existing model of regionalization. The improvement proposal refers to introducing a model of dynamic regionalization and respective vehicle routing. It enables optimal logistic resources allocation, in order to increase the service level and to rationalize operating costs.

KEY WORDS

Parcel distribution; last mile delivery; optimization; dynamic regionalization

1. INTRODUCTION

Postal services involve processes that enable flows of people, goods and energy in space and time, with reference to the given conditions and resources.

The basic purpose of the postal system is to facilitate mobility of consignments and information, hence it should be considered a logistics system. Lately, the significant progress has been made in information and communications technology that triggers new trends in postal industry. New technologies have stimulated development of e-commerce, which is affecting a growing demand for parcel delivery and the strengthening of trade competition by reinforcing postal and logistics services, lowering prices and providing a wider range of services. For postal service providers, it is important to adapt to the new market situation as soon as possible.

Successful enterprise management requires postal service providers to introduce certain organizational changes in order to improve processes and reduce costs. One of the options is optimal allocation of logistic resources in the last mile delivery segment of the parcel distribution, which involves the vehicle routing problem (VRP) and defining the delivery regions. In its basic form, VRP includes a set of users, served by a set of vehicles, within a given time.

This problem in various variants (sub-problems) has been studied in various scientific papers, among which the CVRP - Capacitated Vehicle Routing Problem is the most common variant in considering VRP subproblems. Specifically, among the 144 scientific papers dealing with VRP issues, covered by the 2014. Review [1], 128 papers are related to the CVRP issue. The next sub-problem is VRPTW - Vehicle Routing Problem with Windows Time, which is discussed in 57 scientific journals out of a total of 114 scientific journals. The VRPB - Vehicle Routing Problem with Backhauls is referred by

17 papers, DVRP-Distance constrained Vehicle Routing Problem by 15 papers, and VRPPD - Vehicle Routing Problem with Pickup and Delivery by 12 out of a total of 144 scientific papers.

For the purpose of this paper, the work performance indicators in the last mile delivery system of the leading parcel distribution provider in the Republic of Croatia have been analysed. Based on the respective findings, an insight into the existing model of operations is outlined. The major problem in the observed system is identified at analysis of the last mile delivery workload allocation.

By analysing the existing model of regionalization, a significant disproportion of the allocated routes, with regard to the demand for services, the length of the route and the duration of the route is found. Therefore, in terms of achieving a better overall work performance, optimal regionalization and corresponding delivery vehicle routing are crucial. Since the a.m. parameters change in time, the existing static model of regionalization is not sufficient.

A delivery route is determined by the vehicle, the courier (driver) and the delivery region. In the existing system, delivery regions are static, regardless of their variable work load, which is a big challenge in achieving planned goals. I addition to that, the vehicle routing is performed manually, within the given static delivery regions.

The main idea of the paper is to explore the possibility of abandoning current model of static delivery regions, by introducing a model of dynamic regionalization and corresponding vehicle routing, in order to:

- allocate equal work load to each delivery region/route, by dynamical shifting delivery locations between routes;
- cluster delivery locations in a way that lengths of delivery routes in kilometres are unified;
- optimally utilize working hours (full shift consists of eight hours), by adjusting the real transit time of the route and total working time of the courier.

The work performance of a courier is assessed on the basis of the number of parcels delivered and the kilometres travelled, since one courier can deliver a large amount (number) of parcels in an urban area, while another courier may deliver a small amount (number) of parcels in a rural area.

Taking that into account, a model of dynamic regionalization is needed, which would correspond to the actual structure of the delivery regions and the actual structure of demand for services in the given period. By unifying workload of the couriers (operators), the total operating costs would also be reduced and the service level increased, as well as the productivity of logistics resources.

The proposed model of dynamic regionalization and corresponding delivery vehicles routing is based on the algorithm for solving vehicle routing problem, applicable for the last mile delivery in the parcel distribution. Parcels are to be distributed to a certain number of recipients (locations), at given time, by a certain number of vehicles. The goal is to perform deliveries while making the distances as short as possible, with the optimal utilization of human resources and respective working hours.

2. ANALYSIS OF THE EXISTING MODEL OF STATIC REGIONALIZATION

This paper analyses 268 consignments data from the delivery books, for five different couriers who deliver parcels on the delivery region Zagreb - Sesvete - Zabok. Considering the fact that certain number of consignments are delivered to individual addresses on the same location, such consignments are grouped at start according to the address of the recipient. Consequently, 193 delivery locations were formed for the analysis in five delivery regions. One courier is in charge for each delivery region.

The available data from the delivery books are:

- Number of parcels
- Identification bar code

- Delivery order
- Delivery address
- Parcel weight
- Type of consignment
- Delivery deadline
- Delivery time
- Note
- Courier

The data shown in Table 1 is the outcome of the existing model of regionalization, which is static. The table shows the delivery data for each delivery region. For each region, the following features are shown: quantity (number) of parcels, length of the route in kilometers, service time, duration of the route, starting time and ending time of the respective route.

Table 1 – Work performance indicators at static regionalization

Region	Number of parcels	Length of the route	Service time	Duration of the route	Start	End
Region 1	43	92	1:47	6:53	6:51	13:44
Region 2	29	41	1:12	7:09	7:41	14:50
Region 3	65	178	2:42	5:33	6:44	12:17
Region 4	33	38	1:22	5:29	6:59	12:28
Region 5	23	44	0:57	1:52	13:34	15:26
Sum	193	393	8:00	26:56:00		

Source: Adapted by the authors against [2]

The number of parcels is equal to the number of delivery addresses, and the length of the route indicates the total kilometres of the route. The service time at static regionalization is actually the standard time. The practice is to have the standard time counted as 2.5 minutes per delivery. The standard time refers to the time of delivery of the parcel, without the vehicle parking time and arrival to the recipient and back. The duration of the route represents the couriers effective working hours. Starting and ending time is the time when the courier left and when he returned to the starting point.

The work performance indicators listed in Table 1 show discrepancies of the delivery regions with regard to:

- Number of parcels;
- Length of the route;
- Duration of the route.

The work performance indicators also point out discrepancies in exploitation of logistic resources (couriers and vehicles), hence a need to formulate a better solution, i.e. dynamic regionalization model that would correspond to the actual structure of the delivery region and the demand for services in the given period. By balancing the courier's workload, the total operating costs would also be reduced, and the service level raised, as well as the productivity of logistics resources.

3. PROPOSAL OF INTRODUCING DYNAMIC REGIONALIZATION

The proposal of the dynamic regionalization is based on the algorithm for resolving vehicle routing problems. As one of the versions of the GIS system, the ArcGIS version of the application was used, adapted to the logistics activities.

ArcGIS is used to create optimal routes and schedules based on specific logistic operations, including vehicle capacities, driver specifications, street network limitations, and time window of the

recipients. Users who use the a.m. software solution to plan their routes, typically save up to 30% of the total costs associated with the exploitation of delivery vehicles. [3]

By entering the same input data (data from the delivery books) used in the analysis of the existing (static) regionalization model and by entering respective constraints, the application generates an improved solution compared to the current model.

The biggest challenge during the implementation of the software solution was the geocoding of addresses. Since the system prefers the geographic coordinates instead of the address, the application used addresses from the delivery books in the form of coordinates. The Google Maps tool was used to determine the address coordinates.

As a spatial data management system, the geographic information system appears as one of the interfaces between the Vehicle Routing Problem math model, the actual traffic network and the actual work environment of the agency. [4]

Parcels have to be distributed to a certain number of recipients at given time, by a certain number of vehicles. The goal is to shorten the distances as much as possible, with the optimal utilization of human resources and respective working hours. Selecting appropriate VRP solution for a company that deals with parcel distribution is very complex. The reason for this is the fact that recipient data is changing on a daily basis and very rarely the same delivery time is repeated.

The VRP solution also helps to solve specific problems such as vehicle capacity matching with delivery quantities, high service level and delivery deadlines. Therefore, different variants and extensions of the VRP model, such as vehicle capacity or time intervals, may be convenient for solving different types of the parcel delivery issues.

The basic form of the VRP math model, which combines the objective function and the constraints, is formulated by mathematical expressions (1) to (6).

$$minF = \sum_{i=0}^{n}\sum_{j=0}^{n} w_{ij} \cdot x_{ij} \tag{1}$$

$$\sum_{i=0}^{n} x_{ij} = 1 \qquad \forall\, i = 1, 2, \dots, n \tag{2}$$

$$\sum_{j=0}^{n} x_{ij} = 1 \qquad \forall\, i = 1, 2, \dots, n \tag{3}$$

$$\sum_{i=1}^{n} x_{oi} = k \tag{4}$$

$$\sum_{i=1}^{n} x_{io} = k \qquad \forall\, i, j \in V \tag{5}$$

$$\mathrm{xij} \in \{0,1\} \qquad \forall\, \mathrm{i,j} \in \mathrm{V} \tag{6}$$

where:

- n = quantity (number) of delivery orders
- w_{ij} = cost of delivery from node *i* to node *j*
- x_{ij} = decision variable (binary variable which takes the value of 1 if the vehicle delivers a parcel between nodes *i* and *j*, otherwise takes the value of 0)
- k = number of vehicles

The objective function of the model is given by the equation (1), and it represents the goal of minimizing total transport costs of delivering parcels to the recipients (clients). Apart from reducing transport costs, it is desirable to reduce the number of routes. Reducing the number of routes also reduces the required number of delivery vehicles and human workforce.

The constraints given by the equation (2) and equation (3) indicate that one vehicle comes to the recipient at delivery, and also one vehicle leaves the recipient. The constraints given by the equations (4) and (5) indicate that *k* vehicles leave the DC and that *k* vehicles return to the DC.

The constraint given by expression (6) defines x_{ij} as a binary variable, which means that it can only take values of 0 or 1. It takes the value of 0 for the arcs connecting nodes *i* and *j* which are not included in the VRP solution and it takes the value of 1 for the arcs connecting nodes *i* and *j* which are included. [5]

Considering regionalization issue, using only mathematical methods and models is not sufficient for practical implementation. It is necessary to combine the VRP model with the actual business environment, which is simulated in this paper.

In the analysed example, all recipients and their delivery requests are given before the delivery starts. After collecting and preparing the data for the analysis, data deployment is performed in ArcGIS, according to the basic elements of the delivery process. The elements of the delivery process are schematically shown on Figure 1.



Figure 1 – Basic elements of the delivery process

The first step is to select a delivery region in the application interface. As mentioned above, the available data are related to the distribution region Zagreb - Sesvete - Zabok.

After selecting the delivery region, it is necessary to select the vehicle which is going to be used in constructing the respective route. Common type of delivery vehicle used by the parcel distribution provider are vans (payload ranges from 1000 kg up to 1400 kg).

A problem with setting payload capacity appears in practice, as there is no information on the parcel dimensions available, only the mass of the parcels. However, the majority of the parcels are not heavier than four kilograms. For this reason, the delivery vehicles are never fully loaded, so the vehicle capacity is not a constraint.

A courier has to return to the distribution centre by the end of his shift, so the constraint is the available time, eight working hours per shift, i.e. the total quantity of parcels a courier can deliver within his shift is always much less than the vehicle capacity. The length of a route is not limited (normally it does not exceed 100 km), but because it is required by the interface, 10000 km is entered (could be any number greater than 100).

In allocating couriers, it is necessary to predict and enter the number of couriers who deliver a certain amount (number) of parcels. Setting the time frame is the most important. In this example, the total delivery time is set to eight hours (one shift).

Delivery requirements are related to the parcel information. In order to be entered into the information system and pass the routing, the parcel information must be formatted in compliance with the system interface. The parcel characteristics (reception number, weight, sender data, recipient

data, service type, additional service, delivery time, and more) are entered into a special database that is later used in the application. In this case, total of 193 parcels with their features are entered.

Input data needed for vehicle routing that are related to delivery orders are:

- Number of Shipment
- TWS – Time Window Start
- TWE – Time Window End
- Service Time

TWS and TWE are times which are expressed in minutes, and represent the time when the parcel should be delivered to the user, in order to comply with the delivery deadlines. TWS as the earliest delivery start time is set at 8:00 h or 480 minutes. TWF as the latest delivery time does not have a specific deadline because it depends on the delivery time for each parcel. For example, TWF for a service that includes delivery up to 10 hours is 600 minutes.

In dynamic regionalization, the service time includes the parking time, the vehicle transit time to the recipient and vice versa, and handing over the parcel. Service time is determined by the characteristics of the parcel, and depends on the type of a package, that is, whether it is a regular packet or a parcel with certain supplementary services.

Finally, it is necessary to enter the input data to create the route. The routes are related to the data on the available resources for process implementation.

The input data for creating the route are:

- Start
- Break
- Starting location of the vehicle
- Final location of the vehicle
- Preparation time
- Time of discharge
- Maximum number of parcels
- Maximum driving time
- Total driving time
- Total duration of the route

Start represents the initial working time for courier. Delivery can be done in the morning and afternoon shifts, but also in shifts between, depending on demand for services. In the software application, the planned break of the courier is entered, which lasts 30 minutes.

The starting and ending point for all delivery vehicles is always in the DC (central warehouse). In the observed example, this parameter was set to DC in Zagreb.

The preparation time is the time that the courier is required to prepare the delivery parcels before leaving the DC. The time of discharge is the time which takes for the courier to return the undelivered parcels to the DC and to return the money in cash register.

The maximum number of parcels and the maximum driving time can be set as estimation, though it is recommended not to set to the lowest values, so the maximum number of addresses (delivery locations) is set to 100.

The total duration of the route consists of the courier (driver) working hours including handing over the parcels, break, driving and the time of discharge. The total driving time is a part of the total duration of the route.

Constraints were created according to the input data from the delivery books and according to the instructions of the expert.

For the purpose of converting the actual network of traffic directions into the appropriate graph used to solve the VRP problem, the digital map layers are supplemented by the layer of shortest paths between the given locations. The calculation of the shortest path is performed by the modified Dijkstra algorithm. The accuracy and precision of a practical VRP solution is directly related to the accuracy of traffic data on the digital map. It is necessary that traffic data is accurate and valid, and the data updates must always be performed on daily basis.

One characteristic of this system is that it does not detect roadworks at routing, so it is necessary to collect on-sight data and make manual corrections before verifying the solution.

Upon entering input data into the application, the optimal solution is generated in the form of:

- Route overview report;
- The review of the route schedule.

The route overview report and the review of the route schedule show the number of routes, the order of the address on a particular route and the planned delivery time at each specified address.

4. COMPARING THE PROPOSED DYNAMIC REGIONALIZATION TO THE EXISTING MODEL

Based on the given constraints and input data, dynamic delivery regions have been defined, and they are a combination of the present, static delivery regions. Features of dynamic regionalization are automatic grouping of parcels, adjustments of the routes and adjustments of the required number of couriers with regard to the grouping of the delivery locations. Such model of dynamic regionalization enables better utilization of logistic resources and adapting to the current situation.

Table 2 shows a comparison of the work performance indicators of the static and dynamic regionalization model, for the same input data (recipients/locations). The data is summarised against the observed regions.

Table 2 – Comparison of efficiency in dynamic and static regionalization

	Regions/Couriers	**Total quantity of parcels**	**Total length of routes (km)**	**Total duration of routes (hrs)**
Static regionalization	5	193	393	26:56:00
Dynamic regionalization	4	193	361	25:45:00

Source: Created and adapted by the authors against [2]

Implementation of the dynamic regionalization yields the following optimal solution:

- Four delivery regions/routes are defined;
- One courier/vehicle is assigned to each delivery region/route;
- Each recipient is assigned to a single route;
- All recipients are served and couriers returned to the DC (all routes are finished) within the shift (eight working hours).

Individually, by delivery region, the comparison of the static and dynamic regionalization is shown on Figures 2, 3 and 4.

In Figure 2, the quantities (number) of parcels are compared, that are delivered in static and in dynamic regionalization, for each region. Grey colour represents the quantities that relate to the existing (static) model, while the white colour refers to the delivery optimized by the dynamic regionalization.

With the dynamic regionalization, there is a reduced number of delivery regions/routes with greater number of parcels per region/route. The optimal solution allocates parcels from delivery Regions 2, 3 and 5 to delivery Regions 1 and 4, which consequently eliminate the delivery Region 5 and increases the number of parcels in distribution Regions 1 and 4.

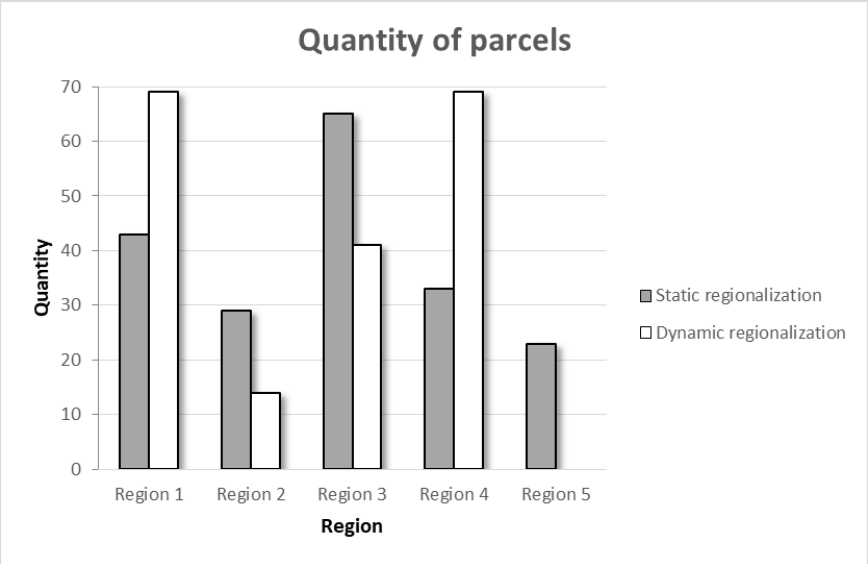


Figure 2 – Quantity of parcels

Figure 3 shows the comparison of the length of the route with the static and dynamic regionalization, for each region. The grey colour shows kilometres in the existing (static) model while the white colour refers to kilometres optimized by the dynamic regionalization. Figure 3 also shows the optimal work load of each route per kilometre. The optimal solution shifts distances (kilometres) from delivery Regions 1, 3 and 5 and allocates them into Regions 2 and 4. In addition to the reduction of the number of delivery Regions, the work load per kilometre is increased in Regions 2 and 4.

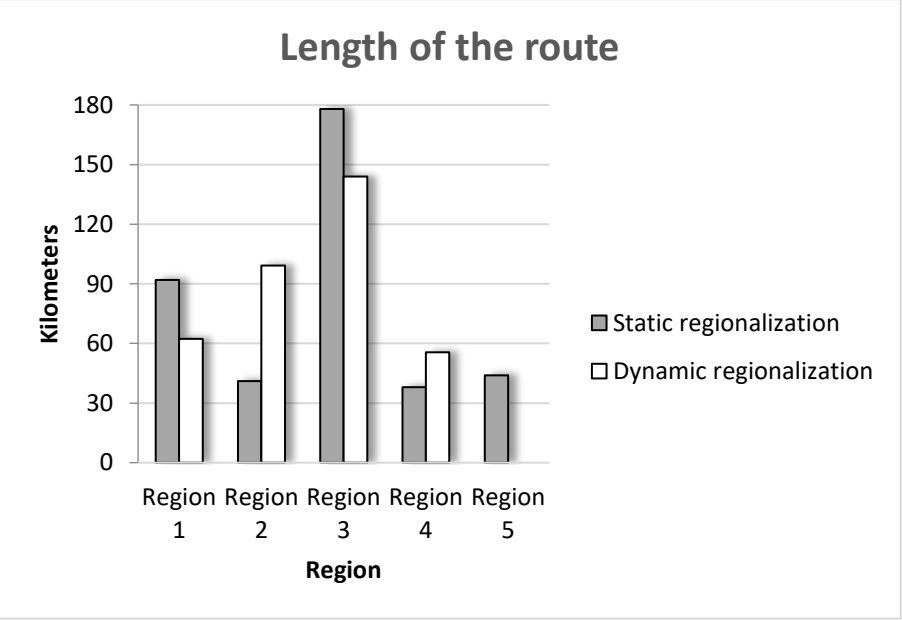


Figure 3 – Length of the route

Figure 4 compares the duration of the route (working hours needed to complete the delivery) in the static and dynamic regionalization model, for each Region. The grey colour shows the duration of

the route related to the existing (static) model, and white colour indicates the duration of the route with the dynamic regionalization.

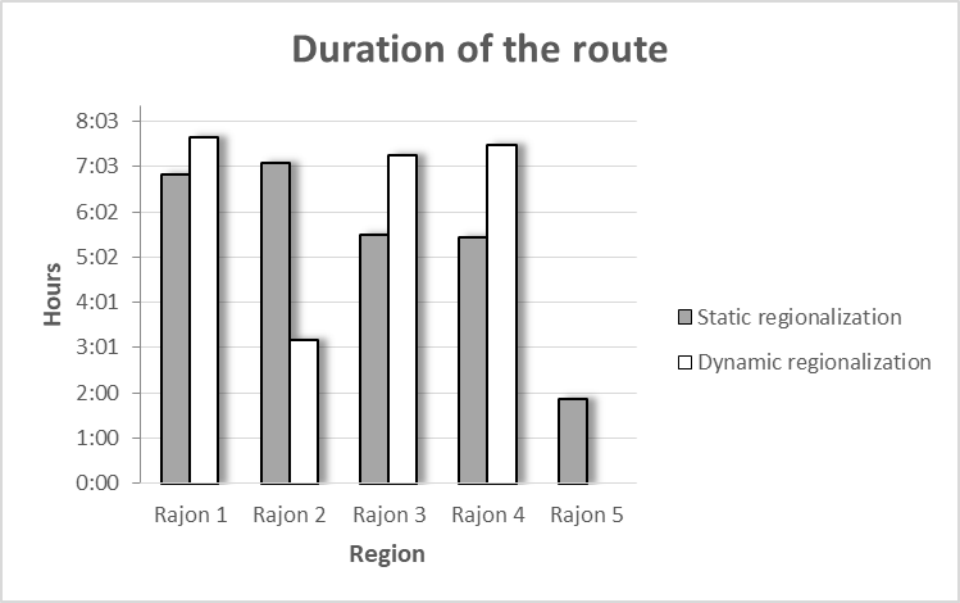


Figure 4 – Duration of the route

It is assumed that the total working time of a courier lasts eight hours. With the basic parcel delivery process, this includes the time that the courier needs to prepare the vehicle, to load the parcels in the vehicle before delivery and to discharge undelivered parcels back to the DC after he finishes the route. The dynamic regionalization enables filling the gap between the real duration time of the route and the total working time of the courier.

5. DISCUSSION OF THE RESULTS

The formation of new structures and transformation of the existing city blocks, as well as reconstruction of roads, are just some of the reasons that open the question of reorganization of the delivery regions. In addition, the dynamic environment requires the need for constant adaptation to new situations.

By implementing and replacing the existing (static) regionalization model with the dynamic regionalization model, it is possible to achieve significant savings in terms of:

- Required workforce
- Efficiency of workforce
- Increasing quality level
- Kilometres passed
- Cost reduction.

The most obvious saving is the fact that dynamic regionalization enables the reduction in the number of couriers who are needed to deliver the same amount (number) of parcels. In the observed example, the required labour force is reduced by 20%.

This increases the operational efficiency of the courier because by automatic grouping of orders, each courier gets multiple delivery addresses at the same locations, which utilizes working hours more efficiently. Automatic grouping of addresses, which generates delivery requests, increases the average number of delivery addresses by 25%.

In parcel distribution, it is important to respect the delivery deadlines. Greater courier efficiency would increase the precision in terms of deadlines, as well as, increase the level of service quality.

The delivery regions information in practice are updated on daily basis in relation to the characteristics of the manually defined static delivery regions, because the organization can never know in advance on how many locations the parcels will have to be delivered. In this situation with the static regions, the courier makes extra kilometres because he has to stay within the boundaries of his delivery region. By implementing dynamic regionalization, the recipients who need to be visited are automatically grouped in respective delivery regions, so the routes are customized to the current situation each day. With dynamic regionalization, the couriers work load in kilometres is increased on average by 15%, which enables them to do more deliveries in the regular working hours.

It is important to say that the a.m. savings in percentages refer to the average values from the observed example, which means that applying the solution proposal to the entire parcel distribution system, the savings may vary, depending on the actual situation at given time.

The interest of each organization is to reduce the costs of perform its activities and to improve the service level. Consequently, the aforementioned savings can also be seen as financial savings that reduce the logistics costs in terms of working hours, employees and mileage. The reduction of logistics costs also reduces the total operating costs.

6. CONCLUSION

The analysis of the existing model of resource allocation in the last mile delivery in parcel distribution system, points out a need to improve the existing model of regionalization and delivery vehicle routing.

Since the parameters of logistic resource allocation change in time, the existing static model is not sufficient. Therefore, in order to improve the overall work performance and raise the service level, introducing the dynamic regionalization model with corresponding delivery vehicle routing is proposed.

The proposed solution is obtained by allocating logistic resources of the existing static model by using the geographic information system (GIS), based on actual data and the dynamic regionalization. The features of the dynamic regionalization and delivery vehicles routing model also enable automatic grouping of orders against the location in real-time. With respect to that, the delivery routes, the required number of couriers and delivery vehicles are modified.

Comparing to the existing static model, significant improvements in terms of productivity and service level are achieved, which is particularly important in the last mile delivery which has direct impact to the customer's perception. This would also reduce overall operating costs in the parcel distribution.

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MARTINA JAKARA, mag. ing. traff.[1]
Corresponding author
E-mail: martina.jakara@fpz.hr
MARKO EMANOVIĆ, mag. ing. traff.[1]
E-mail: marko.emanovic@gmail.com
TOMISLAV BUBALO, mag. ing. traff.[1]
E-mail: tomislav.bubalo@gmail.com
BORNA ABRAMOVIĆ, Ph.D.[1]
E-mail: borna.abramovic@fpz.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb

THE PROMOTION MEASURES FOR COMBINED TRANSPORT IN THE EUROPEAN UNION

ABSTRACT

This paper observes a combination of road and rail transport on the principle of combined transport, since combined transport exploits all the benefits of rail transport, while shortage such as the lack of flexibility, poor accessibility and inability for "door to door" delivery, are complemented by road transport. In combined transport the initial and final phases of transport on small distances are carried out by road transport. There is a wide range of measures designed to support combined transport in the European Union, and Croatia follows the positive trends. The purpose of this paper is to approximate the benefits of combined transport and to show positive examples of combined transport incentives in the Republic of Croatia as the Member state of European Union.

KEY WORDS

Combined transport; road-rail transport; intermodal transport; promotion; regulations

1. INTRODUCTION

Transport of goods in Republic of Croatia has about the same image as in the European Union. Most of goods are transported by road and other transport modes are far less developed. Road transport causes negative impact on the environment and society, so it is really necessary to find and develop alternative traffic solutions based on intermodality.

The characteristic of intermodal transport is that the combination of different transport modes benefits from each of them, while the disadvantages of a single mode are minimized. Every year intermodal transport is increasingly showing its positive characteristics, recognized by the European Union (EU) because most of the problems in the EU transport sector can be solved with intermodal transport. Although the intermodal transport chain is more complex due to transhipment and different transport modes, goods that are shrouded and protected in intermodal loading unit (ILU) have a higher level of protection from origin to end customer. Combined transport is subgroup of intermodal transport which also maximizes the benefits of different forms of transport. Road transport is used as little as possible, most often in initial and final operations and for transport by terminal. Most of the transport route is carried out by rail, inland waterways (IWW) or short sea shipping (SSS). If one observes the national picture of commodity flows in Croatia, most of the goods are transported by road, then rail and very small part with inland waterways and air, so this work will show the incentives mostly for the combination of road and rail transport because they have the greatest potential to be applied in Croatia.

2. DEFINITION OF INTERMODAL TRANSPORT

The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing mode is called intermodal transport. [1] By extension, the term intermodality has been used to describe a system of transport whereby two or more modes of transport are used to transport the same loading unit which can be containers, swap bodies, semitrailers or complete road vehicles in an integrated manner, without loading or unloading, in a door-to-door transport chain. [2] [3] According to Bukold, intermodal transport represents a branch with a right, the specific structure of organization and functioning. [4]

In his PhD thesis, Woxenius defines intermodal transport through three basic conditions that must be met in order for some transport to be called intermodal: (1) the existence of standardized freight units where goods are transported from the start to the end destination; (2) basic freight units shall be in the form of ISO containers, swap bodies, semitrailers or specially designed containers; (3) the load units must change at least two transport modes during the realization of a transport chain. [5] From this it can be concluded that the first basic characteristic of intermodality is the multiple transport of goods from origin to the final destination, while the other characteristic is related to the form in which the goods are transported, which represents standardized cargo units such as containers, swap bodies, semitrailers or complete road vehicles. Intermodality can also be seen as a qualitative indicator of the level of integration of transport modes in the sense that greater intermodality means greater integration and complementarity between modes of transport, which provides better conditions for more efficient functioning of the transport system. Interoperability and interconnectivity are characteristics of intermodal transport which are necessary for the best quality of the intermodal transport chain itself and they need to be promoted at the level of the entire transport network in the EU.

The opinion of the European Commission from 1997 is that the transport system should not offer individual solutions and that a holistic approach is needed. [6] This type of policy greatly encourages intermodal transport considering that the adaptation and implementation of the intermodal system is very demanding but represents a complete solution for the negative environmental impacts of transport and the benefits for society as a whole are immutable. One subgroup of intermodal transport is combined transport where the major part of journey is by rail, inland waterways or sea and any initial and/or final legs carried out by road are as short as possible. [1]

3. THE CONCEPT OF COMBINED TRANSPORT

Combined transport is an individual form of intermodal transport that maximizes the benefits of different transport modes, taking into account to choose most convenient form of transport. This type of transport also includes the organization of door-to-door transport by transporting goods from one mode of transport to another without changing the transport unit. Therefore, combined transport is based on an intermodal transport unit where goods are transported using appropriate transport modes. Road transport is used as short as possible, most often in initial and final operations and for terminal transport. Most of the transport route is carried out by rail, inland waterways (IWW) or short sea shipping (SSS), and the choice of transport modes depends on the route where the transit between different transport modes has to proceed as efficiently as possible. Figure 1 shows an example of a combined transport organization where a short part of the transport from the initial warehouse to the intermodal terminal is performed by road, then the intermodal transport unit is transhipped on railway wagons and this transport mode is used on longest path. At the end, semitrailers are unloaded from wagons and the final stage of transport to the final destination is again carried out on the road to use the flexibility of this transport mode and its ability to deliver from door to door.

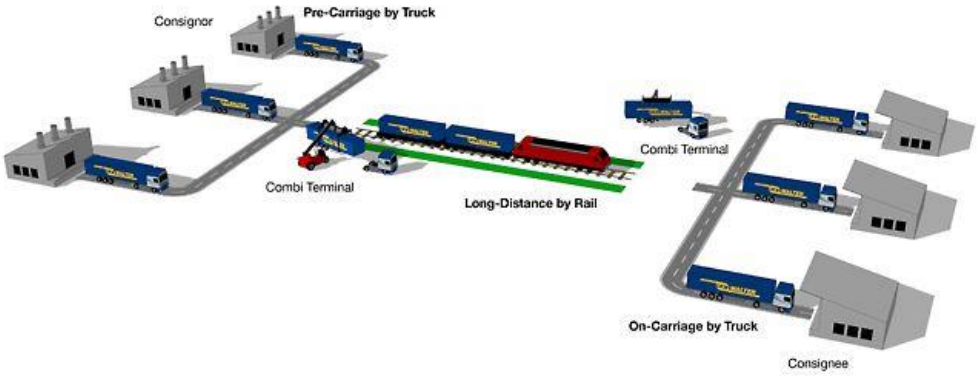


Figure 1 – Model of Road -rail combined transport
Source:[7]

According to Council Directive 92/106/EEC, combined transport operations shall (inter alia) conform to the following provisions [8]:

- The rail, inland waterway or sea sections of the end-to-end journey must exceed 100km as the crow flies;
- In CT rail/road, the initial road leg of the journey must be performed between the point where the goods are loaded and the nearest suitable rail loading station, and the final road leg between the nearest suitable rail unloading station and the point where the goods are unloaded;
- In CT inland waterway/road and CT sea/road, the initial and final road leg of the journey must be performed within a radius not exceeding 150km as the crow flies from the inland port or sea port of loading or unloading.

In terms of industry definitions and understanding of the CT market, until recently this has tended to be split into two broad segments with distinct equipment and service characteristics, namely [9]:

- Maritime CT, primarily related to movement of ISO-standard shipping containers between sea ports and inland terminals, for inter-continental shipments starting or finishing within Europe (e.g. to and from the Far East);
- Continental CT, primarily related to movement of CEN-standard European swap bodies between inland terminals in European countries.

The growth of international trade caused the growth of transport volume as well as the development of international combined transport lines. The concentration of traffic on some routes is particularly suitable for combined transport. Combined transport generates efficiency gains by concentrating small volumes of cargo, such as truckloads, into larger units - block trains, barges on inland waterways or coastal barges. Larger units allow savings in infrastructure utilization, operating costs, and energy consumption, and they are less polluting the environment than multiple individual units. In order for combined transport to be efficient (cost-effective) and competitive, the savings must at least be in balance with the transfer costs at the terminal. The higher the volume of cargo that is transported on a particular route, the easier it is to concentrate cargo. This is why large European transport flows are suitable for the development of combined transport. However, small amounts of cargo may be consolidated after a short road trip to form consignments. If the external costs and the negative impact of road transport are taken into account, the break-even point at which combined transport becomes more economical than the road transport is not as high as it is considered. This distance has been decreasing over the last few decades through the support and increase of alternative forms of transport such as combined transport.

Some other technical-technological features, economic and other benefits of combined transport compared to the classic forms of transport are [10]:

- Reducing the share of transport costs in the total price of goods,

- Faster, safer and more efficient transport of goods from producers to consumers,
- Reduction of heavy trucks on state roads and motorways with reciprocal reducing damage to road infrastructure,
- Significant reduction in the number of accidents, less human victims, significantly less destroyed or damaged vehicles and goods in traffic.

Another advantage of combined transport comes from the simple fact that the intermodal transport unit can wait for significant time before the next transit phase, and that the economic cost is not too high. Contrary to manipulation with the intermodal transport unit, the goods in complete vehicle that comes to the terminal must be unloaded as soon as possible and enabled for the next transport because the waiting costs are high.

4. THE PROMOTION MEASURES OF COMBINED TRANSPORT IN THE EUROPEAN UNION

The share of road transport as the largest environmental polluter among the land forms of transport has to be minimized according to the White Paper of the European Commission [11], which leads to the conclusion that intermodal transport has the greatest prospects in the future as it benefits the advantages of few different modes of transport while minimizing their deficiencies. The goals are to reduce the share of road freight transport and to move goods on rail or inland waterway what is a description of combined transport.

Using intermodal loading units – containers, swap bodies and (craneable) semi-trailers (which hold the cargo carried) – Combined Transport offers a zero-carbon solution to freight logistics [12]:

- The short positioning road legs of Combined Transport enable the use of electric, hydrogen or methane powered trucks to forward the loading units between a transhipment terminal and the point of origin or destination.
- At the terminals, electric cranes perform the transhipment of the loading units between the various modes of transport.
- Electric rail, barges and short-sea vessels offer, already today, the carbon-free forwarding possibility of the cargo over longer distances.

The European Union plans to significantly increase the share of more environmentally friendly modes of transport by 2050, and some of the set objectives are listed below [11]:

- Reduce CO_2 emissions by 60%
- Reduce NO_x emissions by 90%
- Significantly improve the safety of road transport without death and serious injury
- Reduce emissions from ship by 40%
- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors

Road transport is one of the main causes of the negative impact of transport on air purity, greenhouse gas emissions, accidents, noise and congestion, so it creates a problem for the economy and for the health of citizens. Given that road transport is projected to increase for 60% by 2050, the European Commission has prepared a proposal for a Directive of the European Parliament and of the Council amending Council Directive 92/106/EEC on common rules for certain types of combined transport of goods between Member States. One of the main goals of EU policy is to reduce the negative impact of the transport system. Council Directive 92/106/EEC establishes measures to encourage combined transport and is the only legislative act of the European Union which directly promotes the redirection of road freight transport to low greenhouse gas transport modes such as inland waterway transport, short sea shipping and rail transport. [13] If the share of road transport needs to be reduced, it is primarily necessary to make the other transport modes more competitive, more accessible and available. Various modes need to be coordinated horizontally and vertically. This

can be achieved through interoperability and interconnectivity, as well as various legal regulations and incentives. It is necessary to increase the flexibility of non-road modes and increase the capacities - infrastructural, transport and handling.

17 out of 28 Member States (MS) have adopted schemes for the reimbursement of vehicle taxes. This is also the type of incentive mostly applied in the EU. Moreover, Romania has prepared a vehicle tax incentive but has not yet implemented this, due to public budget constraints. Seven MS (Cyprus, Estonia, Finland, Greece, Luxembourg, Romania, and Sweden) have not enforced any other incentive for CT operations except for the measure provided under the CT Directive. [14]

In addition to the obligatory provision of the CT Directive to reimburse road vehicle taxes for CT operations, the survey has identified a wide range of other measures designed to support CT in the EU. They can be attributed to one of the following types of CT incentives [14]:

- Exemption from road vehicle tax (extending the scope of Article 6.2 of the CT Directive);
    - Austria, Czech Republic, Germany
- Exemption from or reimbursement of road infrastructure charges;
    - Only Bulgaria
- Derogation from Directive 96/53/EC allowing higher weights or dimensions of heavy good vehicles in CT operations;
    - Austria, Germany, Spain, Hungary, Portugal, Slovakia, Slovenia,
- Exemptions from driving bans for road vehicles;
    - Austria, Czech Republic, Germany, Croatia, Italy, Slovakia, Slovenia
- Reduced rail network access charges;
    - Bulgaria, Czech Republic, Denmark, Poland
- Aids (direct grants) for CT operations;
    - Austria, France, Italy, Latvia, United Kingdom, few states has this incentive, but support scheme expired (Belgium, Hungary and Spain)
- Aids (direct grants) for investments in CT terminal infrastructure;
    - Ten EU MS provide this is most popular CT incentive – Austria, Belgium, Austria, Czech Republic, Germany, Denmark, France, Netherlands, Poland, Slovakia and UK
- Aids (direct grants) for investments in CT equipment;
    - None, but Czech Republic, France, Slovenia and Slovakia have some form of incentive
- Measures specifically targeted at accompanied CT rail/road services.
    - Austria

The promotion of intermodality and the intensified use of Combined Transport are of utmost importance for the establishment of competitive alternatives to road transport. Therefore, Austria has been introducing early measures for the support of environment friendly modes, such as rail or Combined Transport. The following measures aim at promoting Combined Transport [15]:

(1) Financial support for investment and for operation:

- Innovation programme for Combined Freight transport
- Programme for the Support of Sidings and Intermodal Terminals (Road/Rail/Ship)
- Financial support for operation

- Programme for the Development of Intermodal Transports and for the Promotion of Combined Transport Projects on the Danube

(2) Fiscal incentives:

- Reduction or exemption from motor vehicle tax

(3) Regulatory support measures:

- Payload adjustment
- Liberalised initial and final road leg in Combined Transport
- Liberalised corridors for Rolling Roads
- Liberalised Area for Rolling Roads
- Exemption from the Weekend and Holiday Driving Ban on Lorries
- Exemption from the Summer Holidays Driving Ban on lorries
- Exemption from the Night Driving Ban
- Supplementary permits for using Rolling Roads
- Rest periods on Rolling Roads

5. THE PROMOTION MEASURES OF COMBINED TRANSPORT IN THE REPUBLIC OF CROATIA

According to Woxenius, transport organisers don't have some certain requirements when selecting mode of transport, but it is noticed that environmentally conscious logistics companies rather choose rail than road transport. [5]

In the example of the Republic of Croatia, transport organizers primarily choose road freight due to cost, but if some kind of education about advantages and disadvantages of other transport modes is introduced, and with more promotion measures such as incentives in combined cargo transport, awareness of logistical operators could change. Also, it can be noticed that ecological impact is not relevant for transport companies in the Republic of Croatia because due the economic picture in the state, only financial aspect is important.

By analysing commodity flows in the Republic of Croatia over the last few years, according to the data of the Central Bureau of Statistics and Eurostat it can be noticed that more than two thirds of the cargo is transported by road transport vehicles. By a more detailed overview of land transport in 2018, 84% of freight was transported by road, 14% by rail and 1% by IWW. Since 2014, the constant growth of transported cargo has been recorded. Transport by rail is constantly growing, road transport is growing and stagnating, and IWW in the period from 2015 to 2018 recorded a minimal decline of 4%. In favour of rail transport is the fact is that due to the liberalization of the market in the Republic of Croatia, seven freight carriers are currently active in the rail freight market. In the second quarter of 2018, cargo carriers transported 12% more goods than in the same period last year, or 19% more than in the previous quarter. [16]

At the beginning of 2018, the Croatian Ministry of the Sea, Transport and Infrastructure adopted the Incentives for Combined Freight Transport Ordinance („Official Gazette“, No. 5/18) [17] in addition to the Combined Freight Transport Act („Official Gazette“, No. 120/16) [18]. This Ordinance shows that the Republic of Croatia follows the example of the European Union, recognizing the benefits of this type of transport, and designing a way for subsidies to encourage transport organizers to choose combined transport instead of road transport. Upon adoption of the Ordinance and the Act, the Republic of Croatia as a Member State has sent it to the EU bodies DG Move and DG Comp. After a detailed insight, the EU Commission gave a positive opinion of the measures to be implemented in the Republic of Croatia. These measures have become best practice in the EU.

The incentive measures are as follows [19]:

1. The transport organizer is entitled to a charge of 150.00 HRK (20€) for a truck, a trailer, a semi-trailer, with or without a tow truck, swap body or a container with minimum of 20 feet, which are transported by rail, inland waterways or sea

2. A railway operator who carries goods with combined freight transport shall be entitled to the incentive in the amount of 2.00 HRK (0.26 €) per train kilometer to be paid as a fee for access to the railway infrastructure

3. The owner or user of motor and trailer road vehicles registered in the Republic of Croatia which has been used (within 12 months from the date of the last validation of the vehicle's technical validity) for the initial and/or the final part of the combined transport to or from the transhipment terminal shall be released from the obligation to pay the annual fee for the use of public roads up to a maximum of 50% payable on the registration of motor and trailer vehicles, as determined by a special regulation.

The amount of annual freight charges for public roads is calculated according to the following formula [20]:

$$P = \frac{X}{100} \times 0.5 \times N \tag{1}$$

where for X> 100 is taken X = 100

The meaning of the symbols is as follows:

P - the amount of release from the annual fee for the use of public roads (HRK)

X - the number of realized cargoes in the initial and / or final sections

N - amount of annual fee for the use of public roads (HRK)

According to the Ministry's report, all the HRK 2 million (266,666 €) of the funds provided for the incentives for combined transport have been used up. Out of that amount, 87% was allocated to combined transport organizers, while 13% was allocated to rail operators. Figure 2 shows the share of companies in total allocated incentives. Of the total of 2 million HRK (266,666 €) most were allocated to the transport organizer Adria Rail (72%), while transport organizer Crokombi received 15% of the total amount. By observing rail operators, Train Hungary got 11% and HŽ Cargo received 2%. [21]

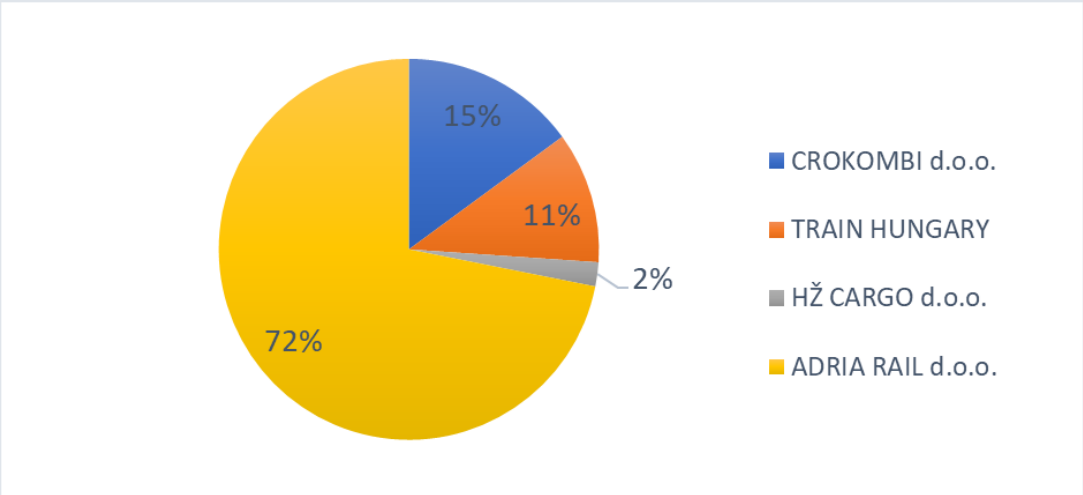


Figure 2 – Share of companies that have received incentives for combined transport in 2018 [21]

It has been noted that the transport stakeholders have united their interests without favouring a certain mode of transport and stimulated with incentives they increase the use of combined transport

in the Republic of Croatia. Given that rail and road carriers, together with transport organizers have also recognized the benefits of these incentives, the Ministry decided to provide a double amount in 2019, or HRK 4 million (533,333 €) , for combined freight transport, and the news compared to 2018 is that each applicant can realize the right to maximum 900,000 HRK (120,000 €) per year. [21]

6. CONCLUSION

Considering the congestion of road traffic, it is necessary to encourage other transport modes and regulate them with legal measures. According to the guidelines of the European Commission White Paper, it is necessary to minimize the share of road transport as the largest environmental polluter among the land forms of transport, which leads to the conclusion that intermodal transport has the greatest prospects in the future as it benefits the advantages of different transport modes while minimizing their deficiencies. The combined transport is an individual form of intermodal transport that maximizes the benefits of various modes of transport. The combined transport functionality is that road transport is used only in the initial and final phases of the transport chain, while most of the transport route is carried out by rail, inland waterways or short sea shipping.

The European Union has recognized the benefits of combined transport and has introduced combined transport as one of the ways to reduce the volume of road traffic. Various measures offer a wide variety of resources to promote combined transport, and measures are adopted depending on the habits and conditions in each Member State. The Republic of Croatia also follows EU trends in promoting combined transport, and in addition to the Combined Freight Transport Act („Official Gazette“, No. 120/16), Incentives for Combined Freight Transport Ordinance („Official Gazette“, No. 5/18) was adopted at the beginning of 2018. With the adopted legal solution incentives are obtained for the entire transport chain, accordingly: (1) transport organizer, (2) the railway operator and (3) the road haulage operator. The European Commission considers the Croatian way of encouragement as a positive example of good practice. No specific solutions can be offered in the traffic system and a holistic approach is needed. Intermodal and combined transport represents a complete solution for the negative impacts of traffic on the environment and benefits for society are immutable. It is necessary to minimize the share of road transport in combined transport model only to the nearest intermodal terminals and on the parts of the route where the transport by rail is unprofitable. Road carriers and railway operators should become aware that for this integrated door-to-door service they should not insist on favouring their transport mode.

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KRISTINA JERINIĆ, mag. ing. aeronaut.[1]
E-mail: kristina.jerinic@hotmail.com
BILJANA JURIČIĆ, Ph.D.[1]
E-mail: biljana.juricic@fpz.hr
PETAR ANDRAŠI, mag. ing. aeronaut.[1]
E-mail: petar.andrasi@fpz.hr
IVANA FRANCETIĆ, B.A[1]
E-mail: ifrancetic@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Department of Aeronautics
Vukelićeva 4, Zagreb, Croatia

THE EFFECT OF LUČKO CTR UPPER LIMIT EXTENSION ON AIR TRAFFIC INDICATORS IN ZAGREB TMA – A PRELIMINARY ANALYSIS

ABSTRACT

The number of air traffic operations and airspace users increase every year. Current airspace organization mostly keeps apart IFR commercial air traffic within terminal control areas from VFR general aviation traffic within control zones or uncontrolled airspace. In this paper a preliminary analysis of the effect of Lučko CTR upper limit extension on air traffic indicators in Zagreb TMA was investigated using EUROCONTROL NEST application for traffic sample from summer period of 2017. Several scenarios were created and simulated with Lučko CTR upper limit extension and air traffic indicators in Zagreb TMA calculated using NEST Scenario Economy. Results obtained from simulations showed that daily only few aircraft were affected by the upper limit change which gave expected negative values of flight time and distance, fuel consumption and CO_2 and NO_X emissions. In the end, some additional issues were discussed for further research.

KEY WORDS

Lučko Control Zone; Zagreb Terminal Control Area; upper limit extension; air traffic indicators; NEST

1. INTRODUCTION

Airspace organization is an important factor in planning of air traffic. Due to the increasing traffic demand, the available airspace should be organised in such a manner to allow maximum capacity while maintaining a high level of safety. With the overall aviation development, there are different airspace users with different, and often opposite, airspace requirements (commercial IFR flights, VFR training flights, unmanned aerial vehicles, military aircraft and operations, etc.). Most of the new technologies, procedures and tools (such as continuous descend approach/operations, global navigation satellite system (GNSS) approach, performance-based navigation, noise mitigation procedures, etc.) are designed to support airspace usage, organisation, design, structure or capacity in relation to instrument flight rules (IFR) traffic. Air traffic flow and capacity management as well as performance reports, statistics and forecast in European airspace are provided only for IFR general air traffic [1,2]. The main reason is the high number of operations and commercial cost-benefit perspective for air carriers and air navigation service providers. Air carriers tend to have less costs. For them, any change in the airspace organisation could lead to the increase in aircraft trajectories, flight time, fuel consumption and exhaust emissions. Furthermore, changes in aircraft trajectories could create new conflict situations and result in the increased air traffic controller workload or compromised safety. Air navigation service providers are financed by the number of IFR operations and consequently by the nautical miles flown. At the same time, requirements for visual flight rules (VFR) traffic are not subject

of such new and improved technologies and procedures and often are left behind. It can be said that the influence of VFR general aviation community and their requirements are not so important as commercial IFR traffic requirements. That is the reason why there aren't many scientific studies or projects that are dealing with airspace reorganisation in the context of VFR traffic.

This paper deals with the preliminary analysis of the upper limit extension of airspace Lučko Control Zone (CTR) from the perspective of VFR general aviation.

By its geographic location, Lučko CTR surrounds Lučko Aerodrome. Above Lučko CTR is Zagreb Terminal Control Area (TMA). The two airspaces share the same vertical limit: the upper limit of Lučko CTR is also the lower limit of Zagreb TMA. Thus, every change in the upper limit of Lučko CTR directly influences the lower limit of Zagreb TMA. The paper disseminates the results from the research which is a continuation of the study started as the student diploma thesis *Effect of Changes in Vertical Boundary of CTR Lučko on Air Traffic Indicators in TMA Zagreb*.

The motivation for this preliminary analysis is based on the informal observations and opinions of pilots who operate within Lučko CTR. According to their opinions, Lučko CTR upper limit extension should be taken into consideration with the purpose of widening operational airspace. The main reason for this opinion is the high number of aircraft operations that causes airspace overload during certain periods. Within Lučko CTR pilots often encounter problems with the altitude allocation and rarely fly at 762 m (2,500 ft) above mean sea level (AMSL). Certain instrument flight rules (IFR) commercial traffic arriving or departing from the Franjo Tuđman Zagreb Airport, operate at levels above Lučko CTR, usually at 914.4 m (3,000 ft) during approach to land, and thus can affect the traffic at lower altitudes. Since commercial traffic at this airport is mostly medium wake turbulence category aircraft, thus light general aviation aircraft within Lučko CTR cannot safely use altitude of 762 m (2,500 ft) above mean sea level (AMSL) but instead operate at lower altitudes. That results in the high number of flight operations during summer time at the same altitude. Additionally, Lučko CTR is mostly used by student pilots who train flight techniques, such as turns, stall prevention and upset recovery, etc. For these purposes, they require specific and undisturbed pilotage zones within CTR from the ground to the upper limit of 762 m (2,500 ft) AMSL. Occupying such zones, sometimes they interfere with the arriving and departing traffic flow and reduce available airspace. Extension of Lučko CTR upper limit could allow the arriving and departing traffic to fly over training pilotage zones without disturbing the traffic below.

The main aim of this preliminary analysis is to see if there is a justified reason to extend the upper limit of Lučko CTR and to investigate the possible effect of that extension on the commercial traffic in Zagreb TMA. Until now, not many scientific researches have been done regarding the airspace reorganisation or flight operations within Lučko CTR. There were few studies done on organisation and IFR procedures within Zagreb TMA and Zagreb Airport. Novak et al investigated implementation of the Continuous Descend Approach (CDA) in Zagreb TMA using aircraft prediction trajectory model based on BADA performance database for Airbus 319. Several flight scenarios were simulated, and results showed benefits regarding fuel consumption, greenhouse gas emission and surface area affected when CDA is implemented. The results were validated with the live traffic data (flight from Split to Zagreb) [3, 4]. Juričić et al investigated capacity calculation and analysis of Zagreb TMA. Several simulation scenarios were developed to examine how different factors affect airspace capacity. New solutions to increase Zagreb TMA capacity were proposed: Zagreb TMA sectorization and implementation of P-RNAV routes [5]. Sužnjević et al investigated aircraft trajectory during final approach phase of flight in terms of accuracy and precision with the aim to determine the horizontal and vertical deviations from optimal approach path [6]. Štimac et al made a research study of noise problems within the area of Zagreb airport through continuous noise measurement. Noise results analysis showed a need for the design of the new procedures of arrival or departure paths within Zagreb TMA [7]. Pavlin et al wrote about the possibilities of developing new capacities for general aviation in the City of Zagreb. Paper gives an overview of the Lučko airfield and proposes a construction of the concrete runway surface what would

enable its usage during the whole calendar year which will increase the number of VFR traffic operations [8].

2. AIRSPACE CHARACTERISTICS

2.1 Characteristics of Lučko CTR

CTR is defined as a controlled airspace extending upwards from the surface of the earth to a specified upper limit [9]. CTR is an airspace that surrounds a controlled aerodrome.

Lučko CTR (Figure 1) surrounds Lučko aerodrome. From the South-Eastern side, its adjacent airspace is Zagreb CTR. Its lower limit is ground while the upper limit is 762 m (2,500 ft) AMSL [10].

The airspace of Lučko CTR has two different functions. The first function is to operate as a controlled airspace when air traffic control is provided by Lučko Control Tower. Then this controlled airspace is appointed as Lučko CTR. It is Class D airspace where generally both, VFR and IFR, traffic are allowed. However, within Lučko CTR commercial and IFR air traffic is prohibited [10]. The second function of Lučko CTR airspace is to operate as uncontrolled airspace Class G when only flight information service is provided by Lučko Traffic. Lučko CTR is specific, because of its working hours. From Monday to Friday, from 6:00 to 14:00 hours it is a controlled airspace, while out of this time, Lučko CTR airspace is a part of an uncontrolled airspace [10]. All aircraft maintain their own separation both when it is a control zone and when it's uncontrolled airspace according to the information received from Lučko Tower and Lučko Traffic service, respectively.

Requirements for VFR flights are the same as in Zagreb CTR and, given that they are the same class of airspace, the speed restrictions are the same being limited to a maximum of 463 km/h (250 kt) IAS below 3,048 m (10,000 ft) AMSL [9]. In Lučko CTR, as well when it is an uncontrolled airspace, a permanent two-way radio communication is required on the frequency of 118.075 MHz [10].

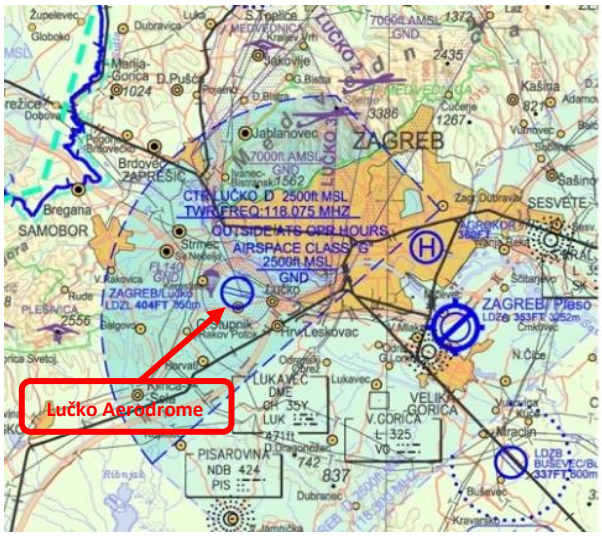


Figure 1 – Lučko CTR and Lučko Aerodrome
Source: [10]

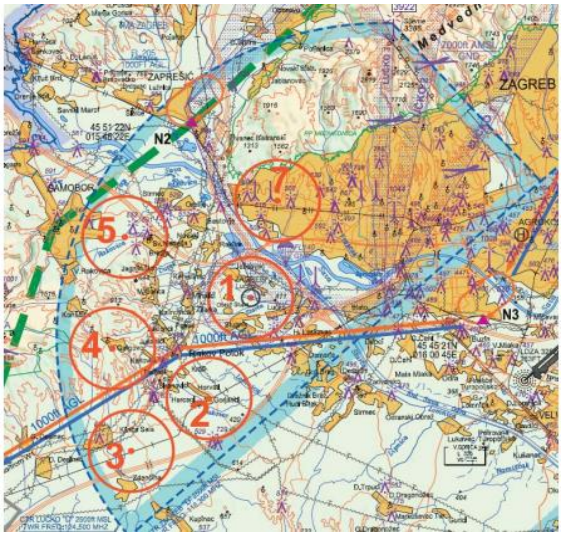


Figure 2 – Lučko CTR pilotage zones
Source: [10]

Figure 2 presents pilotage zones for VFR traffic with defined vertical limits: 1-Lučko (609.6 m (2,000 ft) – 762 m (2,500 ft) AMSL), 2-Horvati (304.8 m (1000 ft) above ground level – 762 m (2,500 ft) AMSL), 3-Zdenčina (304.8 m (1,000 ft) above ground level – 762 m (2,500 ft) AMSL), 4-Galgovo (304.8 m (1,000 ft) above ground level – 762 m (2,500 ft) AMSL), 5-Samobor (304.8 m (1,000 ft) above ground level – 762 m (2,500 ft) AMSL), 7-Podsused (304.8 m (1,000 ft) above ground level – 762 m (2,500 ft) AMSL) [11]. There are two additional zones within Lučko CTR: parachute and gliding zones [11].

2.2 Charcteristics of Zagreb TMA

Control area is defined as a controlled airspace extending upwards from a specified limit above the earth [9] while terminal control area is a control area normally established at the confluence of ATS routes in the vicinity of one or more major aerodromes [12]. Aircraft approaching to land or departing from a controlled aerodrome have to pass through TMA which is characterised with the high number of aircraft turns and level changes. TMA may surround one or more CTRs. Zagreb TMA surrounds Zagreb CTR and Lučko CTR. Also, Zagreb TMA surrounds Varaždin Aerodrome Traffic Zone (ATZ) [13].

Partially, the boundaries of Zagreb TMA follow the Croatian national boundaries. Eastern and South-Western boundaries divide Zagreb TMA from other parts of Zagreb Control Area. The lower limit of Zagreb TMA is 762 m (2,500 ft) AMSL above Lučko CTR and Zagreb CTR and 304.8 m (1,000 ft) above ground level (AGL) elsewhere. The upper limit of Zagreb TMA is FL 205 except on the Southern part where it is 2,286 m (7,500 ft) AMSL (Figure 3) [13].

Zagreb TMA is mostly Class C airspace with a small part of Class D. In Class C airspace, air traffic control service is provided to IFR and VFR traffic, hence IFR flights are separated from other IFR flights and from VFR flights. VFR flights are separated from IFR flights and receive traffic information on other VFR traffic as well as avoidance advice on request [9]. Likewise, all traffic is required to maintain a constant two-way radio-communication.

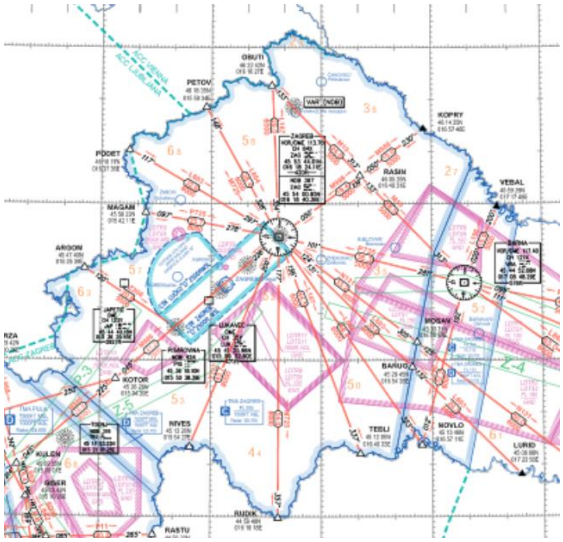


Figure 3 – Zagreb TMA Chart
Source: [13]

Zagreb radar approach control unit provides air traffic control within Zagreb TMA. Radar vectoring is used for arriving traffic for sequencing and for instrument landing system approach (ILS approach). When established on ILS, aircraft are transferred to Zagreb Aerodrome Control Tower. Traffic from KOPRY, PETOV and ARGOM points passes above Lučko CTR and that traffic should be taken into consideration in simulations. Departing traffic mostly uses standard instrument departure procedures (SID) that enables more efficient traffic flows and decreased use of radio-communication and consequently decreased air traffic controller and pilot workload.

2.3 Air Traffic Statistics

According to the statistical data, the air traffic increases significantly in the Zagreb Flight Information region (FIR) every year [14]. The traffic growth from 2006 till 2019 for IFR flights is presented in Figure 4. Most of the traffic is done during the summer season, from May to September with July and August being the peak months.

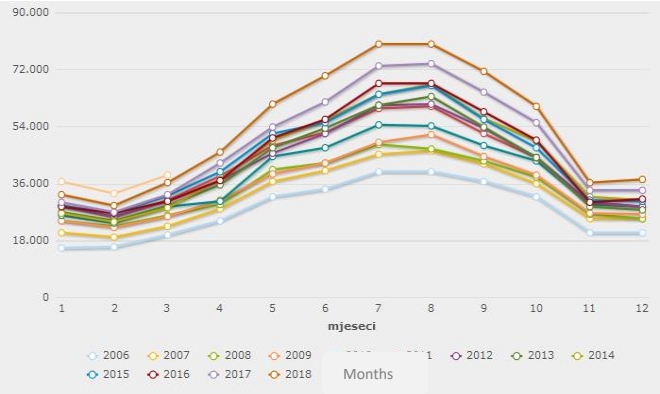


Figure 4 – Number of flights in Zagreb FIR from 2006 till 2019
Source: [14]

In this paper, statistical traffic analysis and simulations were done using EUROCONTROL NEST (Network Strategic Tool) application. NEST uses AIRAC (Aeronautical Information Regulation and Control) data sets obtained from EUROCOTROL Demand Data Repository 2 (DDR2). Each AIRAC data set contains traffic data for 28 consecutive days. Data sets contain traffic volume with initial or actual traffic trajectories. *Initial* traffic trajectories are last filed flight plan data while *Actual* traffic trajectories contain flight plan data updated with radar data [15]. For this research, the AIRAC 1708 was used as a cross section of the two busiest months of the year. It contains traffic data for the period from 20th June 2017 to 16th August 2017.

In that period, total number of flights in Zagreb TMA was 4,627, while an average daily traffic load was 166 IFR flights. For Lučko CTR analysis, following navigation points of Zagreb TMA were particularly examined: ARGOM, MAGAM, GORPA, PODET, PETOV and OBUTI. Total number of flights and average daily traffic load for defined navigation points are presented in Table 1.

Table 1 – Number of flights per navigation points in Zagreb TMA from 20th June 2017 till 16th Aug 2017

Navigation point	ARGOM	GORPA	MAGAM	PODET	PETOV	OBUTI
Total number of flights	466	368	158	457	265	303
Average daily traffic load	17	14	6	17	10	11

Source: obtained by NEST 1.6

During the same period, there were 854 flights in Lučko CTR. Total of 315 flights operated in Lučko Control Zone, while 510 operated within uncontrolled airspace (Table 2). The general aviation traffic made 96.6% of the total traffic in the airspace of Lučko CTR [16].

Table 2 – Statistics of Air Traffic for Lučko CTR from July 20th until August 18th

Number of flights in Lučko CTR		Total	Croatian military forces	General aviation (Control zone)	General aviation (Uncontrolled airspace)	Overflights
20th June 2017-16th Aug 2017		854	19	315	510	10
2017	July	1288	41	352	890	5
	August	934	27	389	502	16
2018	July	1550	45	621	878	6
	August	1322	23	542	736	21
Increase in air traffic	July	20,3%	9,7%	76,4%	-1,3%	20%
	August	41,5%	-1,5%	39,3%	47%	31,3%

Source: [16].

Table 2 also contains the complete traffic data for Lučko CTR for July and August of 2017 and 2018 with the calculated increase in traffic. Comparing the months for 2017 and 2018, it can be noticed that

the increase in traffic is significant. August 2018 had 41,5% more traffic than August 2017. There are more flights when Lučko CTR is operating as uncontrolled airspace.

3. SIMULATION OF LUČKO CTR UPPER LIMIT EXTENSION

NEST simulation programme was used to investigate how the change of Lučko CTR affects traffic in Zagreb TMA. Among statistical analysis, NEST enables scenario development and simulations. The programme includes five simulation algorithms: *Future Traffic Samples, 4D Traffic Distribution, Configuration Optimiser, Regulation Builder* and *Delay Simulation* [17]. All changes and simulations can be analysed via output data (tables, maps, animations).

For this research, NEST 1.6 version and actual traffic data set were used for simulations. Following air traffic indicators were taken for analysis: the number of rerouted aircraft, distance flown, flight time, fuel consumption and emission of CO_2 and NO_x gases.

The main idea how to investigate effects on Zagreb TMA was to create several scenarios with different upper limits of Lučko CTR, i.e. lower limits of Zagreb TMA and then to simulate actual traffic trajectories within Zagreb TMA for each scenario. In all scenarios with extended upper limit, actual flight trajectories that operated below that limit had to be rerouted to avoid Lučko CTR airspace. NEST enables this procedure by choosing function *Scenario - Simulate Trajectory - Exclusion Area*. These rerouted flights would be flights affected by the extension of the Lučko CTR upper limit.

So, the first step in simulations was to create reference scenario of Lučko CTR by using NEST Airspace Editor. Airspace coordinates were taken from VFR manual. Lower limit was set to ground level. Upper limit was set to 762 m (2,500 ft) (Figure 5).

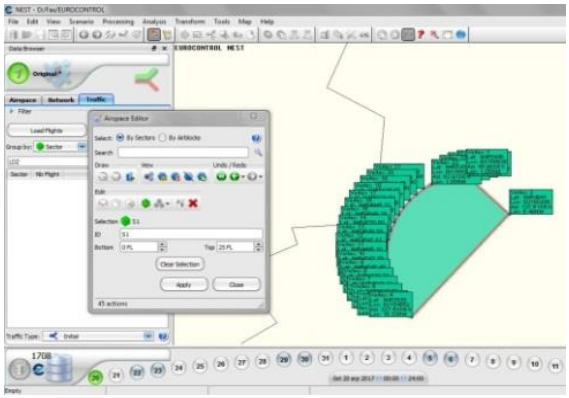


Figure 5 – Creation of Lučko CTR in NEST Programme
Source: NEST 1.6



Figure 6 – Visual Display of Chosen Air Traffic within Zagreb TMA
Source: NEST 1.6

The second step was to simulate actual traffic trajectories for reference scenario for every day of AIRAC cycle. Simulation outputs were Excel files containing tables with traffic data. These traffic data were further used for comparisons of each Lučko CTR upper limit change. Aircraft trajectories can be tagged and displayed in relation to Zagreb TMA (Figure 6).

Five additional scenarios of Lučko CTR were created and traffic was simulated for airspace upper limit set to 914.4 m (3,000 ft), 1,066.8 m (3,500 ft), 1,219.2 m (4,000 ft), 1,371.6 m (4,500 ft) and 1,524 m (5,000 ft). The maximum limit of 1,524 m (5,000 ft) was approximately determined according to the aircraft performance that mostly operate within Lučko CTR such as aircraft horizontal speed and the rate of climb, as well as the horizontal distance from the runway of Lučko Aerodrome to the airspace boundaries.

For every scenario, traffic trajectories were simulated with the exclusion of Lučko CTR and within which simulated traffic did not operate. Every scenario output data was compared to the previously

simulated reference scenario data. After the simulation, NEST data export commands were used to create a new file with the new traffic data. After comparison, the programme created a new Excel file, which displays two scenarios' data. Five Excel files were created for each day of AIRAC cycle, with five upper limits change. Process of instructions in NEST is given in the Figure 7. Each of these inputs opens new windows with more options to choose from and options to insert relevant data for the following simulation.



Figure 7 – Process of NEST instructions
Source: authors

Example of one actual flight plan data from July 30th 2017 used in NEST application is presented in Table 3.

Table 3. – Example of the actual flight plan data used in NEST

Flight ID	Call Sign	Origin	Dest.	AOBT	ATOT	Arrival Time	RFL	Airline	Aircraft Type	WVC	Route Length (NM)	Most Pen. Reg.	Delay (min)
AA663 06811	DLH 5ML	EDDF	LDZA	10:29	10:38	11:45	370	DLH	CRJ9	M	422.62	-	0

Source: NEST 1.6

This is the Lufthansa's flight from Frankfurt to Zagreb which passes through Zagreb TMA and above current Lučko CTR.

4. RESULTS ANALYSIS AND DISSCUSION

4.2 Results analysis

Table 4 contains the simulations results for every day of the AIRAC cycle. The first column contains observed days. Second column contains actual number of flights for the reference scenario. Other columns present the number of flights affected by the upper limit change per scenario as well as the average values for the whole AIRAC cycle.

Table 4 – NEST Simulation scenarios output data

Date	Number of flights for reference scenario	Number of flights affected by upper limit extension per scenario				
		3000 ft	3500 ft	4000 ft	4500 ft	5000 ft
20.7.	171	2	4	4	4	5
21.7.	176	1	3	4	4	5
22.7.	151	2	3	3	3	5
23.7.	142	3	6	6	6	6
24.7.	176	1	1	1	3	5
25.7.	172	3	5	5	5	6
26.7.	174	3	6	6	7	10
27.7.	185	2	4	4	4	6
28.7.	188	2	3	3	3	5
29.7.	149	2	4	4	4	7

30.7.	142	3	5	5	5	6
31.7.	189	1	2	2	2	5
1.8.	160	3	5	5	5	6
2.8.	163	3	4	4	5	8
3.8.	173	4	6	6	6	7
4.8.	179	3	3	3	5	6
5.8.	153	3	5	5	5	6
6.8.	142	3	5	5	5	6
7.8.	174	1	2	2	3	5
8.8.	176	2	4	4	4	5
9.8.	162	4	5	5	6	9
10.8.	163	2	4	4	4	5
11.8.	177	2	3	3	4	5
12.8.	157	2	4	4	4	6
13.8.	140	3	5	5	5	7
14.8.	171	1	2	2	3	5
15.8.	160	2	4	4	4	5
16.8.	162	3	4	4	5	8
Average	166	3	4	4	5	7

Source: obtained from NEST 1.6

There were on average 166 aircraft per day in Zagreb TMA during this defined period. If upper limit of Lučko CTR is extended to 914.4 m (3,000 ft), only three aircraft on average would be affected by this change. For extension to 1,066.8 m (3,500 ft), four aircraft on average would be affected, etc. The highest average number of affected aircraft (seven aircraft) would appear for extension to 1,524 m (5,000 ft).

As it was explained earlier, flights affected by the airspace limit change were flights that needed to be rerouted and had changed trajectories. These inevitably resulted in the longer distance flown and therefore increased fuel consumption and CO_2 and NO_x emissions. The longer flight distance also influences the flight time. By increasing the distance, the duration of flight was increased. The increased flight time means that aircraft is longer within the same airspace and under the same air traffic control unit which could further lead to the higher air traffic controller workload.

A1 — EUROCONTROL - NEST Scenario Economy - three dimensional computing

Comparison thresholds:	
Length:	0,05 NM
Time:	0,00823333 min
Fuel:	0,275 kg
CO2:	0,8635 kg
NOx:	0,0022 kg

Simple report

Scenario Economy for ... (Potential gains/losses)					
Total impacted flights	Length (NM)	Time (min)	Fuel (kg)	CO2 (kg)	NOx (kg)
3	61,847	10,759	190,707	602,670	2,373

Detailed report

Status	Length (NM)		Time (min)		Fuel (kg)		CO2 (kg)		NOx (kg)	
	Nb flights	Total	Nb flights	Total	Nb flights	Total	Nb flights	Total	Nb flights	Total
Increase	3	61,847	3	10,759	3	190,707	3	602,670	3	2,373
Equal	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Decrease	0	0,000	0	0,000	0	0,000	0	0,000	0	0,000
Total	3	61,847	3	10,759	3	190,707	3	602,670	3	2,373

Figure 8 – Example of the NEST Scenario Economy reports
Source: obtained from NEST 1.6

Fuel consumption, among other things, is a very important cost factor in aviation, especially for commercial air carriers that plan flights at such altitudes, speeds and power settings to have minimal fuel consumption with maximum benefit. NEST application enables calculation of these traffic indicators by its function *Analysis-Scenario Economy* (Figure 8).

This figure shows NEST Scenario Economy reports for one-day traffic of defined AIRAC cycle when three flights were affected by the upper limit change. Traffic indicators are calculated according to the simplified model used in NEST application which is based on the formula of Advanced Emissions Model (AEM) [17]. The average and maximum daily values of air traffic indicators per scenario are shown in Table 5.

Table 5 – Air Traffic Indicators per scenarios

Lučko CTR Upper limit extension scenarios	3,000 ft		3,500 ft		4,000 ft		4,500 ft		5,000 ft	
	Average	Maximum (3.8.2017.)	Average	Maximum (23.7.2018.)	Average	Maximum (23.7.2017.)	Average	Maximum (26.7.2018.)	Average	Maximum (26.7.2017)
Number of rerouted (affected) flights	3	4	4	6	4	6	5	7	7	10
Additional distance flown (km)	73.45	144.05	118.01	217.221	119.047	217.221	145.382	308.117	283.226	543.377
Additional flight time (min)	6.16	12.82	11.27	20.22	15	20.22	13.45	26.2	22.81	42.79
Additional fuel consumption (kg)	173.93	265.21	233	370.78	233.82	370.78	361.71	895.96	751.88	1,624.35
Additional CO_2 emissions (kg)	549.65	838.1	726.76	1,171.7	729.38	1,171.7	1,133.53	2,831.61	2,305.17	5,133.31
Additional NOx emissions (kg)	2.2	3.17	2.96	4.3	2.97	4.3	4.61	11.19	9.73	20.75

Source: obtained by NEST 1.6

The flights affected by the extension of the upper limit of Lučko CTR are the flights rerouted from their original trajectories from reference scenario. To a certain extent, that made the negative effects of air traffic indicators in Zagreb TMA. For scenario with upper limit of 914.4 m (3,000 ft) extension, average additional distance flown was 73.45 km, the average additional flight time was 6.16 minutes, the average additional fuel consumption was 173.93 kg, the average additional CO_2 emissions were 549.65 kg and the average additional NOx emissions were 2.2 kg. The same explanation can be applied to other simulated scenarios data.

To investigate maximum negative effects per day, days with the highest number of affected flights were also analysed. If the days had the same number of affected flights, the days with the lowest total number of flights (second column) were taken into consideration for every scenario. It can be noticed that with the increase of airspace volume (higher upper limit), the number of affected flights and negative effects increased. The first scenario had minimum negative effects, while the second and the third scenarios are balanced in negative effects. The last two scenarios had significantly more negative effects. So, the scenarios with 914.4 m (3,000 ft), 1,066.8 m (3,500 ft) and 1,219.2 m (4,000 ft) upper limit extension are more likely to be taken for further, more detailed analysis.

4.2 Discussion

Although there are some negative consequences of the extension of upper limit of Lučko CTR, it can be seen that they are not significant in number of flights affected. Min. 1.8% (three flights) and max. 4% (seven flights) of flights compared to the average number of 166 flights per day in Zagreb TMA would be affected with the changes which is not much and leaves the possibility to continue further research regarding the impact on air traffic controller workload, flight procedures and safety. This Discussion points out several additional issues that need to be taken into consideration as a result of the upper limit change.

1. ATC Surveillance Minimum Altitude (ATCSMA)– used during radar vectoring procedures. This altitude is calculated as an altitude of the highest obstacle plus 1,500 ft (1,000 ft obstacle clearance plus 500 ft safety buffer). Currently, this altitude is stepped-down from 1,676.4 m (5,500 ft), 1,524 m (5,000 ft) to 1,249.68 m (4,100 ft). For arrival traffic from points KOPRY, PETOV and ARGOM for RWY05 this altitude is conflicting with every Lučko CTR scenario. It will be necessary to turn arriving traffic from these points to avoid enlarged Lučko CTR. That will result with longer distance and increased time as well as increased air traffic controller workload (Figure 9).

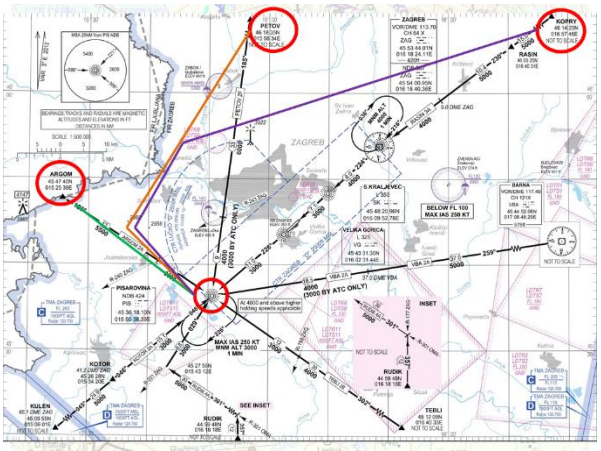


Figure 9 - Effect on radar vectoring procedures for Runway 05 at Zagreb Airport
Source: [13], adapted by authors

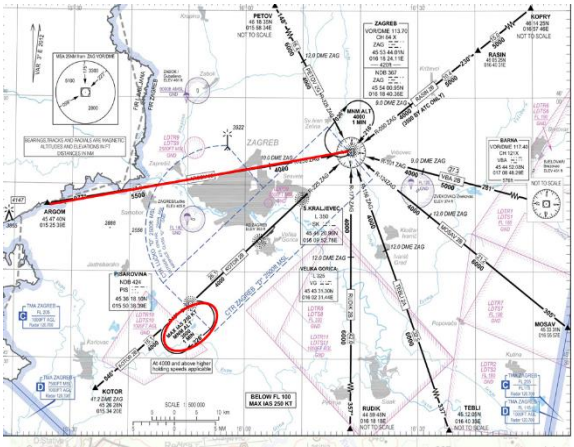


Figure 10 - Effect on the STAR Runway 23 and holding procedure Runway 05 at Zagreb Airport
Source: [13], adapted by authors

2. ARGOM 2B Standard arrival route (STAR) procedure for runway 23 could not exist with the currently prescribed altitudes.

3. Redefining of training pilotage zones and VFR points. Increase in CTR upper limit enables reorganization of current training pilotage zones and locations of current VFR points. Currently, there are five active VFR training pilotage zones and five VFR points spread within Lučko CTR. Some of these training zones are near VFR points causing reduction in horizontal separation between arriving or departing flights and training flights within the zone. Vertical increase of airspace will allow allocation of VFR points underneath or above specific training pilotage zone ensuring safe traffic separation. Repositioning of VFR points gives possibility for increased volume of training zones. Also, with extended upper limits, there is a possibility to increase the number of training zones by stacking one on top of another or creating one high special zone for upset recovery.

4. Holding procedures at PIS non-directional beacon (NDB) – altitude of current 914.4 m (3,000 ft) AMSL should be changed to a minimum of 1,219.2 m (4,000 ft) or 1,524 m (5,000 ft) and set to obligatory right-hand side turn (Figure 10).

5. Standard Instrument Departure (SID) obstacle clearance limit – for RWY 05, SID KOTOR 3L would have a higher limit in climb before turning left (1,828.8 m (6,000 ft) instead of current 1,219.2 m (4,000

ft)). The same thing would be required for RWY 23 SIDs: ZAG4F, PODET3F, PETOV3J and OBUTI3J (Figure 11, Figure 12).

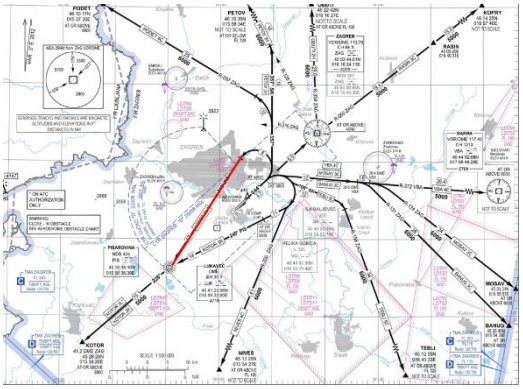


Figure 11 - Effect on the SID for Runway 05 in Zagreb
Source: [13], adapted by authors

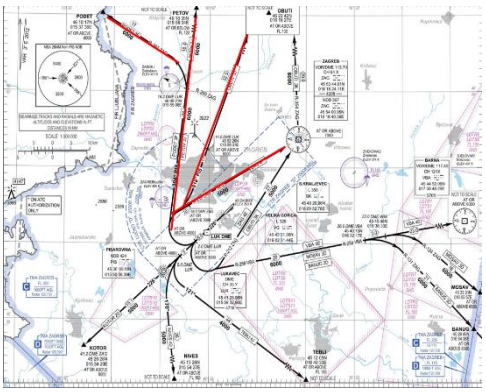


Figure 12 - Effect on the SID for Runway 23 in Zagreb
Source: [13], adapted by authors

Among these five situations, the extension of Lučko CTR upper limit would also influence other traffic, controller workload, number of conflicts and probably the overall air traffic complexity of Zagreb TMA because it would be smaller in volume comparing to the current situation. It is anticipated that such situations could affect safety as well.

5. CONCLUSION

With the increase in traffic, airspace organisation and planning are of utmost importance. The majority of airspaces are organised according to the requirements of commercial IFR traffic, but that traffic sometimes interacts with the general aviation VFR traffic.

This problem should be especially emphasised in the terminal control areas which are specific due to changes of aircraft level and speed and due to specific requirements regarding VFR flights and surrounding airspaces such as CTRs. That could lead to more complex traffic situations, increased air traffic controller workload and lack of airspace capacity. In this paper, air traffic indicators of Zagreb TMA were preliminary analysed according to the assumption of increased upper limit of the neighbouring Lučko CTR.

Preliminary analysis was based on five simulation scenarios that simulated the change of Lučko CTR upper limit – from 914.4 m (3,000 ft) to 1,524 m (5,000 ft). The actual traffic from July 20th till August 16th 2017 was used in simulation scenarios. As expected, extension of the Lučko CTR upper limit caused the rerouting of flights within Zagreb TMA. That had an expected negative effect on the following air traffic indicators: the number of affected flights, distance flown, flight time, fuel consumption, CO_2 and NO_X emissions.

Although this preliminary analysis and simulations showed a negative effect on the traffic indicators in Zagreb TMA, the idea of extension of Lučko CTR upper limit should not be rejected at once since the negative effects are gained from the low number of affected aircraft especially for lower extensions of 914.4 m (3,000 ft), 1,066.8 m (3,500 ft) and 1,219.2 m (4,000 ft). For these three scenarios additional research should be done in the context of ATCSMA. In the case of Lučko CTR upper limit extension, this altitude should be changed. For the scenario of 914.4 m (3,000 ft), ATCSMA should be 1,500 ft above, which results in 4,500 ft MSL instead of the current 4,100 ft. For the scenario of 1,066.8 m (3,500 ft), minimum ATCSMA should be 5,000 ft. For the scenario of 1,219.2 m (4,000 ft), minimum ATCSMA should be 5,500 ft. Two remaining scenarios (4,500 ft and 5,000 ft), would have higher ATCSMA, so it is expected that these scenarios would be rejected from further investigation. Also, it would be necessary to carry out a more detailed research involving human-in-the-loop real-time simulations and

risk assessment that would provide additional data of air traffic controller workload, air traffic complexity, new approach procedures and its impact on traffic safety taking into consideration additional issues explained in the Discussion section of the paper.

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ANNA JODEJKO-PIETRUCZUK, Ph.D. Eng.[1]
E-mail: anna.jodejko@pwr.edu.pl
FRANCISZEK J. RESTEL, Ph.D. Eng.[1]
E-mail: franciszek.restel@pwr.edu.pl
[1] Wroclaw University of Science and Technology
Faculty of Mechanical Engineering
27 Wyspianskiego Street, 50-370 Wroclaw, Poland

RELIABILITY ISSUES IN RAILWAY OPERATION PROCESS PLANNING AND OPTIMIZATION – A LITERATURE REVIEW

ABSTRACT

Very important for the widely defined railway reliability investigation is the correct determination of concepts and methods. Beside the issue of concepts related to system qualities there is the challenge to prepare application of them in the real system, which finally lead to improving their values and as a result the real system. Many of the features are in opposite to each other. The improvement of one causes the deterioration of other ones. The need arises to find a good solution in terms of different features located in given boundary conditions. Therefore, the aim of the paper is to collect the most important concepts for reliability research in the planning of railway processes, as well as optimization methods to find the best solution. Another goal of the paper is to identify gaps in the already finished research in terms of unwanted events. The presented paper is an introduction to a new started research on railway robustness and resilience.

KEY WORDS

railway; reliability; resilience; robustness; timetable;

1. INTRODUCTION

Very important for the widely defined railway reliability investigation is the correct determination of concepts and methods. A concept has to be applicable, and must lead to an added value in the system operation. The detection and classification of failure consequences is necessary in that context. Traffic disruptions are mainly related to execution time and route used for implementation of the timetable. On the other hand, traffic disruptions are the cause of a lower system performance.

Beside the issue of concepts related to system qualities there is the challenge to prepare application of them in the real system, which finally lead to improving their values and as a result the real system. Many of the features are in opposite to each other [37,43,44]. The improvement of one causes the deterioration of other ones. Therefore the need arises to find a good solution in terms of different features located in given boundary conditions. Therefore optimization approaches are necessary. Since the 1950s a variety of railway problems is modelled using mathematical optimization methods to be solved [4]. The railway industry creates a large set of issues that are interesting from combinatorial point of view [15].

The rapid development of a computer technology has influenced the rapid growth of numerical methods used in optimization processes [15,25,35,58]. The exact or random searching method, the genetic algorithms, the ant colonies methodology or the Monte Carlo simulation are the methods, which are examples of tools and techniques used widely during making a decision of a different kind. They are also often applied in the railway networks optimization. A few examples may be found e.g. in [26] and [23] (the search algorithm applied for trains re-routing), [16,40,82] (the genetic algorithms optimization is applied), in [87] (simulation-based methodologies and genetic algorithm

are integrated to reduce the calculation difficulties and to find the solution) or in [42] and [50,57] (the utilization of the ant colony methodology to find the problem solution in a railway network).

Therefore, the aim of the paper is to collect the most important concepts for reliability research in the planning of railway processes, as well as optimization methods to find the best solution. Another goal of the paper is to identify gaps in the already finished research in terms of unwanted events. The presented paper is an introduction to a new started research on railway robustness and resilience.

2. RELIABILITY AND PUNCTUALITY

According to Birolini [10], the basic concepts of the reliability theory can be defined. Reliability is the ability of a system to perform its functions connected to each item under given conditions during a specified period of time. Therefore, all components in a reliable system must be able to function, despite the situation of redundancy. In such a case only the minimum number of redundant components must be able to function, then the whole system will be called as reliable. Thus, no failures at item level are allowed, except the redundant parts.

Dependability or availability allows failure in the system. It is the ability of the system to perform it required functions under specified conditions in a given time period. In other words, after getting the correct input, the output of the system must correct. The output achieving process is not important if the goal will be reached. Quality is the degree of fulfilled requirements described by a set of inherent characteristics [36,41,45,77].

Most often, the notion of reliability is understood as punctuality, meaning a feature that speaks of the processes implementation in accordance with the assumed schedules. Chen [18] lists the most common concepts in the context of railway reliability, giving the definitions:

- reliability - the ability of the system to perform the required tasks in a defined time period, it is often quantified by the probability of performing the required task by the object under given conditions, in a given period of time,
- reliability of railway services - the percentage of trains activated at a given moment (including consumed reserves) of all scheduled trains in the theoretical timetable, this feature does not take into account the size of the generated disturbances (primary and secondary),
- punctuality - percentage of scheduled train arrivals at each stop in all arrivals scheduled in the timetable.

Public transport enterprises often narrow down issues of reliability to the time-correct implementation of transport tasks - punctuality [63]. Research in this aspect is limited to modelling the times of arrivals and departures [8], [63]. Punctuality also includes works on models for the selection of transport modes in public transport [9]. The concept of driving time reliability, i.e. punctuality associated with communication at interchanges is introduced. The notion of driving time reliability appears first of all in the analyses related to passengers [52]. In [56] the reliability of driving time is defined as the probability of traveling a given road at a time lower or equal to the assumed driving time.

Punctuality is assessed as one of the most important measures of process reliability in transport systems [31,59,60,79]. In practice, punctuality is not measured for each arrival and departure of a train to each station, but only at the final station of the course [60]. Artificial neural network models were used for delay prediction of passenger trains [85].

In the context of the timetable implementation, the concept of unreliability is also introduced. It is understood as the deviation of the train travel time in relation to the schedule [60]. The authors give examples of reliability measures of timetable implementation:

- the probability of train arrival after the scheduled time,
- the probability of departure before the time,

- the average difference between the actual arrival of the train and the theoretical one,
- average delay of the train arrival,
- average train arrival delay for delays greater than the set value,
- standard deviation of the arrival time.

Vromans [78] gives the following measures, which are identified with the reliability of the rail transport system:

- punctuality,
- connection punctuality - concerns delays resulting from the loss of a communicated connection,
- number of cancelled trains,
- average train delay,
- average passenger delay.

From the above, a few concepts can be established for the railway operation analysis. Railway system reliability will be the ability to perform the technical system tasks in a given time period, under certain conditions.

The system is operated and used by human. Therefore human failures may also disrupt the processes in the system. Assuming no premeditated failures, human reliability is the ability of operators and users to run the system correctly, according to the established procedures, under certain conditions in a given time period.

The railway service reliability is the ability of the socio-technical system to perform all required service tasks in a given time period, under certain conditions. A service task represents a planned arrival and/or departure to/from a specified station, stop or traffic control point. To match the railway service reliability, the planned trains have to be launched, and they have to be operated by the planned or reserve vehicles, by the planned or reserve train crews, on the planned or reserve infrastructure and under the supervision of planned or reserve traffic control crews. The reserves in vehicles, crews and infrastructure mean resources in each category, which are not planned to use for other operation actions. Therefore they are so-called cold reserves.

Dependability of the railway system is the ability to perform all its tasks which are on the output, thus related to the system users, in a given time period, under certain conditions. The processes can be totally reorganized, the subsystems may be in failure state, the humans may cause failures

3. ROBUSTNESS AND RESILIENCE

The term robustness is used in publications in many different ways. One possible definition of robustness can be the ability of a system to resist imprecisions [67]. It can be also the ability to withstand trouble without significant system or process changes [75,76]. A next definition says that robustness is the system's tolerance for a given set of unwanted events [62], or the ability to absorb small delays by the timetable [5]. However, in the same paper the Author also defines robustness in relation to the recovery time. In [27] robustness is directly applied to timetables by Dewilde. The Authors introduce the term of robust timetables by their ability to minimize time delays after small disruptions. Thus, secondary delays are limited and the recovery time is short.

In [69] robustness is defined through a measure which is the highest primary delay, which causes no missed passenger transfers. In [32] the term of stable timetables is used. The authors analysed periodic timetables, which were named as stable if delays do not propagate from one time period to the next one. The used term stability can be equated with robustness. In later studies Goverde [33] established the concept of locally stable and globally stable systems. In relation to a subsystem, locally stable means a that the total output delays are smaller than the total input delays. Global

stability is related to the whole system, where the initial delays will be supressed in a finite time interval.

In [47] robustness for the station routing problem was obtained. It was realised trough maximisation of the time interval length between crossing train routes. The assumption was, that the increasing of time intervals between trains causes a higher probability of no secondary disruptions. The analysis was done without probability estimation. Separately of such research are performed statistical delay analysis in relation to probability distributions fitting [90]. The stochastic approach for process modelling was used in [12,49,54]

The opposite quality to robustness is vulnerability. In [48] it is defined as system as weakness, which makes it susceptible to destruction during exposition to hazards.

In [47] a timetable is defined as robust if disruptions do not lead to delays. It means that primary delays can be easily absorbed, only a few primary delays cause in propagation to other trains, and delays can be compensated simple dispatcher operations. However, the quality related to dispatching activities is more related to the resilience than robustness.

Resilience can be defined as ability to recover the system performance after a collapse [11,71], [91]. For the recovery can be used all available strategies, including for example rescheduling, rerouting, using of additional resources for maintenance and rolling stock changes. In [48] resilience is defined as system ability to recover form a shock.

Resilience evaluation models do not take into account important factors related to the railway system [6,28,64]. However, the system specific factors have an impact on resilience and robustness. A set of such factors includes the types of unwanted events, timetable structure, mechanism of serious accident occurring and ability of system recovery.

Goverde [33] prepared a recovery time analysis using max-plus algebra for delay propagation analysis. The most important limitation is the usability only for periodic timetable. Thus, not for heterogeneous traffic. Also Kroon et al. [47] use the limit their approach by focussing on the Periodic Event Scheduling Problem for timetable.

4. TIMETABLE PRODUCTION AND OPTIMIZATION

In the first stage of rail transport planning, a timetable is designed for the collision-free train movement on the infrastructure. It specifies the exact times for events that have to occur in given time moment and places, related to specified trains. This level of planning also applies to train routing issues. Rolling stock planning is a problem in allocating rolling vehicles to planned journeys in circulation. However, crew planning is a problem of scheduling the work of train crew members. In order to increase the robustness of the schedule, time buffers are planned. It is important that they are adequately distributed throughout the journey of trains, particularly where it is appropriate.

Publications concerning the evaluation of the timetable take into account time disturbances. The root causes of unwanted events and their impact are not taken into account [46,61,72].

There is a wide variety of optimization methods that may be applied when searching the best solution of an optimization problem, e.g. [39,74,84]. They may be distinguished depending on a taken classification criteria. The historically most widely used are for example: the linear programming, the integer programing, the nonlinear programming, the dynamic programming, the network programming, and the queue theory. They all use mathematical models of a problem and mathematical searching procedures to find the best solution of the problem in given conditions. Examples of optimization problems in the railway area, when the mentioned mathematical approaches are implemented, may be found e.g. in: [86],[68],[13] (the integer programming), [34] (the nonlinear programming), [2,81] (the convex programming) or in [1,4,14] (the network

programming). Additionally, a few reviews of research on the optimization methods applied in various railway network problems are available in [15,22,53].

An automated model for traffic control was presented in [7]. It allows to launch trains according to the timetable as well as to implement changes in the train structure. The model uses online input data about traffic from the system and makes decisions basing on Machine Learning methods. A train priority is described in the database. A route is assigned to a train after a current traffic condition analysis, taking into account route conflicts.

In the paper [29], a binary time series prediction is proposed on the base of conditional restricted Boltzmann machines (CRBM) and echo state networks (ESN). The proposed approach is used for predicting the occurrence of railway operation disruptions. The case study is focussed on failures of tilting systems of railway vehicles. The machine learning approach was used in [51] to model for discovering the railway delay root causes.

A two-objective integer programming model was presented in [86]. The aim of the model is to optimize timetables in terms of energy consumption and the service quality. Headway times and dwell times are controlled to find the best solution. A genetic algorithm with binary encoding was used.

Energy consumption and travel time were included in [87] as the objective. The basis are coasting control methods and simulation-based methodologies, as well as genetic algorithms. The approaches help to reduce calculation difficulties and seek for a close to optimal control strategy. In [35] was a model proposed basing on the trajectory analysis. The nonlinear programming method is used. In [70] were included the energy consumption and the passengers' trip time as main factors for a multi-objective optimization model to find the best speed trajectory under given conditions. Also ant algorithms were used [42,50] for energy optimization.

An optimization-based methodology for train service recovery after unwanted events was proposed in [4]. The approach consists of network optimization models for the service legs in a railroad network. Such a structure gives the ability to evaluate a number of what-if scenarios. The approach combines optimization and prediction actions to analyse what-if scenarios, their impact

In [66] were presented three heuristics, elaborated to search for suboptimal solutions in periodic train scheduling problems. Minimizing of the total travel time for a given network was performed in [1]. The routing problem was formulated as a minimum-cost network flow problem that with a nonlinear objective function. For simplification, the nonlinear travel time function was approximated with a piece-wise linear function.

The further development of the optimization methods, or rather the methods supporting a decision making process, is the result of still wider and dipper data mining [17,20,24,89]. The big data analysis let the methods to be developed, often combined with the experts' knowledge [3,19,88] and used by the machine learning process [65,73]. There can be found quite a number of examples of heuristic algorithms, which are used to reduce an area of a feasible problem solutions space (e.g. [38,66]) or drawing conclusions using the neural networks [55,83].

5. SUMMARY

The great potential of the modern concepts and methods has been even a premise to call a new kind of a processes management in various industry areas as e.g.: "industry 4,0", "logistics 4,0" or "maintenance 4,0". They are also extensively used in the railway area, e.g. to predict system disruptions [29,30,51,85], evaluate its safety [21], design railway logistics network [80] or apply them into Intelligent Signalling Systems control [7].

From the literature review it can be seen the lack of critical incident inventories which threat the planned operation of the system. Also the actual conditions for a selected part of the railway network (infrastructure, rolling stock, running interval) should be taken into account.

Using the concepts and approaches, complex methods for supporting decisions of railway managers under unexpected disruptions should be evaluated. The right reaction in the process of the railway disruption management requires quick analysis of a disruption, identification of constraints resulting from it and taking the decision, which would minimize the negative effect of the disruption or recover the system into its normal operation state as soon as it can. The taken decision ought to be the best in given conditions for the sake of a chosen optimization criteria.

Because of the great complexity of railway networks [15] and processes the feasible area of possible solutions that may be applied in the case of a disruption can be huge. Moreover the number of constraints, which should be taken into account when solving the disruption problem makes the finding of the best (or at least a good) solution not an easy achievement. Thus, there is a need to use algorithms, which are able to find potentially the best solution area, to examine their effects and suggest the best decision to an operational manager. The methods should use the data from a disrupted process in the real time, analyse them and give a quick hint what should be done to lead the system into the normal operation state. When analysing the aforementioned methods supporting the decision making process, the greatest potential lays in the numerical methods concept, which are used by the industry 4.0, and the machine learning idea. The methods exploring process data from the past of a railway system (e.g. neural networks) together with the methods of solutions generating (e.g. the genetic algorithm) can let the supporting system define, which solutions are the most likely to recover the system with as little negative consequences as they can be.

For further research it is planned to develop a method for both, the schedule planning, as well as its implementation. New reliability, robustness and system concepts must be developed. Also optimization methods which will allow to solve such complex problems. In the next steps, a basic optimization method for the timetable with reference to robustness will be presented. After that, a multidimensional resilience concept for recovery action evaluation.

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TOMISLAV KLJAK, Ph.D.[1]
E-mail: tomislav.kljak@gmail.com
JOSIPA JANKOVIĆ, univ. bacc. ing. traff.[1]
E-mail: josipajankovic32@gmail.com
VALENTINA ŠTEFKOVIĆ, univ. bacc. ing. traff.[1]
E-mail: tina09021997@gmail.com
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

CONCEPT OF MULTILEVEL AND MULTILAYER CONSIDERATION OF PHILATELY DEVELOPMENT IN E-ENVIRONMENT

ABSTRACT

The paper sets the concept which can help in more precisely and clearly studying certain impacts of e-environment on Philately. The concept assumes several layers of main impacts which gives certain influences appropriate importance and mutual dependence (relationship). The example of technical and technological areas has been taken to analyse some characteristic indicators and some adequate laws have been observed. In this way the analysis can be performed safely, without fear of mixing impacts from different levels and areas.

KEY WORDS

Postage Stamp; Philately; Postal Technology; electronic communications

1. INTRODUCTION

Under the term e-environment the authors imply also the latest technical and technological communication solutions which are realised over electronically-based (telecommunication and/or computer) networks. At the same time, under the term Philately the authors imply a wider aspect of the definition which includes different philatelic products and not only postage stamps (such as maximaphily, postal stationaries, philatelic literature, revenue stamps, etc.). Neither do the authors limit themselves to the currently defined philatelic classes (and sub-classes) since based on the experience and trends the occurrence of new classes are to be expected depending on the development and adaption of communication forms as well as user requests (in the first place collectors' requests).

The revenues from philately are not to be neglected, and they depend on the region and particularly on the size of the postal operator. They vary in a range of 0.5-2.5% of total postal revenues and the entire market (primary and secondary) is estimated to several billions of US dollars with the constantly rising trend [The future of philately] The number of philatelists is more difficult to estimate due to a large number of philatelists who are not registered. The fact that can be taken with safety is that this refers to several dozen millions of philatelists out of which one can count with several hundred thousand of serious ones. [1]

The authors themselves have been included in various ways in the philatelic and collector's sector so that they are personal witnesses of certain laws that this paper tries to formalise and clearly present.

2. IMPACT OF E-ENVIRONMENT ON PHILATELY

The direct incentive for this paper has been the publishing of the document "The Future of Philately" which listed in detail numerous aspects important for such analysis. What seemed useful to

the authors is the development of a relevant concept i.e. a generalized model of these aspects. Not all aspects, namely, are at the same level i.e. with a direct or indirect dependent role on the impact of e-environment. At the same time, each level consists of several layers as presented in Figure 1. Ecology is left among the layers of the first level as common to all areas of that level since each has related to it in their own way.

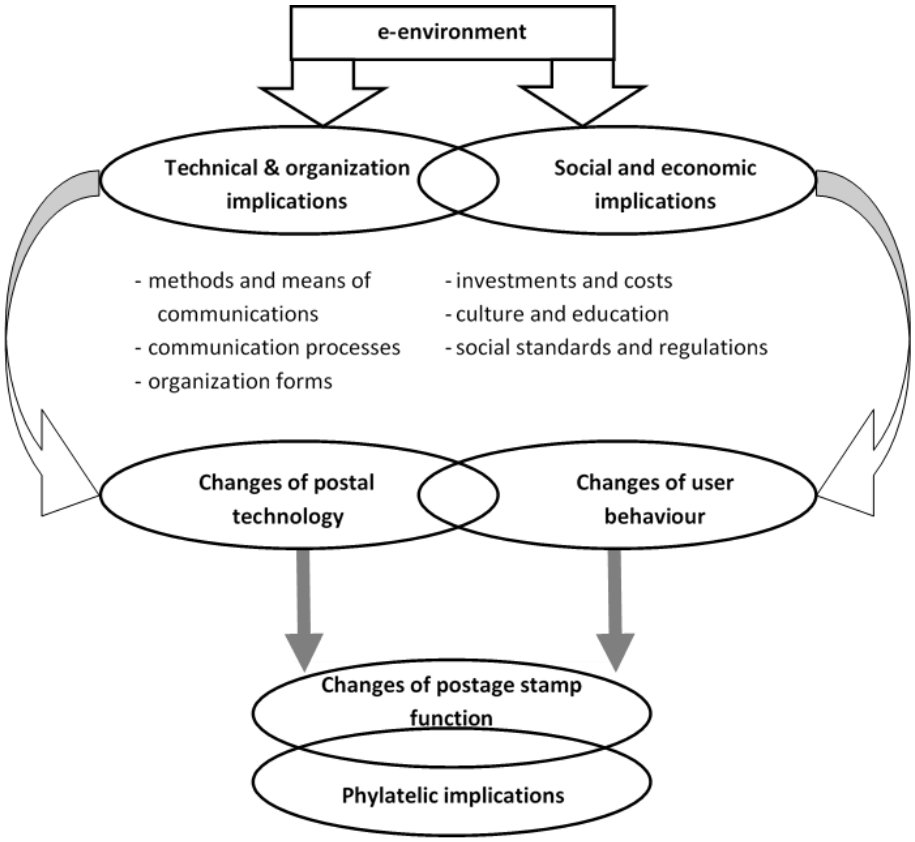


Figure 1 – Elements and relations of multilevel and multilayer concept of e-environment impact on philately

Such a concept provides a possibility of clearer pondering of certain impacts and searching for adequate methods of responding to them. Table 1 indicates some of the measurable values for single areas that can be used to numerically model and follow the interdependence of certain influences.

Table 1 – Overview of values for monitoring e-impact on certain relevant areas

technical	network infrastructure (transfer capacities, number of connections, coverage, terminal devices), realized turnover, number of users, spectrum of services
organizational	forms of organization and communication management, sector institutions
social	number and density of population, gender, age, forms of living communities, customs, education, ecology
economic	investments, costs (hidden and actual), maintenance, security, upgrading
postal	structure of postal items
sociological	culture, upbringing, hobbies, customs
philatelic	number of philatelists, number of philatelic societies, number of exhibitions, values of postage stamps (market, catalogue), indices of philatelic market, number and presence of single philatelic classes, number of philatelic products

However, for the needs of this paper the consideration through this concept will be directed to technical and technological side of the model. With such simplification the analysis is reduced to three main areas of observation with philately being considered as dependent on the changes in the communication technologies.

The model shows that direct influence on the postage stamp (and thus philately as well) is through postal technology. Thus:

$$F = f(PT) \tag{1}$$

F – philately;

PT – postal technology.

Although it was precisely the postal technologies that in the beginning motivated and supported the development of electronic communication forms, today the influences are outside the postal technology domain and occur at the higher level of scope. Thus, postal technology today is under the direct influences of changes that occur in technical and organizational area as consequence of e-environment impact. That is,

$$PT = f(EKT) \tag{2}$$

The interdependence of postal and electronic communications has been intensely studied and analysed over the last several decades and numerous models of forecasting postal traffic according to electronic alternatives have been set [2, 3]. There have been many mistakes and roaming since the situations were swiftly changing and it is therefore even today difficult to find a high-quality and reliable model. However, over time and through empirical monitoring of the situation on the status on the communication market, certain laws have been observed that could already represent a solid base to make good forecasts. From initial forecasts of complete substitution of physical (postal) forms of communication through electronic alternatives to the present knowledge about a strong connection (almost interdependence) of these two forms. In the beginning the electronic communications were only auxiliary activity to postal processes, and today the postal communications is increasingly becoming a link (one of the crucial ones) in different e-logistic processes of e-economics. However, it is obvious that both traffic forms, although having their own areas of activities, supplement each other to a significant extent.

In order to determine the starting data relevant for the consideration of the research topic, we will use the data about the presence of Internet users observed regarding certain regions (Figure 2). One may observe large deviations and the fact that the coverage does not exceed anywhere 90%, and on the average, at the World level it does not amount even to 60%. Also, the speed of implementation is being constantly reduced every five years. [4]

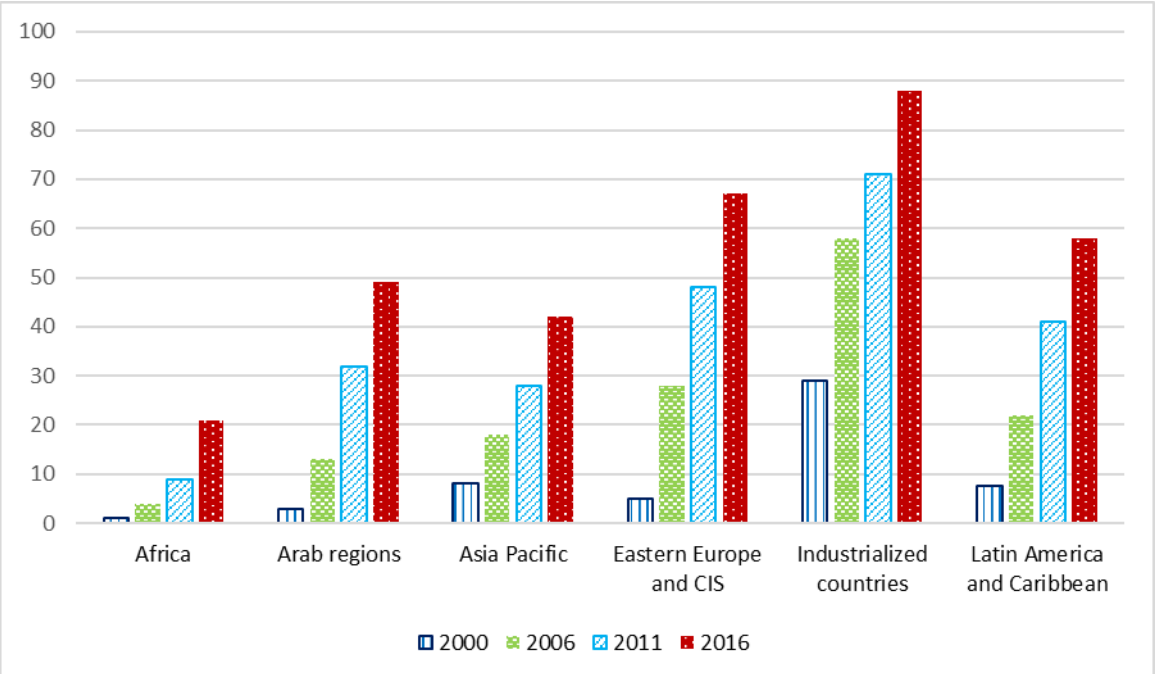


Figure 2 – Proportion of individuals using the Internet (average number of Internet users per 100 people)

On the other hand, the access to postal services has been almost doubly developed and more uniform (Table 2). The deviation occurs again in the African region where the values are equal to those for the Internet, but on the other side are all the other regions, as a rule, more successful than the most developed regions with Internet users and on the World level covering more than 95% of the entire planet population.

Table 2 – Access to postal services by region

Region	Population having mail delivered at home	Population having to collect mail from a postal establishment	Population without postal services
Africa	20.9%	65%	14.1%
Arab region	83.9%	12.3%	3.8%
Asia and Pacific	85.7%	9.9 %	4.4%
Eastern Europe and CIS	97.4%	2.6%	0.0%
Industrialized countries	94.9%	5.1%	0.0%
Latin America and Caribbean	87.8%	10.1%	2.1%
World	80.4%	15.8%	3.8%

Source: [4]

Thus, it is possible that the impacts of the Internet (and indirectly all e-applications that it provides) on the postal traffic have not been shown yet since the technology itself has not been spread sufficiently to have the force of a substituting technology.

Figure 3 shows that the classic physical textual communication has been exposed to pressure and certain substitution primarily by the possibility of remote voice transfer in real time, and more recently through transfer of textual messages by means of various e-devices and e-applications.

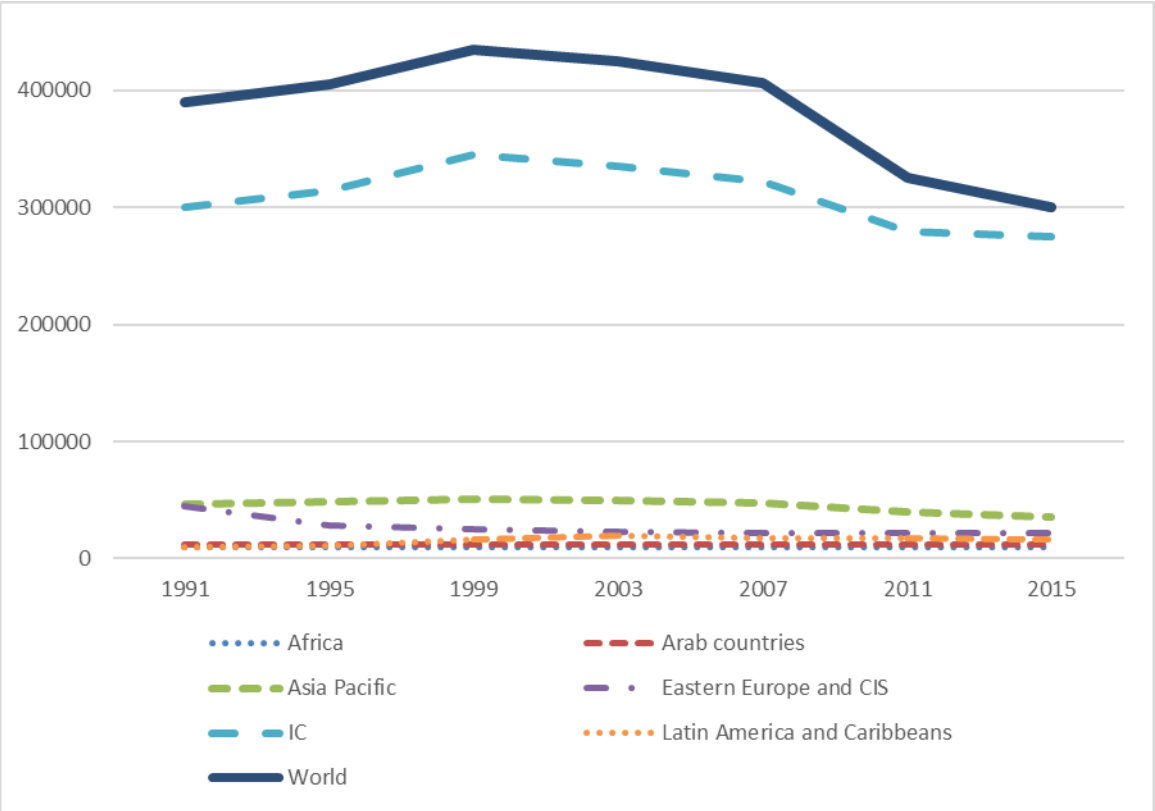


Figure 3 – Evolution of domestic letter-post traffic (millions of items)
Source: [4]

However, at the same time post is becoming more and more a service for the transfer of parcel items i.e. goods communication (Figure 4) although the share of letter items has still remained dominant (in a ratio about 3.5: 1). In philatelic sense this change actually means that the postage stamps (philatelic product) are now more likely to travel within the sent items than on them. The sent items are, namely, more rarely franchised with postage stamps, but postage stamps are now being sent within the postal items (as a rule a mail order, i.e. a shipment of higher value of the bill – because of the security of distance trade).

Naturally, the situation varies depending on the observation regions. If the observation is directed only to IC countries (where e-environment impact is most expressed) another interesting law can be observed. Figures 3 and 4 show, namely, that over ¾ of the total postal traffic is generated precisely in the industrially most developed countries where the electronic technologies are most developed. Figures 3 and 4 present graphical data for domestic traffic since it represents over 90% of total postal traffic, and the rules for international letter and package traffic are similar as for the domestic one (only in a narrower scope).

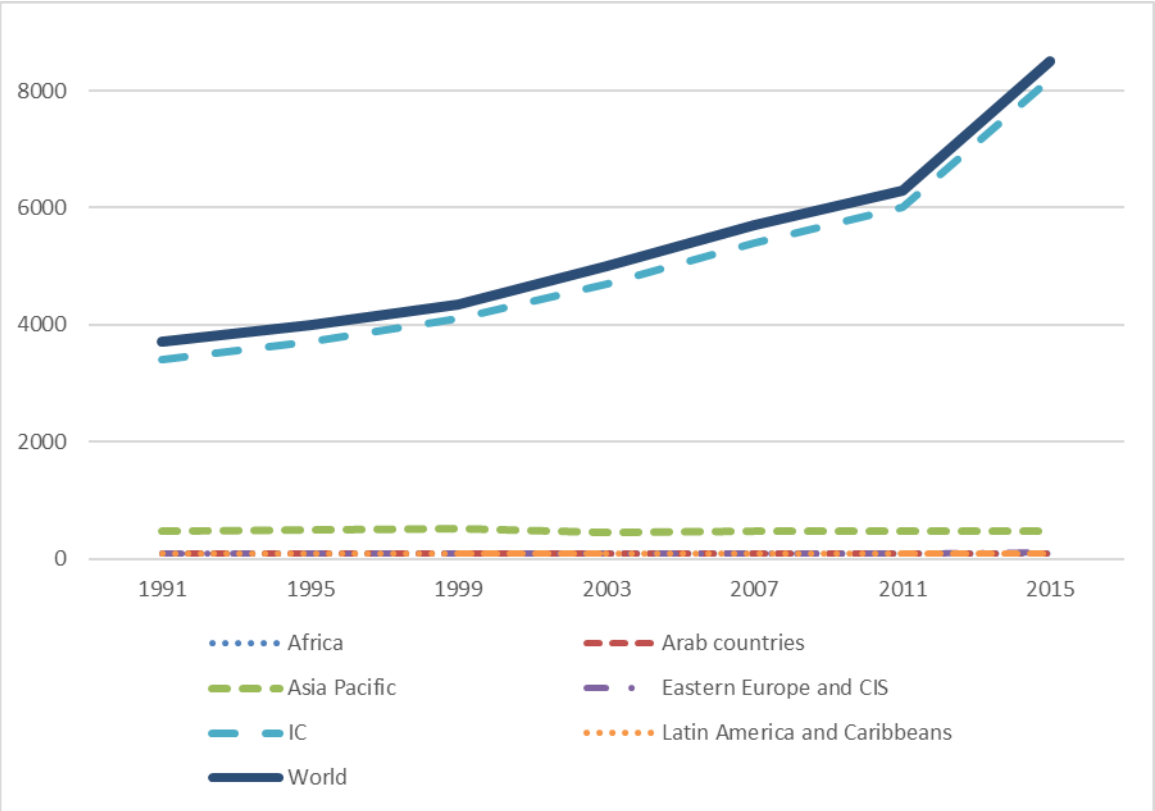


Figure 4 – Evolution of domestic parcel-post traffic (millions of items)
Source: [4]

The next level of observation is the impact of the technical area on the philatelic area. In this sense it is useful to mention the data collected by various philatelic organizations. The collection of data has been organized hierarchically and it is performed for international postal and philatelic institutions (UPU, FIP, AMDP, etc.) by certain national associations and companies. Furthermore, there are data of the American Philatelic Society (APS) which are interesting since they refer to a country with extremely developed e-infrastructure, huge share in the total postal traffic and strong and long-lasting philatelic market. They carried out studies (mainly in the form of surveys) among the philatelists (current, former and non-member philatelists) related to the use of e-communication technologies. They found out that over 80% of philatelists have access to the Internet and that they mainly use various forms of information and knowledge exchange whereas about 60% of them use it for the purchase of philatelic products. In the process about 30% of all purchases are done precisely via the Internet (non-members even 40%). Only 16% of US philatelists do not use the Internet. [APS] Besides, the changes in the method of dealing with philately under the impact of e-technologies have been observed, and the data are presented in Figure 5.

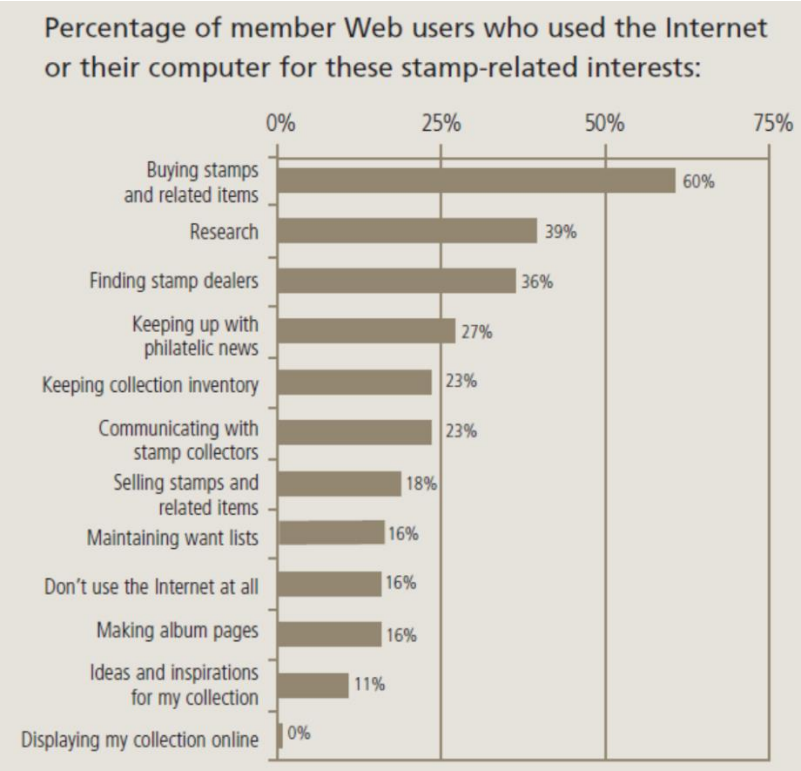


Figure 5 – Percentage of member Web users who used the Internet or their computer for certain stamp-related interests
Source: [5]

A similar research in the Republic of Croatia performed on the philatelists who were purchasing their philatelic products, found out that about 3% of domestic and some dozen percent of foreign philatelist purchase philatelic products via the Internet. Internet, as the means of collecting and exchanging information on philatelic products (web pages, e-mails, etc.) is used by about 80% foreign philatelists and some 30% domestic ones. There is a significant difference in using the e-technology between domestic and foreign philatelists, which is on the trail of earlier observations related to positive correlation of the Internet and the usage of postal services. [6]

The usual on-line purchase sources (as the most frequent collectors' activities) include *e-bay*, *delcampe*, postal operators' web-shops, auction pages, local advertisers, etc. Many of these on-line sources are used also to do research of the market (supply, demand, prices, availability, etc.), but there are also specialized portals with philatelic data that represent reference bases (registers) and substitute classic printed catalogues. However, as happens with everything that is (free) on the Internet, they also need to be accessed with caution since there is no guarantee of reliability and accuracy of all the data. Frankly speaking, neither do the printed issues provide complete safety, especially in case of more comprehensive issues that due to the number of stamps have to be summarized (simplified).

3. OBSERVED LAWS IN TRENDS AND GUIDELINES IN THE DEVELOPMENT OF PHILATELY UNDER THE IMPACT OF E-ENVIRONMENT

Based on the proposed concept the analysis can be done through sociological, economic, regulatory and other aspects. Let us mention only the phenomenon that about 90% of all philatelists are male persons and the majority in their mature years (above 60) with a declining interest of the youth. Also, philately and other collectors' areas are becoming increasingly interesting for the diversification of the investment portfolios (safe yields). However, in accordance with the introduced access, in this

overview our attention will be primarily on the technical and technological aspects those that occur directly in communication processes (postal or electronic).

Advantages (opportunities):

- easier purchase of philatelic products (web-shops, on-line auctions, web advertisers, etc.);
- easier access to information (on-line forums, specialized portals, on-line catalogues);
- easier management of one's own collection (digital applications);
- market balancing (more realistic consideration of supply and demand, and consequently actual prices);
- easier exhibiting (presenting) of one's own collection;
- creation of new forms and items of collecting (e.g. franchise labels);
- better protection against forgery (holography, digital watermark, etc.);
- reliability of legally issued stamps (WADP numbering, WNS);
- expansion of postal stamp functions (work of art, distinctive design, means of promotion, etc.).

Drawbacks (threats):

- changes in postal technology (reduced demand of classic postal stamps, reduced usage of marks, marks / stamps with fewer time data for letter item tracking);
- changes in communication preferences due to sociologic changes under the influence of fast and omnipresent technologies;
- reduced desire to own physical things (life is "lived" in the virtual world);
- disappearance of collection items from everyday life;
- reduced interest in exhibiting and gathering since the majority is done on-line;
- changes in the usage of postal traffic (reduction of letter correspondence);
- development e-agendas with numerous incentives and liabilities of using e-technologies at the expense of physical forms;
- easier publishing and spreading of false information;
- easier making of forgeries of classic stamps;
- dynamics (speed) of changes.

In our opinion the additional dimension to the problem is the fact that the advantages mentioned are as a rule short-term ones, and the drawbacks are long-term ones. Similar to various aids that are "welcome" but disguised they make more damage than benefits if they are applied even when not necessary, and then when this becomes noted it is too late to return back to the old. Then, it is easier to use new aids to help in new situations, thus only additionally deepening the problem (like a vortex).

4. CONCLUSIONS AND RECOMMENDATIONS REGARDING THE DEVELOPMENT OF PHILATELY AND FURTHER RESEARCH

E-environment changes the communication among people (both in the technical and social areas) thus influencing also the methods of collecting items related to classic (physical) communication forms, which change themselves under these influences. Consequently, postage stamps will travel increasingly WITHIN instead of ON the postal items. However, whereas postal communication covers almost the entire population, the coverage (availability) of e-communications has reached only some 60% of the world population and from year to year one may observe a deceleration in the spreading due to numerous infrastructure and investment, and in some places even sociological barriers, so that there is enough space and time for adequate adaption to the changes.

Changes in the technology of postal traffic inevitably change the usage significance of postal stamps, as well as of other postal items (marks, letters, etc.) thus indirectly changing the philately, but in the opposite direction there are positive influences of philately on postal traffic (certain revenues, e-commerce, etc.) so that every effort in this direction is of multiple and long-term benefit. However, it is necessary to change the fundamental principle of the publishing policy of the philatelic products

(to comply to the needs of the postal service) into a new principle of complying to the needs of the collectors.

Although the paper primarily analyses the technical and technological impacts of e-environment on the development of philately, there are numerous social and economic aspects that have a different impact on philately (investment aspect, educational, national, promotional, culture-related, etc.) which have not been excluded by the suggested concept either.

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NATALIA LAKHMETKINA, Ph.D.[1]
Corresponding author
E-mail: naturla@mail.ru
ALEXANDER OLEINIKOV, Ph.D.[2]
E-mail: oleinikov_as@mail.ru
[1] Institute of Management and Information Technology
Russian University of Transport (RUT - MIIT)
9b9 Obrazcova Street, 127994, Moscow, Russia
[2] Freight Village RU
6/2 Presnenskaya Naberezhnaya, 123317, Moscow, Russia

DRY PORTS SIGNIFICANCE FOR THE TRANS-EURASIAN LAND TRANSPORT CORRIDORS

ABSTRACT

As we know, some European industrialized countries do not have direct access to the seas. As a result, these countries do not have the ability to handle goods arriving by sea in ports on their territory. At the same time, the demand for both incoming and outgoing container traffic is growing every year, correlating with the growth of foreign trade operations with China, the United States, South-East Asia, the Middle East and Africa. The creation and development of the "dry ports" of international importance already existing in the territory of these European countries will allow goods to enter them by rail from sea ports immediately upon the arrival of sea container ships to the ports and to process, customs clearance, sorting of goods directly in the consuming countries of these goods without opening seals on containers before arriving at the final destinations, with due observance of customs and legal regimes. This article discusses the concept of "dry port" as an element of transport and logistics infrastructure for the international transport corridors, and the prospects for the development of such facilities in international significance. The main goal of this concept is to create such transport network that connects countries through dry ports on the scale of continental cooperation in Eurasia.

KEY WORDS

transport infrastructure; transport object; Eurasia; transport corridor; “dry port”;

1. INTRODUCTION

The possibility of the transport potential realization and the required infrastructure creation are the key advantages of the transcontinental cooperation in Eurasia. Such a work will lead to the list of positive moments among which are the countries’ transit potential realization, the localization of the industry along the TransEurasian transport corridors, the export development and the strengthen of the continental countries and regions connectivity. The key players in this process are China, Russia, Kazakhstan, Belarus, European Union (EU) countries. The urgency of this issue is rapidly growing in context of unification of the Eurasian economy union (EAEU) and Chinese initiative “One belt one road” (OBOR). For China, it is strategically important to overcome the imbalance in the economic development of the country's internal regions and to set measures is being implemented to develop a new transport infrastructure, which will contribute to the growth of transport to the West. For the EAEU countries, pairing with the Chinese initiative of the OBOR is also relevant. Due to the growing cargo flow, the importance of large transport hubs is increasing [1-6].

A significant part of the research devoted to the interaction of different modes of transport in transport hubs considers the problems associated with the optimization of location and minimizing

the time spent in the hubs without taking into account the mutual influence on the final result of transportation in a new transportation conditions [7-10]. Organization of cargo transportation in the scale of transport systems raises numerous issues related to the effective exploitation of infrastructure of international importance.

The proposal in this paper approach to the organization of the transport hubs infrastructure, based on the use of "dry port" concept provides an integrated solving the problems of cargo traffic on the scale of continental cooperation in Eurasia.

The main focus of this article is to develop a methodology for the formation of integrated infrastructure management of international importance in the concept of "Dry port", taking into account the peculiarities of the use of transport and infrastructure of countries for the formation of new transport solutions in the East-West-East corridors.

2. EURASIAN CONNECTIONS THROUGH TRANSSIB RAILWAYS

A number of EU countries associated with Asia by rail, though not massively, but have already started to enjoy the benefits of TRANS-Eurasian transport corridors. European transport companies, logisticians and consumers of transport services are cautious about the new possibilities of transcontinental transit, and in some cases do not have sufficient information (including the conditions of transportation, cost, timing of delivery of goods, etc.).

Russia's role as an integrator of the Eurasian transport market is growing, a significant part of which is container transportation projects. Significant results were achieved in 2018 by JSC "United transport and logistics company-Eurasian railway Alliance" (UTLC ERA, a joint venture of JSC "Russian Railways", SA "Belarusian railway" and JSC "Kazakhstan Temir Zholy"). For example, in order to optimize the transportation process and reduce its cost, the company is implementing a new technology for sending long container trains, called UTLC XL train (eXtraLongtrain). It is used on the China-Europe-China transit route in order to increase the efficiency of the use of the Alliance Railways' capacities. The standard length of container trains running on the main transit routes is 57 conventional wagons (forty-one 40-foot containers). The long-haul container train consists of 80 conventional wagons consisting of forty-four 80-foot platforms with a full load (eighty-eight 40-foot containers). The average speed of the container train on the Dostyk-Brest section was 1100 km / day.

JSC "Russian Railways logistics" (the Russian Railways daughter company) expanded its railway service of the non-raw export launching the possibility of cargo dispatch of the good, requiring special temperature conditions in refrigerator containers. Thus, in September they introduced the first round route Vorsino (Kaluga area) – Chengdu (China) – Vorsino from Russian to China via Mongolia. At present time there are weekly import and export general and modular cargo consignments from China to Russia and from Russia to China that take 12-14 days. The service is realized in cooperation with the Russian export center supported by Transcontainer and the Russian Railways and in partnership with the Freight Village RU terminal.

The operator of Far East Land Bridge (an Austrian subsidiary of JSC "Russian Railways logistics", FELB) organized the first regular container service from Chengdu (China) to Melzo (Eastern suburb of Milan). As for the reverse loading, it will be provided by the European fruits and sweets. The composition of 40 containers went from China to Italy on January 26. The final destination will be the terminal in Melzo, which belongs to the company Contship Italia. The train will cover about 10 thousand km in 18 days. The route will pass through Kazakhstan, Russia, Belarus, Poland, Czech Republic and Austria. Transshipment from one track width to another (from 1435 to 1520 mm and Vice versa) is carried out at the border crossings Alashankou – Dostyk (on the border of China and Kazakhstan) and Brest – Malashevich (on the Belarusian-Polish border). Rail Hub Milano (RHO) cargo terminal is located at the end point of the Selzo route.

FESCO transportation group in partnership with the Chinese Zhengzhou International Hub (ZIH) has launched a regular container train from Hamburg (Germany) is in Zhengzhou (Henan, China) through the border crossing Grodekovo (Primorye) / Suifenhe (PRC). The transit train from Europe to China through the far East of Russia is the longest of the regular international routes on the Russian Railways network – its total length is 10 294 km, including 906 km passes through the territory of Belarus and 9 685 km – across the Russian Federation. Total transit time is 18 days. The new service cargo flow bases are the goods exported by ZIH from Germany.

However, the growth in long-term traffic is limited by a number of internal and external factors. It is the question how to realize the potential of TRANS-Eurasian transit. One of the key areas of work is the elimination of non-tariff and technical barriers. Infrastructure is obvious among the considered limitations.

For the purpose of reducing the length of bottlenecks, increasing the shipping speed and efficiency of transportation, as well as tonsuring the transportation of additional volumes of freight, the company Russian Railways (RZD OJSC) are implementing the large-scale project on upgrade of the railway infrastructure of Eastern Siberia and the Far East region [11].

In the next three years (2019-2021) it is planned to construct and reconstruct more than 90 stations and 42 crossing loops, about 570 km of additional backbone, to carry out the construction of the new 6.7 km long single-track tunnel.

For the purpose of expanding the Trans-Siberian Route (TSR) geography RZD OJSC elaborates global infrastructural projects.

The most significant initiative in terms of the TSR geographical expansion to the East is the connection of the Trans-Siberian and Trans-Korean Mainlines. On 18 July 2015, the project of the Khassan (Russia) – Rajin (DPRK) railroad section reconstruction was completed. RZD reconstructed the Khassan (Russia) – Rajin (DPRK) railroad section and constructed a universal freight terminal in the port of Rajin. Thereby a new rout for delivering cargo from / to the APR countries to/ from Europe was established. In the long term perspective the project will allow direct railway service between the European countries and the Republic of Korea and significantly improving the attractiveness of the railway transportation of South Korean container freight.

For the purpose of linking the rail system of Central Europe with Trans-Siberian Mainline regions, attracting freight flow to the Asia – Russia – Central Europe rout and enhancing the competitiveness of the rail transportation, the Project of Constructing a 1520 mm Gauge Rail Line along the Territory of Slovakia Terminating at Bratislava and Vienna, is elaborated.

The project of establishing a new Euro-Asian corridor with the destination at Vienna with a logistics infrastructure creation can become a breakthrough for the development of the transport links between Europe, the CIS states and China. The new rail line tends to be attracted to by the freight flows of a number of nations –Austria, Slovakia, the Czech Republic, Hungary, Germany, Switzerland, Italy, Slovenia, Serbia and Croatia.

According to expert estimates, the implementation of the project will result in the global rail transportation competitiveness increase compared to the maritime rout via the Suez Channel, as in well as in attracting new freight flows, primarily, containers.

The complex project on establishing the direct Europe – Russia – Japan service will allow avoiding the need of an additional sea leg when carrying out transportation in connection with Japan. The project includes several large-scale projects which are interconnected and are already being realized by RZD OJSC:

1. increase in handling and carrying capacity of the Trans-Siberian and Baikal-Amur Mainlines;
2. construction of the Selikhin – Nysh rail line with the passage of the Nevelski Strait:

3. reorganization of the Sakhalin region of the Far East railway from width 1067 mm to 1520mm gauge.

The largest railway project in the Far East region of Russia is the construction of the Selikhin – Nysh rail line with the construction of the transport passage through the Nevelski Strait (the bridge crossing through the Sredniy section). RZD OJSC initiates the development of the main project solutions of the construction of the new line, and plans the organizations of activities on allocation of the land. The target reference point of readiness of the design documentation and the beginning of construction works is planned for 2020.

The project will allow creating the basis for further implementation of strategic priorities of the development of Sakhalin:

1. reducing transportation cost for freight carried in the connection with the island;
2. increase in reliability and year-round availability of transport links;
3. establishing the environment for social and economic development of the Sakhalin region and Khabarovsk Krai.

The Selikhin – Nysh line construction project will become the first stage of the development of the direct Europe – Russia –Japan rail connection.

One of the most important projects of RZD OJSC on development of the railway infrastructure according to the Program of creation of the China – Mongolia – Russia economic corridor is the development of the Ulaanbaatar Railway.

The significant growth in volumes of transportation of containerized cargo in the China – Europe service dictated the development of new railway routes. Considering the difficulties in transfer of freight on the Belarusian-Polish border crossing of Brest – Malaszewicze in 2016-2017, Russian Railways carry out a number of activities to increase the handling capacity and to develop terminal infrastructure on the routes of container trains. In particular, in 2017 the terminal and logistic centers of Kaliningrad and Chernyakhovsk serving border crossings of Mamonovo –Branewo and Zheleznodorozhny – Skanva were upgraded.

The transport and logistic center of Kaliningrad which is located at the Dzerzhinsk station, is oriented from the border of Russia to Berlin is 530 km, to Hamburg – 700 km. In the territory of the center covering 28 Hectares the transshipment of containers, heavy and bulked cargo from 1520 cars into 1435 cars is performed. The terminal is equipped with the open cargo site with an option of one-time storage of 1,200 TEUs and 100 thousand tons of bulked cargo, all necessary technical means for handling 450 thousand TEUs and 2 million tons of freight per year.

The transport and logistic center of Chernyakhovsk is oriented to the southeast part of Europe. The distance from the border of Russia to the city of Lodz is 300 km, to Vienna – 780 km, in the territory of the center covering 47 Hectares, the transshipment of containers, bulked, heavy, loads and automotive vehicles from 1520 cars onto 1435 cars is performed. The has the open cargo site equipped with devices for storage of refcontainers with a possibility of one-time storage of 800 TEUs, 15 thousand tons of bulked cargo and 4.5 thousand motor vehicles, all necessary technical means for handling 300 thousand TEUs, 1.5 million tons of freight and 150 thousand motor vehicles per year. At the moment, the overall potential of the handling capacities of these terminals is 750 thousand TEUs per year.

The implementation of all above infrastructure projects will provide improvement of quality of servicing through reducing the average time of cargo delivery determined by the guaranteed observance of time at all stages of a difficult logistics chain.

3. DRY PORTS – AN IMPORTANT COMPONENT OF EFFECTIVE TRANS-EURASIAN LAND TRANSPORT CORRIDORS

The new realities of modern life make us take a new glance at the transport and logistics environment of the infrastructure and a more rational approach to the justification of approaches to the planning of transport activities. At the same time, one of the top issues is whether the transport infrastructure in general and seaports in particular will be able to cope with the increasing volume of freight traffic and the growing demand on effective transport solutions. In modern conditions, long-term strategic development and planning on the basis of common priorities is necessary, especially the increasing of seaports' productivity, the use of new technologies, the increase of the innovation level. However, the primary deterrent to the development of ports is land infrastructure, primarily railway approaches. In this regard, the well-established works of ports and railways, as well as infrastructure capabilities, are fundamental factors in the integration of these modes of transport.

Most of the port stations - the places of different types of transport connection, do not have the possibility of territorial development corresponding to the processing capacity of the port berths. There is a lack of capacity of the stations themselves, that reduces their maneuverability, leads to untimely service of cargo areas of ports, increases the duration of customs clearance procedures, hinders the productivity and turnover of the port terminals. Thousands of wagons belonging to different operators are accumulated and idle at the port stations, which complicates the optimal operation of the transport hub. To eliminate the existing problems, it is advisable to introduce the concept of "dry ports", providing an integrated approach to solving the problems of cargo flows organization [12].

The technology of increasing the cargo turnover of seaports using the terminals providing similar services for the processing of goods outside the seaport except for the loading and unloading of ships on the principle of "dry port" was developed by the world community and fixed at the Conference on trade and development of multimodal transport and container transport in 1982 as the following definition: "internal ground terminal, where the shipping companies issue their own import bills of lading for imported goods, taking full responsibility for the price and condition and from which shipping companies issue their own bills of lading for export shipments" [9, 10, 13]. This definition characterizes the role of "dry ports" from the perspective of the interaction of sea carriers and cargo owners.

From the side of intermodal transport, another definition is more important [14]: "Dry port is an inland land terminal directly connected to the sea port (s) by means of high-capacity vehicles, where customers can deliver/receive their standardized cargo spaces directly at the port». In other words, the "Dry port" is an internal land terminal, which has a direct connection with the seaport through a specially established transport infrastructure. Communication can be arranged by road, rail or river transport.

Despite the variety of definitions, today the term "dry port" is not fixed [15]. Some believe that the "dry port" is a large terminal, primarily having the status of a temporary storage warehouse, with a staff of brokers, freight forwarders, people who will provide services. The others believe that the "dry port" is a transport and logistics center, including port terminals at the checkpoint, created for sorting, temporary storage and customs clearance of goods that are delivered under the simplified transit procedure [3-4, 7, 10, 13].

Intergovernmental agreement on dry ports [16] defines a "Dry port" as a place within the territory of the country with a logistics centre connected to one or more modes of transport intended for processing, temporary storage and statutory inspection of goods transported in international trade and committing applicable customs control functions and formalities.

The term "dry port" due to the definitions by many professionals also means that the port itself is not directly connected with the sea (ocean) but it is a kind of branch of another port in its traditional

purpose. "Dry port" performs the function of a transshipment knot, being a kind of buffer zone, expanding the possibilities and simplifying the implementation of sea freight for traders, geographically located at a considerable distance from the ports. This makes it possible to significantly unload the terminals of sea ports, which has a beneficial effect on the functioning of the entire transport and logistics infrastructure throughout the country. Another important function of the dry port is to act as a customs terminal [15].

The emphasis should be on the fact that the use of "dry ports" as a technology, which helps to improve the performance of ports, it is advisable from the point of view of the unusual ports transfer functions associated with raster toy, inspections, inspections, etc. only if the transshipment of goods administers organized and convenient way [13-14].

The implementation of transport technologies using the "dry port" allows: to increase the processing capacity of sea ports; to improve the efficiency of the transportation process; to reduce the investment burden in the formation of port infrastructure, to ensure faster commissioning of facilities; to reduce the likelihood of conditions for "abandoned trains"; to reduce the environmental load and the load of the road network. The ability to arrange the necessary procedures at "dry ports" will reduce congestion and delays at border crossings in ports, thereby reducing transaction costs for exporters and importers.

To optimize the entire logistics system, it is necessary to have a network of "dry ports", which will handle the needs of all incoming export-import cargo of the cities, located nearby, and then the formation of short smart-trains to deliver goods to final consumers to the specific area of the city. Undoubtedly, the development of the network of "dry ports" will allow the participants of the transport and logistics market to expand the list of services and ensure higher profitability of their business [17].

In accordance with the Intergovernmental agreement on "Dry ports" [16], a list of existing infrastructure facilities operating on the principles of "dry ports" has already been defined in accordance with certain principles: the dry ports are normally located in the vicinity of: inland capitals, provincial/state capitals; and/or existing and/or potential production and consumption centres with access to highways and/or railways including the Asian Highway and/or Trans-Asian Railway, as appropriate. Dry ports have transport connections to other dry ports, border posts/land customs stations/integrated check posts, seaports, inland waterway terminals and/or airports. A lot of things depend on the choice of location to create such an object. "Dry port" should not be "detached" from the seaport on the one hand, and the commodity warehouses on the other. It should be located at the intersection of the main logistics routes. At the same time, "dry ports" should be in transport links with other "dry ports", border points/ground customs control posts/integrated checkpoints, seaports, inland waterway terminals and/or airports. It is also important that the "dry port" has to be versatile, that can provide a full range of services for the processing of various types of goods. Thus, "dry ports" should be integrated into the logistics chains of the unified transport system.

4. METHODICAL BASES OF LOGISTIC CHAINS MANAGEMENT AT EFFECTIVE USE OF PARTICIPANTS INFRASTRUCTURE

Logistics chains management operating the infrastructure effectively calls for the systematic decision by all the transport process participants.

Fulfilling the purposes of coordination and cooperation of the logistics chain participants is it worth highlighting three stages of its formation: strategic planning, tactic planning and operation management [18].

Strategic planning is interrelated and balanced complex of all the interested transportation participants plans, that coincide with the compromise decision while eliminating the contradictions of transportation participants needs and the possibilities of the supplying units (traffic and processing

capacities and so on). The process of such a plans agreement achievement is quite contradictory due to the presence of a plenty of interested market participants and limitation of the technical condition of the infrastructure logistics chain. To create the strategic plan it is required to take into account a plenty of cargo forwarders plans *V* (volumes of each type of cargo forward in tons and transport vehicles of each type and kind, points of load and destination):

$$V \in \{T_i;\ Q_i;\ N_{tr};\ C_d;\ C_a;\ P_d;\ P_a\} \tag{1}$$

so that

T_i - the date of cargo shipment;
Q_i - the volume of cargo "i" shipment;
N_{tr} - a number of transport vehicles required for the transportation;
C_d- shipper;
C_a - consignee;
P_d - cargo shipment point (railway of non-public use, cargo front, platform, railway and the country of shipment);
P_a - cargo destination point (station, railway and country).

Logistics chain database includes the following units' information

$$LSC \in \{W, \sum_{i=1}^{n}\sum_{j=1}^{m} TO_{ij}, t_{lsc_{ij}}, P_{lsc_{ij}}, TE_{lsc_{ij}}, C_{lsc_{ij}}\} \tag{2}$$

so that *W* - potential volume of cargo handling in unit "j";

TO - content of technological operations of processing and movement of the cargo in front of the unit;
t_{lsc} - scheduled time for the operations fulfillment in front of the unit to process and move the cargo flow;
P_{lsc} - traffic capacity of the unit for this kind of cargo;
TE_{lsc} - technical equipment of the unit for cargo flow processing and movement;
C_{lsc} - the price of the cargo processing and movement in front of the unit;
n - a quantity of cargo kinds;
m- a quantity of the units.

After the reception and processing of the information a lot of chain variants and basic units ("dry ports") are being formed. In the process of volumes negotiation there can appear the situation according to which the demand for the certain transport decision is overcoming the proposal. In this case the special proposals for the clients are being worked out. Such proposals are usually: the alternative route choice, the other infrastructure objects ("dry ports"), the kind of transport change, the other terms and type of delivery and so on. Algorithm of the chain strategic planning is iterative, when the shippers' plans are being corrected in accordance with data of the traffic capacities of the supply chain units with the help of the multistage computing procedures (diagram 1).

The logistics chain (or a number of competitive chains) is formed in consideration with the fulfillment of the requirements, announced by the customers (cargo holders, consumers of the transport services), formed on the result of preliminary negotiations of the strategic plan. These requirements are the marginal level of the criterions':

$$Z = \{T^{max},\ C^{max},\ K^{min}\} \tag{3}$$

so that

T^{max} - term of delivery according to the application;
C^{max} - the maximum allowable price of the transshipment;
K^{min} - the acceptable level of the services quality.

The generalized economy-math model of the supply chain is looking like:

$$F_{lsc}=\{C, T, K\} \quad (4)$$

so that

F_{lsc} – model of the chain choice based on the requirements of the transport services consumers;
C – total expenditures on cargo promotion in front of the supply chain;
T – the duration of the cargo presence in the supply chain;
K – the quality of the services in the supply chain.

The chain choice model is worked out in order to choose the most combination of criteria, characterizing the requirements of the transport services consumers. This model makes it possible to enter the additional parameters as it is open.

To get the only decision out of plenty possible decisions there is an approach, based on the idea of identifying the compromise point in the space of optimum criteria's. Meanwhile A is supposed to be a compromise point as the maximum of the squire sum of deviations from the criteria values.

$$A = \left\{ \max \left[\sum_{v=1}^{k} \left(\frac{K_v(A_i) - K_v}{K_v} \right)^2 \right] \right\} \quad (5)$$

so that A_i – a plenty of permissible values of the criteria of optimality;

k – a quantity of the criteria of optimality;
K_v – the threshold level of the criteria values;
$Kv(A_i)$ – acceptable values of optimality criteria.

The aggregative algorithm of the chain variant choice based on the requirements of the transport services consumers (diagram 2).

The effect of the certain logistics chain functioning taking into consideration the variants of "dry ports" as the chain formation units is identified by the maximum possible amount of effects: reduce of the total costs while delivering cargo; reduce of the terms of the cargo presence in the chain; the usage of the supply chain unit infrastructure; the reduce of the time wastes while being in the supply chain unit; the clients' logistics service level; the rolling stock usage [19].

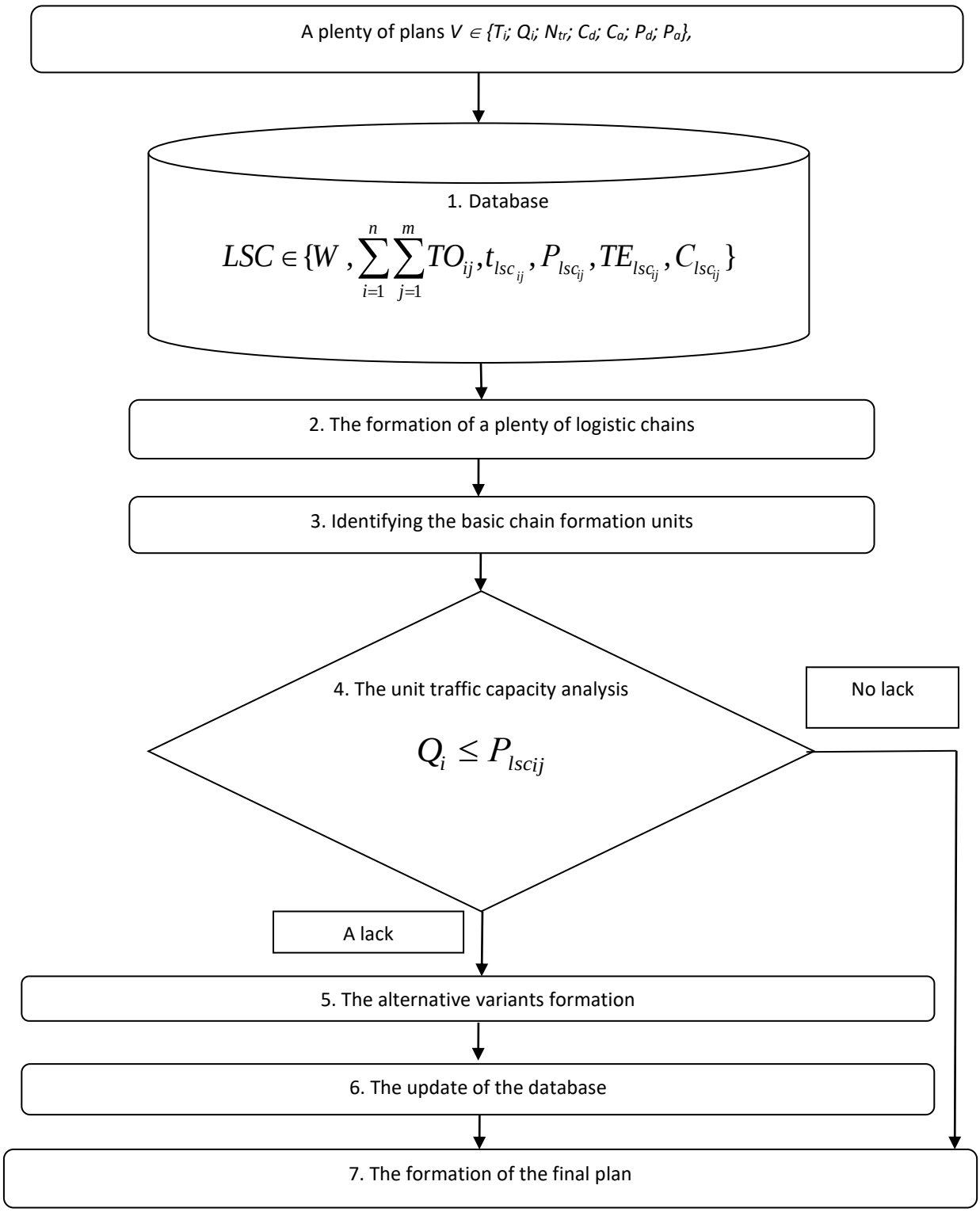


Diagram 1 – The aggregative plan of the strategic planning of the logistics chains

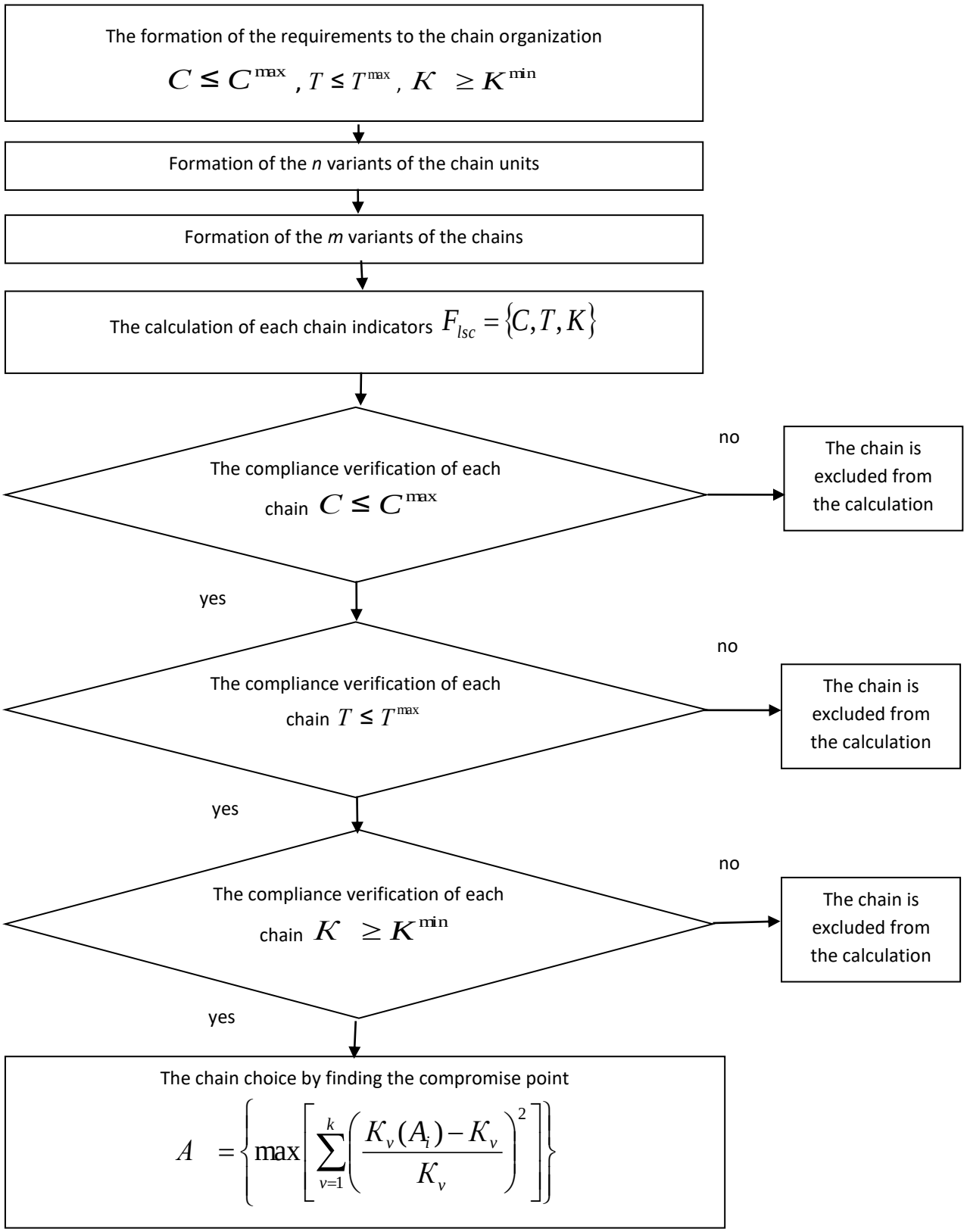


Diagram 2 – The aggregative algorithm of chain variant choice based on the consumers requirements

5. CONCLUSION

Summarizing the research the concept of infrastructure development of international importance, it is revealed that with the growing demand for incoming and outcoming cargo transportation, the creation and development of dry ports of international importance will allow goods to enter by rail from sea ports and carry out the processing, customs clearance, sorting of goods already directly in the countries – consumers of these goods with due observance of customs and legal regimes. The main attention was paid to the methodology of the logistics chains formation through "dry ports", based on the idea of determining a compromise point in the space of optimality criteria in order to choose the best combination of criteria characterized by the requirements of transport services consumers. Continental cooperation in Eurasia demand new transport products that are constantly being developed. This research perspective is necessary, as it provides recommendations for improvements in the operation and efficiency of infrastructure of international importance.

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BRANIMIR MARETIĆ, mag. ing. traff.[1]
E-mail: branimir.maretic@gmail.com
BORNA ABRAMOVIĆ, Ph.D.[1]
E-mail: babramovic@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb

USING PUBLIC TRANSPORT IN RURAL AREA: CASE STUDY ŠIBENIK KNIN COUNTY

ABSTRACT

This paper explores possibilities of introducing the integrated passengers transport between Šibenik and Knin, the two largest cities in Šibenik - Knin county, and rural area between them. The research includes a comparative analysis of public passengers transport in road transport by bus and in railway transport by train. A comparative analysis was made according to public transport competitiveness indicators. The introductory part describes demographic and spatial indicators and traffic infrastructure in Šibenik - Knin county. In the central part of the paper, the indicators of competitiveness were analysed. Finally, the conclusions and the discussion were made and, also, the proposal for improvement of the existing state of affairs and guidelines for further research were contributed.

KEY WORDS

Rural area; public passengers transport, integrated passengers transport; ticket price; frequency; distance

1. INTRODUCTION

The basic prerequisite for the development of each county is mobility. A high degree of mobility allows for greater population movements between urban areas, as well as rural and urban areas. In Šibenik – Knin county the largest transportation is actualized by cars [1]. In order to find out why that is, the integrated passengers transport between the two largest cities in Šibenik – Knin county, which are Šibenik and Knin, will be analysed. Apart from being the largest cities according to the number of inhabitants in the Šibenik-Knin County and thus generating the largest number of trips [2], they are spatially the most distant ones. They are connected by the railway line Šibenik - Perković - Knin and the bus line Šibenik - Knin. The aforementioned lines start from the centre of Šibenik through the peripheries of the city to the centre of Drniš, then on the outskirts of Drniš and Knin to the centre of the last city.

Dell'Olio et al. conducted a study on how to use surveys to determine the desired level of service quality for users of public transport [3]. Dolinayova investigated factors and determinants of modal split in passenger transport [4]. But the main elements of the public transport comparative analysis, defined by Šipuš D. and Abramović B., are: frequency, journey time and cost [5]. Those are, also, the most important elements from the passengers' perspective when choosing the means for public transportation. By analysing these elements, we will examine the offer of public passengers transport in rural area between the towns of Šibenik and Knin and reach a conclusion in order to continue the development of public transport.

2. THE GEOGRAPHIC AND DEMOGRAPHIC FACTORS

Šibenik-Knin county is located in the south of the Republic of Croatia (RH), in the central part of northern Dalmatia (*Figure 1*). The total area of the county is 5,670 km2, which includes 2,994 km2 of land area, or 5.3% of the land territory of Croatia, and island area with the sea, which stretches over 2,676 km2, or 8.6% of the territory of the Croatian coastal sea. The county has 285 islands with a total area of 665 km2. In the east, the Šibenik – Knin county borders with Bosnia and Herzegovina and, in the west, it forms a part of Adriatic sea border with Italy. In the north it borders with Zadar county and, in the south, with Split – Dalmatia county. Today the Šibenik-Knin county includes twenty units of local self-government, of which five units are cities: Skradin, Vodice and Šibenik, as the county's centre, on the coastal area, Drniš on the offshore area and Knin in the continental area of Zagora.



Figure 1 – The geographic position of Šibenik-Knin County
Source: [6]

According to the 2011 census, the city of Šibenik has 46,332 inhabitants. The average age of citizens in Šibenik is 43.4 years. The average age for women is 44.8, while for men is lower, 41.8 years. There are 51.63% of women in Šibenik and the rest are men.

3. INFRASTRUCTURE ANALYSIS

The most important traffic lane in Šibenik – Knin county is A1 motorway from Pirovac to Vrpolje, which, after opening in 2005, significantly lowered the state roads that had the highest traffic loads until then (Adriatic highway and D1 and D59 link (Knin-Pirovac) / D33 (Knin-Šibenik)), especially during the tourist season. Along with the motorway, the great significance have state and county roads that make longitudinal connection in the county possible, such as: the Adriatic (touristic) motorway D8 (Pirovac - Vodice - Šibenik - Primošten - Rogoznica), D1 state road (Knin – Kijevo), D56 (Skradin - Drniš), D58 (Šibenik - Vrpolje) and the state road D27 (Grabovci - Šibenski most). The main longitudinal road route is the Adriatic tourist road (D8 or Adriatic motorway) that connects the county coastal settlements along the coast. The problem of the Adriatic tourist road is its passing through the centres of major tourist towns and settlements creating a traffic burden and traffic jams emerge at the peak of the summer season. The main transversal traffic routes connecting the land and the coast are state roads D33 (GP Strmica – Knin – Drniš - Šibenik) and D59 (Knin – Kistanje - Dubrava near Tisno), both characterized by weaker infrastructure. The quality of the state road D33 is questionable because its elements, from the carriageway, the cross-section and the longitudinal profile and the crossing with the railway line, have been unsatisfactory executed. In the Spatial Plan of the Šibenik - Knin County (2017), the construction of the Knin - Šibenik motorway is planned (*Figure 2*) in order to increase the quality of the transport network and to enable a better traffic link between the hinterland and the coast, as well as to enable a better traffic flow from Šibenik to the border with BiH.

The total length of public classified roads in the Šibenik - Knin county is 1,140 km, the largest length being the county road (443 km). There is an almost identical length of state and local roads and the existence of a 43 km long motorway has great socioeconomic and developmental significance. The state roads in the county are of vital importance to the surrounding area because they allow the coherence of space and the internal connection of the county parts.

In 2016, the average road density of the national road network was 472 m/km^2, while this indicator for Šibenik – Knin county was 382 m/km^2, which indicates a significantly lower traffic density, causing a specific terrain configuration and uneven population density. According to the mentioned indicator, Šibenik – Knin county is among the counties with the least branched transport network.



Figure 2 – Road network in Šibenik-Knin County
Source: [2]

In Šibenik – Knin county the existing railway traffic system has a very poor, outdated infrastructure. That mean that the maximal allowed speed is 60 km/h with large number of speed restriction on the line. The entire railway network in the county is single line and non-electrified. The result of poor infrastructure is reflected in the low interest of the local population for the use of railway traffic. The total length of the railway network of Šibenik - Knin county is 147 km, of which 144 km is used for current passenger traffic.

The main railway link of Šibenik – Knin county, as well as of the entire Dalmatia, is located in Knin where Una railway line connects with Lika railway line (Ogulin – Knin) and the line is heading in the direction of Zadar, Šibenik and Split. The railway network is limited to three major lines from the direction of Knin towards Zadar (passing through Kistanje municipality) and Perković (passing through the area of Drniš), and the Perković - Šibenik line which, in the length of 22 km, makes it possible to connect Šibenik with the hinterland and the rest of Croatia via Lika railway line (*Figure 3)*.

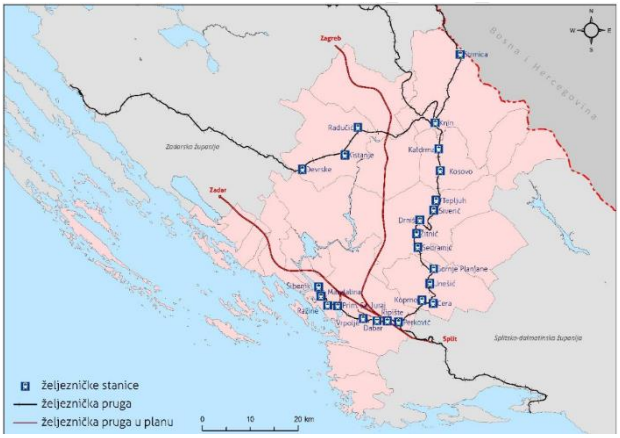


Figure 3 – Railway network map in Šibenik-Knin County
Source: [2]

4. THE PUBLIC TRANSPORT ANALYSIS BETWEEN ŠIBENIK AND KNIN

Possibilities of integrated passengers transport on the Šibenik - Knin route will be analyzed. The Šibenik - Knin relation is particularly interesting, due to the city of Šibenik being the largest city and the traffic centre of the Šibenik - Knin county, and the town of Knin is the second largest city, located at the other end of the county, and, at the same time, these two cities generate the largest number of trips.

In terms of public transport, the city is connected by bus and railway. The passenger transport is performed by the road carrier Autotransport Šibenik d.o.o. and by the railway operator HŽ Passenger transport d.o.o. The road passenger transport takes place over two lines of public transport. One is Šibenik - Drniš - Kosovo - Knin, the other is Šibenik - Drniš - Oklaj - Knin. The public railway transport occurs on the line Šibenik - Perković - Drniš - Knin directly and with layovers.

One of the most important indicators for passenger public transport systems is frequency. It shows how many vehicles have passed through a certain point of the line in a specific time unit. Table 1 will show the frequency of passenger public passenger transport by road in one day.

Table 1 – The frequency matrix of bus departures with stations on the line Šibenik – Knin

from/to	Šibenik	Drniš	Kosovo	Oklaj	Knin
Šibenik	-	5	2	3	5
Drniš	5	-	2	3	5
Kosovo	2	2	-	0	2
Oklaj	3	3	0	-	3
Knin	5	5	1	4	-

Source: Authors

There are 5 daily public transport lines from Šibenik to Drniš and Knin. It is important to note that Drniš and Knin are the next two largest towns in the county. Due to the fact that, on the line Šibenik – Knin, the buses transport passengers through different relations in different times, there are 2 departures to Kosovo (a larger industrial zone) and 3 to Oklaj (a combined industrial zone and more populated settlement). On the Knin - Šibenik line there are 5 departures per day for Šibenik and Drniš. Four out of these 5 departures are through Oklaj for Drniš and Šibenik and 1 over Kosovo for Drniš and Šibenik (*Table 2*). The aforementioned organization of bus lines points out that, as Oklaj is a so-called "mixed purpose zone" (a settlement and an industrial zone) there is a greater mobility on that route, while it is unclear why there is at least one other line for Kosovo in peak hours due to economic and industrial activities in that area. The mobility between individual destinations on the line is hampered by the lack of own lines from larger centers where journeys are generated, e.g. from Drniš towards Šibenik or Knin.

Table 2 – The frequency matrix of train departures with stations on the line Šibenik – Knin

from/to	Šibenik	Perković	Drniš	Knin
Šibenik	-	6	6	6
Perković	5	-	6	6
Drniš	5	5	-	6
Knin	5	5	5	-

Source: Authors

On the intercity railway line Šibenik – Perković – Knin there are 6 departures from Šibenik to Knin and 5 departures from Knin to Šibenik. Perković presents the layover point on the line Šibenik – Knin and vice versa. In the direction Šibenik – Knin there are two layovers, while in the opposite direction

there is only one. Larger destinations, such as Drniš, do not have their own departures towards either to Knin or Drniš, which makes the mobility between those places difficult.

5. ESTIMATING MOBILITY (CURRENT STATE)

The time interval between departures on the Šibenik - Knin bus line is not equal, actually it is not in tact. It is uneven, due to the traffic from two different directions on that line and, what's more, the line is not designed for the increase of mobility, only for the transport of people from and to work. On the route Šibenik – Knin – Drniš the time interval between the first 2 departures is 4 hours and 15 minutes and between the second and third, actually the last, departure, the time interval is 5 hours. We must note that there are no evening departures in this direction. On the route Šibenik – Drniš – Kosovo – Knin there are no morning departures, but the time interval between the afternoon and evening departure is 6 hours. In return voyages over both directions from Knin to Šibenik we have the same inequality of departure.

When it comes to railway lines from Šibenik to Knin, there are three morning departures with a time interval of 1:27h and 1:50h. The one afternoon departure is at 15:55h and two evening departures with the interval of 1:46h. On the return voyage, there are five departures, three are in the morning - the first two have the interval of 20 minutes and the interval between the second and third is 2:04h. The afternoon departure is at 15:10h and the evening one is at 19:55h. It is evident that time intervals are great and that these lines are mainly designed for the preferences of the working population.

On the railway line Šibenik – Knin – Perković, the longest journey time has the train 5820 and the shortest train 5806 (*Figure 4)*. The train 5820 transfers in Perković where is a 2 hours and 26 minutes wait for the train from Split to Knin. The rest of the traveling time is spent on driving and embarking and disembarking passengers on passing stations. Along the train 5820, there is a layover with the train 5828 which travels from Šibenik to Knin for 1 hour and 44 minutes, which is only 5 minutes longer than the fastest train without a transfer. This time difference between the train with and without layover causes contemplation on the current state and possibilities of introducing a new organization of railway traffic on the mentioned area. The trains 5820 and 5828 do not have any access points from Perković to Knin but they stop in Unešić and Drniš. To note, all trains move along the same route and there are no differences in distances.

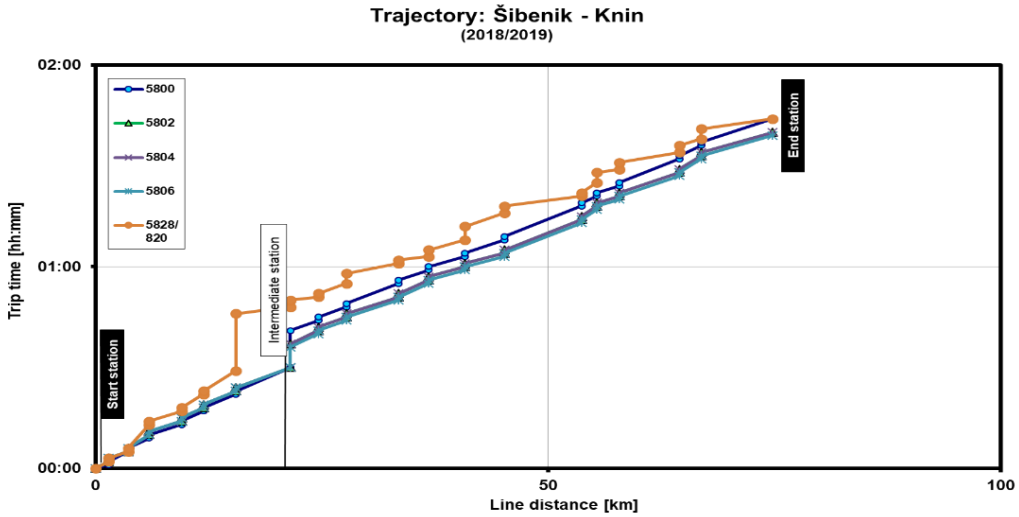


Figure 4 – The train graphical timetable on the line Šibenik – Knin
Source: Data processed according to the source [7]

The public bus transport occurs over two lines Šibenik - Drniš - Kosovo - Knin and across the Šibenik - Drniš - Oklaj - Knin line. On the line Šibenik - Drniš - Oklaj - Knin there are three buses in the direction

of Knin. The longest journey time has a bus number 3, which is 1 hour and 35 minutes (*Figure 5)*. The minimum travel time has a bus number 1 which is 1 hour and 25 minutes (*Figure 5*). The bus number 1 departs at quarter past 6 and the bus number three leaves at half past 3 pm. The journey time is longer on the line of the bus number 3 because it starts at peak time and by the time of the arrival in Knin the traffic increases due to export economic activities. The lines on the graph 2 intersect at a number of places which means that, depending on the part of the road, the journey times interchange. This means that at certain time of the day when the bus travels, some part of the road is more congested than during some other part of the day of the travel.

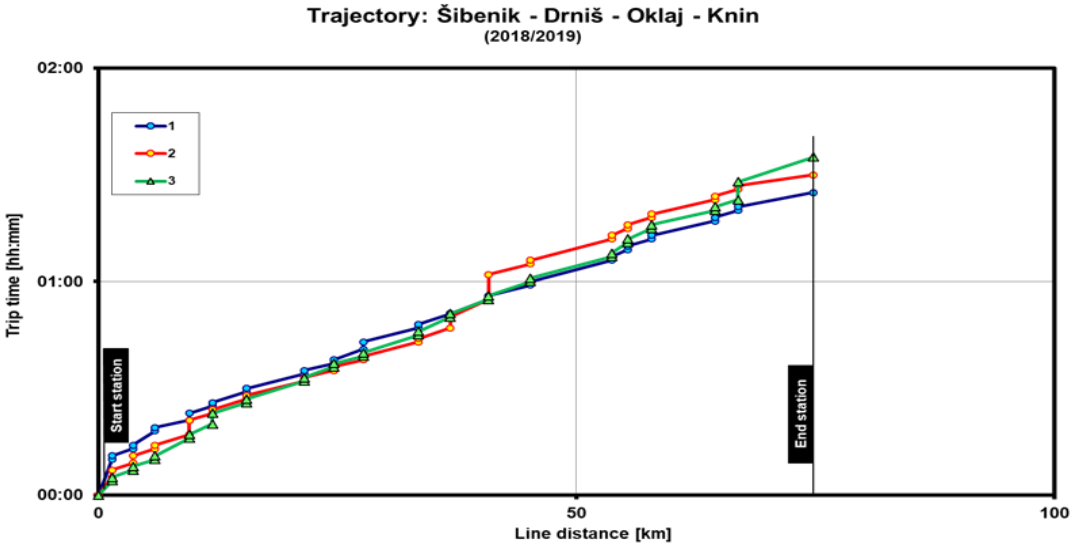


Figure 5 – The bus graphical timetable on the line Šibenik - Drniš - Oklaj - Knin
Source: Data processed according to the source [8]

On the line Šibenik - Drniš - Kosovo - Knin, two buses run in the direction of Knin. The first bus leaves at 14:15h and the other at 20:15h. The first departure has a longer journey time which is 1 hour and 29 minutes (*Figure 6*). The second voyage lasts 1 hour and 15 minutes. First departure takes place during peak hours and during the day when there is more traffic than at night. The second departure is at night time when traffic is down, and the export activity and the movement of trucks in Knin are reduced. The lines of the graph are not interrupted which is a clear evidence of congestion at the time of travel.

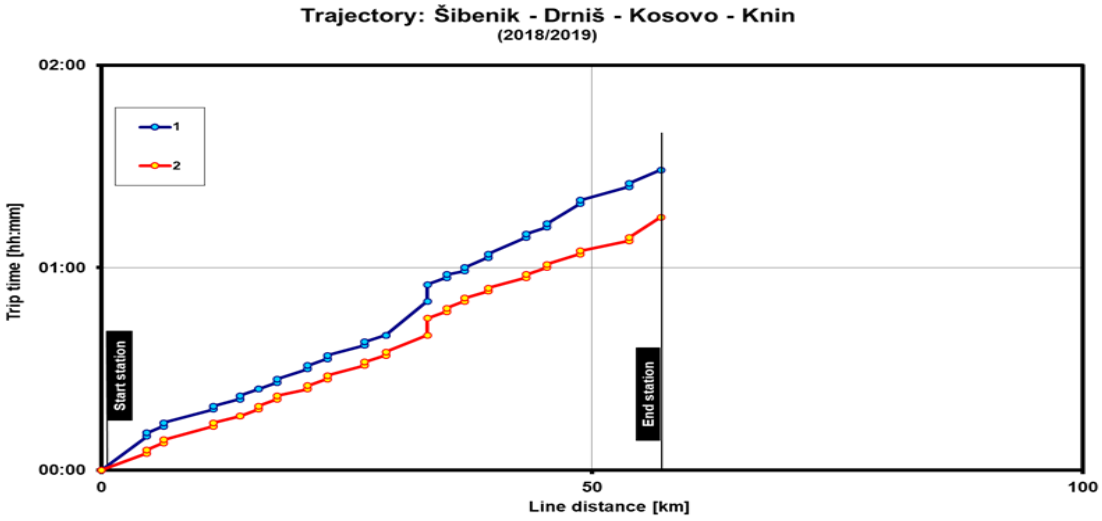


Figure 6 – The bus graphical timetable on the line Šibenik – Drniš – Kosovo – Knin
Source: Data proccessed according to the source [8]

Table 3 – The price matrix of the departing trains along Šibenik – Knin route [kn]

from/to	Šibenik	Perković	Drniš	Kosovo	Kaldrma	Knin
Šibenik	-	14.30	37.60	42.70	43.20	54.67
Perković	14.30	-	28.77	29.80	33.60	40.37
Drniš	36.20	28.77	-	10.40	11.70	18.47
Kosovo	42.70	29.80	10.40	-	9.10	11.70
Kaldrma	43.20	33.60	11.70	9.10	-	10.40
Knin	54.67	40.37	18.47	11.70	10.40	-

Source: Authors

On the route Šibenik – Knin the cost of railway transport is in average 54.67 HRK. The average price is calculated because prices vary during the day, depending on the hour and the train transporting passengers. The lowest price of transport is 50.50 HRK in the day and the biggest is 68.50 HRK. The modal price is 50.50 HRK, and at this price there are only 4 trains per day available, whereas at the price of 68.50 HRK there is only one train. The most expensive price is for the transport with a layover which lasts 3 hours and 41 minutes. The target group on this line are not passengers who want to come directly from Šibenik to Knin. The transport price to Drniš is 37.60 HRK and from Drniš to Knin 18.47 HRK (*Table 3*).

Table 4 – The price matrix of the departing trains along Šibenik – Knin route [kn]

from/to	Šibenik	Tromilja	Drniš	Kosovo	Knin
Šibenik	-	15.00	31.00	39.00	44.00
Tromilja	15.00	-	24.00	31.00	39.00
Drniš	31.00	24.00	-	17.00	30.00
Kosovo	39.00	31.00	17.00	-	17.00
Knin	44.00	39.00	30.00	17.00	-

Source: Authors

The price of the bus service on the line Šibenik - Drniš - Kosovo - Knin is 44 kn from the beginning to the end point. Comparing the bus and railway transport and the stations on the line, the price ratio is interesting. The railway transport Šibenik – Perković costs 14.30 HRK and that is similar to the transport from Šibenik to Tromilja which costs 15.00 HRK. Distances are the same but, in comparation, stations are not competitive with each other because of the spatial distance between them. Transport Šibenik - Drniš by bus amounts to 24.00 HRK, and the average price at the railway is 37.60 HRK. The lowest price for the railway transport Šibenik - Drniš is 36.20 HRK, and the highest is 43.20 HRK. If we depart from Šibenik, it is evident till Drniš that the railway is not competitive to the bus transport. The transport from Šibenik to Knin over Kosovo is 44.00 HRK and by the unique railway line the average price is 54.67 HRK. The lowest price for the railway transport through Kosovo is 50.50 HRK and the highest 68.50 HRK. According to the prices of cargo, the railway is more competitive on shorter distances, so the transport between Drniš and Knin over Kosovo costs 18.47 HRK and the price for the bus is 30.00 HRK. At this point of view, the line Kosovo - Knin is also a more competitive rail by price, because compared to the bus it is cheaper for 5.30 HRK (*Table 4*).

Table 5 – The price matrix of the departing trains along Šibenik – Knin route

from/to	Šibenik	Tromilja	Drniš	Kosovo	Knin
Šibenik	-	15.00	31.00	39.00	44.00
Tromilja	15.00	-	24.00	31.00	39.00
Drniš	31.00	24.00	-	17.00	30.00
Kosovo	39.00	31.00	17.00	-	17.00
Knin	44.00	39.00	30.00	17.00	-

Source: Authors

On the line Šibenik - Drniš - Oklaj – Knin, the price of the bus transport from the beginning to the end point is 46.00 HRK. Regarding the relations within the Šibenik - Drniš line the price is the same as for the Šibenik - Drniš - Kosovo - Knin line, which amounts to 31.00 HRK. The Drniš - Oklaj line by bus is 24.00 HRK, and the competitive station, Kaldrma stop, on the railway line is 11.70 HRK. The Oklaj - Knin line by costs 22.00 HRK, while Kaldrma - Knin is 10.40 HRK. The total distance on the Šibenik - Knin line is more affordable by bus for 8.67 HRK than by railway, while the relations within the line are more favorable to the rail (*Table 5*).

In Table 6, a comparative analysis was performed according to the 4 indicators. Commercial speed is the smallest with the bus transport on the line Šibenik - Drniš - Kosovo - Knin. The highest commercial speed is on the line over Oklaj because of the few bus stops till Oklaj and due to the favorable traffic infrastructure. The main advantage of the railway should be the speed, but due to the bad state, the railway in the Balkans has not been able to use it since the 1990s [9]. The railway is the most expensive and the most affordable is the bus line from Šibenik to Knin over Kosovo. The price per kilometer is the lowest when it comes to rail transport, and the highest is through Kosovo. The 18th hour coefficient is an indicator used to show the frequency of departures of a bus or railway line on an active day-time line that is 18 hours. With such an indicator we eliminate the impact of traffic during the night which is negligible. One of the basic conditions for encouraging passengers to use railways is to create a sufficient number of train departures a day [10]. This means that the 18th hour coefficient should be drastically reduced or, at least, try to equalize the values of the same coefficient for the bus as well as for railway. Since commercial speeds (due to direct impact on driving time, actually the journey time) and the price are one of the key elements for attracting passengers to the railway and bus lines are not satisfactory [11]. Therefore, it is necessary to turn to innovative forms of passenger public transport.

Table 6 – Comparative analysis of bus and railway lines

	Commercial speed [km/h]	Price [kn]	Price / distance [kn/km]	The 18th hour coefficient
Željeznica (Šibenik – Knin)	44.14	50.50	0.68	3.6
Autobus (Šibenik – Drniš - Oklaj – Knin)	47.22	46.00	0.72	6.0
Autobus (Šibenik – Drniš - Kosovo – Knin)	36.63	44.00	0.79	9.0

Source: Authors

6. CONCLUSION

A developed passenger public transport is a precondition for increasing general mobility. The passenger public transport in the Šibenik-Knin county, between Šibenik and Knin occurs in two ways by bus and railway. A positive occurrence is that there is competition on the market of passenger transport between the same destinations, but, after the existence of competition, what can further

improve the service and reduce the cost of transport is co-operation and proactive transport management.

In the first instance, co-operation and proactive transport management includes integrated passenger transport. Researching the railway and bus line Šibenik – Knin, errors in the management and planning of such isolated modes of transport are obvious. These mistakes are parallel bus and railway lines in a large percentage, reduced mobility and accessibility to specific locations, empty transport capacities, speed and poorly integrated lines that include layovers.

The study also concluded that the advantages of railway, as well as the benefits of bus passenger transport, are poorly exploited. This demotivates the population to use the passenger public transportation and affects the increase of cars on the road. Future research needs to go in the direction of integrating the individual advantages of each single transport sector into a single traffic system with the aim of increasing mobility, reducing journey time, introducing a single transport ticket and increasing the volume of business of a carrier. This research would have made the underlying condition of switching from car to public transport and achieving potential numerous economic, environmental and social benefits.

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MARETIĆ DOMAGOJ, mag.ing.traff.[1]
E-mail: domagoj.maretic4@gmail.com
TOMISLAV ROŽIĆ, Ph.D.[2]
E-mail: trozic@fpz.hr
BOŽIDAR IVANKOVIĆ, Ph.D.[3]
E-mail: bozidar5400@gmail.com
[1] student at University of Zagreb Faculty of Transport and Traffic Sceinces
Vukelićeva 4, 10000 Zagreb
[2] University of Zagreb
Faculty of Transport and Traffic Sceinces
Vukelićeva 4, 10000 Zagreb
[3] Affiliation 3
Affiliation Address 3

OPTIMIZATION OF DISTRIBUTION NETWORK USING METHODS FOR SOLVING THE PROBLEM OF VEHICLE ROUTING

ABSTRACT

Goods are often distributed to its consumers through logistic service providers, to insure product's availability, timely, at the right place and at the lowest cost. In this paper, we carried out the analysis of the existing distribution network which was planned by a company, using the Optimap and Driving Route Planner calculator software, so there is an opportunity to optimize the distribution network with the aim of reducing transport costs. Optimization is carried out by re-designing distribution network routes, using methods of heuristic solving of the travelling salesman problem (TSP). The results that have been obtained were compared with existing ones for each route in the distribution network. They have been compared from the aspect of distance and overall transport costs.

KEY WORDS

distribution network; optimization; routing methods; transportation costs

1. INTRODUCTION

For the consumer's perception of a product or a service, distribution network represents the main supply chain stage which includes wholesale and retail traders, logistic operators and carriers. The cost of an average shipment distance can be as high as 20% of the value of the goods [1], and the availability of products to users is largely dependent on the efficiency of the transport process. Optimization of the distribution increases the value of the goods so that the total costs are lower than the selling price. Therefore, the purpose of this paper is to analyze the distribution network of the particular company Quehenberger Ltd. in the area of northern and eastern Croatia, and by applying the method of heuristic solving of the TSP and routing algorithms to design new routes to speed up the distribution process and reduce overall transport costs.

The goal is to get the delivery vehicle, at a minimum cost of transport, from the starting point back to the source, visiting every single location only once. Overall 12 routes in the Republic of Croatia were optimized. Six belong to the area of northern Croatia, while others are in the area of eastern Croatia (Slavonia region). The optimization process for existing orders projects new routes using the specified routing methods. Order is a set of locations with required quantities of goods for each location. For each order, a route is designed according to each of the above methods. After completion of all design, the comparison of the routes, the shortest is obtained, which is used to calculate the distribution costs. There are five types of freight vehicles that distribute goods depending on their size, capacity and volume, and are chosen depending on the mass and volume of cargo. Quehenberger Ltd. uses the

outsourcing services on the observed routes. Vehicles outsourcing is paid according to distance, so shortening the route reduces the cost of distribution. The paper presents a comparison of costs after designing new routes in the area of northern and eastern Croatia. Finally, the cost-effectiveness of the billing system per kilometer and per pallet for both areas was analyzed. Solutions are proposed in case of higher costs in distribution. An analysis and comparison of the existing distribution network was also carried out in this paper, calculated by the company, using calculation software Optimap and Driving Route Planner, as well as the results obtained through the heuristic solution of the TSP.

2. METHODS AND ROUTING ALGORITHMS

Routing methods are some of the methods whose algorithms solve TSP by a heuristic approach [2, 7, 8]. The paper uses Clark-Wright saving algorithm, method with indicator T, branching and limiting methods, Nearest neighbour algorithm and Christofides algorithm. Clark-Wright's "savings" and T-method algorithm will be used as the basic methods for comparing the obtained results: the method of branching and limiting, the Nearest neighbour algorithm and the Christofides algorithm.

2.1. Clark-Wright algorithm of savings

The algorithm starts from a solution for n locations from a n-1 route running by one vehicle from the starting point (base) to just one consumer and back to the base or the starting point. Then, inductively, step-by-step, two routes are combined that bring the greatest savings, while satisfying task constraints [3].

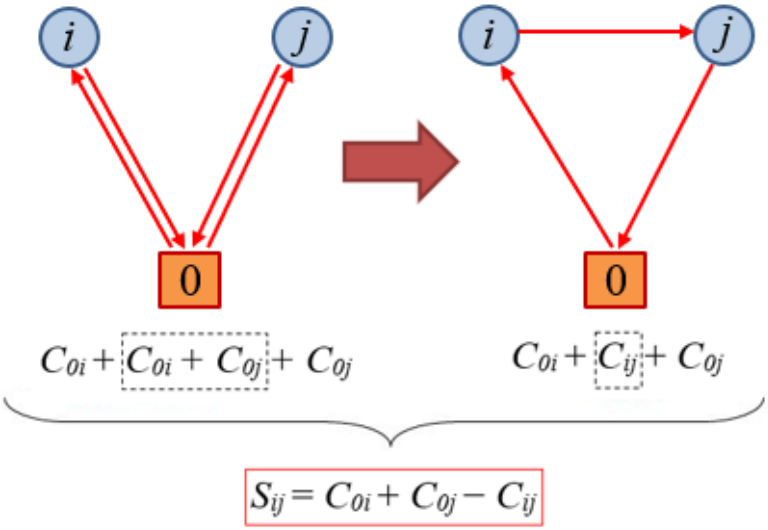


Figure 1 – Calculation of savings using Clark-Wright algorithm
Source: [3]

The formula for calculating the savings with the Clark-Wright algorithm reads:

$$S(i,j) = d(0,i) + d(0,j) - d(i,j) \quad (1)$$

Clark-Wright's route planning savings algorithm is performed in four steps [3]:

Step 1: Calculating savings with formula (1) for each pair (*i*, *j*) of nodes served.
Step 2: Building ranked savings list that starts with the highest.
Step 3: Include branch (*i*, *j*) into a partial route under conditions:
(a) Locations *i* and *j* are not included in any existing partial route
(b) One of the location *i* or *j* is included in the partial route, but not as an internal one

(c) Locations *i* and *j* are included in two different partial routes, but none are internal nodes in those routes

Step 4: When the savings list is depleted, the algorithm ends.

2.2. Clark-Wright algorithm of savings - method with status indicator T

The procedure for calculating the shortest route according to the method with indicator T starts with the calculation of the savings [3]. The resulting savings are placed in a triangular matrix in which the corresponding indicator values are added. The indicator T will show whether two locations are: i and j or 0 (starting point) and j, are directly related and have one of three possible values [3]:

a) $T_i = 2$ – the vehicle goes from the starting point to the *i* - location and returns to the starting point. T = 2 indicates a circular, two-way delivery with return
b) $T_{ij} = 1$ – the vehicle goes directly from location *i* to location j and marks one-way delivery.
c) $T_{ij} = 0$ – the vehicle does not go directly from *i* to *j*.

	x_1	x_2	x_3	x_4	x_5	x_6
x_0	**T=2**	**T=2**	**T=2**	**T=2**	**T=2**	**T=2**
	x_1	s_{12}	s_{13}	s_{14}	s_{15}	s_{16}
		x_2	s_{23}	s_{24}	s_{25}	s_{26}
			x_3	s_{34}	s_{35}	s_{36}
				x_4	s_{45}	s_{46}
					x_5	s_{56}

Figure 2 – Display of triangular matrix of savings and indicators for calculation of the shortest path
Source: [3]

The next step is to determine the highest value of savings in the triangular matrix, and the locations with maximum S_{ij} can be connected if they are not already on the same partial path and if $T_{0i}, T_{0j} > 0$.

2.3. Method of branching and limiting

The algorithm begins by creating a matrix of distance between locations:

	x_1	x_2	x_3	x_4	x_5
x_1	∞	d_{12}	d_{13}	d_{14}	d_{15}
x_2	d_{21}	∞	d_{23}	d_{24}	d_{25}
x_3	d_{31}	d_{32}	∞	d_{34}	d_{35}
x_4	d_{41}	d_{42}	d_{43}	∞	d_{45}
x_5	d_{51}	d_{52}	d_{53}	d_{54}	∞

Step 1: Subtract away the minimum element in each row (*ui*) from each value of that line.
Step 2: Subtract away the minimum element in each column (*vj*) from each value of the column.

Fields containing zero candidates are for establishing direct links between locations. For each such field, a penalty for not using the proposed link is calculated, not including field (i, j) [4]:

$$penalty\ on\ (i,j)\ =\ minimal\ row\ element\ i\ +\ minimum\ row\ element\ j.$$

2.4. Nearest neighbour algorithm

Nearest Neighbour Heuristic - NNH provides an initial solution for testing corrective heuristics. The method quickly obtains initial solutions but is far from optimal. It is based on the greedy addition of the closest peak to a partial route. The algorithm consists of three steps [4]:

Step 1: Pick one vertex to start.
Step 2: Include the nearest unaddressed vertex in the route to the last added vertex.
Step 3: Repeat the second step until you connect the last one to the starting vertex.

2.5. Christofides algorithm

The Christofides algorithm is based on a minimal crucible tree and the formation of the Euler graph [5] by matching the even number of vertices of odd degree. The proposed route of a traveling salesman is transformed by shortcuts into the Euler cycle [5]. The algorithm has four steps [4, 5, 6].

Step 1: find the shortest corresponding tree that joins n nodes and mark it with A
Step 2: the number of odd degree nodes (k) of the tree A is always even. Match the odd nodes so that the total length of all the branches obtained is the smallest.
Step 3: nodes obtained by matching form network B. Draw a network $C = A \cup B$.
Step 4: network C has no odd nodes. Euler's path [5] in network C is approximately a solution to the problem of a travelling salesman.
Step 5: check nodes visited more than once, and improve the acquired salesman's route taking into account the inequality of the triangle:

$$d(a,b) \leq d(a,c) + d(c,b) \qquad (2)$$

3. RESEARCH RESULTS

Before designing new routes, it is necessary to calculate the cost of transport for each type of delivery vehicle that distributes the goods on the observed routes. The types of delivery vehicles used for distribution in the observed areas, depending on the quantity and type of cargo, are marked according to load capacity, number of Euro pallets (EUP), dimensions and prices. During the calculation, the exchange rate for 1 EUR was 7.40 HRK. The value of the price is rounded to two decimal places:

- type 1: up to 1.5t load capacity and up to 6 EUP, dimensions up to 4000 × 2000 × 1900, or up to 17 m^3, transport cost 0.34 EUR/km,
- type 2: up to 3.5t load capacity and up to 14 EUP, dimensions 6000 × 2480 × 2400 or up to 40 m^3, transport price 0.54 EUR/km,
- type 3: up to 5t load capacity and up to 16 EUP, dimensions 7100 × 2400 × 2400 or up to 40 m^3, transport price 0.54 EUR/km,
- type 4: up to 7t load capacity and up to 18 EUP, dimensions 7460 × 2480 × 2300 or up to 44 m^3, transport cost 0.67 EUR/km,
- Type 5: up to 12t load capacity and up to 22 EUP, dimensions 8800 × 2500 × 2600 or up to 60 m^3, transport cost 0.81 EUR/km.

The selected shortest route solution defines the shipping cost. The vehicle type is selected according to mass and volume of cargo, and pre-defined transport rates. The cost of transport is the product of the rate for 1km for the selected vehicle type and the shortest route. Table 1. shows the length of the shortest route for each routing method and the length of the shortest route. The first six routes belong to the north, while the following routes belong to eastern Croatia (Figures 3. and 4.). Route HR-43365 is divided into two parts for the size and delivery time, under the same code for easier display.

Table 1 – Results of the shortest routes obtained by routing methods

Route	***Clark-Wright algorithm of savings*** (km)	***Method with indicator T*** (km)	***The method of branching and limiting*** (km)	***Nearest neighbour algorithm*** (km)	***Christofides algorithm*** (km)	**The best solution** (km)
HR-43627	332	332	332	382	332	**332**
HR-43689	307	307	307	328	307	**307**
HR-43753	260	260	260	260	260	**260**
HR-43472	201	201	201	201	201	**201**
HR-43882	274	274	274	294	303	**274**
HR-43881	327	327	327	328	347	**327**
HR-43344	617	617	602	674	624	**602**
HR-43827	644	644	674	644	644	**644**
HR-43761	677	677	677	683	683	**677**
HR-43365	634	634	634	723	678	**634**
	606	606	606	630	630	**606**
HR-43443	678	678	678	678	713	**678**
HR-43960	628	628	645	662	665	**628**

Figure 3. shows the location of the observed route in the northern part of Croatia, while Figure 4. shows the location of the observed route in the area of eastern Croatia. Each route is marked with one color for easier recognition, and the code of each route is of the same color as the route of a particular route.

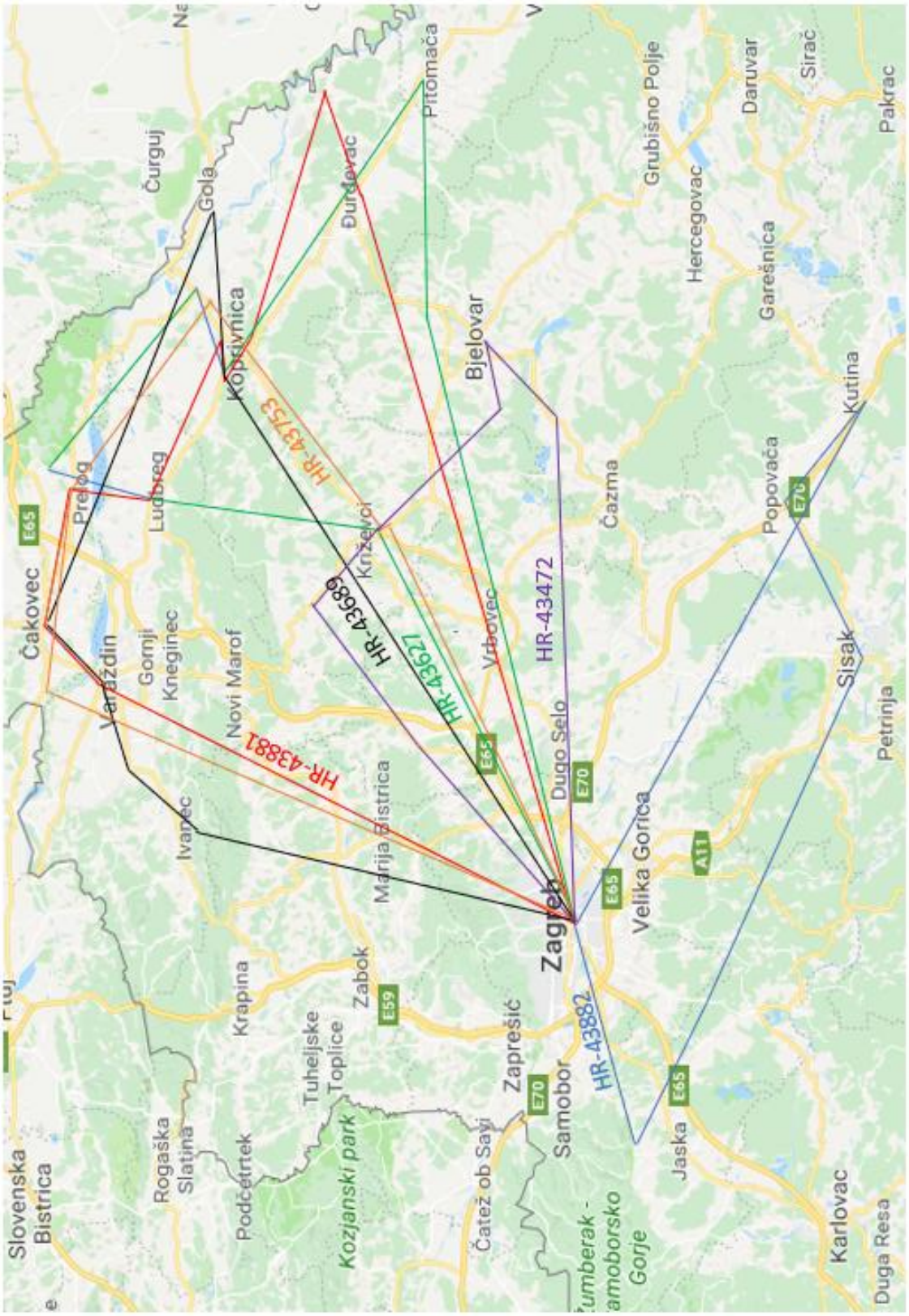


Figure 3 – Observed routes in northern Croatia

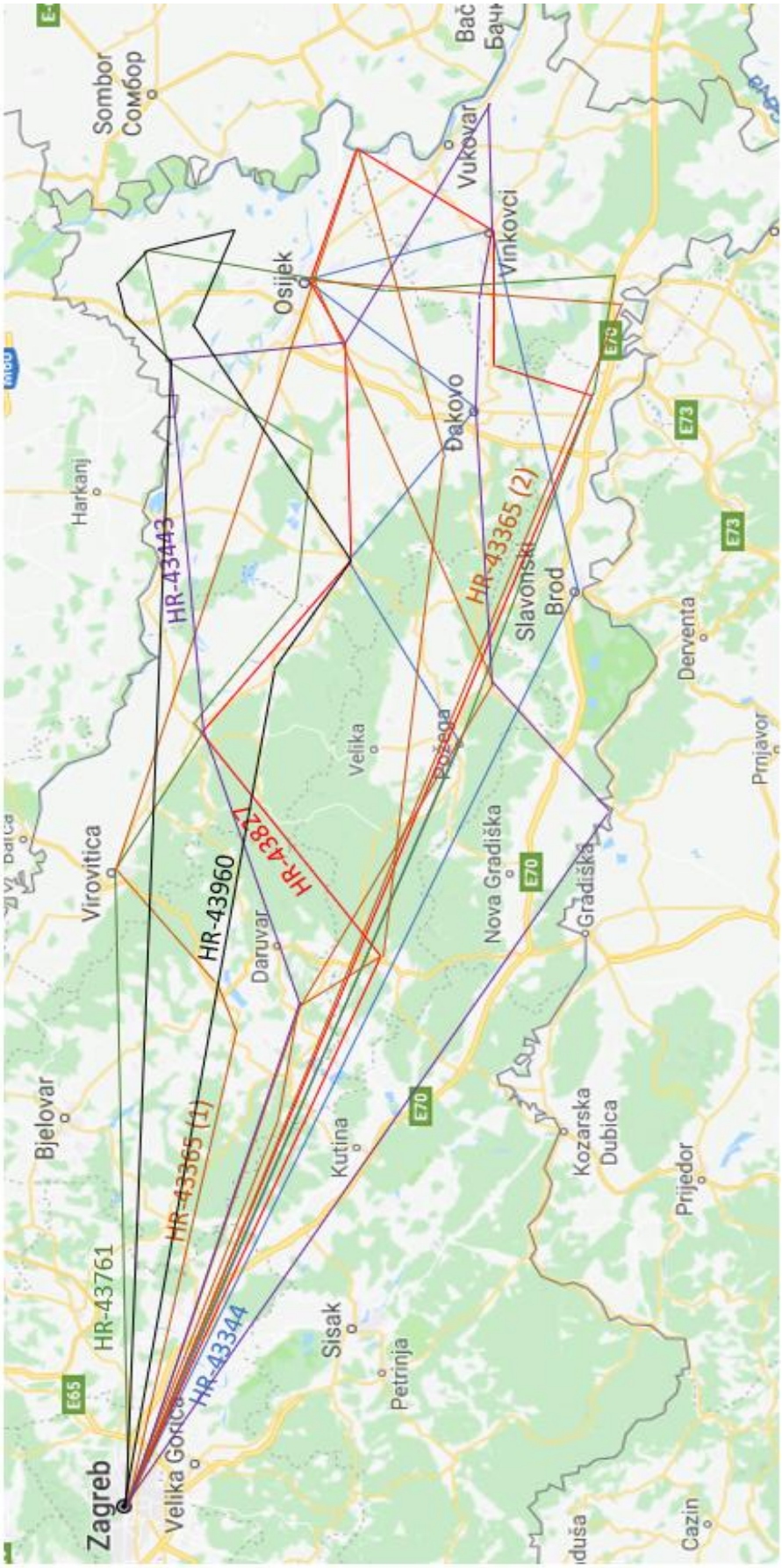


Figure 4 – Observed routes in the eastern part of Croatia

Clark-Wright savings algorithm and the *Method with indicator T* have best solutions in 92.3% of cases and 12 out of 1 possible routes. The reason for the same solutions, despite various calculations, is based on the savings calculated for both methods according to the same formula (1). The effect of Branching and limiting method is 84.6%, i.e. it designs the best solution for 11 of the possible 13 routes. The *Nearest Neighbour Algorithm* designs better solutions for four of the possible 13 routes, or 30.7% routing effects. *The Christofides algorithm* designs the best solution for five of the possible 13 routes, or better effect for 38.4% routes. Thus, *Clark-Wright algorithm of savings* and *Method with indicator T* proved to be the most effective methods, while *The Nearest Neighbour Algorithm* proved to be the most effective in designing the best solution.

For the observed routes in Northern Croatia, HR-43753 and HR-43472, all five methods gave the same best solution, i.e. 201 and 260 kilometers of the shortest route length. It is also apparent that four of the five routing methods provide a better solution for routes HR-43627, HR-43689, HR-43827 and HR-43443. The HR-43344 route is the only shorter route designed only by *the Method of branching and limiting*, while in other routes a better solution is obtained by using at least two methods.

In Figure 5, which compares routing methods, there are larger deviations in the area of eastern Croatia, while in the area of northern Croatia the length of the route is approximately equal. Obviously, there are fewer lengths of routes in the north than in eastern Croatia. The deviation of the curve is influenced by the distance of the base from the distribution location, which is far greater in the area of eastern Croatia. The approach of *The Nearest Neighbor Algorithm* to the solutions obtained is the least effective and therefore has the greatest discrepancies. Curves of the *Clark - Wright algorithm of savings and Method with indicator T* overlap because they both provide the same solution on all routes.

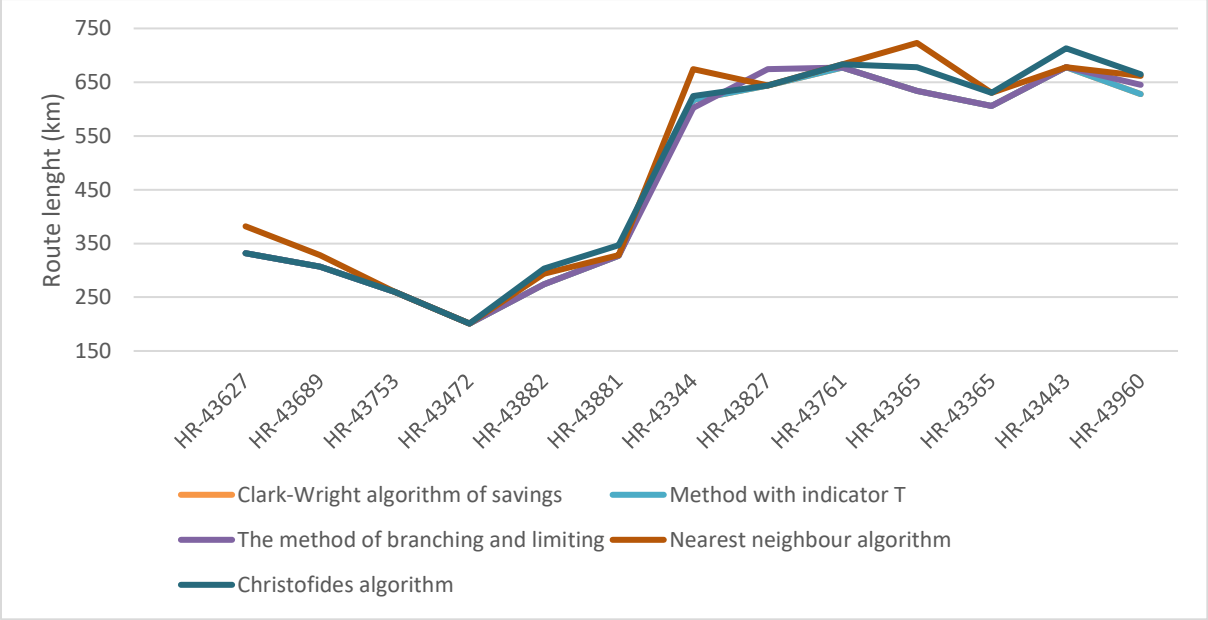


Figure 5 – Relationship of Routing Methods

Table 2. lists the lengths of the shortest routes obtained with software to plan and optimize routes - *the OptiMap and Driving Route Planner* and the shortest routes obtained by routing methods. The software has designed a better solution for four routes, from which *OptiMap* software has provided a better solution for three routes, while *Driving Route Planner* has provided a better solution on one route. The last column in Table 2. represents the difference between route lengths obtained by routing methods and a shorter route length between the two software. Values within the red rectangle indicate the shortest route length obtained by software or routing methods. The savings in the lower

part of the table in the eastern Croatia are considerably higher due to the markedly longer routes in comparison to northern Croatia.

Table 2. Comparison of Solutions Obtained with Optimap Software and Driving Route Planner and Routing Methods

Route	***OptiMap*** *(km)*	***Driving Route Planner*** *(km)*	**Routing Methods** *(km)*	**Savings** *(km)*
HR-43627	350	353	332	**18**
HR-43689	308	304	307	**-3**
HR-43753	275	265	260	**5**
HR-43472	202	231	201	**1**
HR-43882	274	305	274	**0**
HR-43881	324	325	327	**-3**
HR-43344	597	600	602	**-5**
HR-43827	648	646	644	**2**
HR-43761	695	698	677	**18**
HR-43365	698	700	634	**64**
	649	648	606	**42**
HR-43443	670	670	678	**-8**
HR-43960	687	679	628	**51**

Table 3. shows the relationship between the transport costs paid by the company to the outsourcing companies for the transport service under the name; the current transport cost and the costs incurred by the *OptiMap* and *Driving Route Planner* software as well as the costs incurred by routing methods. The costs in Table 3 represent a multiplication of the route length from Table 2. and the rental price of a vehicle that distributes on a particular route. The difference in costs can be due to the difference in the length of the route, i.e. the shortest route and because of the type of vehicle that performs the distribution, i.e. the outsourcing price of the vehicle per kilometer.

Table 3 – Comparison of current transport costs, expenses of Optimap, driving route planner and costs received by routing methods

Route	Current transport costs (EUR)	***OptiMap*** (EUR)	***Driving Route Planner*** (EUR)	Routing methods (EUR)
HR-43627	243,24	189	190,62	179,28
HR-43689	229,73	166,32	164,16	165,78
HR-43753	182,43	93,5	90,1	88,4
HR-43472	135,13	109,08	124,74	108,54
HR-43882	162,16	147,96	164,7	147,96
HR-43881	216,22	174,96	175,5	176,58
HR-43344	364,86	483,57	486	487,62
HR-43827	290,54	349,92	348,84	347,76
HR-43761	560,81	375,3	376,92	365,58

HR-43365	310,81	376,92	378	342,36
		350,46	349,92	327,24
HR-43443	263,51	361,8	361,8	366,12
HR-43960	208,11	370,98	366,66	339,12

Figure 6. shows the comparison of the shortest routes obtained with OptiMap and *Driving Route Planner* software, as well as routing methods. Given the shorter routes of northern Croatia, the lengths are approximately equal and the deviations are smaller and the savings are minimal. Therefore, in the figure 6. the curves of the route lengths in the northern Croatian part are overlapping, so the deviations are not visible. The deviations in Figure 6. are visible at the distribution route of eastern Croatia, where savings are more visible due to the larger lengths of the route and the distance from the base to the distribution locations. Routing methods solutions are highlighted in green, while the solutions provided with *OptiMap* software are labeled with blue color and the solutions obtained with the *Driving Route Planner* software in red.

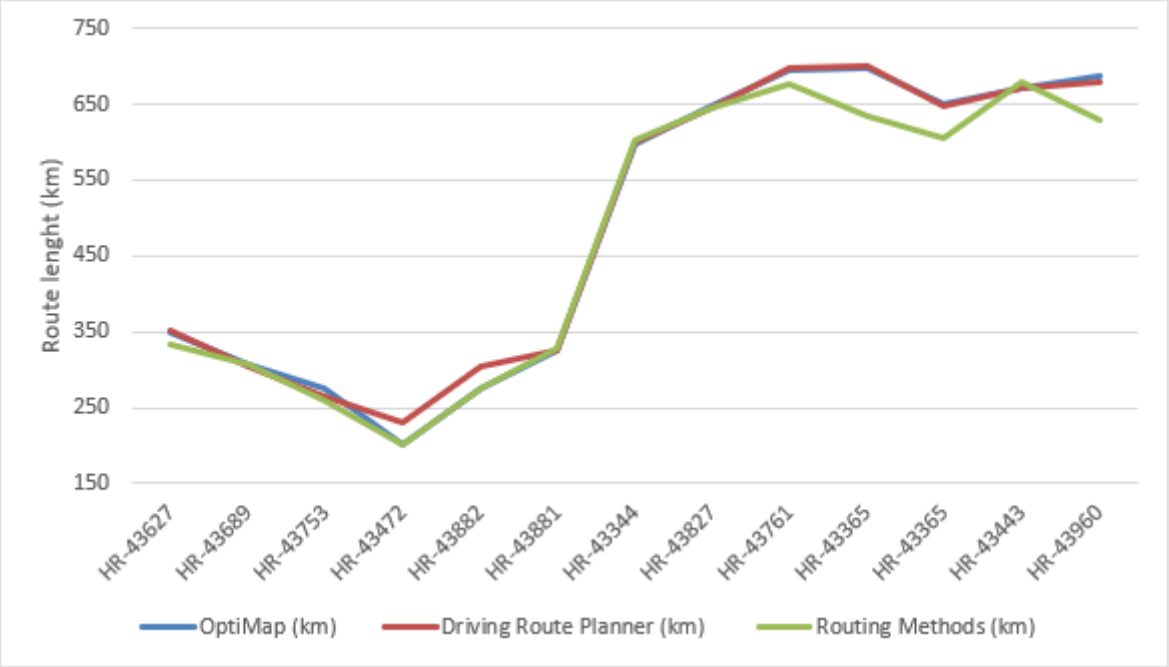


Figure 6 – Relationship between Optimap, Driving Route Planner and routing method

After the design of new distribution routes, it is necessary to calculate the cost of transport for each type of delivery vehicle that distributes the goods on the observed routes. Table 4. shows the route of HR-43627, which is located in northern Croatia, as an example. Initially we are to determine the amount of packaging that includes the number of pallets and the total weight for transport. For this route it was necessary to distribute 8 EUP with a total weight of 2803 kg.

Table 4 – HR-43627 route data

Time of delivery	Storage center	Destination	Package amount	Gross mass (kg)	Route code
10.3.2017 0:00	Zagreb	Kapela	2	1245	HR-43627
10.3.2017 0:00	Zagreb	Pitomača	1	100	HR-43627
10.3.2017 0:00	Zagreb	Drnje	1	75	HR-43627
10.3.2017 0:00	Zagreb	Donji Kraljevec	1	212	HR-43627
10.3.2017 0:00	Zagreb	Ludbreg	1	250	HR-43627
10.3.2017 0:00	Zagreb	Koprivnica	1	142	HR-43627
10.3.2017 0:00	Zagreb	Križevci	1	779	HR-43627

For distribution of cargo on route HR-43627, a type 2 freight vehicle is selected, which can transport 8 EUP of 2803 kg. The outsourcing price of the selected vehicle is 0.54 EUR/km. The shortest route obtained by Routing method is 332 km, so the transport cost, obtained by the multiplied cost and length of the route HR-43627 is 179.28 EUR. Table 5 shows the amounts that the company pays for the distribution of goods and the company has distributed, on the route mentioned, for 243.24 EUR. Routing methods for HR-43627 route resulted in savings of 63.96 EUR.

Accordingly, the cost of other routes is calculated. Table 5. shows the current and new transport costs obtained by routing methods for all routes according to the type of vehicle. Savings and additional costs are stated. Given that it is paid according to the mileage, it is necessary to choose such a type of cargo according to the amount of cargo that only one delivery vehicle is sufficient for the distribution of the goods. After selecting the vehicle, routing methods are determined by the shortest tours, cost and savings are counted.

Table 5 – Distribution costs by vehicle rental

Route	Current shipping cost (EUR)	Method of payment	Load weight (kg)	Number of pallets	Vehicle type	New transport cost (EUR)	Savings (EUR)
HR-43627	243,24	Vehicle rental	2803	8	2	179,28	**63,96**
HR-43689	229,73	Vehicle rental	1381	12	2	165,95	**63,78**
HR-43753	182,43	Vehicle rental	753	5	1	87,84	**94,60**
HR-43472	135,13	Vehicle rental	1823	7	2	108,65	**26,48**
HR-43882	162,16	Vehicle rental	1980	7	2	148,11	**14,05**
HR-43881	216,22	Vehicle rental	2285	9	2	176,76	**39,46**
HR-43344	364,86	Vehicle rental	2919	21	5	488,11	**-123,25**
HR-43827	290,54	Vehicle rental	4246	11	3	348,11	**-57,57**
HR-43761	560,81	Vehicle rental	10391	19	3	548,92	**11,89**
HR-43365	310,81	Vehicle rental	1897	8	2	342,70	**-48,65**
			2321	5	2	327,57	
HR-43443	263,51	Vehicle rental	2271	10	2	366,49	**-102,98**
HR-43960	208,11	Vehicle rental	2865	8	2	339,46	**-131,35**

Routing methods provide new lengths of the shortest routes, thus reducing the cost of transport in a proportional manner. In some routes, there is an additional cost, most often due to a deal between

the outsourcing company and the company on the quantity discount for the distribution of cargo for a large number of parties.

In addition to the calculation of transport costs per kilometer, the transport costs per pallet for all routes in Croatia are calculated. By comparison, a more cost-effective payment method was established.

At longer distances shown in the area of eastern Croatia, the payment of transport per kilometer is not profitable, as the average distance per route is approximately 640 km. It is only profitable if there is a larger amount of cargo or if another method of charging is applied, such as a collection charge per pallet. Using the distribution method per pallet location, it is clear that transport costs are lower compared to the vehicle rental method, primarily in the area of eastern Croatia. For a better distribution cost ratio, it is necessary to use a mixed payment method for the distribution of central and northern Croatia by leasing a vehicle and for eastern Croatia per pallet with an open possibility of combining the method of charging depending on the amount of cargo and distance.

Table 4. shows the amount of cargo that the outsourcing company must deliver to users on route HR-43627. There is a need to distribute 12 pallets, where the cost per pallet is 24.32 EUR, so the total transport cost per pallet for route HR-43627 is 194.59 EUR. More packets of less weight for the same location can be stacked in one palette or, in order to achieve savings, the packs can fill the empty cargo space of the vehicle.

For example, for a certain delivery place, five packages of 50 kg total weight should be required. Since the bearing capacity of 1 EUP is 800-1000 kg, the five packages can be placed one pallet. If these packets match the other load on the already used pallets, savings have been made. Table 5. shows the transport costs calculated according to the pallet as stated above. Transportation cost was paid by the company to the outsourcing company for each particular route. Since shipping is payable by a pallet, the new price is a multiplier of pallet price and pallet size on each particular route.

The last column in the table shows savings of the costs incurred. Table 6. compares the results of tables 4. and 5. with the aim of selecting the optimal solution.

Table 6 – Costs per pallet

Route	Transport cost (EUR)	Method of payment	Load weight (kg)	Number of pallets	New price (EUR)	Savings (EUR)
HR-43627	243,24	Per pallet	2803	8	194,59	**48,65**
HR-43689	229,73	Per pallet	1381	12	291,89	**-62,16**
HR-43753	182,43	Per pallet	753	5	121,62	**60,81**
HR-43472	135,13	Per pallet	1823	7	170,27	**-35,14**
HR-43882	162,16	Per pallet	1980	7	170,27	**-8,11**
HR-43881	216,22	Per pallet	2285	9	218,92	**-2,7**
HR-43344	364,86	Per pallet	2919	21	510,81	**-145,95**
HR-43827	290,54	Per pallet	4246	11	267,57	**22,97**
HR-43761	560,81	Per pallet	10391	19	462,16	**98,65**
HR-43365	310,81	Per pallet	1897	8	194,59	**-5,4**
			2321	5	121,62	
HR-43443	263,51	Per pallet	2271	10	243,24	**20,27**
HR-43960	208,11	Per pallet	2865	8	194,59	**13,52**

Transport costs per pallet vary depending on the amount discount, placement of the cargo in the vehicle or direct agreement between the company and the outsourcing company. Table 7. compares the costs of renting a vehicle (NV) and per pallet (PM).

Table 7 – Comparison of costs and savings

Route	Transport cost (EUR)	PM (EUR)	Savings-PM (EUR)	NV (EUR)	Savings-NV (EUR)
HR-43627	243,24	194,59	**48,65**	179,28	**63,96**
HR-43689	229,73	291,89	**-62,16**	165,95	**63,78**
HR-43753	182,43	121,62	**60,81**	87,84	**94,60**
HR-43472	135,13	170,27	**-35,14**	108,65	**26,48**
HR-43882	162,16	170,27	**-8,11**	148,11	**14,05**
HR-43881	216,22	218,92	**-2,7**	176,76	**39,46**
HR-43344	364,86	510,81	**-145,95**	488,11	**-123,25**
HR-43827	290,54	267,57	**22,97**	348,11	**-57,57**
HR-43761	560,81	462,16	**98,65**	548,92	**11,89**
HR-43365	310,81	194,59	**-5,4**	342,70	**-48,65**
		121,62		327,57	
HR-43443	263,51	243,24	**20,27**	366,49	**-102,98**
HR-43960	208,11	194,59	**13,52**	339,46	**-131,35**

Table 7 shows that savings are significantly higher when renting vehicles (NV) on the routes of northern Croatia (top of the table), when the cost calculation is performed on the mileage route. The lower part of the table shows that the cost for eastern Croatia is higher when calculating the cost per pallet, except in the HR-43344 route that deviates from the rest.

The reason for this savings relation may be a smaller number of North Croatian distribution locations than the number of locations in the east where the length of the route is higher. The average length of the northern Croatian route is 283.5 km, while the average length of the route of Eastern Croatia is 638.4 km. Distances from the base of the route of distribution are far greater in the east of Croatia, in Slavonia. Thus, for the northern part of Croatia, it is more feasible to pay the rent of vehicles per kilometer, while for eastern Croatia it is more feasible to pay transportation per pallet. The reason is the amount of cargo that is greater in transport in the eastern Croatia than in the northern part of Croatia, where there a possibility to negotiate a discount due to amount of goods when paying per pallet, is bigger than paying the rented vehicle per kilometer.

4. CONCLUSION

For the purpose of reducing transport costs, the optimization process was carried out on the distribution company example. By designing the routes on the existing distribution network, the values of the shortest routes have been obtained, which are the main factor in reducing transport costs. By the earlier mentioned routing methods, twelve new routes have been designed in the area of northern and eastern Croatia, and the shortest ones are considered. Transport costs are calculated by multiplying the length of the shortest routes and the price per km for the selected vehicle. After such a calculation of transport costs, the existing transport costs and costs incurred after re-designing the route were compared. By comparing costs, you can see savings for almost all of the aforementioned

routes. The calculation of transport costs is calculated according to the pallet, i.e. the amount of transported cargo. With calculations of both methods of payment, the results show that it is more feasible for the company to pay for the transport per kilometer in northern Croatia. Cargo transport in the area of eastern Croatia is more cost-effective per pallet unit, due to the greater distance from the base to the locations that need to be supplied and the larger lengths of the routes. As more cargoes are transported to eastern Croatia, there are possible arrangements for quantity discounts and other benefits. By combining these methods of payment, it is possible to make significant savings in transport regardless of whether it is achieved by outsourcing or by own transportation of the production company.

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MUSTAFA MEHANOVIĆ, Ph.D.[1]
E-mail: mustafamehanovic@bih.net.ba
AHMED AHMIĆ, Ph.D.[1]
E-mail: ahmic.ahmed@gmail.com
DRAGO EZGETA, Ph.D.[1]
E-mail: drago.ezgeta@tel.net.ba
[1] Faculty of Traffic and Communications, University of Sarajevo
Zmaja od Bosne br. 8, 71000 Sarajevo, Bosnia and Herzegovina

MANAGEMENT OF COMPANIES FOR TRANSPORT OF PASSENGERS IN DIGITAL TRANSFORMATION CONDITIONS - INNOVATION IN TRANSPORT AND TELECOMMUNICATIONS

ABSTRACT

The paper presents the approach of digital transformation of company management in the transport of passengers in the city area. The influence of digital technologies on the management of business processes in the transport of passengers, but also in the business environment of these companies, is evident. For these reasons, management and business can no longer be viewed only in traditional frameworks. It is necessary to establish management in the transport of passengers on a process approach with the application of digital technologies, digital content and digital communications. In practice, it has been shown that the strategic approach of management to digital transformation, both in passenger transport companies and in the operation of communication operators, provides good results.

KEY WORDS

Digital transformation of business; Strategic approach; Passenger transport; Process approach

1. INTRODUCTION

In the organizational parts of the company of passenger transport in cities, certain *processes* take place as elements of functioning. The concept of company functioning depends on external and internal requirements and factors.

One of the key factors that can be internal and external, and whose successful application certainly contributes to improving corporate governance is digital transformation. The precondition for successful application of digital transformation in the management of processes in the production of transport services has the degree of *digital transformation* of *communication operators*.

It is evident that the companies in the transport of passengers are now in an unfavorable position because of the complexity of the processes and the management of these processes. System approach to process analysis and intelligent systems management (ITS), with a clear strategic approach to digital transformation, efficiency and functionality is significantly improved.

The place and role of communication operators in the management of a transport company becomes apparent when the process of tracking and managing the processes in the enterprise is presented. It should include, among other things, defining the management goal, defining the system of public transport of passengers and its structure, defining subprocesses in the overall process of production of transport services in the transport of passengers in the city, the necessary activities for establishing the management and optimal functioning, the need for resources, human resources and equipment.

The methodology for the processing of the mentioned issues and the response to the objectives set out in the goal is structured in the following sections: *the basics, the management of the*

company in the passenger transport, the digital transformation of the company in the transport of passengers, the expected contribution of the digital transformation of the company's operations in managing the transport of passengers in cities and conclusions.

2. BASIS FOR THE ANALYSIS OF THE ROLE OF COMMUNICATION OPERATORS IN THE CONDITIONS OF DIGITAL TRANSFORMATION TO MANAGEMENT OF ENTERPRISES FOR TRANSPORT OF PASSENGERS TO THE CITY

The concept of digital transformation is described in various ways, and as a phenomenon, the word has become often mentioned not only in the field of technology and business, but even more widely. Through the Internet search engine it is possible to form a picture in a short time how much the actual term "digital transformation" is. For the term "digital transformation" in the search engine, about 276,000,000 results were found in a time of 0.75 seconds, [1].

More recently, the notion of digital transformation is understood as a change occurring at the individual, organizational or social level, the importance of which is relevant to the given area in relation to the previous state, which is under the influence of some of the information and communication technologies. These information and communication technologies are social networks, mobile applications, analytical tools and applications, [2].

In a broader context, the definition of digital transformation is relevant as the change that digital technologies cause or affect in all aspects of human life [3], which in this case is acceptable in order to clarify the impact of digital transformation on passenger transport management in cities.

The reason for the special attention is the assessment that most organizations believe that half of their income will come from digital channels by 2020. Furthermore, the World Economic Forum estimates that the total economic value of digital transformation in business and society will amount to $100 trillion in 2025. This represents vital macroeconomic trends that represent the most significant potential new business potential for each company and the company in passenger transport. The largest opportunities for growth in companies can be achieved if they take advantage of space in these rapidly expanding digital markets. Trends in the digital transformation for 2019 may be slowed down by difficulties on the business and technology side. As a result, companies should avoid mistakes made by others, and thus, during the digital transformation process, new insights and understanding are gaining, which reduces efforts to achieve the goal.

The importance of technological innovations is very important in the process of managing a company in the transport of passengers in cities. This can be concluded on the basis of the European Strategy for Cooperative Intelligent Traffic Systems, which states that: "The wave of technological innovations and business models that cause changes in the market has led to an increasing demand for new mobility services. At the same time, the sector responds to the urgent need for a safer, more efficient and sustainable transport. The consequence of this transformation is an extremely great opportunity in the social and economic sense that Europe must use immediately in order for its citizens and businesses to benefit from this transformation."[4]. *The guidelines for digital transformation in traffic and transport* on the European network of roads are basic directions of strategic action in urban areas.

The digital traffic system needs to be considered horizontally, encompassing various types of transportation and industry. Emphasis can no longer be just at the infrastructure level (eg on roads and vehicles). Digital technologies also relate to the level of data that includes statistical data such as digital maps and traffic regulations, as well as dynamic data such as real-time traffic information. These data are then used to develop the level of innovative services and applications that are available across the network. To make better use of digital technologies, it is necessary to ensure market access and fair competition at each level, as recommended in Internet platforms [5].

Although today's vehicles are already connected in many aspects, in the near future it will be in direct interaction with each other as well as in interaction with road infrastructure. Interaction is the area of cooperative intelligent traffic systems (C-ITS), which will allow road users and traffic operators to share and use information that was not previously available and coordinate their activities. This cooperative element, which allows digital connectivity, is expected to significantly increase road safety, transport efficiency and driving comfort by helping the driver to make the right decisions and adapt to the traffic situation.

Intelligent Transport Systems (ITS) are advanced applications that, without the use of intelligence, as such, aim at providing innovative services that relate to different modes of transport and traffic management and allow different users to be better informed and make safer, more coordinated and "smarter" use traffic network, [6].

ITS integrates telecommunications, electronics and information technology with transport engineering to plan, design, manage, maintain and manage transport systems. The application of information and communication technologies to the road transport sector and its links with other modes of transport will significantly contribute to the improvement of environmental performance, efficiency, including energy efficiency, safety and security of road traffic, including the transport of dangerous goods, public safety and mobility of passengers and cargo, at the same time ensuring the functioning of the internal market, as well as increasing the level of competitiveness and employment. However, ITS applications should not affect issues related to national security or which are necessary in the interest of the defense.

3. COMPANY MANAGEMENT IN PASSENGER TRANSPORT AND DIGITAL TRANSFORMATION

The digital transformation of process management in a passenger transport company should be in line with the objectives of the public transport company, which are, among others, the following goals, [7]:

- Growth in the volume of passenger transport;
- Satisfaction of transport requests;
- Improve the quality of transport services;
- Reducing the negative impact on the environment;
- Growth of total revenue;
- Growth of gross salaries of employees;
- Gain profit;
- Realization of dividends on capital;
- Increase in the allocation to meet the general need.

3.1 The concept of the functioning of the company

The concept of company functioning depends on dynamic external and internal requirements and factors, (*Figure 1*).

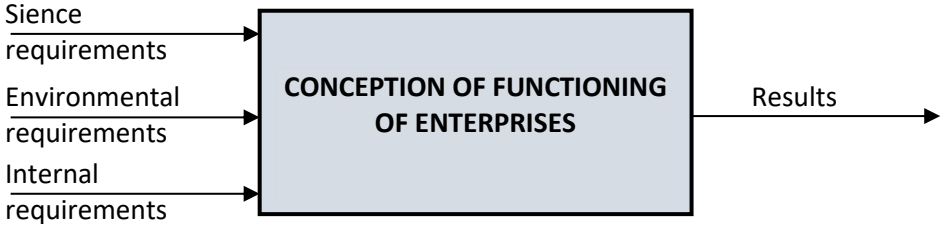


Figure 1 – The concept of the functioning of the company
Source: Author

The environment of public passenger transport companies consists of:

- Users of transport services;
- Suppliers of goods and services;
- Banks;
- Other institutions.

Inputs of company:

- Spare parts;
- Material;
- Services;
- Energy;
- Information;
- Capital.

Outputs of company:

- Transport services;
- Other products and services;
- Information;
- Waste;
- Money; and other.

3.2 Management of the company

The management of a company in public urban passenger transport is based on the principle of *feedback*. The management system needs to be digitally transformed in order to improve the business of the company. The basic elements of the management system are:

- The organizational unit under management,
- Information system,
- Company management,
- Management Board (Supervisory Board),
- Assembly of the company, (*Figure 2*).

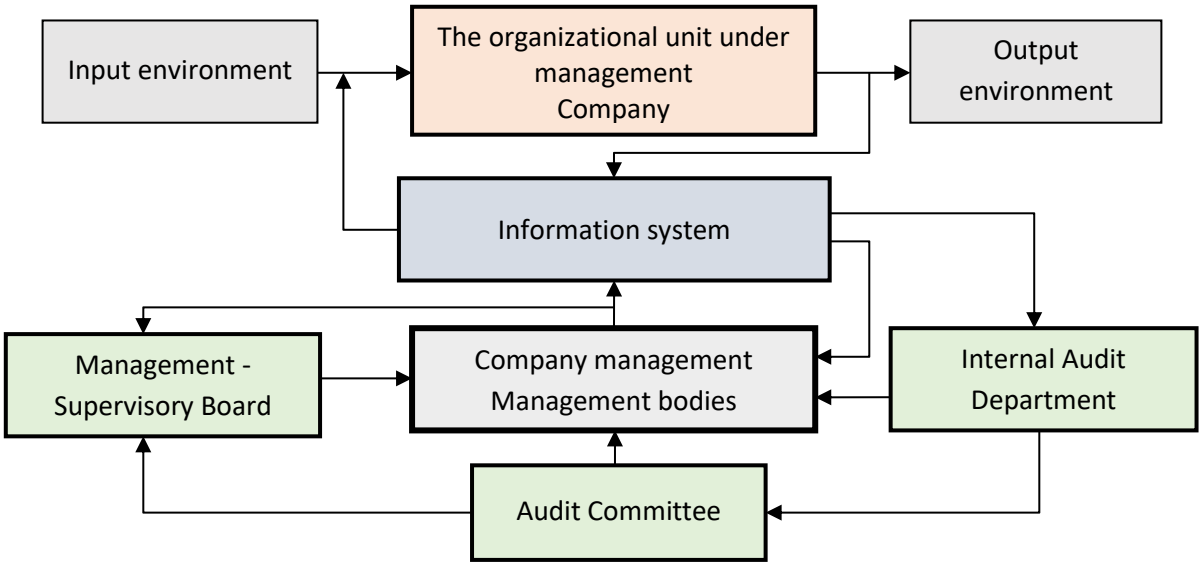


Figure 2 – The basic elements of the system of managing the company of public city transport
Source: Author

3.3 Data flow chart in the passenger transport company

Based on the list of documents for passenger transport companies, it is possible to create data flow diagrams for the digital transformation of process management and the enterprise, as described on the example of KJKP GRAS doo. Sarajevo, 2015. The flowcharts used for certain documents whose meaning is given in (*Table 1*). The diagram is for each organizational unit, and (*Figure 3*) presents a flow chart for transport sectors.

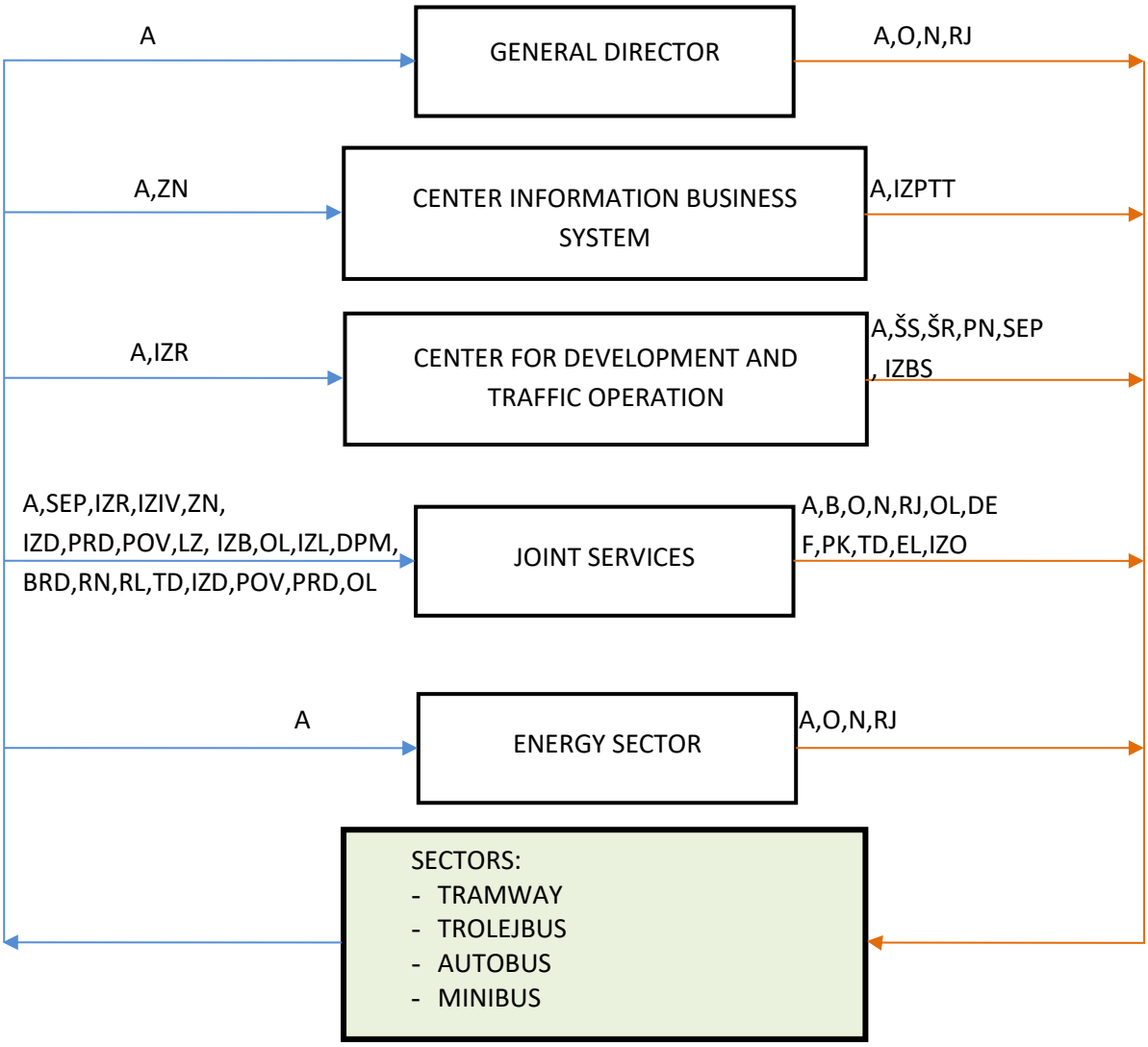


Figure 3 – Diagram of data flow in relation to the basic sectors in the company
Source: Author

Table 1 – Meaning of document labels in data flow diagrams

Tag	*Meaning of tag*
A	Information, reports, requests and minutes
B	Bonuses for a warm meal
BIZ	Cashier report
CD	Customs declaration
CRV	Central Timetable
DEF	Defective lists
DO	Letters
DPM	Permit for material failure
DRD	Permission to operate another shift

Tag	*Meaning of tag*
EL	Elaborates
FAX	Faxes
ENR	Internal orders
IZB	Vouchers for a hot meal
IZBS	Report on traffic safety
IZBSU	Statement of Balance Sheet and Success
IZBV	Report on the number of missed rides
IZD	Material delivery
IZEL	Electricity consumption report
IZFS	Report on traffic functionality

Tag	*Meaning of tag*
IZGKM	Report on fuel consumption and kilometers traveled
IZGP	Urban Transport Report
IZIN	Investment Report
IZIV	Vehicle Safety Report
IZKRS	Report on the movement of labor
IZL	Exit
IZO	Report on calculation of work orders
IZP	Repairs report
IZPG	Fuel consumption report
IZPKB	Budget revenue receipts report
IZPOS	Business and Employment Report
IZPPK	Report on total revenues from the sale of tickets
IZPPT	Report on the consumption of PTT impulses
IZPR	Company report
IZPZ	Report on salaries and employees
IZR	Work report
IZSK	Report on warehouse capacities in the economy
IZT	Technical Report
IZTP	Report on the work of the technical inspection
KVP	Tickets and securities
LZ	Personal responsibility
N	Commands
NR	Orders
O	Decisions
OD	Answers
OL	Bill of lading
OP	Realized income
OPK	Calculation of sold tickets
OT	Notices
PGO	Vacation Plan
PK	Login failure
PL	Plans

Tag	*Meaning of tag*
PM	Receiving material
PN	Travel orders
PON	Offers
POS	Call from court
POV	Reports of materials
PP	Payroll
PR	Projects
PRD	Transmitters of materials
PRG	Complaints
PRJ	Suggestions
PRO	Prospectuses
PRS	Verdict
PS	Letters
RA	Accounts
REK	Complaints
RJ	Solutions
RL	Worksheets
RN	Work orders
SEP	Traffic and Exploitation Indicators
ŠR	Schemes of work
ŠS	Scheme of service
TD	Technical documentation
TŽ	The lawsuit
UG	Contracts
UR	Entry of goods
ZA	Conclusions
ZAP	Nullity record
ZB	Buffet charge
ZN	Request for Procurement
ZP	Requests for an offer
ZPK	Record of receipt of tickets
ZSP	Request for an official trip
ZT	Debt collection
ZŠ	Charging the bar

3.4 Process organization and digital transformation of company management in passenger transport

In the conditions of global competition in the passenger transport market, companies can achieve a competitive advantage only by offering cheaper and quality transport services, and in order to realize these goals, efficient and innovative business processes are needed. Research has shown that the successful implementation of business change projects is of great importance for the application of appropriate software tools for modeling business processes and business process management.

The development of an integral business process model enables documentation, analysis, standardization and improvement of business processes. By integrating organizational knowledge (business rules, procedures, norms and best practices) into the business process model, a knowledge foundation is created as the basis for developing an enterprise knowledge management system.

Businesses in passenger transport operating in the open market in the European Union, or in cities in which the European Union's directives and rules seek to apply, should also adopt a sufficiently applicable concept of business process orientation.

The process orientation model that can be applied in business process modeling consists of three variables and fifteen elements.

Table 2 – Operationalization of enterprise process orientation model

Variable	*Element*
Process aspect	An average employee sees business as a series of related processes.
	The organization often uses terms such as: process, input, output from process (output, result), and process owner.
	Processes within the organization are defined and documented with clearly defined inputs / outputs for customers and suppliers.
	Business processes are defined so that most employees understand how they are taking place.
	Business intelligence is based on processes (not on business functions).
Workplaces	Jobs require the issuance of a large number of multidimensional (complex) tasks.
	Employees can independently solve problems at the workplace.
	Due to ongoing process changes, employees must continuously learn.
Management and process measurement	In the company we measure the efficiency (time, costs ...) of business processes.
	Process efficiency measures are defined.
	Resources are distributed depending on processes (not business functions).
	Concrete targets have been set for individual process efficiency measures.
	In the company, we measure the quality of the output (s) of the process.
	Online data quality control in processes has been established.
	The flow of information through the process is smooth and efficient (for example, it does not require a multiplex input of the same data).

Generally speaking, all business process modeling tools generate business process folders that display events (user-to-customer service, customer-service payment), activity (customer order-customer service processing, invoice-issuance of transportation maps), and conditions (waiting for a customer to serve, waiting for delivery).

Throughout the process, information (data) and processes take part in the resources.

The methodological concept of the software tool determines the process (phases, steps) of the project implementation.

4. DIGITAL TRANSFORMATION OF COMPANY MANAGEMENT IN THE PASSENGER TRANSPORT

The digital transformation of the company's management of passenger transport should be strategically positioned in the development of public companies (issues of joint development, ODVAS work framework - Open -Dital-Virtual-Agile-Smart):

- Owners of enterprise and management take special responsibility for exploiting the potential of digital technologies;
- With current operations, it is important to set up smaller organizational units that will, through experiments, explore and encourage / create product and process innovation;
- In the digital transformation, the transformation of cooperation in ecosystems (the environment of enterprises);
- The typical model of cooperation should be TripleHelix: economy-university-government;
- The digital transformation working frame should include: Open-Digital-Virtual-Agile-Smart (ODVAS work frame).

Of key importance for the digital transformation of process management in a passenger transport company is the management of various communication networks such as the Internet, mobile networks of all generations (GSM, GPRS, EDGE, UMTS, LTE), computer networks, etc. Since equally important is the digital transformation of the operation of communication operators in the focus, they must also have the knowledge needed to manage the quality of networks and processes in communications, such as managing customer relations through sales, marketing and support.

With the use of digital technology in the passenger transport company, the way to connect service users and businesses needs to change with the goal of establishing two-way communication. In this way, an economic effect is achieved by reducing the cost of collecting and distributing information.

The data storage system should be based on cloud computing.

The digital strategy of the company should be applied to all digital initiatives:

- Collecting all the necessary information,
- Planning,
- Identifying risks and chances,
- Maintain digital strategy and
- Creating sub-strategies (digital marketing, mobile business, web strategy, customer relationship management (CRM) and others.

5. EXPECTED CONTRIBUTIONS OF DIGITAL TRANSFORMATION BY MANAGEMENT TRANSPORT OF PASSENGERS TO THE CITY

Many innovations in transport and telecommunications have been proposed over the past century. These include new technologies, new ways of organizing and new ways to manage those systems. All in all, the innovations that have been adopted have changed the way in which we conduct our business, as the costs and efforts associated with overcoming the distance are reduced. However, many additional options have been proposed, but they have never been adopted, or have been adopted only in very limited and altered form. In some cases, many were expected from the inauguration, and were first adopted and later abandoned, [8]. Due to the conclusion that certain innovations have been adopted and others are not necessary, it is also necessary to determine realistic expectations in this case.

The expected strategic contribution to the digital transformation of enterprise management in the carriage of passengers and business operations can be achieved, first of all, through:

- Development and use of the system in the environment
- Development and use of virtual systems
- Continuous improvement of service user experience
- Support innovation and experimentation
- Securing digital networking and managing digital channels
- Securing cyber security
- Development of e-services, interoperability, standards
- KET technologies (robots, drones, artificial intelligence, 3D printing, energystorage ...).

6. CONCLUSION

The digital transformation of the company's business in the transport of passengers becomes an integral part of modern business. The success of the implementation of digital transformation of business becomes the measure of the general business success of the company in the transport of passengers and is in function of the dynamics of the transformation of digital technologies of communication operators.

In passenger transport companies, especially for the transport of passengers in the city area, a significant number of processes take place on the basis of or programs designed for the needs of the company, and their fate does not depend on their efficiency, but also on the connection with other levels of management, in which the decisive role have communication operators.

In a business environment, which is obviously and inevitably globalized, dynamic and highly competitive, the strategic approach to digital transformation of business in the sector is almost the only way to complete the processes of digital transformation of the company's business in passenger transport in order to bring positive business movements. Improving business performance should be seen through quantitative business success indicators, but also through qualitative, extremely important features of the company, such as innovation, creativity and the ability of the company to develop.

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MATEA MIKULČIĆ, Ph.D. student[1]
E-mail: matea.mikulcic@fpz.hr
TOMISLAV JOSIP MLINARIĆ, Ph.D.[1]
E-mail: tmlinaric@fpz.hr
MIA VIDUKA MILAS, Ph.D. student[2]
E-mail: mia.viduka@altpro.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] Altpro d.o.o.
Velika cesta 41, 10020 Zagreb, Croatia

NEW SPECIFIC TRANSMISSION DEVICE FOR PROVIDING THE REQUIRED SAFETY LEVEL BETWEEN ETCS AND INDUSI TECHNOLOGY

ABSTRACT

INDUSI technology is one of the most widely used types of train protection. By replacing INDUSI and other national protection systems with the ETCS (European Train Control System) across the world over the last decade, there has been a need to design a solution that would connect those systems in the upcoming migration period. For this purpose, an STM (Specific transmission module) has been developed that allows the traffic of existing and new trains on sections with and without ETCS equipment. This paper aims to extend existing knowledge of STM technology by presenting the development and main features of a new AP STM device from Altpro, and to give a comparison with similar solutions from other manufacturers. All the necessary data has been collected from previous research, during the development of AP STM and from official publicly available documentation from other manufacturers. However, observed constraints in the form of accuracy, detail and confidentiality of collected data impose caution when interpreting this analysis. The emergence of a new AP STM solution for INDUSI and ETCS compatibility will certainly contribute positively through increased interoperability of national and international trains, strengthening the supply market and expanding its applicability to existing and emerging markets.

KEY WORDS

PZB STM development; railway interoperability; train protection system; ERTMS; PZB 90;

1. INTRODUCTION

After introduction and review of previous research, the second section of this paper gives a brief overview of selected methodology for gathering information and conducting this research. It also combines the initial stages of new AP STM (Specific transmission module) development for PZB 90 (germ. Punktförmige Zugbeeinflussung) protection technology. Third one describes the most important characteristics of the AP STM solution and its integration with the rolling stock. This section also gives a comparison of new AP STM solution with the existing solutions for this type of train protection system. The fourth section contains discussion on obtained results. Overall conclusions are drawn in the final section.

1.1 Wider context of research

Safety is given special attention in all modes of passenger and freight transport, so it is also in the railway transport. Railway accidents often cause significant human and material damage. Therefore, the high level of safety is ensured by signalling and train control systems, and as such, their task must

be unquestionable. During the last few decades there has been migration from numerous and mutually incompatible national train protection systems in Europe to a single ERTMS/ETCS (European Rail Traffic Management System, European Train Control System). The trackside part of the system [1] can be installed as an overlay to an existing signalling system or as a single system on the new lines. The onboard part of ETCS in the vehicle exchanges information continuously with trackside part of the system and timely informs the driver through the cab signalling, supervising the maximum speed allowed for operation.

Complexity of the ERTMS/ECTS system [2] depicts the fact that its application is divided into four different levels and that there are several technical baselines of the ERTMS software (System Requirements Specifications) due to constant improvement of technology. Also, the interactions between individual onboard parts of ETCS equipment, and those between vehicle and trackside equipment are standardised. From the possible ERTMS levels, in this paper ERTMS/ETCS Level NTC (National Train Control) or Level STM is specially considered. In the literature [1] this application level is characterised by an environment in which ETCS equipped trains operate on a line equipped with a national control technology using the standardized STM device. Trackside part of the national protection system i.e. signals and train detection devices, generate information essential for train movement, and STM device transmits that information to the train in an understandable form for the ETCS vehicle equipment. STM is extremely useful in the temporary conditions of partial rail equipment with ERTMS/ETCS, to allow safe and interoperable traffic on the rest of the network with the national protection system as well as in international traffic. Within the next few years, STM technology is likely to become as important as the ERTMS system since it is difficult to precisely predict when a complete switchover to the ERTMS system will be achieved.

1.2 Previous research

Ever since the ERTMS/ETCS system installation started across the European railway network, there was a need to explore the possibilities of migration from national protection and signalling systems. Still, only few researchers have addressed these issues. Obrenovic et al. [3] in their paper gave an overview on general opportunities and threats of migration, considering heterogeneity of train control systems, and technical and operational constraints. Lackhove et al. [4] explored migration strategies in more detail. They presented the method for evaluation and optimization of migration strategies from different perspectives (the infrastructure, the vehicle, the integrated point of view) and for easier stakeholder negotiations. However, these papers do not go into deeper analysis that would involve the relevant vehicle migration within the anticipated strategies, primarily on the application of the STM technology.

There are more industrial studies on this subject than scientific ones. First reports are related to the development and emergence of new STMs from different manufacturers and national various protection systems. In that context Nordmann [5] mentioned STM solution while was describing development of the Bombardier's dual-concept platform product with basic PZB and LZB systems (germ. Linienförmige Zugbeeinflussung). Another version of STM from Bombardier Transportation was adjusted for specific Netherlands automatic train protection. Its development, functions and testing was described in [6]. Witt [7] also presented the objectives and the installation of the EBI Cab 500 PZB solutions. On the other side, Löwe [8] emphasised in his paper structure of PZB solution from Siemens together with possible upgrading options. Similarly, the optimal migration to ETCS focusing on different solutions provided by Siemens is explored in [9]. All the above-mentioned papers explain in more or less detail the development, functionality or ability of applying the appropriate STM within a certain platform for one or more train protection systems, but also have a common limitation on the point of view only from the aspect of one of the manufacturers.

Apart from the STM solutions of the mentioned manufacturers, a new AP STM solution will be available soon on the market for the PZB/INDUSI train protection system. For this reason, it is necessary to explore more in detail what impact this will have. However, this paper does not impose a

choice of specific solution from any supplier but provides the full range of available options in the field of STM technology that links the incompatible existing PZB/INDUSI and not so far ERTMS/ETCS technology.

2. METHODOLOGY

In order to conduct all relevant information about STM technology, analytical and descriptive approaches were applied. The findings in this paper are based on data obtained within performed researches of new AP STM solution whose development is still in progress, international data obtained directly from competent organizations, manufacturers officiant and publicly available documentation, and data linked with already implemented STM solutions for PZB 90 protection technology at various rail carriers.

PZB 90, like his predecessor INDUSI, is train protection system with inductive transmission of data between line and the vehicle used in traditional signalling [1,10]. Thanks to reliability, simplicity, efficiency in stopping trains and financial accessibility, INDUSI is one of the most frequently used systems in Europe. It is applied in Austria, Germany, Croatia, Slovenia, Romania, Serbia, Bosnia and Herzegovina, Montenegro, Macedonia and Israel at line length in total of more than 70 000 km [1,10,11]. The whole system is consisted from the three different balises along the right side of the line, and two locomotive balises (for both directions) and central unit for processing the information onboard. Those three balises (magnets) are associated with distant signals in the braking distance to the main signal. Activated trackside magnet transmits the information of the signal aspect to the train's central unit over the locomotive balise. That information is therefore transmitted in one point, unlike the ETCS system where it is transmitted continuously. According to this information, driver response and awareness, train emergency braking is introduced when the speed is exceeded. Those protection systems ensure safe and functional operation of the railway traffic at a maximum of 160 km/h. According to the National Implementation Plan for ERTMS in Austria [12], as one of the most representative user of the INDUSI system, complete decommissioning of PZB system is expected for the second half of the 2030s.

Descriptive and quantitative data were collected during the 14 months long first phase of the industrial research for the development of the AP STM prototype. A great majority of work on the STM concept was done in the development area of the firm Altpro, while other studies were carried out within the Department of Railways at Faculty of Transport and Traffic Sciences, University of Zagreb.

Obtained data are result of the following implemented activities [13]:

- Identification of potential markets and areas of application at the European and world level,
- Formulating a technological concept (defined technical specifications and the selected technology platform),
- Experimentally proving and evaluating the technological feasibility of the concept, and
- Validating the integrated AP STM prototype in the laboratory.

A technology platform for the new STM device is a precondition for the development and integration of individual modules into the entire system. Based on analysis between concentrated central system and distributed system with a central unit, the second system topology was chosen. When selecting the appropriate technology platform for the new STM device, the following advantages of this distributed concept were considered [13]:

- Distinctly separated modules with a clearly defined interface, for easier implementation and testing of individual modules,
- Easy upgrade of individual modules,
- Failure of an individual module does not affect other components in the system,
- Simpler integration on traction vehicles, and
- Flexibility and modularity of the whole system.

However, since the evolvent of this new AP STM solution is still ongoing project in the second phase of experimental development, there are no definite measurable indicators and majority of the explicit information is not permitted to publish in the exact form out of respect for the company's trade secrets.

While conducting the necessary information regarding STM solutions from other manufacturers, only solutions from those manufacturers that are known to enable the connection between PZB and ETCS technology were considered. However, most available materials have a common informational character with insufficient facts for carrying out a detailed comparison planned for this article. For this reason, certain simplifications were applied.

Gained information from the whole research was processed through inductive content analysis to identify important features of new AP STM solution and to determine similarities and differences with other considered solutions through examination, data reduction and comparison.

3. RESULTS

Given the large number of existing incompatible national protection systems, each combination of national track devices requires a special configuration of STM device, adapted to the requirements of the associated protection system. It is already known that Altpro has the appropriate knowledge of basic INDUSI functions and the necessary experience in production of INDUSI autostop system type RAS 8385 onboard and trackside parts [11] to engage in further development of train protection technology and design. This has significantly contributed to the accelerated development in the field of control technology. The current result of development research at Altpro is prototype of a solution for efficient unification of independent automatic stop system with PZB 90 functionality and AP STM module for connection with ETCS technology. In this way the final AP STM specification platform will be able to work with all INDUSI systems around the world through simple configuration of the device according to specific customer requirements.

3.1 Automatic stop system with PZB 90 functionality

ATPS RAS 90 (Automatic train protection system) is an INDUSI system designed to have PZB 90 functionality. This system consists from central unit and peripheral units. Central unit [14] has five basic modules with the possibility for additional extensions (i.e. STM Com module) in a single 19-inch rack. Within it, the central processing module is fully configurable and fitted with operating system with PZB 90 and/or other specific functionality. It basically allows measurement of the vehicle's speed, display of the current speed, control of a braking system, managing other ATP subsystems, recording system statuses and respecting the functionality of the PZB system.

Peripheral units [14] are cabin DMI (Driver Machine Interface) for interfacing between driver and ATP, locomotive balises, braking unit, pressure sensors, GPS (Global positioning system) module and speed sensor. Those units may vary in number and type of devices (sensors, indicators, screens, relays, valves etc.). Due to simpler and more reliable interchange with reduced cabling on the vehicle, they are connected to central unit over appropriate CAN (Controller Area Network) bus connection.

As already known, to manage transitions from ETCS equipped lines to the lines with INDUSI protection technology during train operation, ETCS onboard systems relies on integrated STM technology. Once integrated in the vehicle, new ATPS RAS 90 system [14] will receive impacts from INDUSI trackside balises through locomotive balise, while simultaneously tracking and calculating speed recorded by its own odometry and computing the distance passed by default curve parameters. According to received signalling data, selected driving mode, current speed, speed gradient, travelled distance and driver response, ATPS RAS 90 will initiate emergency and service brake according to the PZB 90 algorithm and functionalities. This will prevent and reduce a material damage and human casualties due to improper handling of the train drivers. In case of any disturbance or failure, the

system will report this condition and activate the brakes as a precondition for bringing the vehicle into a safe state, i.e. stop the vehicle.

3.2 AP STM Com module

As previously mentioned, AP STM module is a second part of Altpro's modular designed autostop system. AP STM module [15] enables connection between ETCS onboard units and national PZB/INDUSI based rolling stock equipment for integrated and dynamic transitions between both systems. The STM unit reads data from the existing trackside INDUSI equipment and converts it into a format that is transmittable to the ETCS onboard system. The integration of AP STM as a part of Altpro's autostop system solution in ETCS environment is shown on Figure 1. STM Com module is magenta coloured. The INDUSI system indications can be integrated on the same DMI (Driver Machine Interface) as for ETCS system. In the same way it is possible to provide the signalling data from the INDUSI system to the driver. The data entry procedure is also shared to avoid the multiple entries and therefore potential error introduction by the driver.

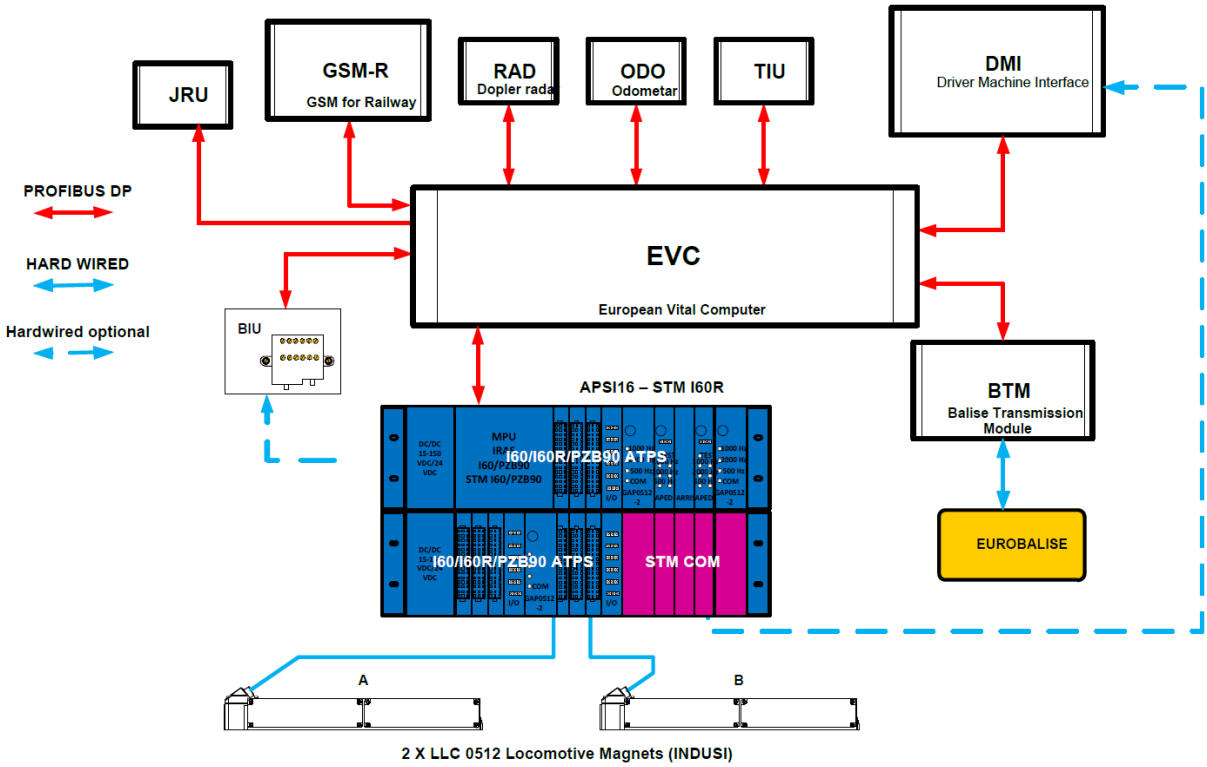


Figure 1 – Block diagram of AP STM solution in ETCS environment
Source: [15]

The ETCS guidelines, standards and FFFIS (Form Fit Functional Interface Specification) requirements for technical interoperability have been applied through the development of AP STM solution [15]. For digital communication between decentralized periphery in the field (i.e. AP STM device, JRU (Juridical Recording Unit), TIU (Train Interface Unit), etc.) and process control system EVC (European Vital Computer), PROFIBUS DP type of protocol is used as a worldwide standard. This way the subsystems from different suppliers can communicate mutually if they meet the same requirements and are physically connected to a single bus. AP STM supports the FFFIS Subset 035 baseline 2 communication interface and the set of protocols in Table 1.

Table 1 – Implemented UNISIG FFFIS layers

UNISIG FFFIS layers	
Safe Time Layer	Subset 056
Safe Link Layer	Subset 057
Redundancy Supervisor	Subset 057
Application layer	Subset 058
Fieldbus Data Link Layer	Profibus EN 50170
Physical Layer Driver & Control	Profibus EN 50170
Physical Layer	Profibus EN 50170

Source: [15]

Standard EN 50128 for functional safety is followed for software design and implementation, while AP STM hardware is designed per safety standards EN 50129 and implemented as a single PCBA (Printed circuit board assembly) [15]. So-called two out of two (2oo2) architecture was chosen for AP STM, thus enabling SIL4 (Safety integrity level) conformance. That means that there are two identical mirror sub-systems implementing the same features and operating at the same time while cross-checking each other. Both sub-systems must be operating and producing the same results for system to operate. Otherwise safety functions are activated for ensuring the highest level of system safety. By analysing available solutions, SoC (System-on-Chip) platform from disclosed manufacturer was selected as the optimal for base. CAN bus functionality is implemented on those cores and offers redundant autostop system's internal communication. This further improves system reliability.

3.3 Other INDUSI STM solutions

As reported [9], integration of conventional train protection system to the EVC is possible in several ways. Although, there are also solutions where, for example the STM is embedded in the ERTMS/ETCS equipment (internal STM) and other ways, the preferred solution is to merge the STM via standardized PROFIBUS to EVC, i.e. via the external STM. According to the statistics in Figure 2 carried out by European Union Agency for Railways [16] on ERTMS constituents supply market in Europe for 2018, there are four suppliers when it comes to the interface of external STM. It is noted that ERTMS suppliers do not necessarily produce some of these ERTMS products themselves, and those products could also be obtained from a third-party producer. However, it is not known whether this applies to the considered category of external STM. Regardless of the different suppliers of STM solution, the technical interoperability of onboard equipment via STM interface and trackside equipment in the different existing and new lines is ensured by FFFIS and SRS requirements.

Only STM solutions of those manufacturers that are known to enable the connection between PZB 90 and ETCS technology were considered in this paper. For example, Hitachi Rail STS, a recently renamed Swedish company Ansaldo STS, has supplied onboard automatic train protection systems manly in the Nordic countries (Sweden, Norway and Finland), so their STM solution was not included in the performed analysis [17].

Since there are no many publicly available data with detailed characteristics of an individual STM solutions, those solutions that were dealt with in the literature review and introductory part of this paper have been considered. To be more precise, the Trainguard platform from Siemens and EBI Cab platform from Bombardier Transportation were selected. Both manufacturers have long experience in the field of train protection offering different solutions for the ETCS migration.

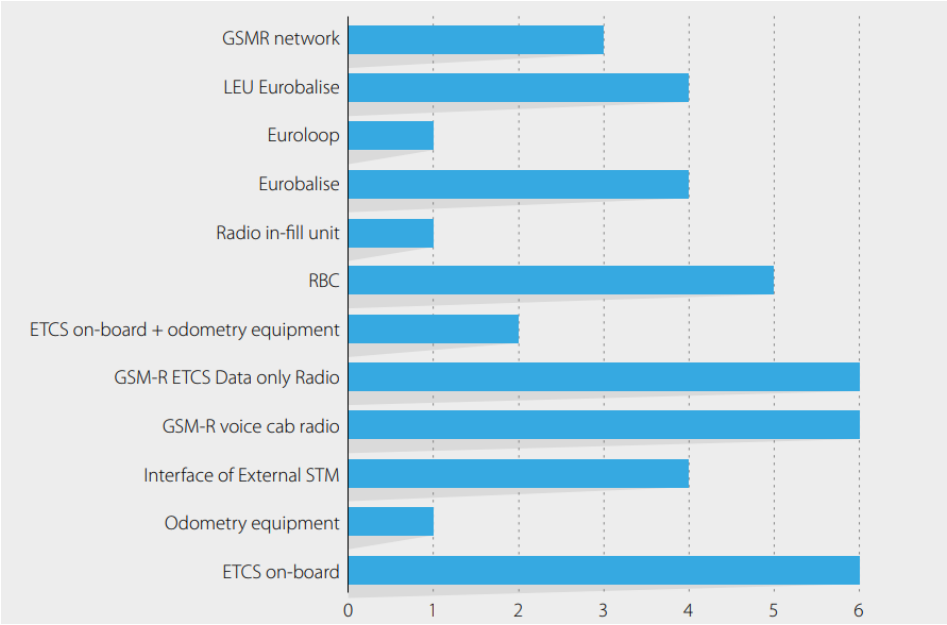


Figure 2 – Number of suppliers within ERTMS constituents supply market in Europe, 2018
Source: [16]

Trainguard Basic Indusi [8,9] has a modular structure based on the Secure Microcomputer System from Siemens' Train Control Computer platform with high reliability and complete PZB 90 functionality. It is characterized by the ability to convert into an ETCS onboard equipment with integrated INDUSI/PZB 90 functionality (onboard computer based on the EVC, DMI and data recorder upgradable to the JRU) by expansion of the boards and peripheral elements and updating the software. It has MVB (Multifunction vehicle bus) control technology and 2oo2 architecture in a 19 -inch rack with six unit's height. There are two types of Trainguard Basic Indusi [18], a classic and standard version, with a difference of the standard version being easier to upgrade to ETCS. In combination with PZB module a Semi-STM can be formed, which can also be used as a stand-alone system. By replacing the MVB with a Profibus, standardized PZB STM can be used in combination with Trainguard 200 Bi, which has the ETCS Level 2 functionality achievable.

INTERFLO is a platform-independent solution from Bombardier Transportation which comes in few versions, i.e. INTERFLO 250, 450 and 550 [19]. Those versions are specially designed to allow train traffic on secondary and regional lines and high speed and commuter lines for three ERTMS levels (Level 1, Level 2 and Level 3). There are also EBI Cab 500 and EBI Cab 2000, where EBI Cab 500 has a PZB functionality, a possibility of stand-alone, and it is used on the lines with the PZB 90 train protection. An EBI Cab [5] distributed onboard platform is main part of the INTERFLO system based on the ETCS architecture. By integration of the national ATP systems into the ETCS based architecture, the equipment size and final costs are reduced [20]. This is particularly related to installation and maintenance costs. The main part of the INTERFLO system interfaces to the national ATP antennae via STM. Communication between the PZB STM and other train control components is via an FFFIS compliant Profibus interface. In the vehicle, all components of the EBI Cab 500 [7] are contained in one 19 - inch rack inside a lockable control cabinet. Modularity of the components with MVB technology allows easier upgrade and adaptation to different customer requirements.

4. DISCUSSION

Currently, there is a relatively limited number of external STM technology providers on the market. Based on experience of the conducted research development of the AP STM prototype, such number is probably associated with the complexity of the entire manufacturing process which is quite timely and financially demanding. Development of new onboard components for train protection depends

heavily on financial capabilities and experience of the manufacturer, the size and requirements of the selected control technology market, the planned life expectancy of the protection system, and the size and age of the fleet for which compatibility with ETCS is required.

Similar to surveyed manufacturers, Siemens and Bombardier Transportation [7,9], Altpro's AP STM solution is based on previous experience in working with control and protection technologies, mostly INDUSI/PZB technology. This is important because knowing the functionality of the basic INDUSI system makes it easier to upgrade to a higher level. Despite the nationwide deployment of ERTMS/ETCS, the assumption is that INDUSI will continue to be used for a longer period of time, since it is a widely applicable system with longevity of existence. As such, it will exist as long as both all INDUSI equipped traction vehicles and railway lines are fully upgraded to ETCS. Financial constraint was not specifically mentioned in the paper so far, but it also additionally contributes to the uncertainties for the implementation of ERTMS equipment. This essentially affects all ERTMS/ETCS implementation projects in Europe and the world, which are consequently at different stages. During that migration phase, STM technology has the crucial role for smooth transition between old and future train protection system, enabling existing and new vehicles to operate on ERTMS equipped network as well as on lines with classic train protection solution. This type of technology should be more explored in scientific papers.

Unfortunately, in this paper it was not possible to deeper investigate the similarities and differences between AP STM solution and PZB STM solutions from other manufacturers as expected. Firstly, it could not be clearly defined from the information on their official pages and materials whether they produce an external or internal type of STM solution. Secondly, some of the data on STM solutions from Siemens and Bombardier Transportation were taken from the older literature. Therefore, the results and their interpretation mentioned in the following analysis should be taken with caution, since it is possible that over the years there have been changes due to the advancement of technology and hence changes in the presented STM solutions. In fact, research in this paper cannot give a detailed comparison between considered STM devices at the structure level due to lack of enough detailed technical data on the structure of the STM device from Bombardier Transportation and Siemens, as well as respecting Altpro’s trade secrets in the case of AP STM device. Accordingly, there is certainly room for improvement.

Despite those limitations, the most important findings mentioned in this paper are associated with features and development process of new AP STM prototype for INDUSI and ETCS compatible train protection by Altpro. Comparison of presented PZB STM solutions can be performed at the application level. All explored solutions meet the requirements for technical interoperability and include the functionality of PZB 90 technology with the ability to upgrade and adapt to specific requirements. Likewise, they have ability to stand alone, but are largely dependent on the remaining onboard equipment offered by their manufacturer. When used, all considered solutions will provide level of supervision similar to the one achieved by the original INDUSI/PZB protection system, which means they will affect the train speed profile according to signal aspect and if necessary emergency stop it. In that case, the integrity of the train will depend on INDUSI train detection equipment, without interfering with the ETCS equipment. However, all discussed solutions may differ in the selection and performance of the modules used either separately or jointly with ETCS equipment (e.g. the same DMI as for ETCS system or additional) and the rest which is not defined by FFFIS requirements or some other specifications. In addition, the assumption is that these solutions also differ in the final price.

5. CONCLUSION

Overall observations indicate that a considerable time will pass before ETCS becomes the only train protection system in Europe and the world. During that time, auxiliary ways of connecting ERTMS/ETCS technology and other incompatible national train protection technologies are coming to the fore, and in particular the STM technology. However, the present findings of this paper indicate inadequate

engagement with this topic in the scientific field, so further studies will need to be undertaken to improve existing knowledge.

Within this paper, significant insights have been gained in the field of STM technology for ETCS and INDUSI train protection system. A prototype of new AP STM device from Altpro was presented and compared with several similar solutions from other manufacturers. After being tested and verified, this solution will improve interoperability by providing national technical requirements and operating rules through the application of independent automatic stop system with PZB 90 functionality and AP STM module for connection with ETCS technology. Its importance is also manifested at the market level. More STM solutions on the market will contribute to lower costs per unit, and thus result in wider availability. In that case, the target market for this solution does not necessarily have to be limited only to the countries and bigger railway undertakings that have been using the INDUSI protection technology for years but may also be expanded to those countries and small railway undertakings that still do not have right solution for safe and reliable train protection.

Despite the fact that there are limitations due to accuracy, detail and confidentiality of collected data, some similarities and differences between research solutions can still be highlighted. For example, increased interoperability and safety of national rail systems, joint progress of transport services towards modern ETCS control technology and wider use of signal-safety devices in the railway traffic. In any case, the overall conclusion is still incomplete and requires further investigation.

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ANESA MUMINOVIĆ, student[1]
E-mail: mannix9575@gmail.com
IGOR GROFELNIK, teaching assistant[2]
E-mail: igor.grofelnik@um.si
MATEVZ OBRECHT, assistant professor[2]
E-mail: matevz.obrecht@um.si
MATJAZ KNEZ, associate professor[2]
E-mail: matjaz.knez@um.si
[1] University of Rijeka
Faculty of Maritime Studies
Studentska ulica 2, 51000 Rijeka, Croatia
[2] University of Maribor
Faculty of Logistics
Mariborska cesta 7, 3000 Celje, Slovenia

KEY FACTORS INFLUENCING CONSUMERS' WILLINGNESS TO PURCHASE ELECTRIC VEHICLES: A STUDY OF CROATIA

ABSTRACT

Development of electric vehicles is nowadays the most dynamic and developing technological innovation in both private and freight transportation. Research (interpreted further in the paper) showed that some of the key aspects of the dynamic development of electric vehicles includes the operational costs of electric vehicles and the impact of using electric vehicles on environment. This research demonstrates a study that is designed to help understand how people's future car buying decisions are made and how government policies can help influence the purchase of electric vehicles in Republic of Croatia. The survey includes almost 500 participants to identify the most important parameters of consumer behavior related to purchase of electric vehicles. The survey includes different factors, such as financial and technical aspects, environmental performance and vehicle design. Results have revealed that the most relevant factor for purchasing electric vehicles is total vehicle price, and that the segment of potential electric vehicles buyers is much larger than we initially anticipated. Such vehicles are more attractive for the younger generation, according to our results.

KEY WORDS

Electric vehicles; purchasing behaviour; decision factors;

1. INTRODUCTION

Transport has a direct impact on the environment and at the same time it is very dependent on it. Transport physically impacts the environment by causing changes in both nature and people. One of the biggest polluting factors is road transport and due to this fact, one of the more important questions becomes how to limit its environmental impact. According to Anzek & Uzelac [1] almost 9/10 of the total number of the population lives today in the cities, and there is a tendency that this figure will grow. Parallel with the increase in the number of inhabitants, the level of motorization is increasing as well, and this causes numerous problems related to the traffic in cities.

Road transport is responsible for almost 72% of total greenhouse gas emissions in the EU in 2016 [2] and such a big energy consumption impacts on climate change and highly affects ecosystems, the economy, human health and wellbeing. Greenhouse gas emission is a problem of common concern to everyone, which requires a global response, to limit the risks and impacts of climate change. World

Health Organization has estimated that each year, more than 7 million premature deaths can be attributed to the combined effects of outdoor and indoor air pollution [3].

Health effects of pollution are vast and complex. Strong effects of pollution on health are shown in city environments due to heavy transport. Solid particles in the air and harmful emissions are harming many people. 90 percent of EU citizens are exposed to harmful effects of dust particles, ozone, nitrous oxide and other dangerous organic chemicals. Exposure causes acute health problems. The mortality rate has risen due to increasing amounts of dust particles; newer studies also alert to the effects of sulphur dioxide and smoke emissions [4]. Exhaust emissions also contain carcinogenic particles, which have further effect on mortality rates. From the facts we can conclude that the effects of transport present a very high risk for environment as well as the health of general population. It is imperative to increase the awareness about emissions in order to make reasonable decisions [5]. That is why alternative transportation technologies and alternative fuels are reliable and the best long-term solution to these problems.

Emissions from conventional internal combustion based vehicles are one of the key air polluting factors. For example, US transport sector in produces over 1.5 billion metric tons of CO2, or roughly one third of the total greenhouse gas emissions in the United States [6]. By European Environment Agency data, in the EU in 1990 oil consumption in the transport sector took 98% of the total use of fuel in the transport, and in 2016 usage of oil was 94%. Given data shows that oil consumption in transport sector in the EU has minorly reduced (comparing 1990 and 2016), but the dependency on oil in 2016 is still very high at rate of 94% as compared to 1990 at rate of 98% [7]. Gonzalez et. al. [8] mean that transport is a key sector for the proposal of strategies to curb the upward trend in CO2 emissions in Europe. The share of CO2 emissions emanating from the transport sector has risen in from 32% in 1990 to 45% in 2015. Road transport accounts for 92% of CO2 emissions from the transport sector, and between 1990 and 2015 CO2 emissions from cars accounted for half of the road transport emissions. We can say with certainty that fossil fuels are the major energy source that are being used in road transport today which leads to serious environmental issues such as air pollution and greenhouse emission. It is a well-known fact that fossil fuels release carbon dioxide, nitrogen dioxide, sulphur dioxide, carbon monoxide and other gases, and when they are burnt, they leave severe aftereffects on the biosphere. Fossil fuels are non-renewable sources of energy as they are derived from pre-historic fossils and won't be available once they are fully used. Their sources are limited, and they are disappearing at a fast rate. According to Eurostat, Report on - Oil and petroleum products [7] crude oil and petroleum products have the highest share of energy consumption in the EU which makes the EU the world's second largest producer of petroleum products after the United States.

Traditional economic development was based on unfettered economic growth and it has degraded the environment and depleted natural resources. So it is necessary to find alternative development paths and changing human behaviour [9]. In the last few years the awareness of climate change has been gradually increasing within the governments and general public globally, resulting in the commitment of most countries to cut their emissions to a certain level [10]. The EU showed a strong willingness to fight climate change and reduce greenhouse emissions and is a huge supporter for the development of sustainable energy. Over the years, the EU generated various conventions, strategies and plans on how to fight climate change. Some of them are The Paris Agreement, European 20-20-20 Targets, EU proposal – 2030 climate & energy package, EU plan for a competitive low-carbon economy by 2050, and other plans and strategies that are being developed for each individual country in the EU.

The main objectives for all strategies and conventions is to limit global warming below 2°C, reduce greenhouse gas emissions (GHG) by 20%, raising the share of EU energy consumption produced from renewable resources to 20% and improving EU's energy efficiency also by 20% by 2020. Also, they have three key targets for the year 2030: at least 40% cuts in GHG emissions (from 1990 levels), at least 27% share for renewable energy and at least 27% improvement in energy efficiency [11].

It is presumed that two key factors will cause major transition of the transportation sector: the accessible availability of alternative energy sources and the negative effects of transportation on the environment. Limited fossil fuel supplies are running out fast and demand is only increasing, which is why the alternative and renewable energy resources are the key answer to reduce dependence on fossil fuel and to lower impact on the environment. By using renewable energy sources, dependence on fossil fuel gas and oil reserves would reduce, which means that the rising cost of energy bills will be avoided, and energy security will be improved.

As road transport being the biggest contributor to GHG emissions in the EU, different policies are being suggested to decrease the amount of harmful GHG emission. Most cities suggest and encourage their citizens to decrease the usage of personal transport and to increase the usage of public transport and the use of bicycles. However, most consumers are not inclined to let go their primary means of transportation, mainly because of strong feelings of convenience and independence associated with car use [12]. Problem of GHG emissions produced by traffic has also forced the implementation of new urgent measures intended to protect their citizens, applying new driving restrictions, regulations and banning most pollutant internal combustion engine vehicles when air quality reaches unacceptable levels of toxicity [13].

By European Environment Agency data, road transport was responsible for almost 72% of total GHG emissions in 2016 and of these emissions, 44% were contributed by passenger cars, while 19% came from heavy-duty vehicle [2]. Knowing this information, it is therefore essential to promote environmentally friendly alternatives (AFVs). Vehicles that run on alternative fuels such as liquefied petroleum gas (LPG), compressed natural gas (CNG), biofuels, and hydrogen and drive trains such as electric vehicles (EVs), hybrid electric vehicles (HEVs), and hydrogen fuel cell vehicles (HFCVs) offer an attractive solution for the reduction of the environmental impact of personal transportation [14]. Investments in alternative fuel vehicles (AFV) are therefore highly important since they cause less pollution; enable the use of local resources; lower import dependency; and increase EU competitiveness at the same time. European citizens and companies need a steady and reliable supply of energy at affordable prices in order to maintain their living standards. At the same time, the negative effects of energy use, particularly fossil fuels, on the environment must be reduced [15].

Since potential demand, consumers' wishes, preferences and decision factors are highly important for all car brands and car dealers offering AFVs, these factors have already been studied under very different conceptual frameworks and methodologies, with the main purpose of finding the right leverage to encourage demand for AFVs. However, understanding of consumer preferences is also important for policy decision-makers since they are responsible for long-term development of the transportation sector and infrastructure related to AFVs. Technological forecasts based on AFV-related research are also crucial for top managers of industry-leading car makers, who are to steer the automotive industry towards a transition to a more sustainable future [12].

To assess the economic value created through environmental investments, the Japanese Ministry of Economy, Trade and Industry [16] established a method for capital investment into environmentally friendly facilities. They recommend comparing alternatives that incorporate not only the economic assessment, such as net present value, but also the environmentally harmful substance reduction benefits such as GHG reduction. Managers then must make a decision based on both financial value and physical value. The first challenge is how to create corporate value from environmental impact reduction. Lyon and Maxwell [17] argue that corporations can differentiate their products by improving their environmental qualities and thereby charge a higher price; and that green investors may be an increasingly important factor in determining corporate environmental activity. Fairchild [18] uses a game-theory approach to demonstrate that the investment cost and the extent of consumer and investor green awareness affect corporate incentives to make environmental investments. Machlachlan and Gardner [19] point out some important differences between socially responsible and conventional investors in terms of their beliefs, the importance they ascribe to ethical issues, their investment decision-making style and their perceptions of moral intensity. Kokubu [20]

suggests that green stakeholders, such as green consumers, consider the environmental impacts of purchased products, and green investors appreciate corporate action and corporate policies toward environmental conservation, and will accept additional cost and investment in environmental conservation if this is justified by the reduction of environmental impact. The implication of the above-mentioned studies is that value from environmental investments can be created by attracting green consumers who are willing to pay a product price premium, and by attracting green investors who are willing to pay a share price premium. Green stakeholders, such as green consumers and green investors, accept the price premium equivalent to the economic value of environmental impact reduction [21].

Another factor worth mentioning is exploitation of EV's in private sectors, by so-called households. Study performed by Ulmer et al. [22] found that costs are more important than environmental benefits when purchasing ethanol-fuelled cars. Golob and Gould [23] also made a survey about personal vehicle trials and found out that people would choose EV on the basis of very low running costs rather than environmental benefit. Oil price is also an important factor for commercialization of alternative fuels. Popp et al. [24] found that relative fuel prices are of great importance when choosing a new car. Importance of fuel economy is even higher in case of an increased belief in the ability to positively influence the environment. O'Garra et al. [25] for example noted that key determinant of acceptability of hydrogen vehicles is high prior awareness of the existence of hydrogen fuel, which is in turn related to gender, age, education and environmental knowledge. Similar research with similar results was carried out by Thesen and Langhelle [21].

Looking at Croatians neighbours, all of them started investing in usage and promotion of electric vehicles as a plan to fight climate change and reduction of GHG emission in Europe. In 2016 Hungarian government subsidized the sale of electric cars in Hungary at a cost of 2 billion HUF (EUR 6.45 million) and the government dedicated to developing e-mobility and they are estimating that nearly 30,000 electric vehicles will be used in Hungary by 2020 [26]. Federation of Bosnia and Herzegovina unfortunately doesn't offer any incentives for imports of electric vehicles. Having in mind BiH's obligations under European energy and pollution prevention directives, including global trends in the automotive industry, they must initiate broad public debates on possible legislative changes in transport sector. In June 2018, Minister of Foreign Trade and Economic Relations of Bosnia and Herzegovina has met with representatives of the Federation of BiH Chamber of Commerce to discuss an initiative to reduce taxation and improve the regulatory framework for imports of new and electric vehicles [27]. In 2017, Republic of Serbia started the introduction of incentives for the use of electric vehicles. In 2018, a study was started with a proposal of optimal solutions, which would serve as a basis for a draft of regulations with 2019 as the deadline [28]. The data for complete results still needs to be processed. In Montenegro, there are only 74 registered electric vehicles. Montenegro government offers certain tax reliefs for eco-friendly cars: when registering the electric vehicle in Montenegro, buyers don't have to pay a passenger car taxation ranging from EUR 25 to EUR 1,500, but the country lacks in the charging points. There are only 6 charging points in total and they're part of hotels, and some charge €5/per hour [26]. As for Republic of Slovenia, they are being a great example for Balkan countries. In 2016 the project for the construction of fast charging stations network on the motorway was finished. It includes 28 quick charging stations, which makes Slovenia one of the best-covered countries within the European Union. Also, there was an eco-fund established for the purpose of establishing and promoting electric mobility. As the result of this measure, there was an increase in sales of electric vehicles, with 75% more e-vehicles sold in 2016 than in previous years. Besides that, Government of Slovenia has also prepared a strategy and an action plan to promote the use of alternative fuels, which will include measures to further promote e-mobility. Also, in 2017, Minister of Public Administration, minister of Infrastructure and co-founder of Avant Car signed the agreement on the electric vehicles sharing through the Avant2Go service for the needs of the state administration. With this pilot project, Slovenia positioned itself as one of the first countries in the world introducing modern services resulting from the sharing economic business model [29]. Avant2Go had one-year trial, and at the end of 2018 Avant2Go shared their positive results: in only

one year, in the capital of Slovenia (Ljubljana) there 45 different take-back stations, they record the growth in usage of car sharing, total of 3 million of non-emission kilometers and a new electric car has been introduced - Smart (Fortwo) [30].On the following Figure 1. we can see the number of registered electric and hybrid vehicles from 2007 to 2018.

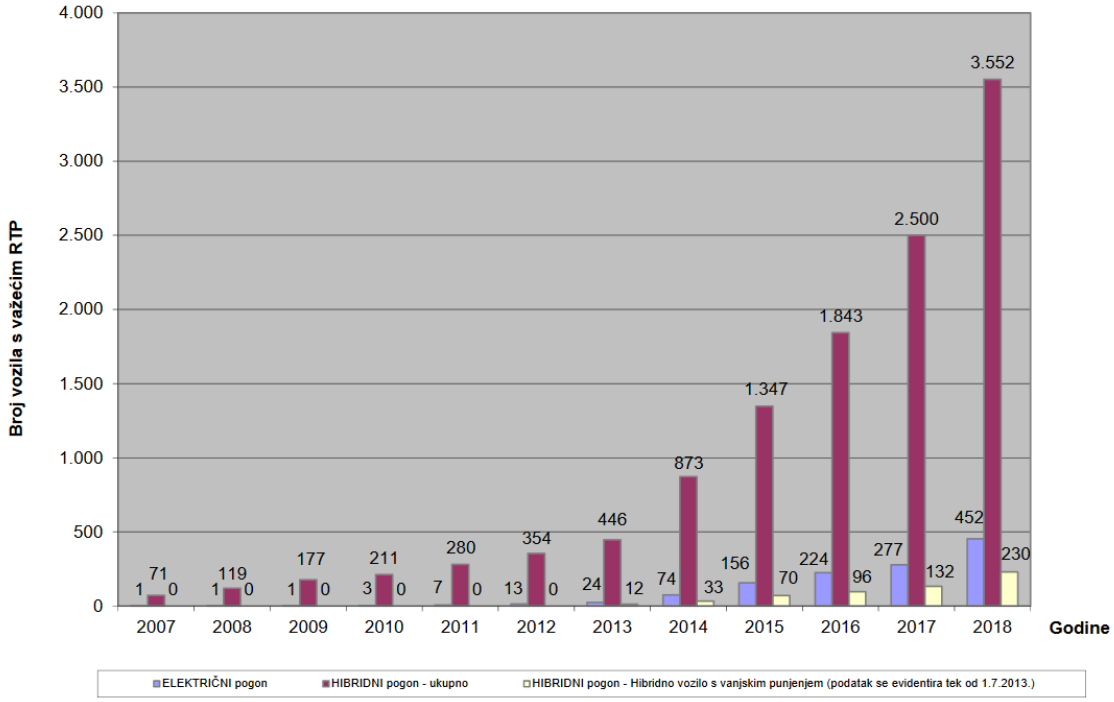


Figure 1 – Vehicles with electric and hybrid drive [31]

On 25th of April 2018, The Fund for Environmental Protection and Energy Efficiency of Croatia, opened a public call for co-financing purchase of eco vehicles. 12 million of Croatian kuna (EUR 1.6 mil) was at disposition for co-financing electric bikes, electric scooters, motorcycles and quadricycles, plug-in hybrids and electric cars. Co-financing for the purchase of eco vehicles was up to 40% of the cost of the car. Just a day later, on 26th April, the Director of Fund had to close the call because already the limit for requests have been achieved within the available amount. Such a big interest for purchase of electric vehicles shows that Croatian citizens follow the world's trend that go in the direction of the greater use of electric vehicles.

2. METHODOLOGY

The study presented in this paper is a research study. Collected data consists of primary and secondary data. For the primary data collection, a pre-structured survey from Borthwick and Carreno [32] (Table 1.) was modified and distributed in Croatia. Research was done from January to February in 2019. The survey was distributed only over the Internet. The participants were able to discontinue the survey at any time.

The study presented in this paper is a research study. Research was done from January to February in 2018. Collected data consists of primary and secondary data. For the primary data collection, a pre-structured questionnaire from Borthwick and Carreno [32]. was modified and distributed in Croatia. In this part of the paper, partial results are presented which provides answers to the research questions and testify to consumer attitude toward development of electro mobility. The population of this survey are households that currently own a vehicle, and people who currently do not own a car or do not have daily access to a car when they require it. Focus group of study was adults. The sample

includes 466 participants whose current opinion about relevant vehicle performance aspects and financial factors for vehicle purchasing decisions was studied.

Survey was started by 677 participants but was completed by 466 participants, which is why different data will be shown in study.

Among study participants, 80% (523 out of 657) currently own a car or have access to it as they require it, and only 20% (134 out of 657) currently do not own or have daily access to a car as they require it. Considering Croatian demography with more women than men, 76% of participants were women and 24% were men.

In terms of age structure, there was the largest representation of consumers aged up to 24-years-old (344 participants, 51%) and 25 - 34-years-old (161 participants, 24%).

The collected data was processed and analysed with statistical software SPSS. K-Means Cluster Analysis was used for data classification which was carried out by separating the data into groups. To facilitate data analysis, Principle Component Factor Analysis was employed to reduce the number of situational variables, which resulted in 7 broad factors as presented in Table 1.

Table 1 – Situational factors of importance in a future vehicle purchasing decision by Borthwick and Carreno [32].

Factors	**Attributes**
Financial considerations at the time of purchase	Vehicle price VAT and other purchase taxes Value for money
Future financial considerations	Insurance group for vehicle Maintenance/repair costs Warranty (length and coverage) Biannual/annual VED Trade-in value
Fuel and performance	Fuel consumption (miles per gallon/kilometers per liter) Engine type/size Fuel type Fuel economy Performance/drivability
Exterior design features	Vehicle make Model of vehicle Vehicle size Style/appearance/color
Interior design features	Safety features Security features Equipment levels Entertainment system Acceleration time
Load space	Luggage/storage space Passenger capacity Body shape
Environmental considerations	Emissions of CO2 and other greenhouse gases Emissions of other air pollutants Vehicle noise

Secondary data was collected with compilation method from various scientific and professional papers, researches and project reports focused on the research topic at hand.

There were also some limitations to the study, such as a limited time frame and subjectivity of peoples' personal opinions which can be dynamic and can vary through time. Another limitation is the statistical sample which may not actually represent the whole population.

Secondary data was collected from various scientific and professional papers, researches and project reports focused on the research topic at hand.

In this part of the paper, partial results are presented which provides answers to the research questions and testify to consumer attitude toward development of electromobility. The population of this survey are households that currently own a vehicle, and people who currently do not own a car or do not have daily access to a car when they require it. Focus group of study was adults. The sample includes 466 participants whose current opinion about relevant vehicle performance aspects and financial factors for vehicle purchasing decisions was studied.

Survey was started by 677 participants but completed by 466 participants, which is why different data will be shown in study.

Among study participants, 80% (523 out of 657) currently own a car or have access to it as they require it, and only 20% (134 out of 657) currently do not own or have daily access to a car as they require it. Considering Croatian demography with more women than men, 76% of participants were women and 24% were men.

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The collected data was processed and analysed with statistical software SPSS. K-Means Cluster Analysis was used for data classification which was carried out by separating the data into groups. To facilitate data analysis, Principle Component Factor Analysis was employed to reduce the number of situational variables, which resulted in 7 broad factors as presented in Table 2.

Table 2 - Survey - following factors/questions:

Factors	**Attributes**
Vehicle aspects of the future car	Entertainment system Overall condition of vehicle (if you buy a used car) Safety features Luggage space Engine type/engine power Body shape Gear box (manual/automatic) Mileage (if you buy a used car) Fuel consumption (km's per liter) Acceleration Vehicle size Vehicle capacity (no. of seats) Brand name Vehicle Model Overall equipment Style/appearance/color
Future financial considerations	Maintenance/repair costs Insurance Finance deals (credit option) Value for money Annual road tax Fuel economy Trade-in value Warranty (length and coverage) Height rate VAT and other purchase taxes The overall value of car
Environmental considerations	Emission of CO2 and other GHG Emission of other gasses Vehicle noise
Participants attitude toward buying an EV	I would feel good if I would buy an electric car. Because of my own principles and beliefs, I do not feel obliged to buy an electric car. People who drive cars that are emitting a large amount of exhaust gases greatly contribute to creating the greenhouse effect. I would feel bad if in the future I do not buy an electric car. Electric cars are more expensive than other types of cars. In the future, I intend to buy an electric car. Most people would support my decision to buy an electric car.

	I am not interested in buying an electric car. It would be very difficult for me to buy an electric car. I do not feel any personal responsibility for reducing GHG emissions associated with cars.
Consideration to buy EV if fuel price increase	0%, +10%, +20%, +30%, +40%, +50%, +60% More than 60%
Consideration to buy EV if EV price decrease	0%, 5%, 10%, 15%, 20%, 25%, 30% More than 30.
Influential measures to be in the future	The VAT rate would depend on the degree of GHG emissions (the owners of cars with higher gas emissions would pay higher VAT). Introducing the Support Fund to purchase EV's where payments would depend on the degree of GHG emissions (owners of cars with higher gas emissions would pay more). The price for car registration would depend on the degree of GHG emissions (owners of cars with higher gas emissions would pay more). The Government would provide additional funds for all car owners, where an old car would be replaced with a new, lower-emission gas car. The introduction of environmental tax that would depend on the level of GHG emissions (owners of cars with higher gas emissions should pay a higher environmental tax). The height of the parking tickets would depend on the degree of GHG emissions (the owners of low-emission cars would pay a smaller toll). Introducing a separate driving line for low-emission vehicles (e.g. public buses driving line, taxi driving line, etc.)
Age	16 to 24 years 25 to 34 years 35 to 44 years 45 to 59 years 60 to 74 years 75 years or greater
Gender	Male Female
Residence:	Zagrebačka, Krapinsko-Zagorska, Sisačka, Karlovačka, Varaždinska, Koprivničko-Križevačka, Bjelovarsko-Moslavačka, Primorsko-Goranska, Ličko-Senjska, Virovitičko-Podravska, Požeško-Slavonska, Brodsko-Posavska, Zadarsko-Kninska, Osječko-Baranjska, Šibenska, Vukovarsko-Srijemska, Splitsko-Dalmatinska, Istarska, Dubrovačko-Neretvanska, Međimurska, City Zagreb

There were also some limitations to the study, such as a limited time frame and subjectivity of peoples' personal opinions which can be dynamic and can vary through time.

3. RESULTS AND DISCUSSION

The study was designed to reveal the factors that affect the purchasing habits of people in Croatia regarding to electric vehicles. The results reveal new perspective of buyers, and indicate which factors are the most important for the purchase of electric vehicles.

Results showed that two non-financial factors are crucial when deciding on a car purchase:

1. ''overall condition (when buying a used car)''and
2. "fuel consumption (km/l)".

Other very important factors are:

1. "safety features (air-bag, immobilizer, alarm)",
2. "mileage of vehicle (when buying a used car)",
3. "body shape (e.g. hatchback, coupe, etc.)",
4. "vehicle size (exterior)",
5. "passenger capacity",
6. "engine type/engine power",
7. "style/appearance/color",
8. "entertainment equipment" and "luggage space".

Said factors with average scores (in %) are presented on Figure 2.

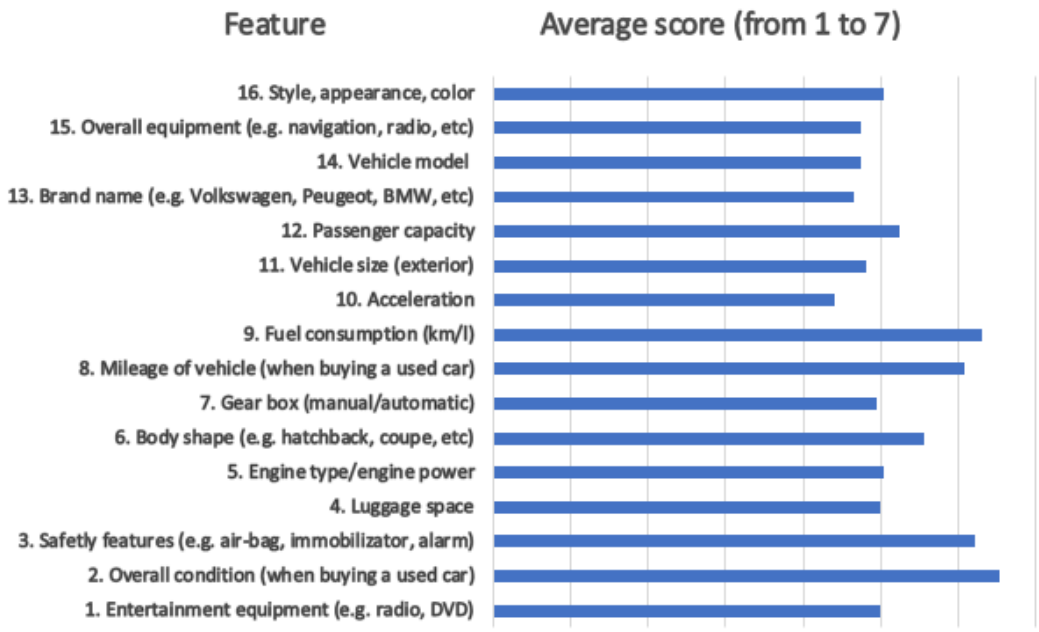


Figure 2 – Important vehicle performance factors (on a scale from 1 to 7 where 1 means NOT IMPORTANT and 7 means VERY IMPORTANT).

When looking at financial features, participants voted that the most important factor seems to be "the ratio between value and quality (when buying a vehicle)". Second feature, also very important, is "the total price of the vehicle".

People also put emphasis on "maintenance and repair costs", and "fuel economy". Two less important features are "insurance costs" and "VAT and other taxes connected when buying a vehicle". Results are presented in Figure 3.

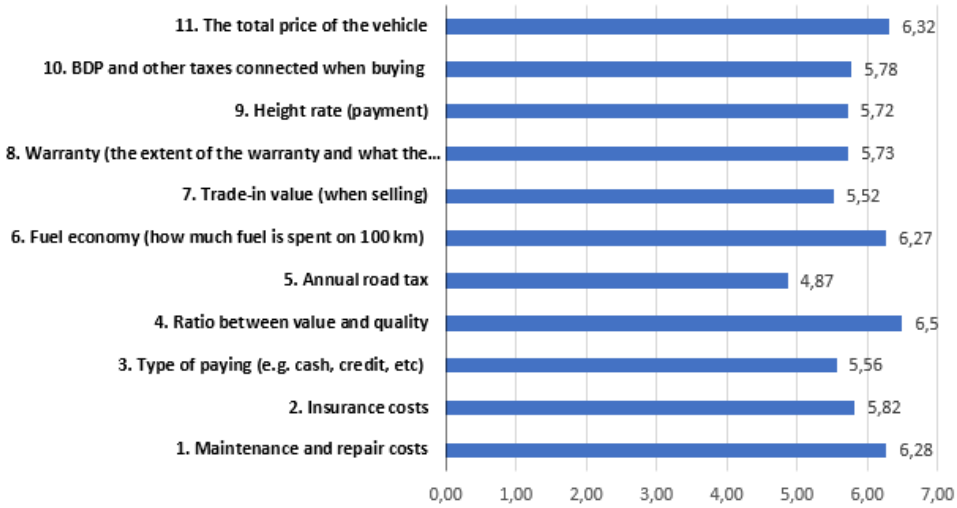


Figure 3 – Important financial considerations (on a scale from 1 to 7 where 1 means NOT IMPORTANT and 7 means VERY IMPORTANT)

A survey by Lane and Banks [33] identifies fuel economy as one of the most important car purchase factors. Other two most important purchasing factors were size/practicality and vehicle price. When it comes to fuel economy, buyer's primary concern is the size of running cost rather than concern about the environment. Even when a person is "green oriented", lower carbon emissions are often taken as a bonus after the main objective of lower running costs has been secured. Carbon emissions and environmental awareness mostly do not have influence on car choice. Vehicle owners are aware of carbon emissions only if carbon emissions are tied to road taxes, and few car owners can give correct information about carbon emissions for their recently purchased vehicle [21].

When asked at which increase of fuel prices (in %) participants would consider buying an electric vehicle:

- 19,6% would consider if prices rise +30%.
- 17% of participants would consider buying an electric vehicle if prices rise +50% and
- 15% of participants would consider if prices would not rise AT ALL.

Results are presented in Figure 4.

Furthermore, participants were asked about importance of characteristics of vehicles that affect on environment (on a scale from 1 to 7 where 1 means NOT IMPORTANT and 7 means VERY IMPORTANT):

1. Average grade of "Emission of CO2 and other gases that affect the GHG effect" has a score of importance of 5.04.
2. "Other gasses" has importance of 4.9, and
3. "Noise/sound of vehicles" has a score of 5.2, making it the highest important environmental influence of vehicles.

Another key result of this research shows that when people are buying a car, they are more interested in the total price of the car than in the price of different taxes that are related when buying a car.

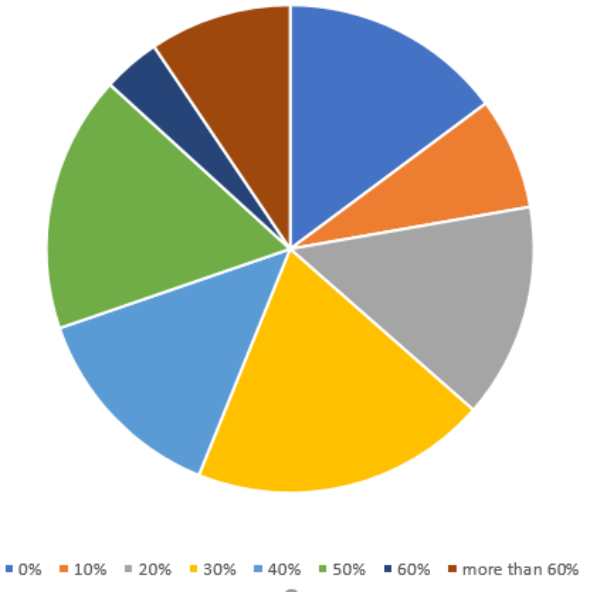


Figure 4 – Consideration to buy an electric vehicle if fuel price increase

When asked at which decrease of an electric vehicles price (in %) participants would consider to buy an EV:

- 6% of respondents are already thinking about buying an electric car despite their relatively high prices
- decrease by 10%, 2,4% of participants
- decrease by 25%, 11% of participants
- decrease by 30%, 20,4% of participants
- the highest result was if prices decrease by more than 30%, where 46% participants would be seriously think about purchasing an electric car.

Results are presented in Figure 5.

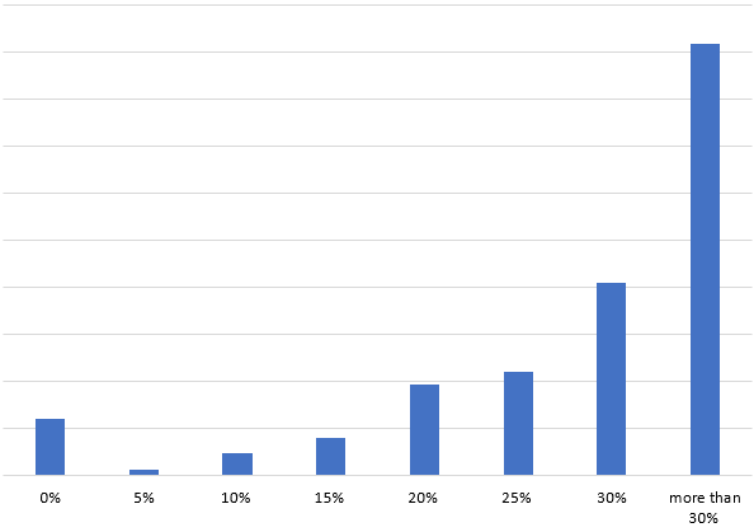


Figure 5 – Percentage of respondents seriously thinking about purchasing an electric vehicle dependent on potential price decrease of an electric vehicle

The study also included different influential measures, which would encourage customers to purchase electric vehicle. Participants chose which option/measure personally fits them better on a scale on a scale from 1 to 7. Results are presented in Table 3.

Table 3 – Influental measures which would encourage customers to start buying electric vehicle on a scale from 1 to 7 where 1 means NOT IMPORTANT and 7 means VERY IMPORTANT

Question		1 – not important	2	3	4	5	6	7 – very important	Average result
The VAT rate would depend on the degree of GHG emissions (the owners of cars with higher gas emissions would pay higher VAT).	number of participants	28	19	17	66	71	96	169	5.3
	% of participants	6%	4.1%	3.6%	14.2%	15.2%	20.6%	36.3%	
Introducing the Support Fund to purchase EV's where payments would depend on the degree of GHG emissions (owners of cars with higher gas emissions would pay more).	number of participants	24	16	20	63	85	92	166	5.4
	% of participants	5.1%	3.3%	4.3%	13.5%	18.2%	19.7%	35.6%	
The price for car registration would depend on the degree of GHG emissions (owners of cars with higher gas emissions would pay more).	number of participants	25	13	24	62	89	94	159	5.3
	% of participants	5.4%	2.8%	5.1%	13.3%	19.1%	10.2%	34.1%	
The Government would provide additional funds for all car owners, where an old car would be replaced with a new, lower-emission gas car.	number of participants	11	4	15	37	60	103	236	6
	% of participants	2.3%	0.9%	3.2%	8%	12.9%	22.1%	50.6%	
The introduction of environmental tax that would depend on the level of GHG emissions (owners of cars with higher gas emissions should pay a higher environmental tax).	number of participants	25;	17;	28;	68;	73;	101;	154;	5.3
	% of participants	5.4%	3.6%	6%	14.6%	15.7%	21.7%	33%	
The height of the parking tickets would depend on the degree of GHG emissions (the owners of low-emission cars would pay a smaller toll).	number of participants	62;	22;	35;	65;	68;	81;	133;	4.8
	% of participants	13.3%	4.7%	7.5%	14%	14.6%	17.4%	28.5%	
Introducing a separate driving line for low-emission vehicles (e.g. public buses driving line, taxi driving line, etc.)	number of participants	94;	46;	40;	71;	68;	49;	98;	4.1
	% of participants	20.2%	9.9%	8.6%	15.2%	14.6%	10.5%	21%	

When asked about attitude towards buying an electric vehicle:

- 52% of participants say that they would feel good if they would buy an electric vehicle
- 33.7% of participants think that people who drive cars with a great amount of exhaust gases greatly contribute to creating the GHG effect
- 23.4% of participants intend to buy an electric vehicle in the future
- 7.3% of participants don't feel any personal obligation to buy regarding to reduction of GHG emission connected with cars
- 31% of participants say that electric vehicles are not more expensive than other types of cars
- 7.7% think that they are more expensive than other types of cars.

Table 4 presents us average result of participants attitude toward buying an electric vehicle.

Table 4 - Participants attitude towards buying electric vehicles (on a scale from 1 to 7 where 1 means NOT IMPORTANT and 7 means VERY IMPORTANT)

Question	Average result
I would feel good if I would buy an electric car.	**5.8**
Because of my own principles and beliefs, I do not feel obliged to buy an electric car.	**3.4**
People who drive cars that are emitting a large amount of exhaust gases greatly contribute to creating the greenhouse effect.	**5.4**
I would feel bad if in the future I do not buy an electric car.	**4.3**
Electric cars are more expensive than other types of cars.	**5.2**
In the future, I intend to buy an electric car.	**4.9**
Most people would support my decision to buy an electric car.	**5.2**
I am not interested in buying an electric car.	**2.9**
It would be very difficult for me to buy an electric car.	**3.2**
I do not feel any personal responsibility for reducing greenhouse gas emissions associated with cars.	**2.9**

4. CONCLUSION

Nowadays people became dependent on a car in everyday situations. Driving to work, kids to school, shopping, visiting, travelling and other. The number of car owners is increasing every day because every person enjoys in the freedom to travel and comfort. This is the main reason why everyone wants to own their own car.

People love comfort and freedom while travelling. Having your own car means no need to be limited to fixed routes and timetables of buses, trains and other public means of transport. Having own car, people can do whatever they would like, from traveling alone or with someone, to listen to music they like, to fill the car with groceries, so kids could scream without worry to get judging looks from bystanders. Having own car means there is no need to be in a crowded public transport, with lots of people and sometimes no place to even sit.

Having so many cars, on our Planet, especially since most of the cars are fossil fuel-based, is destroying the environment. Non-renewable energy, global warming, air pollution, dust, noise, terrible effect on human health are just some of the disadvantages of fossil fuel-based cars.

That were the key factors to start inventing in more eco-friendly types of cars with less or zero C02 and other gas emission. Taken that in mind, over the last couple of years, the production of electric cars is getting bigger and cheaper and its predicted that they could soon reach the cost of conventional cars. Such a turn-around on the car market perfectly targets people who are thinking about getting an eco-friendly, electric car.

The main point of this research was to find out information to help understand how customer's future car buying decisions are made and how government policies can help influence the purchase of electric vehicles in Republic of Croatia.

80% of the participants already own a car or have one to use in everyday life.

Results revealed that that lots of participants actually already think about buying an electric vehicle, even although selling prices are currently higher than conventional fuel-based cars. If prices of electric vehicles would decrease (as expected) in the next few years, Croatian car market could be booming with purchase of electric vehicles due to big interest.

Beside decrease of electric vehicle prices, participants revealed that they would be interested to think of buying an electric vehicle if fuel price would increase by 30 to 60 percent.

Participants also expressed that if government would issue different EV related measures, like lower VAT rate, additional fund for replacing conventional car for an electric one, lower car registration for EVs, lower height of the parking ticket for EVs', they would most likely buy an electric car.

Having an electric car has its benefits, which are of high importance for buyers, when looking at financial and environmental side. From financial side, charging a car is free on all charging station in Croatia, and customers could also charge their car at home and work. Electric cars are much easier to repair and assemble since they have fewer moving parts which saves lots of costs on overall maintenance and repair. Government gives tax incentives, so the purchase of the brand-new car is easier. Also, some insurance companies offer cheaper car insurance if electric vehicle is bought.

Looking at environmental side, participants in survey voted that noise and sounds from car are the most important environmental influence and electric vehicles are almost silent, which is in today's era of high noise pollution, is very important. Overall results results gave a bright and positive direction for future of usage of electric vehicles in Croatia.

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DORIS NOVAK, Ph.D.[1]
E-mail: dnovak@fpz.hr
SORIN EUGEN ZAHARIA, Ph.D.[2]
E-mail: sorin.zaharia@gmail.com
MIRA PAVLINOVIĆ, Ph.D.[3]
E-mail: mzokic@fpz.hr
ROMAN ROMANOVIĆ, dipl. ing.[4]
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] Politehnica University of Bucharest
Splaiul Independenţei nr. 313, Sector 6, Bucharest, Romania
[3] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[4] Croatia Control Ltd
Rudolfa Fizira 2, 10410 Velika Gorica

RECOGNITION OF PRIOR LEARNING BASED ON COMPETENCE-BASED TRAINING IN AVIATION SECTOR

ABSTRACT

Higher education faces many challenges in the way of adapting to the labour market. In the aviation sector, the Competence-based training (CBT) concept and methodology has evolved over a long period of time to increase air traffic safety in all its segments. CBT is based on strictly prescribed standards in terms of theoretical knowledge and practical skills. These standards guarantee that the person can perform jobs prescribed by the workplace. This paper gives an overview of the concepts of recognition of prior learning (RPL) and CBT and proposes their inclusion in the higher education system. For this purpose, an example of ATCO training at the university level and the methodology used for RPL are presented.

KEY WORDS

recognition of prior learning, competence-based training, higher education

1. INTRODUCTION

The processes in society have greatly overcome the academic rigidity that is presently dominant in the higher education. The possibilities of on-line education today are easily assessable. Therefore, it is possible to obtain informal competences that are well-accepted in the labour market. Even though these opportunities are recognized, the academic community does not formally set out ways of recognizing such education in the absence of national regulations and other mechanisms that would provide universities with a safe entry into the process of recognition of competences acquired outside the higher education system.

Higher education is considered to be the basic instrument for stimulating competitiveness between individual regions and countries and has been identified as the central point for initiating changes that have encouraged transformations in the social, economic and cultural life of different countries [1]. At the turn of the 21st century, higher education, still regarded as the main innovator, underwent transformations in the direction of increased sensitivity to the needs of business environments. The 21st century marks the return to the development of the skills of future employees: such a view raises the possibility of focusing on the tertiary education system to meet the current needs of the economy. In a dynamic technological and economic environment, the need for lifelong education is increasingly emphasized. The rate of persons with higher education and increased mobility (geographical and

professional) among other things contributes to the development of societies. The new paradigms represent a major challenge for higher education institutions. Teaching aspect of higher education institutions should create favourable environment for the lifelong learning process and provide users with the necessary assistance during their lifetime. It is no longer enough to restructure curricula to meet the needs of the existing economic and social environment - simple adaptation of didactic forms will not be enough. It has become crucial to develop instruments of effective support for individual growth by opening up flexible and alternative pathways to personal development.

Depending on the reaction of universities to the increasingly complex and uncertain environment, European universities will fall into different categories. One of these categories, which is interesting for us, is the category of entrepreneurial universities that is characterised by a dynamic and interactive attitude towards the society. These universities are able to influence the environment to the same extent that the environment, in turn influences the environment. This is essential for the very complex aviation environment, in our case the process of knowledge and experience recognition. In this context, the systematic transfer of knowledge supplants the classical mission of research and education adding new missions: technology transfer, continuing education and adjustment to labour market demand [2].

An especially important qualitative leap is the abandonment of the idea that higher education degrees automatically guarantee high qualifications, which should enable the individual to achieve a lifelong professional success. The need for universities to become a part of the lifelong learning process is recognized in the Charter of Lifelong Learning, which was presented by the European University Association in the European Universities' Charter on Lifelong Learning in 2008 [3]. This document defines one of the basic ways of actively involving the university in lifelong learning concept - specifically by introducing the recognition of prior learning. In order to use all the potential and the benefits from higher education, it is essential for universities to develop systems to assess and recognize all forms of prior learning. This is particularly important in the context of lifelong learning in a global era where knowledge is acquired in many different forms and places [3].

There are many challenges ahead in reforming the education and training system, so that tomorrow's working population has needed skills and competences to meet labour market demands in a better way and to reduce unemployment. When analyzing the problems that employers encounter when they look for an adequately educated workforce, it should be pinpointed that the possession of skills represents the fourth factor/company growth risk and that 40% of employers in the EU do not find the employees they need until 27% of jobs remain vacant due to inadequate availability of potential employees on the labour market [4]. In a research conducted in the EU, knowledge-based learning (vocational education) has resulted in a reduced unemployment rate. Individuals who have completed vocational education find a job faster than those whose education is more general. Moreover, due to the digital revolution that has been incorporated into the education process, the generation Z has changed the attitude towards education. They have become the consumers of education who learn on the move (on the train, on the bus ...), outside the classroom and out of their homes. They do not refer to learning as a commitment but as an experiment. For entrepreneurial university it is a priority and a practice to respond to the challenges of society by creating new entrepreneurial academic structures as incubators, technology transfer centres, science parks and specialised department for lifelong learning [2]. By its proactive attitude, the entrepreneurial university is able to ensure an adequate response in terms of lifelong learning and learning outcomes for new jobs demanding new skills.

In the air transport sector, a highly regulated sector including very specific training institutions and comprising of a wide diversity of regulated occupations, which involve specific training and award of licenses, the development of university entrepreneurial attitude is very welcome for a better match between the labour market demand and the learning outcomes offered. Generally, but especially in aviation, training programs are distinguished by type, level and objectives of training. Hence, there is a need to determine very precisely the learning outcomes and to correlate them between the various

training options and to create also bridges between these training pathways. Recognition of competences and correlation of learning outcomes may provide support for designing coherent professional pathways and complementarity of general training in the aviation field, provided by high schools or universities and specific training for occupations in the sector.

When we refer to the air transportation, this subject does not follow the usual educational pattern due to the strict requirements of the industry which imposes the necessity of being licensed and certified in order to be able to work in such an environment. The major question arising is to what extent are universities capable of providing competent graduates ready for direct insertion in this highly regulated field of work? The following paragraph describes the main pathways for education and training.

There are two main pathways (*Figure 1*): the academic one, which consists in bachelor, master and doctorate study programs, which can be followed by or can alternate with postgraduate trainings; the vocational one, ensured by various training providers, such as airlines, handling companies, regulatory bodies, private trainers, in compliance with European Aviation Safety Agency (EASA) and International Civil Aviation Organization (ICAO) regulations. Our concern is to create as many bridges as possible between the two pathways [5].

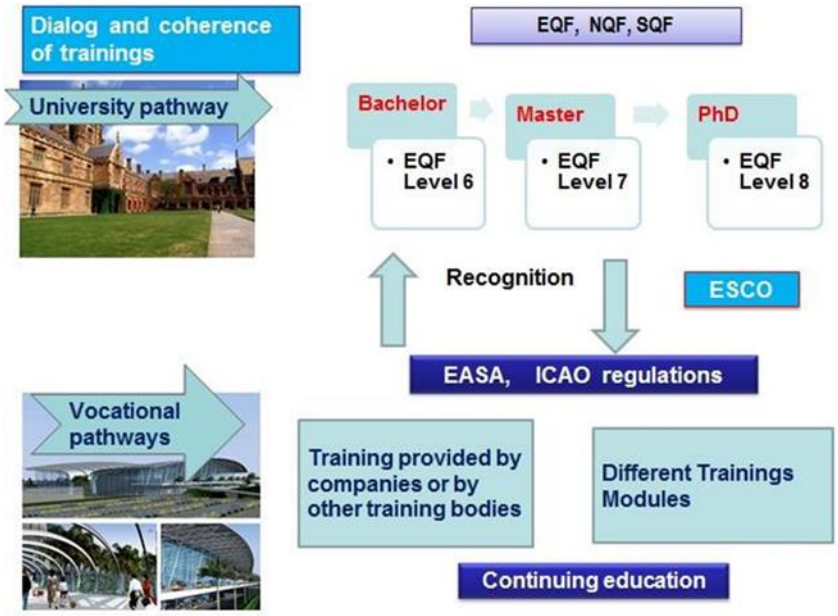


Figure 1 – Pathways for training in air transport
Source [3].

Connection with university pathway and EASA/ICAO regulations are trough EQF (European Qualification Framework), NQF (National Qualification Framework) and SQF (Sectoral Qualification Framework). Context of recognition of prior learning regarding those frameworks will be discussed in chapter 4.

2. RECOGNITION OF PRIOR LEARNING

Recognition of Prior Learning (RPL) includes evaluation of previously acquired learning outcomes and competences gained with previously acquired formal, non-formal and informal learning. Formal education or formal learning is defined as any institutional form of education, including practical training or qualification programs prescribed by law, necessary for the proper performance of a particular occupation.

University studies and programs are equally an integral part of formal education. Upon the completion of such education, a public document shall be issued stating that the holder has acquired certain qualification. Formal learning, which takes place in the educational institutions, is recognized by the national authorities, and as a result, diplomas, certificates and other form of public documents are issued. Formal learning framework is in accordance with educational regulations regarding teaching and other qualifications, or educational curricula.

The definition of non-formal learning encompasses all institutional forms of learning beyond the curriculum of education and training after which qualifications are acquired. Non-formal learning takes place outside formal learning environment but within some kind of organizational framework. It arises from learner's conscious decision to master a particular activity, skill or area of knowledge and is thus the result of intentional effort. But it does not need to follow a formal syllabus or be governed by an external accreditation and assessment [5]. It includes preschool education and postgraduate studies that enable the upgrading of knowledge within specific areas of education. Examples of this type of learning are training programs, programs funded by an employer who wants his employees to master new computer software, or courses for unemployed people who want to acquire / improve their knowledge in some areas, improving their position on the labour market. After such programs, no special qualifications or professional licenses are awarded, but their participants receive new information, deepen understanding of certain phenomena and shape their opinions and significantly develop other skills and abilities. A sum of completed training programs can result in acquisition of new competencies. For this reason, it is necessary to adequately formalize their recognition and evaluation. Non-formal learning is an addition to formal learning or to its alternative. For achieving this, it is necessary create a bond between a university policy and new academic structures, and practice and entrepreneurial management. The academic entrepreneurial structures as continuing education departments, technological parks or incubators offer to students an environment for non-formal learning by practical activities and direct application of knowledge leading to the achievement of new skills that facilitate the employability and flexibility on aviation labour market.

Informal learning refers to non-institutional learning, whether it takes place in a targeted or unintentional (unconscious) way. In a high technical society, there are many available information and knowledge resources that enable professional development for those interested. Informal learning takes place in everyday situations, in the family, in the workplace, in the community, or through the interests and private activities of individuals. It involves the acquisition of new competences beyond formal curricula conducted by an educational institution (without the help of lecturers / instructors / trainers), independently, with the aim of achieving specific learning outcomes and / or by involuntary (unconscious) learning. In some cases, informal learning uses the term experiential learning (which can be understood as practical, empirical learning), as it relates to acquiring knowledge through experience.

Recognition of pre-acquired sets or units of learning outcomes is a process recognizing the existence of units of learning outcomes in the register of national qualification's framework. This recognition is approved by a public document issued by an institution authorized to implement a program for acquiring or by an institution approved for evaluating sets of units of learning outcomes. Previously acquired unit of learning outcomes is the smallest unit of learning outcomes acquired by formal, non-formal and / or informal learning, and it is demonstrated in the evaluation process.

Validation of competencies previously acquired by formal, non-formal and informal learning (recognition of prior learning in a wider sense) is the process conducted according to the predefined and accepted criteria and standards and according to the national legislation. That criteria are defined by the relevant evaluation programs from the register that is a part of the national qualification framework. It also includes the procedures for issuing certificates of an authorized institution or organization which guarantee that they are able to perform the evaluation process and to possess the needed learning outcomes. The automatic recognition of previously achieved learning outcomes can also be carried out for learning outcomes that are not in the register of the national qualification

framework and are acquired through formal education and are proved by a public document issued by an authorized institution.

The program of validation of units of learning outcomes is a description of a standardized learning outcomes assessment process in relation to sets of learning outcomes and qualification standards from a national register. It outlines the learning outcomes, assessment methods, organization and duration of exams, the examiners, the insurance of the credibility of the valuation, etc. In many cases, the validation of acquired knowledge and experience is a mission of departments for continuously education working closely with stakeholders of the sector.

3. METHODS OF RPL

In order to enhance coherence of training in the air transport industry, a dialogue between university - trainer within the sector - employer is crucial for the joint development of tools defining learning outcomes for each training level, such as National Qualifications Framework (NQF), Sectoral Qualifications Framework (SQF) or other specific systems such as those used by Eurocontrol, Competence Based Assessment System (CBAS). The similarities of the two approaches, QF and CBAS consist in similarities in structure and descriptors of competences and in ways of achieving progression through qualifications levels. This theoretic attempt may be a first step towards highlighting the convergence between the two components, education and training, and it might lead to significant harmonization for the air transport field, a very interesting example due to the international standards and requirements strictly supervised by the international aviation bodies [6].

Although there are formal and extensive EU guidelines on setting up the valuation process associated with the NQF, some countries in Europe and around the world have put in place their practices and methods for supporting the evaluation. When analysing a broad spectrum of existing practices, three common valuation elements can be identified [7]. These are: identification, documentation and assessment of existing knowledge and skills and finally certification.

The identification process is most often supported by mentors / facilitators or other RPL experts whose task is to inform participants about the evaluation process, standards and documents that will be used within it. Through this process, the interested participant identifies the potential competences he possesses as well as the relevant evidence (i.e. previous achievements which are formally documented) if they exist. The process of identification is in most cases related to the desired qualification or to a set of integrated units of learning outcomes as participants tend to confirm the competences, they already possess in order to acquire specific qualification (either complete or partial) or to facilitate access to further education for the purpose of acquiring certain qualifications.

During the process of documenting, which is often accompanied by portfolio, all relevant formal and informal learning documents as well as relevant past achievements are gathered by a participant using a set of pre-defined relevant third-party standards, i.e. RPL providers.

The assessment process is critical to the evaluation because it uses the same standards for evaluating the competencies that an individual possesses according to a predefined learning outcomes list that are most often defined by the qualification standard. The recognition method can be divided into two groups: methods used to extract evidence and methods used to present evidence.

The two groups of methods are not clearly separated. It is sometimes difficult to classify other existing methods in one of these two groups. In order to get a better picture, the method of extracting evidence can be used to make individual competences visible, while other methods are used as an evidence of acquired competences. Cedefop's Glossary [6] provides a definition of the assessment process. It describes it as a process that includes all available methods to assess achievements of an individual or a group.

Based on the definition, one should be aware that there are different methods for determining the complexity and diversity of non-formal and informal learning. However, every available method should guarantee reliability, validity, fairness, the range of cognitive and practical skills and the appropriateness of purpose. To an RPL expert, the appropriateness of the purpose is the main factor when choosing among a variety of available methods. It helps to adjust the assessment method to the specific needs of the RPL candidate, while considering formal education requirements that could for example impose necessary set of integrated units of learning outcomes for specific qualifications and the technical limitations of such an approach.

For a better understanding of the difference between these two types of assessment methods, the quality of the evidence used during the evaluation should be emphasized. According to EU guidelines for evaluation of non-formal and informal learning, reliability, validity, authenticity and sufficiency are key elements of evaluating evidence [9].

An example of a good practice is France with a clear legislation for validation of knowledge and experience. Despite their good general experience, the validation is less efficient in aviation field.

4. COMPETENCE-BASED TRAINING

Concept of the Competence-Based Training (CBT) has been applied in aviation for several years. The concept and the methodology developed during the 1950s became a mainstream concept sometime in the 1980s [10]. The reason for applying this concept lies in the fact that a person who carries out certain tasks in aviation must meet strictly prescribed standards. Fulfilling these standards in terms of theoretical knowledge and practical skills is a prerequisite for person's licensing by a competent regulatory body, which guarantees that the person is able to perform jobs prescribed by the workplace.

The traditional way of training was based on the criterion of satisfying the minimum requirements for acquisition of certain knowledge, skills and attitudes, to achieve a certain qualification required for a license. This qualification can be in line with a formal assessment and validation process that is obtained when a competent body determines that the individual has achieved prescribed learning outcomes. This is the formal definition of qualification according to the European Qualification Framework or EQF [11]. CBT differs from the traditional way of training in a way that the individual possesses the necessary competences to safely, effectively and effectively perform assigned duties and responsibilities at the workplace. The CBT does not conceptually differ from the underlying EQF principle where a learning outcome is defined as a statement of what a learner knows, understands and is able to do upon the completion of a learning process. Learning outcomes are specified in three categories - as knowledge, skills and autonomy and responsibility [11]. This shows that qualifications - in different combinations – encompass a wide range of learning outcomes, including theoretical knowledge, practical and technical skills, and others. In Manual on Air Traffic Controller Competency-based Training and Assessment [12], ICAO defines knowledge, skills and attitude as follows:

- Knowledge: specific information required enabling a learner to develop and apply the skills and attitudes to recall facts, identify concepts, apply rules or principles, solve problems, and think creatively in working environment. Knowledge is an outcome of the learning process.
- Skill: an ability to perform an activity or action. It is often divided into three types: motor, cognitive and metacognitive skills. Skills are developed over time and with practice.
- Attitude: a continuous internal mental state or disposition that influences an individual's choice of personal action towards some object, person or event and that can be learned. Attitudes have affective components, cognitive aspects and behavioural consequences. To demonstrate the "right" attitude, a learner needs to know how to behave in a given context.

In this context competences are defined as a combination of skills, knowledge and attitudes required to perform a task to the prescribed standard. Standardization in aviation is of great

importance because it has a positive impact on the establishment and maintenance of a high-level uniform civil aviation safety. CBT actually enables that a person is trained and evaluated during a certain period (depending on the job he/she is trained for) in accordance with standards that define the levels of knowledge, skills and independence. The CBT and the assessment provide a clear picture what an individual can do (outcome of training), ensure that the prescribed standards are achieved and, what is very important for aviation, train people to know what should be done in their workplace.

Prior to the assessment, a candidate for CBT must undergo structured training to ensure that standards are achieved. These standards are defined as licenses, ratings or endorsements. Accordingly, training should be planned in such a way that the skills, knowledge and behaviours that are to be taught are elaborated in detail. In addition, the training plan should be structured in such a way to logically follow the training segments, explain the used methods and explain the way in which records will be kept. It is also necessary to elaborate how and when assessments should be performed. CBT Implementation Plans, that are structured in this way, should be supported by appropriate documentation and made available to training staff. Finally, the implementation of the plan must be monitored and controlled by responsible persons.

A person cannot be awarded an endorsement, a licence or a qualification unless the person is assessed in accordance with appropriate standards. In order to ensure the quality of the assessment, the set standards must be measurable, objective, valid, authentic, sufficient and current. Therefore, CBT and assessment procedures are the most important, rigorous and objective way of individual assessment in relation to the prescribed standard. Teaching methods may differ in different training organizations, but the final outcome must be that a trainee meets a consistent and appropriate standards and requirements.

Assessment is a process of comparing evidence of individual achievements with respect to the standard. According to [12], assessment means the evaluation of practical skills leading to the issue of the license, rating and / or endorsement (s) and their revalidation and / or renewal, including behaviour, and practical application of knowledge and understanding, being demonstrated by the person being evaluated.

Collecting evidence should be carried out according to established principles. This means that the evidence must cover all the performance criteria and knowledge of the standard being validated, that the evidence should be collected by the assessor (authenticity), sufficient evidence should be collected for establishing the competence of an individual and based on performance criteria and all aspects of competence (sufficiency).

5. RECOGNITION OF PRIOR LEARNING BASED ON COMPETENCE-BASED TRAINING

Competence-based training can be used for recognition of prior learning in higher education. In addition, the qualification awarded by a higher education institution can be used to acquire the appropriate license or authority. Furthermore, an example of the university study program of Aeronautics is the program at the Faculty of Transport and Traffic Sciences of the University of Zagreb, where undergraduate study module for professional (commercial) pilots is structured in a way to follow the theoretical knowledge prescribed by the Acceptable Means of Compliances and Guidance Material to PART-FCL [13]. All the subjects prescribed by this document are included in the study program, with additional courses in which engineering skills and knowledge are developed. The program is Level 5 according to EQF and carries 180 ECTS credits. Upon student's request, the CAA may verify the frozen ATPL endorsement in a way to recognise Faculty exams in terms of the required level of theoretical knowledge. This is allowed only if the institution (the faculty/the program) is approved by the Agency. It is important to emphasize that the subjects of the study program are carried out in a much larger extent than prescribed by the regulation. The same methodology applies to the undergraduate study of Aeronautics for the ATCO module.

Based on the RPL methodology, it is possible to grant certain endorsements or licenses to persons who intend to enrol into the study program (modules for commercial pilot or ATCO). Thus, the process of evaluating informal and non-formal learning for enrolment and continuation of studies in the undergraduate study program of aeronautics applies only to those candidates who have completed four-year high school education before 2010 and who have or have had an air traffic controller license or appropriate commercial pilot licences. Based on such license, it is considered that the candidate successfully completed informal education that was organized and structured outside of the higher education system and that he / she acquired the relevant informal education with the scope of work of the license as an air traffic controller.

Determination and documentation of evidence is carried out based on an ATCO license [14]. The licence, which is not valid at the time of submission, confirms that the candidate has successfully completed non-formal education outside the institution of higher education. It is also an evidence of the competences acquired by the candidate and is treated as evidence from work or the physical evidence from work related to targeted or specific outcomes. This is an evaluation method used to extract evidence. The ATCO licence is the proof that the candidate has successfully completed basic training, rating training, and unit training. Additional evidence suggests that the candidate has completed continuation training and development training. For candidates who meet the requirements for enrolment (having completed four-year high school education), an assessment is carried out. The methodology and process of evaluating non-formal and informal learning is based on the guidelines for the practical implementation of RPL, which include:

- Initial information, orientation and determination of evaluation purpose
- Determination and brief documentation of evidence of prior learning
- Usage of an appropriate evaluation method
- Interpretation of evidence and assessment of achieved learning outcomes

Under certain conditions, the Faculty allows exemptions, as an ATCO candidate is considered accredited by the evaluation process. The exception refers to a total of 19 subjects/courses. The methodology is also applicable to candidates with a professional pilot license.

6. CONCLUSION

This paper gives an overview of the concepts of recognition of prior learning and Competence-based training. Presentation and elaboration of RPL is illustrated by an example of aeronautics study program. Although in this case licensed air traffic controllers enrol at a higher education institution with appropriate license which is based on the CBT, the concept can be applied to other professions in aviation sector.

Higher education institutions conducting recognition of prior learning should establish special organizational units that coordinate RPL process and ensure the quality and consistency of applied procedures. A good environment for developing the recognition of experience and knowledge is the entrepreneurial university, which by its organisation is able to give an adequate response to aviation demands. Regardless of the different denominations of these units, which depend on the functions performed within the university, all units aim at a successful implementation of the process of recognition of prior learning. Significant changes in the methods and practices of learning that characterize the knowledge society have led to the process of learning being no longer equal with formal education as such. This is a great challenge for formal education and education policies, as they now need to adapt to lifelong learning policies. Most countries around the world introduce a qualification framework that defines learning processes through the learning outcomes gained during education and training. Universities also need to adapt to changes in the fundamental understanding of educational processes and policies. When the results of informal and non-formal learning are recognized as potential equivalents to formal learning outcomes, this means that higher education

institutions gain a new feature, and the recognition of prior learning gives them the ability to help individuals obtain formal confirmation of learning outcomes outside the formal education system.

Even a brief analysis of a competence development, regardless the one we choose from the EQF approach or from the CBAS approach, shall lead us to the conclusion that both approaches involve the "Matrioska" principle: each level of competence must integrate the previous level and lead to a higher competence, which would indicate the progress and development of trainees from one module to another, and from one level of qualification to another. This approach in the design and understanding of the qualification as a building built by competence bricks, creating trinomial structures such as awareness – self-control – development, is common to both approaches and it may be an important advantage for harmonising all types of diplomas and licenses.

A new feature is also the offer of a new type of educational service. These services are based on establishing (through clear evidence and procedures) whether and to what degree an adult who has not completed a formal education process has mastered the specific learning outcomes that are achieved in formal education. The results may relate to the different curricula, modules and study groups available at a university. In order to properly coordinate the implementation of these specific services in the area of lifelong learning, it is necessary to meet at least two conditions: the first one is to have a legislation for this validation of knowledge and experience achievement and the second is to build up specific organisation and rules for implementation of recognition. The EQF, ESCO and CBAS create the premises for the implementation of recognition of prior learning and of experience achievements but the national legislation is essential for recognition. Institutions usually establish special organizational units in charge of recognition of prior learning (recognition centres) or for the entire lifelong learning activities of the university. They are supervised at the university level. The experience of some countries suggests that the recognition centres are established by the decision of the university administration, or within other lifelong learning projects or the recognition of previous learning undertaken at an institution of higher education. The main reason for setting up a recognition centre is that it is easier to manage the procedures for recognition of prior learning within the university if there is a unit in charge of coordinating them. It is also important to provide the appropriate conditions for managing the process of securing recognition quality within the university / faculty itself. The process of recognition of prior learning in any higher education institution can be broken down into several basic roles. Terminology can be slightly different from institution to institution - faculties and universities. Roles in the recognition process can be divided into administrative ones (coordinator, committee), counselling (advisor for recognition) and academic-didactic nature (evaluator). Depending on the regulations of the institution, the process of recognition may be more centralized (when coordinators and advisors work in the recognition centre) or decentralized (when consulting and evaluation itself take place at a faculty, department or institute). Depending on the specific needs of an institution, it is necessary to decide where the organizational structure will accommodate the unit for recognition of the previous learning. The unit can be located at the central level of the university / faculty and answer to (for example) the part of the department responsible for the teaching process. The Recognition Centre can be a part of a larger structure, such as a unit responsible for lifelong learning processes (Lifelong Learning Centre).

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SAŠA PETAR, Ph.D.[1]
E-mail: sasa.petar@unin.hr
ANA GLOBOČNIK ŽUNAC, Ph.D.[1]
E-mail: agzunac@unin.hr
ANTE KLEČINA, bacc. oec.[2]
E-mail: anklecina@unin.hr
[1] University North, Varaždin/Koprivnica, Croatia
Doctor Žarko Dolinar Square 1 (Trg dr. Žarka Dolinara 1), 48000 Koprivnica, Croatia
[2] Varaždin County
Franjevački Square 7 (Franjevački trg 7), 42000 Varaždin, Croatia

INTEGRATED PASSENGER TRANSPORT AS A MEASURE OF INCREASING QUALITY IN PUBLIC TRANSPORT SERVICE

ABSTRACT

Public transport should provide connectivity and reachability of destinations which is more efficient and delivers more prospects than reachability dependent only on automobiles. Integrated passenger transport (IPT) is a term most commonly used for integrated passenger public transport systems which give public transport operators cooperation based on common ticketing system and timetable harmonization for easy changing from mode to mode or from operator to operator. The goal of this paper is to show that IPT system gives the public transport operators the quality of transportation service and mobility in general which is comparable with quality of mobility by personal automobiles. The project USEMobility was surveying the real reasons why people use public transport instead of their cars. The research showed that reachability of stations, stops and destinations was the main driver for customers to start using public transport. These findings are cross-examined with other data from developed public transport systems which do apply IPT, such as timetables, modal share, usage trends, etc. This was done in order to prove that IPT provides quality transport service which is not only attractive for the customers but also steadily increases ridership in a long-term period.

KEY WORDS

integrated passenger transport; public transport; reachability; common tariff; transport service

1. INTRODUCTION

Mobility is a basic human requirement. Modern civilization is completely dependent on transport which connects geographically distant spaces and due to its advancements, the world has become a "global village".

Although today global economy benefits largely from fast travels from one part of the world to another, the most important trips for practically all people are the short distance trips. These are usually traveling to work, to school, to university, to run different errands either for business or pleasure, by walking, biking or driving a car, taking a train, a bus, a tram or any other form of public transport. Although many possibilities exist, each mode does not have the same economic or social effects, effects on the environment, energy consumption, safety, etc.

Walking and biking might be the best ways for everyday travel. However, when it comes to larger local distances, using public transport and personal car is a better way to travel. Public transport is several times more efficient than cars in categories like climate change, pollution, energy consumption and safety. Connectivity assured by public transport also has bigger economic effects than the one which relays purely on automobiles. In a long run, every Euro or US Dollar invested in public transport systems, returns almost 4 Euros or US Dollars back to the national economies (APTA, 2014).

Integrated public transport system or just integrate public transport (IPT) is a system that offers very high efficiency and quality of service already proven in many regions worldwide. This system offers common tariff and common ticketing for all the modes and operators in certain city or region. It also offers harmonized timetables among all modes for easy transfers, thus providing huge number of frequent connections offering numerous trip possibilities. This results with high reachability of the entire regions where the system is in operation. Although such systems are successfully in operation for more than 50 years, there are still many countries, which still do not use such it despite its efficiency.

In order to support the implementation of integrated passenger systems this paper examines three hypotheses. The first hypothesis (H1) is: integrated public transport, by its functionality and efficiency, can offer a significant quality and competitiveness of public transport for most local trips in comparison with a personal automobile. The second hypothesis (H2) is: the reachability (of stations, stops and final destinations) plays an important role when users make their decision whether to take public transport or not. The third hypothesis (H3) is: the frequency of departures of public transport vehicles (e.g. on a certain line or more lines) is not crucial for user's decision to take a trip by public transport.

In order to test the hypotheses, the surveys from USEMobility project, which was funded by Seventh Framework programme of the European Union, were used. It was a behavioural study, carried out in 6 EU countries, that was examining the real reasons why people choose public transport instead of their cars. A lot of data from yearly reports from different authorities that run integrated passenger transport systems was used also. The long-term increase of the ridership of a certain system was considered as an indicator that shows it was attractive for citizens to use it.

2. INTEGRATED PASSENGER TRANSPORT SYSTEMS DEFINITON

Integrated transport is a term which could have originated from a Latin word "integratus" which means: made from parts that create a whole and they are strongly interconnected (Zelenika, 2001).

Integrated public transport system, also integrated public transport, is a system of public transport that unites different public transport modes in a defined region. Such system uses all the advantages of all the transport modes in the system, while the cooperation of the modes in most occasions cancels the downsides of using only one transport mode. It allows building intermodal terminals, places where easy transfers are possible, timetable harmonization and common tariff with common ticketing system for all the modes in the system (Master plan for integrated passenger transport, 2017; Klečina et al., 2015).

Different modes of public transport (trains, metros, trams, buses, trolleybuses, ships, etc.) have developed separately during time, with more or less cooperation among operators. The idea of an integrated public transport system was developed by transport experts and it was first applied in Hamburg region in 1965 (Der Hamburger Verkehrsverbund, 2016). Since the operators are "uniting" for cooperation they implement a common ticketing system and such organising is known as tariff and transport association. That does not mean that transport operators are being united in a unique company. They still stay separate enterprises but their businesses in the new system is being regulated by contracts given by governing body usually called Transport authority. This means that in such system, and many of them are operational in regions worldwide, sometimes a large number of operators cooperate, every one of them supplying services on designated lines, and they all recognize one common ticketing system (one ticket for all).

3. STUDY METHODS - PROJECT USEMOBILITY

USEMobility, European Union project funded from Seventh framework programme (FP7), carried out from January 2011 until February 2013. There were seven partner organisations from Germany, Austria, Belgium, Hungary and Croatia involved in the project (CORDIS, 2018).

USEMobility was a project based on a behavioural research investigating real reasons why people switch from using personal automobiles to using public transport. The survey was carried out in 10 regions plus six national surveys covering six European Countries. The regions and countries covered with the survey were (Knuth, 2012):

1. Salzburg region (S-Bahn Salzburg), Austria,
2. Styria region (S-Bahn Steiermark), Austria,
3. Brussels region (STIB/MIVB), Belgium,
4. Zagreb region (HŽ-ZET), Croatia,
5. Varaždin and Međimurje (HŽ), Croatia,
6. Breisgau region (S-Bahn Breisgau), Germany,
7. Hamburg-Cuxhaven region (Metronom), Germany,
8. Rhein-Neckar region (Rhein-Neckar S-Bahn), Germany,
9. Budapest-Esztergom region (MAV), Hungary,
10. Gelderland/Connexion Valleilijn region, Netherlands,
11. National survey, entire country, Austria,
12. National survey, entire country, Belgium,
13. National survey, entire country, Croatia,
14. National survey, entire country, Germany,
15. National survey, entire country, Hungary,
16. National survey, entire country, Netherlands,

The sample size was 10.000 citizens. The survey was completed in two stages, the first one in June and July 2011 and the second one in October 2011. The citizens who could primarily enter the survey were the ones that switched from frequent car usage to frequent public transport usage in the period five years prior to the survey. The citizens who did the opposite, meaning that they switched from public transport to frequent usage of personal cars, were also included. They all had the chance, while filling the questionnaire, to clearly state their reasons why they made such a decision (CORDIS, 2018). Integrated public transport was, at the time of the survey, not applied in only two out of ten investigated regions, and in one region was only partly applied.

In this project's survey reachability was defined as a possibility to reach a desired place, equally as reachability of a certain station or stop (of public transport) and as reachability of certain destination (Knuth, 2012). In the category of reachability three different categories were surveyed: good connectivity with public transport close to the place of residence, good connectivity close to the final destination and general possibility to reach the desired destination. The examined citizens who preferred the public transportation gave the same level of importance to each of these three categories: for the first two 68% and for the third 70% (Knuth, 2012).

The USEMobility survey was concluded in 2012 and its approach was very innovative. Transnational survey with similar methodology was not conducted afterwards, therefore only the results from USEMobility were used for this paper. In case new similar surveys will be carried out, new results will be used in next papers.

3. FREQUENCY OF DEPARTURES AND CONNECTIONS

Figure 1 shows the most important findings of the USEMobility survey and these are main pull in and push out factors for users to either use or abandon the usage of public transport. The green part (more often PUB) shows the importance of different factors which pulled in the users to start using public transport more often and used personal cars less often. The red part (less often PUB) shows the importance of different factors which push out the users from using public transport often. They stared using their personal cars more often instead (Knuth, 2012).

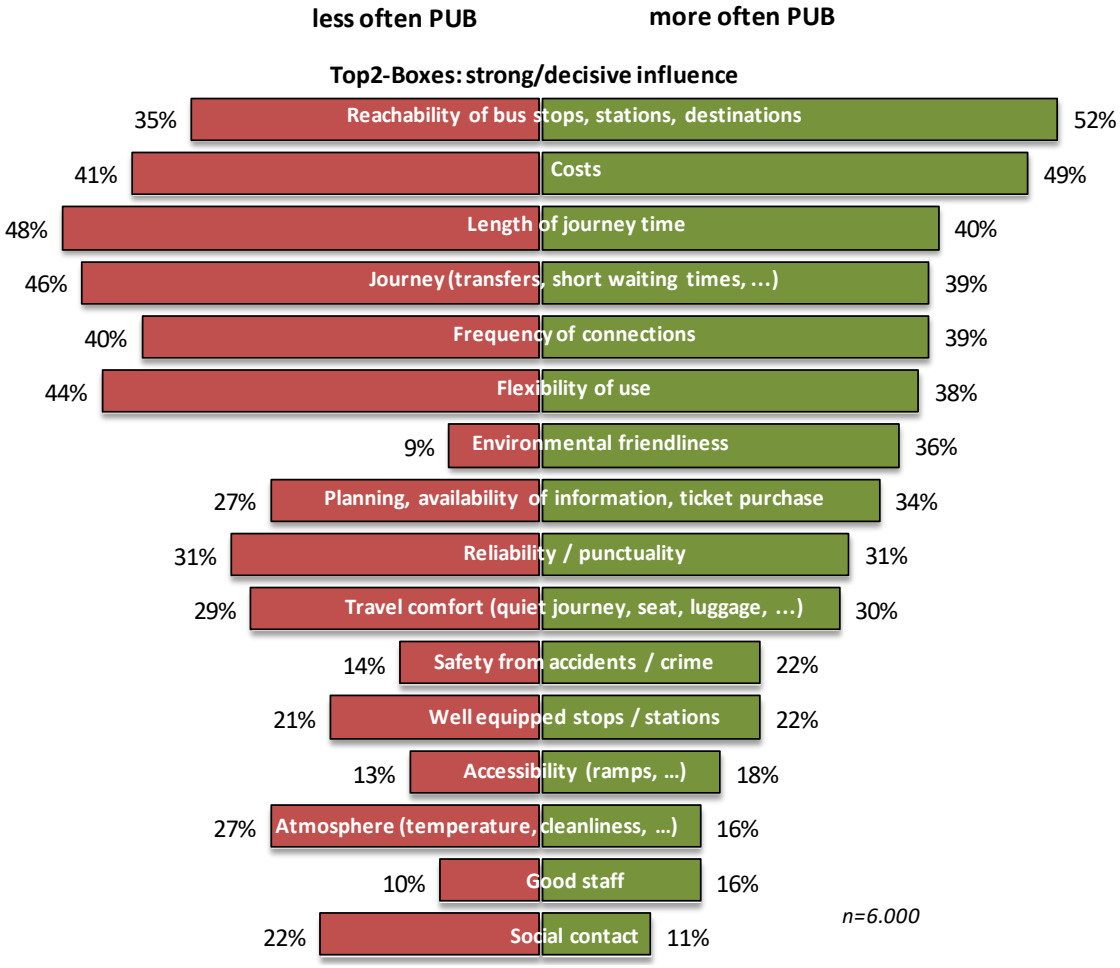


Figure 1 – The influence of the primary PUB+ pull-in (green) and PUB- pull-out factors related to usage of public transport in surveyed countries (Germany, Austria, Netherlands, Belgium, Hungary, Croatia), project USEMobility
Source: Knuth, 2012

Under Flexibility of use (Figure 1) five categories were surveyed: Restricted times of operation, Poor intervals and frequency of departures, Poor connection to other means of transport, No possibility to take other people along and No transferability of the ticket. The results from these five categories were combined into Flexibility of use. The category with the most influence as a push out factor from public transport (users which stopped using public transport and switched to personal cars) was "Poor intervals, frequency of departures" with the influence of 55% (Knuth, 2012). When it came to pull in factors (users that stopped using personal cars and switched to public transport) "intervals, frequency of departures" was second most influential with 53% (Knuth, 2012).

Flexibility of use, according to USEMobility project survey, is a strong public transport pull-in factor. It was the ranked sixed (39%), which can be considered as an important factor when it comes to users'

decision to use public transport more frequently. It is also a strong public transport pull-out factor (away from public transport). In the survey it was ranked third (44%). Ranked fifth was Frequency of connections when both pull in to public transport (39%) and push out from public transport factors (40%) were considered.

This clearly suggests that the absence of frequent departures (flexibility of use) and sufficient number of connections pushes users away from public transport. On the other hand, if frequent departures and sufficient number of connections exist, it is a strong pull in factor for users to use public transport systems.

4. COVERAGE AND FREQUENCY OF DEPARTURES IN THE REGION OF STUTTGART

Figure 2 shows the coverage by railway passenger public transport systems in Stuttgart region in Germany with approximately 2,9 million residents living there. The public transport system in the region is managed by Transport authority called "Verkehrs and Tariff Verbund Stuttgart-VVS (Transport and tariff association Stuttgart-VVS)" (VVS, 2016). The system is integrated, meaning IPT is applied.

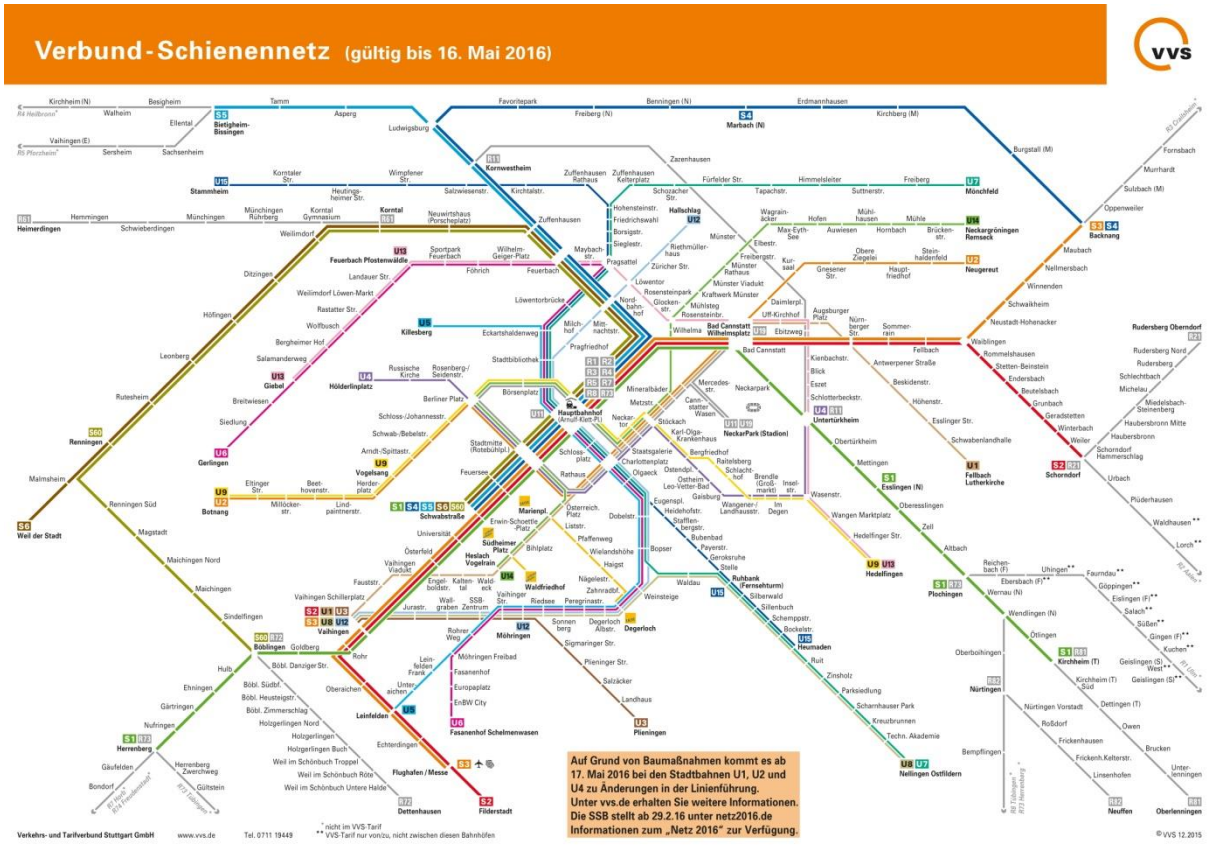


Figure 2 – Suburban rail (thicker) and light rail (thinner) network in the integrated public transport network of the metropolitan region of Stuttgart in Germany. State 2016.
Source: VVS, 2016.

Many suburban and light rail stations and stops are also intermodal, meaning they are also bus stations or stops, well connected with bus lines as well.

Operating hours is the time from the first departure in the day (usually early in the morning) until the last departure in the same day (usually late in the evening or even night). During that time other

departures are deployed according to timetables. If the departures during the day are in regular intervals (e.g. every 10 minutes, every 15 minutes, every 30 minutes, every 60 minutes or similar) such timetable is called clock-face timetable. Stations and stops where public transport vehicles arrive in regular intervals (clock-face timetable) and make possibilities for the users to continue their journeys with connecting lines (departing also in regular intervals) are called hubs (Bundesministerium für Verkehr und digitale Infrastruktur, 2015). Such systems, with these regular arrivals and departures, offer connections among large number of lines in the hubs, and therefore offer the reachability and coverage of the entire designated region.

S1 Herrenberg - Stuttgart - Plochingen - Kirchheim (T) DB VVS

MONTAG - FREITAG

Herrenberg	ab	13.16		13.46	alle	14.46		15.16	15.31	15.46	alle	16.46		17.16	17.31	17.46	alle	18.46		19.16	19.31	19.46	20.01
Nufringen		13.19		13.49	30	14.49		15.19	15.34	15.49	15	16.49		17.19	17.34	17.49	15	18.49		19.19	19.34	19.49	20.04
Gärtringen		13.22		13.52	Min	14.52		15.22	15.37	15.52	Min	16.52		17.22	17.37	17.52	Min	18.52		19.22	19.37	19.52	20.07
Ehningen		13.25		13.55		14.55		15.25	15.40	15.55		16.55		17.25	17.40	17.55		18.55		19.25	19.40	19.55	20.10
Hulb		13.28		13.58		14.58		15.28	15.43	15.58		16.58		17.28	17.43	17.58		18.58		19.28	19.43	19.58	20.13
Böblingen		13.30		14.00		15.00	15.15	15.30	15.45	16.00		17.00	17.15	17.30	17.45	18.00		19.00	19.15	19.30	19.45	20.00	20.15
Goldberg		13.32		14.02		15.02	15.17	15.32	15.47	16.02		17.02	17.17	17.32	17.47	18.02		19.02	19.17	19.32	19.47	20.02	20.17
Rohr		13.38		14.08		15.08	15.23	15.38	15.53	16.08		17.08	17.23	17.38	17.53	18.08		19.08	19.23	19.38	19.53	20.08	20.23
Vaihingen		13.40		14.10		15.10	15.25	15.40	15.55	16.10		17.10	17.25	17.40	17.55	18.10		19.10	19.25	19.40	19.55	20.10	20.25
Österfeld		13.42		14.12		15.12	15.27	15.42	15.57	16.12		17.12	17.27	17.42	17.57	18.12		19.12	19.27	19.42	19.57	20.12	20.27
Universität		13.44		14.14		15.14	15.29	15.44	15.59	16.14		17.14	17.29	17.44	17.59	18.14		19.14	19.29	19.44	19.59	20.14	20.29
Schwabstraße		13.50	14.05	14.20	alle	15.20	15.35	15.50	16.05	16.20		17.20	17.35	17.50	18.05	18.20		19.20	19.35	19.50	20.05	20.20	20.35
Feuersee		13.52	14.07	14.22	15	15.22	15.37	15.52	16.07	16.22		17.22	17.37	17.52	18.07	18.22		19.22	19.37	19.52	20.07	20.22	20.37
Stadtmitte		13.53	14.08	14.23	Min	15.23	15.38	15.53	16.08	16.23		17.23	17.38	17.53	18.08	18.23		19.23	19.38	19.53	20.08	20.23	20.38
Hauptbahnhof (tief)		13.55	14.10	14.25		15.25	15.40	15.55	16.10	16.25		17.25	17.40	17.55	18.10	18.25		19.25	19.40	19.55	20.10	20.25	20.40

Figure 3 – A sample of the clock-face timetable of the suburban railway line S1 in the region of Transport and tariff alliance Stuttgart ("alle 15 (30) Min" means "every 15 (30) minutes").
Source: VVS, 2018.

Figure 3 shows a sample of the clock-face timetable during afternoon on a part of the suburban railway line S1 in Stuttgart region. The similar frequency of departures is being repeated throughout the entire day, starting from around 5 AM until 0:30 AM the next day. On weekends and holidays the frequency of departures is around 30 % lower in comparison with workdays. On weekends, departures are even available every hour between around 0:30 AM and 5:30 AM offering the service to residents and tourist during late night outs (VVS, 2018). Such operating hours correspond with some conclusions from USEMobility project. The concept of integrated and harmonised timetables should be combined with longer operating hours and adequate frequency of departures. Such measures will increase the flexibility and attractiveness (Geißler, 2012).

5. INTEGRATED PASSENGER TRANSPORT SYSTEMS RESULTS

Integrated public transport systems are being applied by most of the developed regions worldwide and they attract many citizens to us it. The ridership in such well-organised systems is constantly increasing.

Several examples of successful systems will be presented here. Transport and tariff association Stuttgart is being active since 1978. From 2007 until 2017 the ridership in the system has risen from 321 million passengers to 382 million passengers (Der Verbundbericht 2017, 2018). In the region of German city of Hamburg where Hamburger Verkehrsverbund (Hamburg transport association) is the managing transport authority for its integrated system, there were 537,6 million passengers in 2004 while there were 738,3 million recorded in 2014 (HVV, 2018). In South Moravia in Czech Republic integrated public transport was introduced in 2003 when overall number of passengers was 12,9 million. In the year 2006 the number of passengers transported had risen to 26,7 million (IDSJMK, 2018). In the Canton of Zürich, in Switzerland, where integrated public transport is managed by Zücrher Verkehrsverbund (Zürich transport association), in 2012 there were 605 million passengers carried. This number has risen to 651 million passengers carried in 2017. In 1990, when suburban railway was

introduced in the Canton of Zürich, there were 100 million passengers transported during the that first year. In 2017 the number of passengers transported was 304 million (ZVV, 2018).

The better way to measure the success of integrated passenger transport systems would be the use of modal split. Since the collection of modal split data would take a long time, the only used data for this analysis were those mentioned above. Modal split is planned to be analysed in the upcoming papers.

6. CONCLUSION

Integrated public transport system offers good connectivity for a certain region and it can, for most purposes, replace the mobility that relies exclusively on cars. Therefore, if a person does not necessarily require a personal car it can fulfil its mobility needs by public transport.

Results from good practice examples additionally support the implementation of such systems. In the regions where they were successfully applied, an increase in ridership is present. In some systems, during the last 20 or more years, the number of passengers had risen several times. It is possible that such good numbers are not in correlation with pure demographic increase or the increase in GDP. The probable cause for the increase is the attractiveness of the integrated systems. Better way to measure the success would be the modal split. It is planned to analyse it in these regions in the upcoming papers.

Hypothesis (H1) was confirmed due to determined advantages and the established rise of ridership in integrated systems. Frequent departures, clock-face timetables, harmonised timetables among different operators and modes, departures from early morning until late in the night, common ticketing and all other advantages of integrated public transport allow good mobility and good reachability.

The second hypothesis (H2) was also confirmed by examining the results of the USEMobility project survey. Reachability plays a key role when it comes to users' decision whether to use public transport or not. Survey clearly determined that for the users that mostly use public transport, the most influential pull-in factor was reachability (52%). For those who mostly use personal cars, it was the sixth most influential push-out factor (35%) that had driven them away from public transport usage. The example from Stuttgart region, were a good coverage by railway network is assured, shows that ridership is increasing.

Third hypothesis (H3) was refuted. The fact that low frequency of departures in public transport does not correspond with the overall number of passengers in the public transport system is not true. The frequency of departures matters, and this was also proven by research from USEMobility. The Flexibility of use ("intervals, frequency of departure" is the most influential factor in this category which was combined out of five factors) is a strong pull-in factor towards public transport usage ranking sixth (38%) among frequent public transport users, while among frequent car users it ranks third (44%) in the list of push-out (away from public transport) factors. The example from Stuttgart region, where suburban railway S1 line was examined, shows that frequency of departures varies from 30 minutes in off-peak hours to 15 minutes in peak-hour periods offering good mobility. The users value such services and the number of passengers in the system is constantly increasing.

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IVICA PERIŠA, mag. ing.[1]
E-mail:ivica.perisa@pevec.hr
MATIJA HABUŠ,univ. spec. transp.[2]
E-mail:matija.habus@unin.hr
MARIO ŠAFRAN, Ph.D.[3]
E-mail: mario.safran@fpz.hr
GORAN KOLARIĆ, M.Sc.[4]
E-mail:goran.kolaric@mzo.hr
[1] Pevec d.d.
Savska cesta 84, 10360 Sesvete, Croatia
[2] University North
University Center Varaždin
Jurja Križanića 31b, 42000 Varaždin, Croatia
[3] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[4] Ministry of Science and Education
Donje Svetice 38, 10000 Zagreb, Croatia

POSSIBILITIES OF IMPROVING TRANSPORT PROCESS IN THE COLD CHAIN

ABSTRACT

Frozen goods, goods under controlled temperature conditions, and perishable goods impose on logistic operators the task of organizing a cold chain transport service at a high level. In order to organize the process of cold chain transport with as minimum negative effects as possible, it is necessary to improve organization through development and modernization. This is possible by implementing new materials for upgrading the cold chamber and with implementation of new hardware and software solutions that contributes with improvements of transport system. Various innovative solutions have been researched for the purpose of improvement of cold chain transport and it includes the usage of vacuum panels for insulation of cold chambers, vibration, door opening and temperature change, use of ISO roll containers and the use of electric or hybrid cargo vehicles. The innovative solutions requires high costs for the implementation and they aren´t always available on the marker.

KEY WORDS

Cold chain transport; insulating materials; sensors and alarm systems; electric vehicles

1. INTRODUCTION

The cold chain transport as a part of a complex logistics chain represents an unbroken series of activities related to the production, storage, distribution and cargo transportation, transportation of goods and products under controlled temperature conditions. In order to keep the cold chain under regulated and controlled temperature conditions, there are required specific elements of logistics system which are including adequately equipped facilities (refrigerated and chilled rooms and chambers), vehicles (specific technical characteristics) and expert personnel (coordinated and coordinated by each process). It is especially important to plan and maintain a cold chain under controlled conditions due to the natural properties of the goods, the biological and chemical composition of the goods and the purpose of the consumer goods. Transport as an essential element of the cold chain must ensure as little loss as possible, especially if the goods and / or products are not

heat stable or subject to changes in temperature oscillations. For this very reason, the cold chain process needs to be improved and developed through the implementation of new technologies and innovative solutions so that the purpose of the cold chain's functioning and organization can follow the contemporary global needs for products from controlled temperature industry, especially foods that man daily use for food such as fresh fruit and vegetables, meat products, meat products, dairy products, etc., then distribution of vaccines and medicines, human organs transport, chemical transport and military needs.

2. LITERATURE REVIEW

The issues of this paper are based on the facts that arise from the data obtained from the research carried out in the area of the logistic chain organization that is defined as the cold chain. According to a report prepared by the Association of Commercial and Industrial Chambers of India and supported by the National Bank for Agriculture and Rural Development, Cold Chain Logistics (Transforming Agri-Food Supply Chain) from 2018 [3] it is said that the cold chain is oriented towards world globalization, which implies increasing demands and needs for fresh food, and consequently the need for innovations in development with the aim of increasing capacity and infrastructure modernization in order to reduce the risk of organizing the logistics chain without the need to increase stockpiles or costs in a particular sector. Also, the Food and Agriculture Organization of the United Nations estimates that by 2050, to increase production and availability of food by 70% to provide sufficient food supply to more than 9 billion people and would be a major challenge for the world. The following report, published by the International Trade Administration, Department of Commerce, U.S.A.- Top Markets Report Cold Chain, 2016 [4] says that the development of a cold chain system multiplier that can generate exports and open up new markets in multiple sectors over a longer period of time. Companies in the United States understand the need for sustainable and efficient cold chain systems and spend hundreds of millions of dollars each year to build and maintain cold storage and transportation systems. Every year, the United States loses billions of tons of fresh food products and millions of dollars on exports due to bad cold chain systems in developing markets, talking enough about the importance and opportunities of developing the cold chain. The document under the title Temperature-controlled transport operations by road and by air which is a part of the WHO Technical Report Series, No. 961, 2011 [5] discusses about guidelines how to design a model that will provide a general technical introduction to the active and passive packaging and transport systems used to distribute TTSPPs, describes how to pack the temperature controlled products correctly and in the transport environment, describes the correct use of the various types of temperature and humidity monitoring devices, describes the documentary evidence that should be provided to regulatory authorities and other interested parties so that quality assurance and regulatory compliance can be demonstrated and maintained. According to an article published at the "Research Gate" from 2008 titled RFID Technologies for Cold Chain Applications supported by the International Institute of Refrigeration [6] describes a RFID technology as a promising technology that can provide numerous benefits in temperature monitoring and performance of perishable supply chains. It said that the main limitations are: a relatively high cost, difficulties in calculating a ROI and reliability and accuracy. An article also published at the Research Gate from 2009 with title Use of PCM accumulator and temperature-controlled transport of foodstuffs [7] discusses about a study which investigates the use of PCM batteries as a device that will maintain the appropriate temperature if the cooling unit is temporarily switched off as a part of freight vehicle powered by a diesel engine.

3. POSSIBILITIES OF COLD CHAIN TRANSPORT DEVELOPMENT

3.1 Possibilities of cold chain transport development

By implementing new technologies in the cold chain transport, efficiency is obtained by increasing capacity, better utilization and long-term maintenance of the required temperature regime for a specific goods, semi-finished product or finished product. New technologies improve the entire transport system, and the focus of this units is the temperature regime as the most critical element of the cold chain.

3.2 Materials for the upgrade of the chamber

The panel-forming material is the most important element of the chamber because it affects thermal insulation, ie costs. If the manufacturing element is inadequate, maintaining the temperature in that chamber will be difficult. Insufficient material or filling in a thermal insulating panel causes increased costs through energy consumption, higher costs of refrigerant maintenance, or in the case of stationary cooling systems (eutectic panels), shortens the time and radius of the distribution due to the need to rebuild the set temperature. Increased energy consumption is associated with increased environmental pollution.

The production of the panels takes place the so-called modern "wet process" in which the insulating elements are connected, vacuumed and compressed under pressure and result in obtaining a compact watertight monoblock ready for assembly as a unit called a chamber. Such production is valid for conventional panels, but unconventional way includes the use of vacuum or gas as insulation inside the panel. The comparison of the insulator is shown in Table 1, and the evaluation is done on a scale of 1 - with the smallest values up to 5 - the highest values. The lack of such panels is very high sensitivity to damage, high cost of production as well as maintenance prices for daily exploitation. The advantage is the worst thermal conductivity K, with values up to 7 times the current insulators used.

Table 1 – Comparison of conventional and unconventional insulators in the production of panels for conveyor upgrades of transport vehicles

Specifications:	**vacuum**	**CO2**	**polyurethane**	**polypropylene**
Thermal conductivity value - K	0.005	0.017	0.02	0.033
Complexity of making (5 very complex, 1 lack of complexity)	5	5	2	2
Sensitivity to temperature change (5 high conductivity, 1 low conductivity)	1	2	3	4
Loss of insulation properties (5 big loss, 1 no losses)	1	1	2	3
Risk of damage to damage (5 high risk, 1 no risk)	5	5	2	2
Maintenance price (5 high price, 1 low price)	4	4	2	2
Maintenance price (5 high price, 1 low price)	5	5	2	2
Investment Allocation (5 high investments, 1 low investment)	4	4	3	2
Insulation measure (5 large masses, 1 small mass)	1	1	3	4
Total value:	26	27	19	21
Selection order:	3	4	1	2

Source: Made by authors based on available data

The problem of vacuum maintenance between the panel walls and alarms during air blasting is attempted by the panels pressure sensors, which emits values to the control receiver. The panel susceptibility challenge remains, but the detection time of the probe and the reaction with the sensor drastically decreases. Figure 1 shows a vacuum sensor panel.

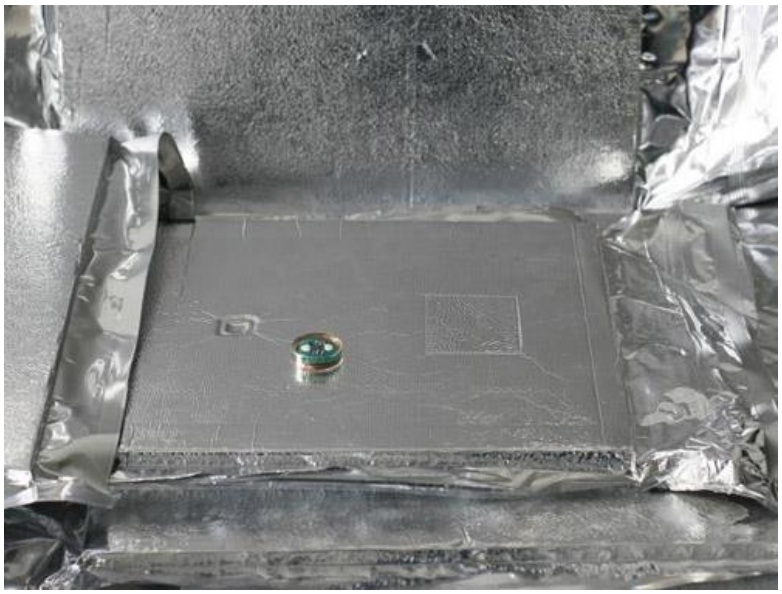


Figure 1 – Vacuum panel with pressure sensor inside the section
Source: [17]

3.3 Alarm systems and archiving irregularities (impact sensors, rollover, and the temperature difference)

Operations in the logistics chain include many activities, where occur unpredictable situations caused by a variety of influences. Transport, as the binding activity of all operations, is the most exposed to risks and requires the assurance of these risks.

The risks to which we can more or less influence are:

- traffic accidents of the means of transport
- fire or explosion
- natural disaster
- not delivering the entire collection
- Theft (partial or complete)
- manipulative damage
- weather conditions (rain, snow)

The cold chain requires additional insurance because it enters a group of sensitive goods and is therefore necessarily secured by the so-called special hazards (dissolving, partial temperature drop, loss of power during transport, etc...). Sadly, or unhappily, insurance is the repair of the damage caused while the purpose of the damage is prevented before they occur or is in progress. [18]. For such cases, indicators (sensors) are inserted into or into transport packaging. The sensors are divided according to the purpose of: striking, rolling, vibration and temperature sensors, while dividing them according to their ability to use indicators and recorders. Indicators are usually one-time use and do not require a power supply or monitoring applications, while the recorders include a tracking device, with its own power and application, and thus the instant response to irregularities.

3.3.1 Shock sensor

Impact (or shock) sensors provide instant alert when a specific load experienced a sudden surge force. During shipping, transportation, warehousing or use, the products and equipment are subject to shock, rollover, and sometimes breakdown. Often, these powerful shocks or impacts cause damage to sensitive components that remain hidden during initial inspection. The result of damaged or broken components may only be visible when the operator or new owner attempts to use the damaged item. Since the damage was not obvious from the outside, a potential new buyer may assume that the provider has sent the damaged equipment. Impact sensors are mostly used in transport of electronics, ceramics, glass, plastic. An impact sensor example is shown in Figure 2. [19].



Figure 2 – Shock sensor
Source: [19]

Table 2 - Technical specifications of impact sensor

Specifications:	
Sensitivity Range	25G, 37G, 50G, 75G, 100G
Duration	0.5 – 50ms
Tolerance	± 15%
Operating Temperature	-25°C to 80°C
Shelf Life	2 years from date of sale when stored at standard temperature and pressure (20°C, 1 ATM)
Size	96.52 x 96.52 mm

Source: [19]

3.3.2 Rolling sensors

Tilt sensors (rolling sensors) act as simple visual indicators of the most extreme slope where the load was exposed in relation to the vertical. The tilt sensor is set discreetly or on the load where the sensor works equally. The slope sensor tracks a particular rotational axis and visually shows when the packet moves from the initial position or inclination. A sensor or indicator is sufficient to inform if the cargo was tilted, no matter the direction. The sensors are attached to the packaging with the glue of the glue and after they are rotated next to a particular position, they can´t be reset. Examples of rolling sensors are shown in Figures 3 and 4. [19].



Figure 3 – Rolling sensor with no direction of swing and degrees
Source: [19]

Table 3 – Technical specifications rollover sensor without direction and tipping degrees

Specifications:	
Activation Angle	80° ±5° from vertical
Monitoring Range	Single plane
Adhesive	2 mil high tack acrylic
Humidity Tolerance	5% to 99% noncondensing
Temperature Tolerance	-40°C to 60°C
Composition	Rigid polystyrene housing with non-magnetic steel indicator
Arming	Arms coincident with removal of adhesive liner
Size	74.168 x 60.198 x 5.334 mm
Installation	Pressure-sensitive adhesive or holes to accommodate screws, nails, or staples
Customization	Cobranding available on orders over 5.000 pieces
Adhesive Shelf Life	2 years

Source: [19]

Table 4 – Technical specifications of the rollover sensor with the direction of rolling over, and inclination degrees

Specifications:	
Activation Angle	10° increments from 30° axis (±5°)
Monitoring Range	Single plane and rollover
Adhesive	1 mil high tack acrylic
Humidity Tolerance	5% to 99% noncondensing
Temperature Tolerance	-40°C to 60°C
Composition	Clear PTE housing and plastic indicator
Size	116.84 x 116.84 x 7.62mm
Installation	Installation Pressure-sensitive adhesive exposed when liner and arming pin are peeled away
Adhesive Shelf Life	12 months (before application)

Source: [19]

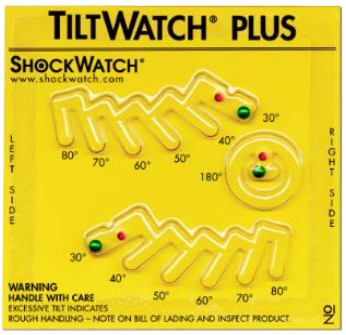


Figure 4 – Rollover sensor with directional swing and tilt degrees
Source: [19]

3.3.3 Vibration sensor

The sensor vibration is monitoring system in real-time that monitors information on vibrations and shocks, and measures what are their values. Anomalies in the trends and indications of irregularities in the work enable timely reaction by preventing expensive repairs and machine shutdowns. Systems are used to monitor conveyors, conveyors, oil pumps, mining machines. The vibration sensor example is shown in Figure 5. [19].

Table 5 – Technical specifications of vibration sensor OpsWatch and OpsWatch EX

Specifications:	**OpsWatch**	**OpsWatch EX**
Operating Temperature Range	-30°C to 85°C	-40°C to 85°C
Size	121.92 x 78.74 x 55.88mm	162.052 x 149.86 x 38.1mm
Weight	0.5 kg (w/o battery)	1,35 kg (w/o battery)
Power Source (Both Units)	External Power (static mode) – 2 x 3.6V Lithium Thionyl Chloride (backup)	
Battery Life	Up to 12 months	
Sampling Rate	1000-5000 samples per second	

Source: [19]



Figure 5 – Vibration sensor
Source: [19]

3.3.4 Temperature sensor

The temperature sensor (data logger) is a portable device for temperature data measurement. Its main purpose is reading and recording temperature in indoor and outdoor environments. The sensors were used in a wide range of activities, and a major contribution was made in the supply chain. Temperature sensors (recorders) consist of two main parts: a temperature sensor (or multiple sensors) and a recording system. The recording system selects the temperature measured at predetermined intervals and saves measurements. The sensors are used in cold chain transport as proof to the consignee that the cargo was maintained at the required temperature conditions, in which part of the carriage there was an inconsistency, and as evidence in the case of claims for damages by the recipient. One-time temperature indicators are another option for use in cold chain transport, which are equally efficient and easy to use. Indicators are tapes or simple attachment that signal colors if the temperature during transport was higher or lower than ideal for that load. Certain models can also indicate the time period outside the ideal temperature. Examples of temperature sensors are shown in Figures 6 and 7. [19].

Table 6 – Technical specification of single temperature indicator with overdrive warning

Specifications:	
Indication Type	Visual, irreversible white to red color change in activation window
Activation Method	Manual: Pull-tab
Activation Temperature Levels	Sensitivities available between -18°C and 37°C
Temperature Accuracy	+1°C/ +2°F
Mounting Method	Pressure-sensitive adhesive
Dimensions	Short-Run: 46 x 19 x 1.5mm Long-Run& Duo: 98.1 x 19 x 1.5mm

Source: [19]



Figure 6 – One-time temperature indicator with overflow warning
Source: [19]

Table 7 – Technical specifications of temperature recorders function computation time

Specifications:	
Monitor Recording Options	Multi-use
Temperature Measurement Range	-30°C to 75°C
Temperature Accuracy (Standard Unit)	± 0.5°C (across the entire measurement range)
Temperature Accuracy (Probe Unit)	-30°C to 2°C: ± 1°C 2°C to 8°C: ± 0.5°C 8°C to 75°C: ± 1°C
Dry Ice (Probe Unit)	-30°C to +75°C: ± 1°C -80°C to -30°C: ± 3°C
Temperature Measurement Range Dry Ice	-80°C to +75°C
Memory Capacity	4000 logged data points / 16 million histogram data points
Downloadable Data	Available during transport / storage without stopping the recorder
Battery Life	Up to 3 years

Source: [19]



Figure 7 – Temperature recorder with time counting function
Source: [19]

3.4 Achieving and maintaining the temperature of unconventional refrigerating units

Strict environmental standards, environmental impact, reduced energy consumption, better utilization and faster achievement of set temperatures are all demands placed on manufacturers and providers of logistics services. Satisfying strict standards is an extremely demanding task, whereby some new cost that has not existed or was negligible in previous systems is often present. The key element for achieving the set temperature in a given space is a refrigerant that encapsulates the potential of the eco-norms. The coolant is a medium that transfers absorbed heat to the cooling system. The decisive properties of refrigerants are compatibility with the environment and their impact on the ozone layer or global warming. Cooling agents are used in open and closed processes. In the open procedure, the coolant is drawn from the container into the body and goes into the environment. In a closed process, the refrigerant is maintained in constant circulation. Open systems use a refrigerant whose production consumes large amounts of energy (eg. nitrogen or CO_2 / carbon dioxide) and their efficiency is lower than that in closed systems. Because of this ecological reason, most refrigeration system manufacturers are designed as closed systems. Figure 8 shows the comparison of all refrigerant gases used in refrigeration systems [20]. GWP is an international unit that indicates the global warming potential and is compared with carbon dioxide with value = 1.

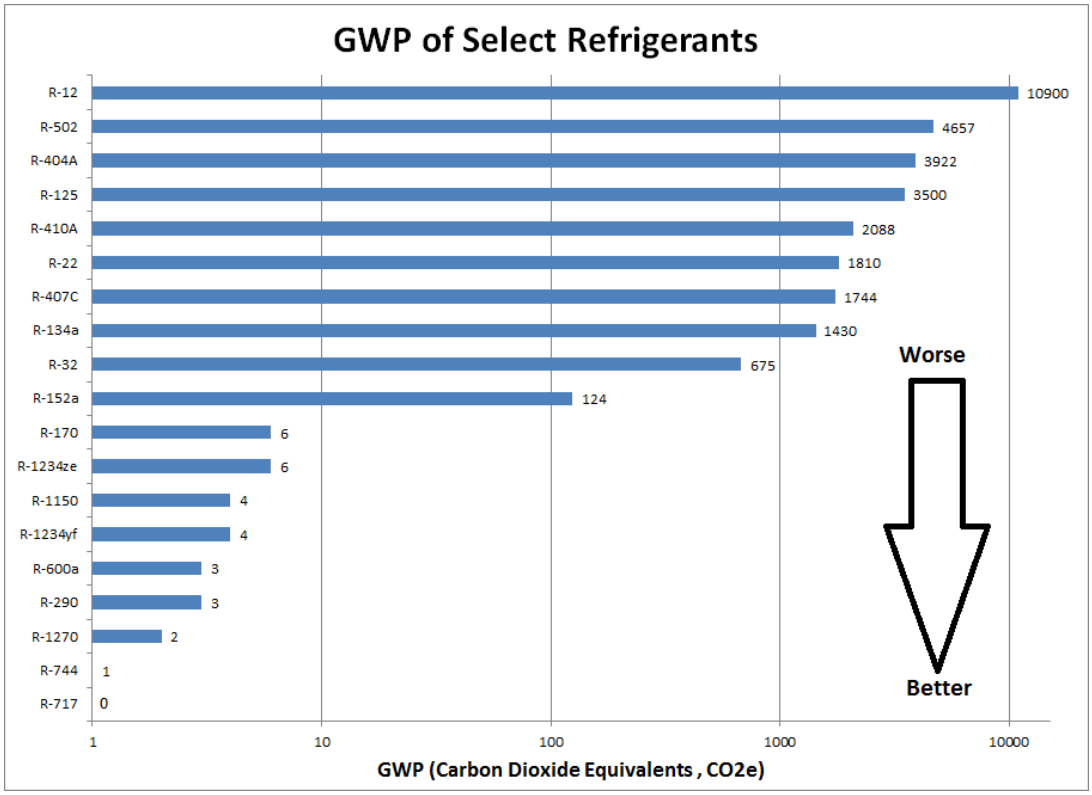


Figure 8 – GWP (Global Warming Potential) value of refrigerants
Source: [20]

Most manufacturers focused their research towards the use of new gases in cooling systems, where the highest potential have carbon dioxide (CO_2) labeled R-744 and propane (C3H6) labeled R-1270. The lack of a carbon dioxide system is the compression of the same, with the complete cooling cycle producing more pollution and equating it with the gases of the worse GWP index. On the other hand, propane is highly inflammable, which is why it is badly rated on the safety classification and is not yet mass-sized. The most prolific gas used for cooling over 150 years is ammonium (NH4) labeled R-717, but its toxicity is the cause of non-use in refrigeration and transport chains [20].

3.5 Use of ISO Containers in the Cold Transport Chain (cryo, eutectic)

The way of delivering cargo from the point of departure to the arrival point where the cargo will be stored, is the most accurate with the delivery process using ISO roll containers. The ISO roll container of the Olivo producer from France is shown in Figure 9 and shows the container in the transport stage with the closed door and with the open door before the start of the filling in the warehouse.



Figure 9 – ISO Roll Containers from Olivo manufacturer
Source: [21]

The advantage of the ISO containers is in the process of working and essential for maintaining the default temperature. The ISO container is kept open for several hours before loading into the storage room to reach the ambient temperature. Upon ordering and commissioning, the ISO container is driven on its own wheels by commissioning and full commissioned cargo. After completion of commissioning, the container is fed to a part of the warehouse containing frozen eutectic boards or drawers with "dry ice" (dry ice is carbon dioxide in a solid state at a temperature of -79 ° C) and is filled with one of the possible solutions to the foreseen part at the top of the container. Liquid and solid carbon dioxide is an important refrigerant, especially in the food industry. Dry ice is always below -79 °C, at standard pressure. Liquid carbon dioxide as a refrigerant has an industrial label R-744 and was used before the discovery of R-12 or Freona-12 and may experience a recurring increase in use, as there are fears that the refrigerant R-134a contributes to climate change. Environmental protection is a better solution, does not affect to the formation of the ozone holes, is not poisonous and non-flammable, so it is a great option to replace freons in cars and other refrigeration techniques. The container with its insulation effectively protects the contents from the influence of outside temperature, dust and moisture, while the eutectic boards and "dry ice" allow for the achievement and maintenance of the temperature inside the container. Natural circulation of warm and cold air is switched off by the need for additional ventilation.

Table 8 – Key data for ISO containers Olivo Roll 900

Specifications:	
External Dimensions (WxLxH)	800 x 1.200 x 1.860 mm
Internal Dimensions (WxLxH)	610 x 1.000 x 1.493 mm
Internal volume	910 L
Coefficient K	0.29 W/m²K
The weight of the empty container	136 kg
Insulating material	Polyurethane foam
Panel wall material	Molded polyethylene
Container format	Euro palette 800 x 1.200 mm

Source: [21]

Since the analyzed ISO container is in dimensions as euro pallets, which can be seen along with other data in Table 8, there is no need to change the mode of delivery nor the capacity utilization of truck cargo space. After loading the ISO container with the cargo and with the medium for achieving and maintaining the temperature, the ISO container will be loaded onto the freight vehicle with the lifting or loading ramps and brought to the point of unloading. Arriving at the place of unloading, the container is unloaded the same way, but at this stage of delivery is the biggest advantage of ISO containers in relation to the Euro palettes or any other type of palettes. The ISO container is brought to the chambers or cooled place of the product exposure, and only then opens and switches to a storage with controlled temperature. This is why exposure and possible contamination of the product is minimized. The lack of delivery of ISO containers is a high investment, a reduction in usability compared to the Euro palette, process slowdown, and room cost in the warehouse under the temperature regime.

3.6 Development and application of electromobility of vehicles and refrigeration systems

Electric vehicles are vehicles driven by an electric motor, powered by electricity, stored in a battery, or other devices for energy storage. Electric cars were popular at the end of the 19th and early 20th centuries, but innovations in internal combustion engines and mass production of a cheaper petrol vehicle led to reduced use of the vehicle on an electric drive. Electric cars with the main disadvantage that are linked to the price and range distance, have many advantages compared to vehicles with internal combustion engines. Benefits are linked to reducing air pollution, reducing greenhouse gas emissions, full or less dependence on oil, higher engine power utilization and lower costs during exploitation. Choosing the electromobility freight transport could be quieter, cleaner and more sustainable. On November 16, 2017, the entrepreneur Elon Musk introduced a freight vehicle of the future that was fully powered by electricity. This vehicle is a Tesla Semi truck and is shown in Figure 10.



Figure 10 – Tesla Semi truck - the first truck with electric motors
Source: [22]

Table 9 – Comparison of Tesla Semi-truck with electric engine and long-distance tugboat with diesel powered engine

Specifications:	**Truck type engine:**	
	Tesla Semi- electric engine	**Diesel engine**
Acceleration (No load) 0-100 km/h	5s	15s
Acceleration (With load- max. load) 0-100 km/h	20s	60s
Uphill	100 km/h	72 km/h
Range (Full load- 100 km/h)	800 km	Not mentioned
Drag coefficient Cd	0.36	0.65-0.70
Charging time	30 min za 650 km (Origin or Destination)	15 min for full tank (1500L)
Warranty	1.610,000 km	Service at 150.000 km
Operating costs - 161 km route (A-B-A) - 100 km/h (average speed) - 36 t GVW - $2,50 USD per gallon diesel - $7c kwh Electricity price	$2.016 USD/ km Semi convoy $1.36 USD/ km (better than rail)	$2.265 USD / km
Engine power	320-500hp	Each 271hp (4 engine- 1084hp)
Price	$120.000 USD - $150.000 USD	$150.000 USD- $200.000 USD

Source: [22]

In addition to the Tesla's semi-electric powered truck, the Mercedes Benz, Scania, MAN and Volvo Trucks are also involved in the development of electric mobility, which are actively developing and self-driving trucks without drivers [23, 24]. Electric vehicles are quieter, more energy efficient and cleaner compared to fossil fuel vehicles. One of the two reasons for this is the battery, which is an important way of manufacturing, material manufacturing, reach and duration. It is in the battery that is the development potential for cold chain application. Today's batteries range from 300 to 800 km in truck transport, which applies exclusively to driving, ie vehicle movement or composition. When using an electric truck in freight transport in a cold chain, the capacity of the drive battery needs to be further burdened by the cooling system to maintain the temperature regime. The temperature regime would have drastically affected the vehicle's range, for example if the main vehicle carrying the ice-cream cargo at -20°C and outside temperature is about +30°C, the range will be much shorter comparing the vehicle with a lower temperature regime and in lower outside temperature. In addition to the stated problem of battery range, it is extremely important to be made of degradable materials, provided with lithium ion technology that is an essential element of cobalt exploited in a sustainable and responsible manner, and that there is a process of disposal in an ecologically way after the life cycle of the battery. Volvo Trucks is developing their trucks in the direction of using "worn" battery for later storage of solar energy which is far less demanding of energy storage for heavy goods vehicles [24]. In order to make the best use of battery capacity, as well as vehicle movement, the regeneration system that is generated during braking and extreme acceleration is an option that must become the standard in production. Electromobility is developing in the direction of connecting a number of scientific fields shown in Figure 11, and the common goal is to reduce environmental pollution and maintain sustainability.

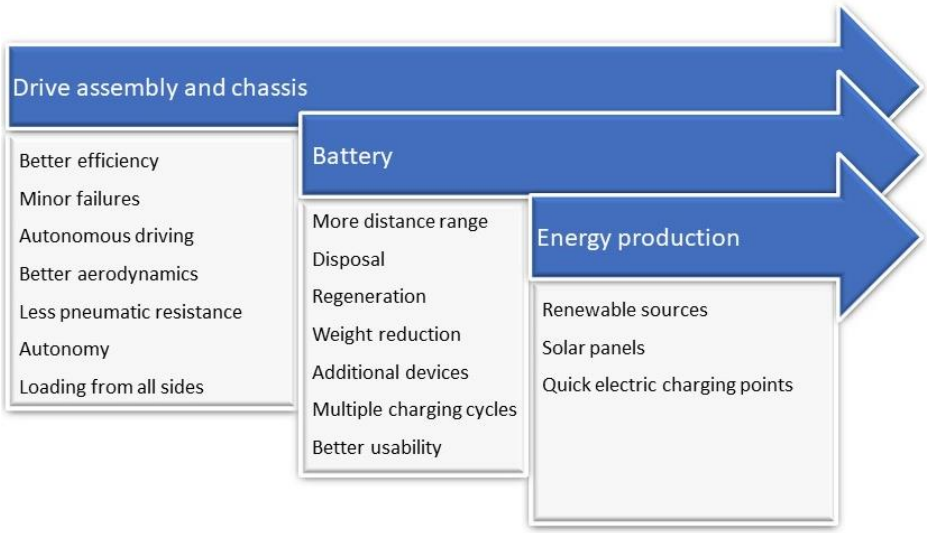


Figure 11 – The development of related fields of electromobility
Source: Made by authors based on available data

4. CONCLUSION

Republic of Croatia, as part of the European Union, has access to a large market. According to research, around ten years ago, 1.300 specialized ships for freight under the temperature regime, 80.000 refrigerated wagons, 650.000 refrigerated containers and 1.2 million vehicles with a temperature regime were traded around the world. The market with perishable cargos with a special temperature regime is growing and the demands for quality are increasing. For the logistics service providers in the cold chain transport market, market growth is an opportunity, but also a challenge, especially in the Republic of Croatia, which increases the number of inhabitants twice in the summer months. Cooled cargoes, as well as all other cargoes with the required temperature regime, require achieving and maintaining the set temperature along the entire supply chain. This condition provides complexity and weight throughout the chain. The cold chain must be uninterrupted from entering the raw material into the production to the end customer, whereby the logistics manager must possess certain knowledge, experience, infrastructure, certificates and tools required. In the case of cooled operations, maintaining the cold chain creates complexity of transport and opportunities for improvement. Initial investment, expensive maintenance, personnel training, continuous monitoring of processes and procedures, environmental and acoustic standards of refrigeration equipment, and all other challenges are the reason for the limited interest of logistics for entry and development of transport in the cold chain. This is precisely the reason for the lack of transport and warehouse capacities in the cold chain in Europe and in the World, which on the other hand affects the price of providing this service and creates the opportunity to enter new "players" into a profitable market. Innovations are the future of transport development in the cold chain. Under the pressures of cost and environmental standards, the segment experiences a revolution that is ultimately good for the company, for the buyer, and for the future of the population. Innovations in the field of isolation chambers improve insulation properties, while reducing cost and weight. Temperature rise sensors and indicators reduce risks and accurately display the time of irregularity, which is extremely important in the sea shipping cold chain transportation that runs for months without supervision and generates high costs and expensive court cases. Progress in achieving the required temperature regime is also high in the field of refrigeration devices and insulated roll containers, which, by applying new gases and energy sources, have an impact on the better efficiency and performance of the device, with small or none impact on the environment. The innovation that are todays present and related to electromobility has entered the segment of freight vehicles in 2017 and takes market share in motor vehicles every year. It is a revolution that meets all the criteria of ecology, usability, exploitation of

natural resources, which will also affect the cold chain in the cold temperature range through noise, fuel consumption, failure and power usability. It is extremely interesting to experience the accelerated development that affects the improvement of the process in the transport chain, but which on the other hand has an ecological note and encourages sustainability, which is certainly a confirmation of humanity on the right track.

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MARJANA PETROVIĆ, Ph.D.[1]
E-mail: marjana.petrovic@fpz.hr
IVICA LJUBAJ, mag. ing. traff.[1]
E-mail: ivica.ljubaj@fpz.hr
TOMISLAV JOSIP MLINARIĆ, Ph.D.[1]
E-mail: tmlinaric@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukličeva 4, 10000 Zagreb, Croatia

INCREASING QUALITY OF SERVICE IN RAILWAY PASSENGER TRANSPORT - CASE STUDY

ABSTRACT

The paper outlines a proposal for a new organisation of railway passenger transport on the railway lines of northern Croatia. By using the OpenTrack simulation tool, variants of passenger transport organisations were tested by setting the frequency of train departures to half an hour. On railway sections where it was not feasible to achieve such a cyclic timetable, the simulation examined the ways how to make such timetable possible – in other words, what that would mean for the railway carrier and the infrastructure manager.

KEY WORDS

railway; passenger transport; simulation; frequency; cyclic timetable;

1. INTRODUCTION

When railway passenger transport is in question, the quality of the service thereof is what essentially dictates passenger satisfaction or dissatisfaction. The satisfaction can contribute to a greater number of passengers, while dissatisfaction leads to the opposite. Passengers perceive the quality of the transport service also through the area they reside in, their life habits, and it changes with time. Increasing the level of the quality of public transport service would lead to an increase in the number of passengers, thereby disburdening the road traffic. During the entire journey from origin to destination, a railway carrier can have an impact on the waiting time, a partial impact on the journey time, while the journey to/from the station/stop is beyond its control yet have an effect of the number of users.

The quality of public passenger transport is assessed by questioning the users of the transport on the quality of the service. The questions are drawn up based on predefined factors that represent the quality of the service, [1]. The authors examine the factors that impact on the increase in transport service demand of a certain type [2]. According to the [3] the fundamental features of the quality of public transport are price, journey time, the frequency of departures, and the expense of reaching public transport.

In this paper, the authors focused on the increase in service level by increasing the service frequency. A model of the targeted area was developed in OpenTrack which simulated different variants of train departures, and an analysis was conducted on the significance of certain variants for the railway carrier and the infrastructure manager. Only by using this type of simulation tool it is possible to conduct detailed analysis of feasibility of proposed measures and their effect, in this case, on infrastructure manager and/or railway carrier.

2. THE ANALYSIS OF THE CURRENT STATE OF THE TARGETED AREA

This part of the paper analyses the infrastructure of the analysed area, as well as the way the railway passenger transport has been organised. As there are a lot of stations and stops, not all will be described in this paper, although all were analysed in order to develop the model in OpenTrack. Figure 1 illustrates the analysed area.



Figure 1 – The illustration of the analysed area.
Source [4]

2.1 The analysis of official locations of the analysed area

Varaždin train station is a sequential station and marshalling yard. It is located on the railway lines R201 Zaprešić–Čakovec, R202 Varaždin–Dalj, and L201 Varaždin–Golubovec. The Varaždin station is open to reception and dispatch of passengers in domestic and international transport, as well as the reception and dispatch of all types of cargo (except for I RID packages) in domestic and international transport [5].

Koprivnica train station is located along the M201 Gyekenyes (State Border)–Koprivnica–Dugo Selo and R202 Varaždin–Dalj railway lines. The station is a railway, marshalling, and border yard open to reception and dispatch of passengers and wagon shipments in domestic and international transport [6].

Ludbreg station is located on the R202 railway line, and according to its function in train traffic regulation, it is an interstation. Train traffic regulation is carried out in station distances. It is open for reception and dispatch of goods and for the domestic passenger transport [7].

Čakovec train station is located on the following railway lines:

- M501 Čakovec–Kotoriba–State Border,
- R201 Zaprešić–Čakovec,
- L101 Čakovec–Mursko Središće–State Border.

The station is a marshalling, sequential station, and border yard, open for reception and dispatch of all types of goods, wagon packages, and passengers in domestic and international transport [8].

Donji Kraljevec station is an interstation located on the M501 line. It receives and dispatches passengers and wagon shipments [9]. Budinščina train station is also an interstation on the R201 railway line [10].

2.2 The current passenger transport organisation

For the purposes of the paper, it was necessary to analyse the train timetable. The authors have analysed the trains operating according to the year 2017-18 timetable. Table 1 lists the train routes and the number of trains on certain routes. All tracks in the analysed area were presumed to be single-track and unelectrified. The train traffic was not cyclic, which is a shortcoming in transport service quality.

Table 1 – The number of trains on certain routes in the analysed area

Route	Number of trains
Koprivnica – Varaždin	16
Kotoriba – Koprivnica	3
Varaždin – Mursko Središće	3
Mursko Središće – Čakovec	3
Macinec – Čakovec	14
Zagreb – Čakovec	1
Zagreb - Varaždin	15
Kotoriba – Zagreb	4
Budinščina – Zagreb	1
Zagreb – Mala Subotica	1
Zagreb – Kotoriba	1

Source: [11]

3. CONSTRUCTION OF A SIMULATION MODEL OF THE ANALYSED AREA

This section of the paper analyses the procedure of constructing the model required to conduct a quality simulation on it. Such construction enables a detailed examination of the simulation of various traffic situations, the simulation of different variants of proposed solutions as well as testing their features and levels of solving identified problems. Furthermore, a quality simulation ensures a completely new and different traffic organisation that aims to utilise the railway infrastructure or railway vehicles in a better or different way. For that reason, a macro-model will be built with a detailed overview of translations and other official places, so as to obtain an in-depth and accurate representation of real-time situations in railway transport. Constructing such a model requires professional software made for those purposes, such as OpenTrack.

The most important part of the entire construction of the model is to collect accurate input data. This data, pertaining to the railway infrastructure, is found in the official documentation of the infrastructure manager, and usually include station documentation, longitudinal track profiles, data on the analysed track and stations, data on the signalling and safety equipment and interlocking, as well as other documentation required to construct the railway infrastructure. Conceptual structure of the model is shown on figure 2.

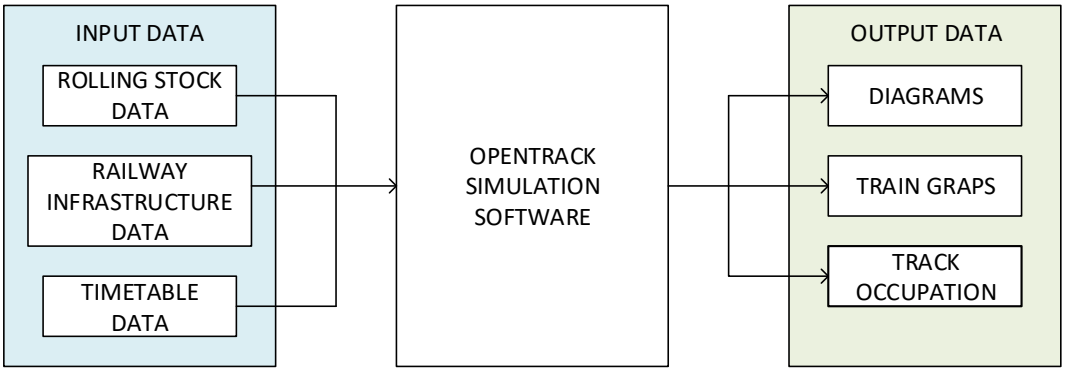


Figure 2 – Conceptual structure of the model

In addition, the construction must use accurate and up-to-date data from the timetable in order to work with accurate and detailed journey times. Timetable documentation also lays down the journey time between every official location, as well as the maximum allowed train speeds on certain sections. Before the construction of the model, for every train we need to determine its mass, the basic and the hauling features of the vehicles. Locomotives, combination of locomotives and wagons, and DMU or EMU trains can be used as hauling vehicles. The data on vehicles and trains are owned by the vehicle owners, in this case, railway carrier for transport of passengers and cargo, who need to be contacted in order to obtain the data.

After all the required data has been collected, the process of construction begins, whereby all the relevant information of a certain track is entered: the location of each elements with regard to the start of the track and its plan (kilometre points), the features of the track (gradients, radius, allowed and limited train speed, etc), and signals. Upon the entry of the signal, signal rules are defined that pertain to the corresponding track (types of signals, allowed manners of transport of trains, etc.), as well as safety elements required to represent the real-world train traffic as accurately as possible. After the construction of the model, motor train units and locomotives are entered into the database and compositions of trains required to operate train traffic are determined. Before the testing stage, the model creates trains with actual real-time timetables. After the testing, the quality of the constructed model and the entered locomotives and trains is examined so as to further improve the model and correct potential mistakes to make the model as realistic as possible, i.e., to simulate accurate actual real-time situations. Comparison of the travel time that are achieved in the model (yellow) and the real timetable is shown on figure 3. This step completes the construction of the model and the model is ready for further use and testing of proposed solutions, variants, and other concepts.

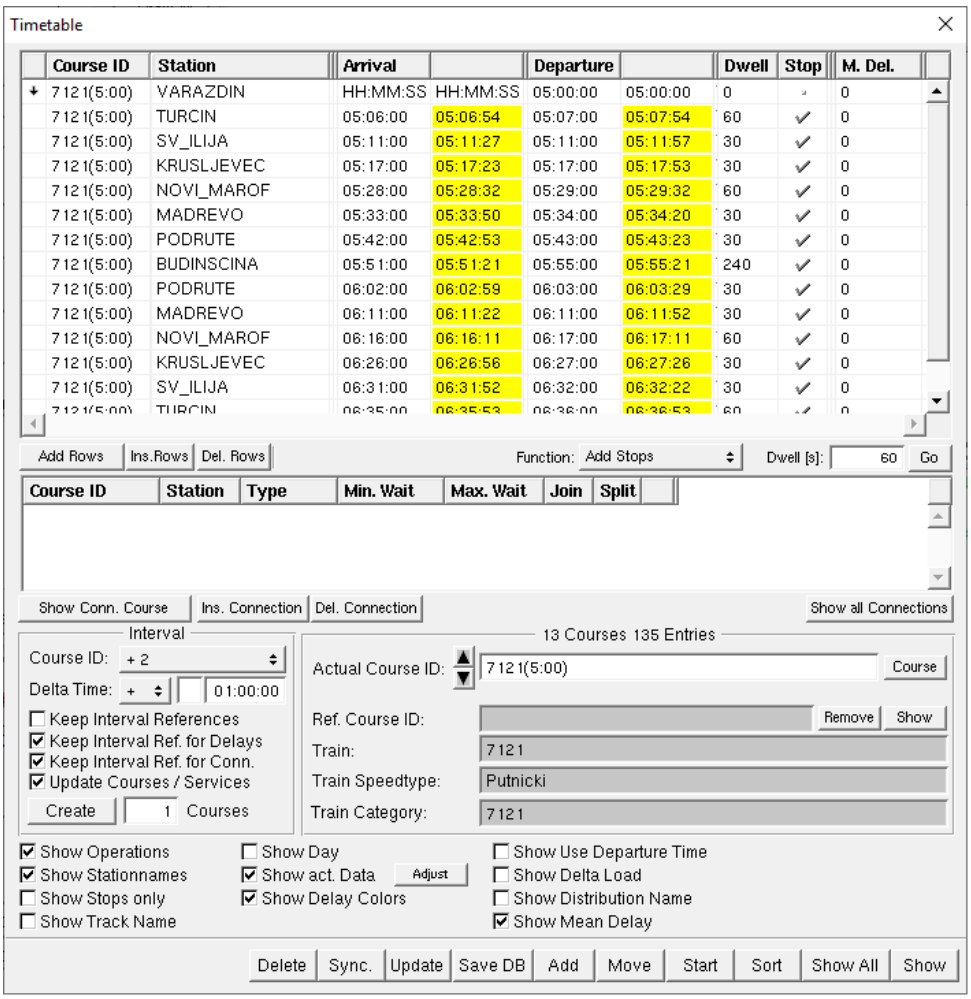


Figure 3 – Comparison of real timetable and travel time in the model

A single model does not have to include the entire analysed area since the software enables merging several models into one which is then used as a polygon for testing. Therefore, the models in this paper were made for some sections of the R201 and the corresponding stations, M501 railway line and its corresponding stations, R202 and its corresponding station, and L101 and its corresponding stations. The models examined and tested various train compositions and speed because the computer models make it possible.

In this paper, several models were constructed and the results of the simulations, conducted separately, were analysed together. This means that due to the complexity of the entire model, a segment was analysed at a time, in order to reduce that complexity and the analysed area, after which the obtained solutions would be viewed as complete solutions.

4. PROPOSAL FOR A NEW PASSENGER TRANSPORT ORGANISATION – A CASE STUDY

This part of the paper analyses the different variants (figure 4) of carrying out the timetable by using the simulation tool. The authors were interested in whether it was feasible that trains depart their origin stations every 30 minutes without making organisational or investment changes to the railway transport system. The headway of 30 minutes is considered very high in the context of a regional railway line, that would increase level of service significantly. On sections where this was not possible, additional steps were made in the form of satisfying the requirements in which such a cyclic timetable would be possible.



Figure 4 – Proposal of different variants
Source: [5], authors edit

4.1 Modeling of the Varaždin–Koprivnica section

The section between Koprivnica and Varaždin is the 42-kilometres-long regional railway line R202. There are five stations along the line (including Varaždin and Koprivnica) and five stops. The developed model aimed to test two variants. In the first one, trains would depart stations Varaždin and Koprivnica every 30 minutes, whereby each of those trains would operate to Ludbreg station which would serve as a turnover station for the train composition. The trains arriving from Koprivnica in Ludbreg, intersect in Rasinja station and stop at the Ludbreg turnover station for 4 minutes for passenger boarding and disembarking. The trains from Varaždin to Ludbreg would intersect in Jalžabet station and stop in

Ludbreg for 3 minutes for boarding and disembarking. For such a timetable to be feasible, two train assemblies are required for each origin station, and the journey time for the entire section would be 49 minutes with a compulsory transfer which would diminish the effect of a shorter journey time due to the transfer or a part of passengers travelling along the entire section (Figure 5).

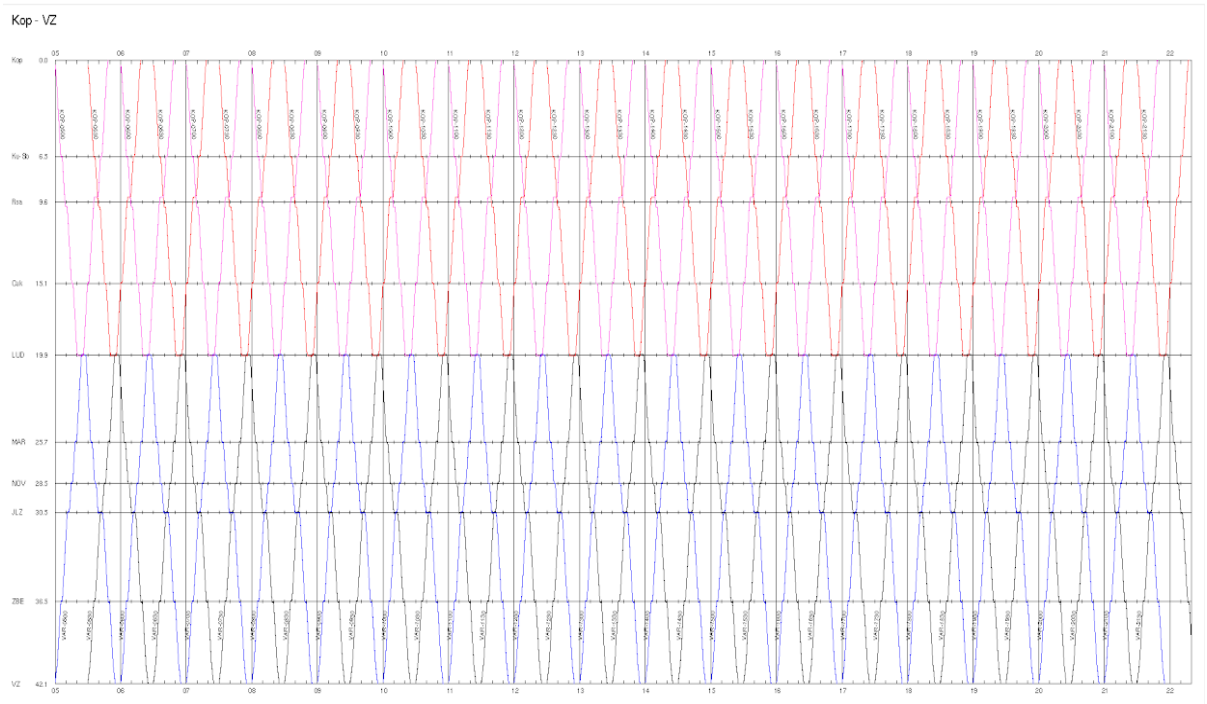


Figure 5 – An overview of an extract from the simulated timetable on the section of the Varaždin–Koprivnica railway line
Source: Model, Authors edit

Another variant was a solution in which a train departing Varaždin every 30 minutes. This variant needs the possibility of trains intersecting in stations Ludbreg, Rasinja, and Jalžabet. The longest time spent in a station due to the intersection would be used by trains arriving from Varaždin to Rasinja station, where they stop for 4 minutes and 20 seconds. For such a timetable, the railway undertaking needs four assemblies (Figure 6), and the journey time amounts to 51.5 minutes. The comparison between the two variants reveals that for passengers, the most favourable option was the second variant because they do not need to transfer along the entire section. The railway undertaking requires 4 train assemblies to set up such a timetable, and no additional expenses are incurred to the infrastructure manager.

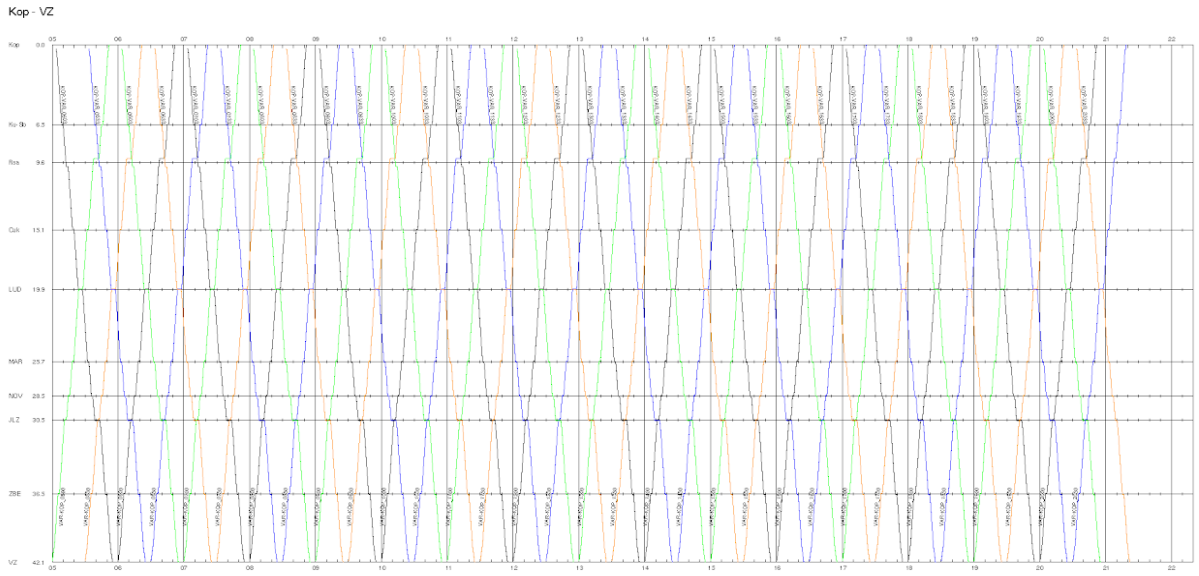


Figure 6. – An excerpt from the timetable of the simulated model, a section of the Varaždin–Koprivnica railway line
Source: Model, Authors edit

4.2 Modelling the sections that gravitate towards Čakovec station

In this part of the paper, a model of the tracks gravitating towards Čakovec was made, along with a simulation of train traffic in several variants. The first one, which is the basic situation, enables a 45-minute cyclic timetable from stations Macinec to Donji Kraljevec, with trains intersecting at Čakovec station. For such a timetable to be feasible, the railway undertaking requires three assemblies (Figure 7).

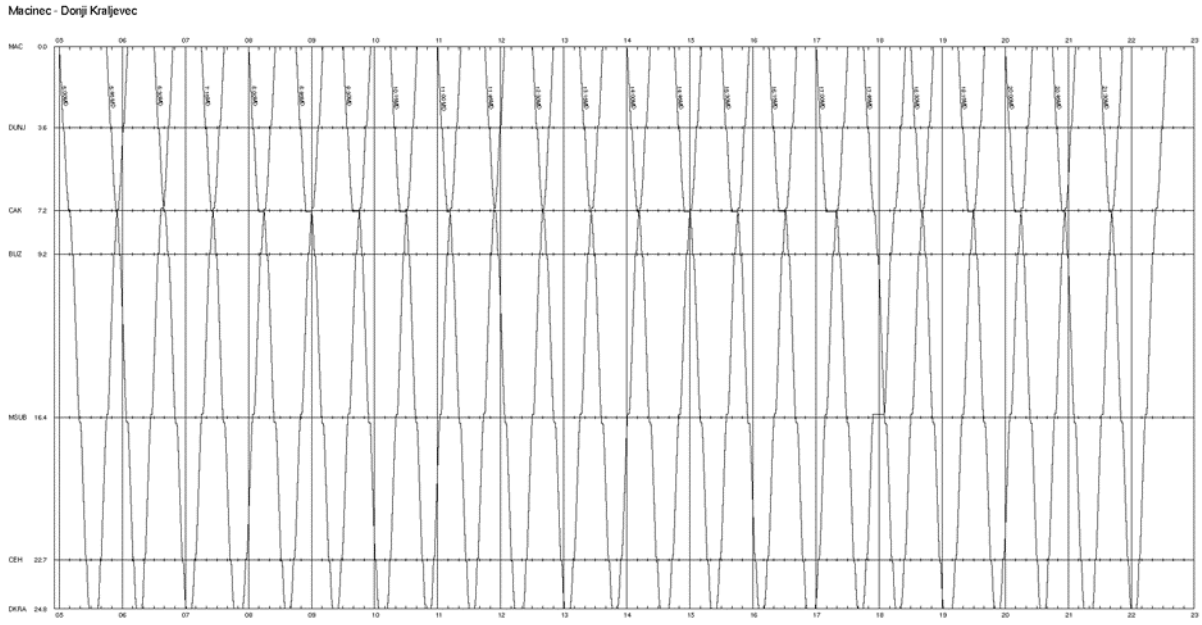


Figure 7 – An excerpt from the timetable of the simulation model, basic situation
Source: Model, Authors edit

A second variant resembles the first apart from the additional modifications in the infrastructure model by means of additional official places where trains can intersect. These modifications enable trains to depart every 30 minutes, which requires three sets of assemblies (Figure 8).

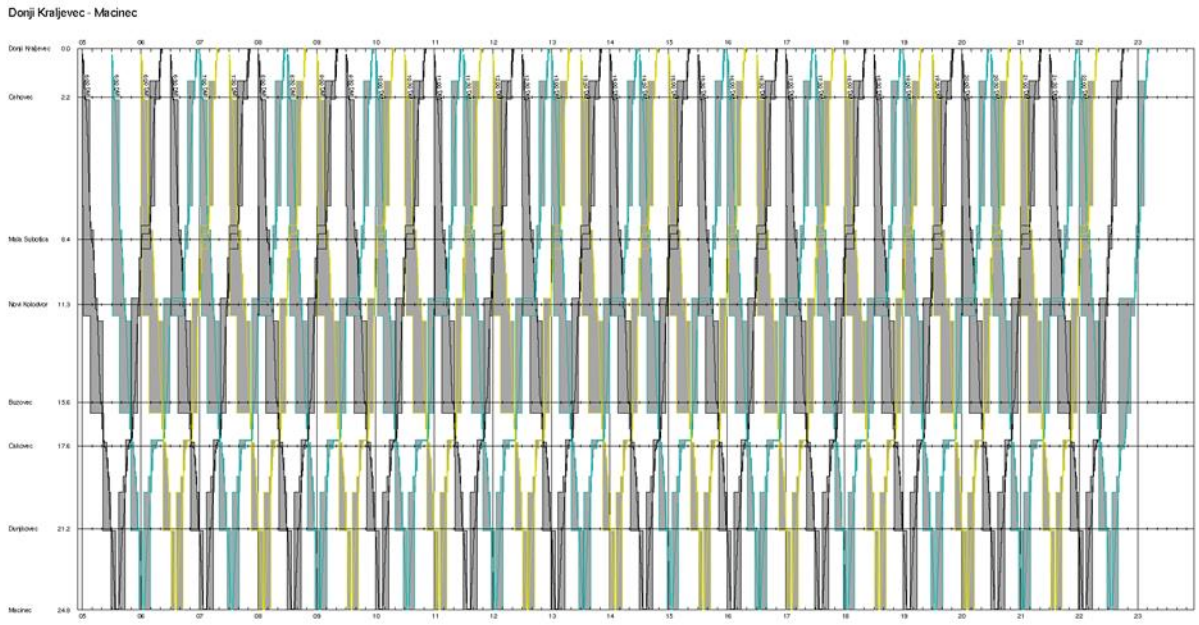


Figure 8 – An excerpt from the timetable of the simulation model – the second variant
Source: Model, Authors edit

Another variant was simulated on the northbound section of Čakovec station, heading towards Mursko Središće. The aim was not to achieve the 30-minute headway due to the infrastructure constraints and the number of passengers. A train departs Čakovec station, the journey time is 50 minutes, which means only one train assembly is required for the entire circular route along the section (Figure 9).

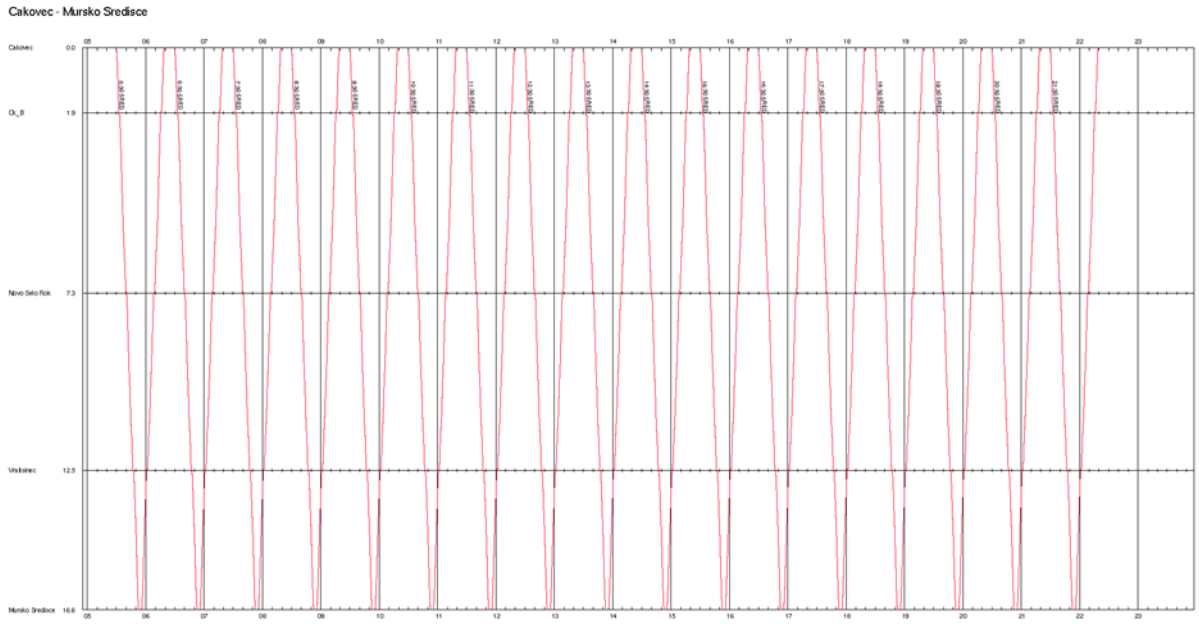


Figure 9 – An excerpt from the timetable of the simulation model on the Čakovec–Mursko Središće section
Source: Model, Authors edit

4.3 Modelling the Budinščina–Varaždin section

Budinščina–Varaždin is a 32-kilometre section along the R201 regional railway line. There are four stations and four stops located along it. The first variant simulates the current conditions of the infrastructure with actual speeds and real-world longitudinal track profile. In order to ensure a 30-

minute departure frequency, train intersection has to take place in Novi Marof station, whereby all trains must hold for the intersection for 10 minutes. Due to that long of an intersection time, it was concluded that the 30-minute cyclic timetable is not feasible, so it was increased to 45 minutes. To achieve a 45-minute timetable, the railway undertaking requires three assemblies (Figure 10).

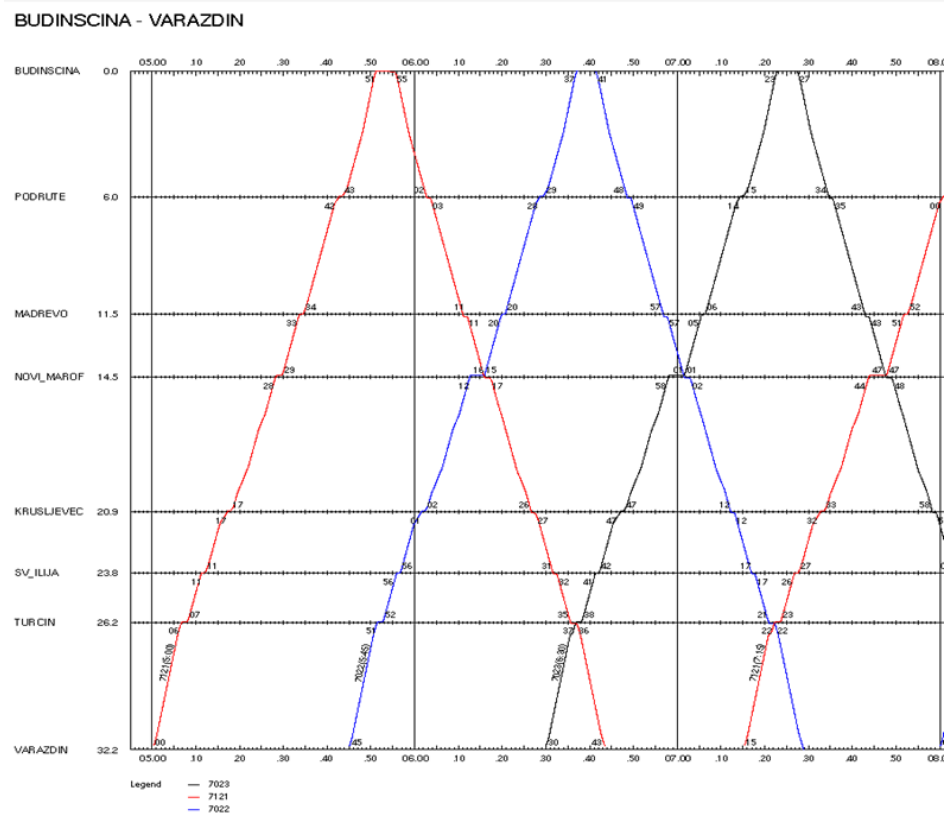


Figure 10 – An excerpt from the timetable of the simulated model of the Varaždin–Budinščina section
Source: Model, Authors edit

In a 30-minute cyclic timetable, trains would hold for too long for an intersection. In order to avoid that, certain modifications of the infrastructure are needed, which is what the second variant corrects. According to it, the allowed train speed would need to increase to 120 km/h on the open section, and to 40 km/h in the station sections. To make the variant feasible, the railway undertaking must have three train assemblies, and the infrastructure manager must ensure significant additional funding to make the infrastructure meet the demands of the increases speeds. An excerpt from the timetable of the second variant is shown in Figure 11.

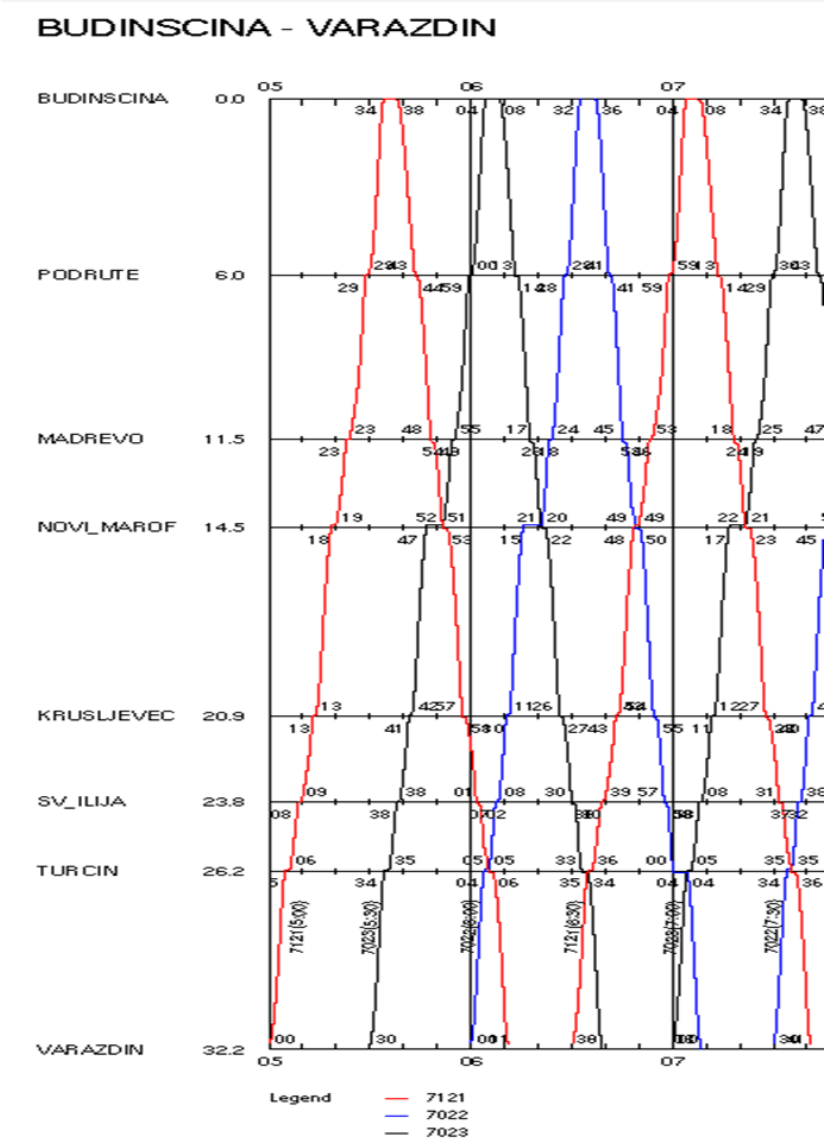


Figure 11 – An excerpt from the timetable for the second variant
Source: Model, Authors edit

5. CONCLUSION

The authors in this paper used a simulation model to examine what an increase in departure frequency would mean for the corresponding railway lines. It is one of the fundamental factors of the quality of public transport which may contribute to passenger increase. It is not easy to simply increase the frequency of departures because it depends on the available transport means of the railway carrier, the state of the infrastructure (number of tracks, allowed speeds, possible intersections on single-track lines), and on transport service demand. For the purposes of this research, a model of the analysed area was made, which simulated several departure variants.

The analysed area was observed through the flow of passengers who naturally gravitate towards a bigger town or city. For the people living in the vicinity of Čakovec, for instance, it was natural for them to gravitate towards the city for various reasons. The same thing applies to the areas around Varaždin and Koprivnica.

The authors of the paper have attempted to set up a headway of 30 minutes analysing what impact such a timetable would have on the railway carrier and the infrastructure manager. If it was not

feasible to use the 30-minute timetable, measures were identified which would need to be taken by the infrastructure manager to ensure such a timetable.

Unfortunately, this high level of service in regional passenger transport was not possible to achieve on all observed sections. By analysing different variants, it was concluded that along the Varaždin–Koprivnica section, it was possible to utilise the 30-minute cyclic timetable without having to invest in the infrastructure. It was, however, not feasible to carry out such a timetable on the tracks heading to Čakovec, without investing significantly in the infrastructure which would require additional official places where trains could intersect. On the Budinščina–Varaždin line, a 30-minute cyclic timetable could only be made possible if train speeds were to increase to 100 km/h and 40 km/h for open sections and station sections, respectively.

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VINKO RAJIČ, univ. bacc. ing. traff.[1] (student)
E-mail: rajicvinko@gmail.com
KARLO JURŠIĆ, univ. bacc. ing. traff.[1] (student)
E-mail: karlo1jursic@gmail.com
IVAN GRGUREVIĆ, Ph.D.[1]
(Corresponding author)
E-mail: ivan.grgurevic@fpz.hr
MARIJA VLAJČIĆ, mag. ing. traff.[1]
E-mail: bebekmarija05@gmail.com
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Department of Information and Communications Traffic
Vukelićeva 4, 10000 Zagreb, Croatia

TESTING WIRELESS TELECOMMUNICATION NETWORK IN PUBLIC URBAN PASSENGER TRANSPORT VEHICLES IN THE CITY OF ZAGREB

ABSTRACT

The paper presents the pilot testing of the wireless telecommunication network (Wi-Fi) i.e. the signal level measured on board vehicles of public urban passenger transport (PUPT) in the city of Zagreb. When speaking about the PUPT vehicles in this case this refers to the electric PUPT vehicles, i.e. trams operating on certain regular routes of the Zagreb Electric Tram (ZET) as the public urban transport operator in the city of Zagreb. Based on several scenarios of collecting data, the quality of the Wi-Fi network on selected trams and tram routes according to day and time of day has been tested. By analysing certain results of field measuring and their comparison and combination, certain parameters have been correlated and the obtained results interpreted. In order to achieve this the measuring method has been used that uses the mobile applications and then the collected field data were analysed and synthetized. The goal of the carried out pilot testing is to determine the current state of the Wi-Fi network in ZET trams as the initial phase of systemic testing of the quality of access to the Internet service for the end users. The purpose of the pilot testing is a systemic improvement and optimization of the already existing Wi-Fi infrastructure that has been implemented in the vehicles of the selected PUPT.

KEY WORDS

wireless telecommunication networks (Wi-Fi); public urban passenger transport; tram; measurement; interference

1. INTRODUCTION

The development of information and communication (ICT) sector and multiple convergence both at the business as well as the technological level have resulted in an increase in the needs for wideband access to the Internet. The supply followed the convergence trend in the form of applications that allow the user the access to the service. These are available to the users on terminal devices. Besides, the need has occurred to make the ICT service available to the users at any time, at any place and independent of the terminal device [1]. Therefore, it may be concluded that the users' requirements have increased and that the quality of the life of citizens has been increasingly relying on the software solutions available through the application. The development and implementation of the fourth generation networks have resulted in exponential increase in transfer speeds, thus setting the base for the development of the concept of Internet of Things (IoT). With the development of the fifth generation networks, IoT has become a reality which can be seen in the concepts of smart houses or

smart cities. Therefore, the public transport vehicle manufacturers as well as network operators realize their contribution by introducing wireless telecommunication networks (Wi-Fi) networks into the public urban passenger transport (PUPT) vehicles. Although the possibilities offered by the implementation of this technology are much greater than the common search of the Internet performed by the average user/passenger; this is, however, the initial purpose only. In the last decade, there are numerous examples in Europe and in the world regarding the implementation and development of the provision of services of wireless Internet access in the vehicles of public urban transport (i.e. trams: Adelaide, Dubai, Edinburgh, Prague, Zurich, Zagreb and many others). It is therefore, very important to determine a certain level of service quality as well as the requirements set by the users / passengers through their usage of service. The paper has been focused on the definition of the current state of the actual wireless infrastructure and its functionality as well as the simplicity of accessing the network.

Software tools (mobile applications) used in this pilot testing of wireless telecommunication networks are WiFi Monitor [2] and WiFi Analyzer [3]. These software tools have been selected, out of a series of the existing tools, due to their availability and user-friendliness, and regarding the testing phase (pilot) they can be installed on mobile terminal devices. The software tools are characterised by a user-friendly interface as well as simple interpretation of the results, considered in more detail further in the text. The Wi-Fi- network testing has been carried out by using two available mobile terminal devices, Blackview Arrow V9 and Huawei P9 Lite. On these devices the previously mentioned applications have been taken over. The very specifications of the devices and the measurement method will be analysed in more detail further in the paper. Pilot testing has been carried out with the aim of determining the current situation with regard to wireless telecommunication networks in ZET trams as the initial phase of systemic testing of the quality of access to the Internet service for the end users of the public urban transport. Further phase of systemic research can represent the base in making decisions on the improvement of Wi-Fi networks in the vehicles of public urban passenger transport of the city of Zagreb. With a systemic enhancement and optimization of the current wireless network infrastructure implemented in the vehicles of the selected public urban passenger transport, and by using various methods of testing the wireless networks, it is possible to select adequate methodology to determine certain parameters or combinations thereof, in order to obtain maximally precise results of the situation in the observed wireless telecommunication network. A comparison analysis of the measured results and the expected values of parameters have provided a good base to perform further, more detailed studies with better software tools (professional versions of software tools). The motive for the carrying out of the proposed (pilot) testing is the non-availability of relevant research carried out in the PUPT vehicles in the Republic of Croatia, more precisely in the city of Zagreb.

The second Section presents an overview and review of the current research from the analysed area. The third Section gives the description of the scope of research and a functional description of the carried out research. The fourth Section describes the analysed wireless telecommunication network used in trams of public urban passenger transport with the description of the network system inside and outside the vehicles. The fifth Section provides and comments on the results of the carried out measures by means of the two used software tools. The conclusion (sixth Section) synthetizes all knowledge obtained by the carried out research and gives guidelines and plans for future research.

2. REVIEW OF THE CURRENT RESEARCH

Before the data started to be collected by means of field measurements on board PUPT vehicles, the current available relevant research has been studied. The reason is to make it possible to make comparison with the already existing papers and possibly use similar or same study methodology. There are numerous studies related to the issues of interference in wireless networks [4], [5], [6], [7]. A special group of research related to interference among different wireless frequencies i.e. comparison of wireless networks of 2.4 and 5 GHz for the needs of indoor and outdoor locations [8],

[9], [10]. Also, the studies have been observed that analyse the problems of interference between ZigBee, Bluetooth and Wi-Fi/LTE (*Long Term Evolution*) [11], [12], [13], [14], [15].

The research focused on the papers related to the implementation of wireless networks on board passenger vehicles and public urban passenger transport [16], [17], [18]. In paper [16], a research has been carried out in the city of Bucharest (Rumania) about the possible Wi-Fi interference in wireless communications implemented within the automotive environment. The goal of this research was to assess the possibility of implementing the network communication equipment to collect information about the environment that are then used in autonomous vehicles. This research takes into consideration the possible interference caused by Wi-Fi transmitter that could have impact on communication between the autonomous vehicle and the environment.

Through an analysis of the used data from wireless networks on board vehicles it is possible to determine the behaviour patterns of the users and their interest thus segmenting the users according to their interest [19], [20]. The authors [19] analyse the behaviour of the Wi-Fi network on board a bus and the users' behaviour, as well as their behaviour patterns based on the numerical data of the web search history in order to configure the network in the maximally efficient way (by collecting the users' behaviour patterns).

With passive *sniffing* of Wi-Fi devices by means of MAC addresses an efficient flow count of public urban transport users is possible, with the final goal of generating time sequences of the users of public infrastructure in the context of the Internet of Things [21], [22], [23]. The authors [22], studied the topic of estimating the number of passengers using the method "*Wi-Fi probe request*", and the purpose of research was to find a reliable method of estimating the number of passengers on board PUPT vehicles. The third Section describes the scope of the carried out research.

3. SCOPE OF RESEARCH

The scope of research includes testing of Wi-Fi network on board vehicles – ZET trams on three tram lines (11, 12 and 17) that includes three points of measurement (*Figure 1*). Three tram lines were selected regarding the travelling route, type of tram (low-floor), installed network equipment as well as the number of passengers, in accordance with different times of the carried out measurements (in March 2019):

- at 7 o'clock in the morning;
- at 3 o'clock in the afternoon; and
- at 10 o'clock in the evening.

Based on the data taken over from ZET, an overview of the tram lines on which the measurements have been carried out, has been obtained [24]. Figure 1 shows lines 11, 12 and 17 and sections of lines have been marked as well as the points at which the field measuring has been carried out. These lines have been selected because of their travelling route, i.e. because they start from different terminals and all converge on the Ban Josip Jelačić Square where the number of passengers is the largest. One can observe that in Figure 1 the selected tram lines overlap in certain sections / travelling route. One can take as an example line 17 that overlaps with tram line 12 from the stop at the Technical Museum all the way to Draškovićeva Street. Therefore, effective measurement in a certain direction can be continued by taking into consideration the second measurement that moves along the same direction. Therefore, measurements were carried out so that the mentioned lines pass through the centre of the city, where there is a sudden increase in the number of users / passengers and meet on the Ban Josip Jelačić Square, where the volume of users culminates due to the largest number of passengers.

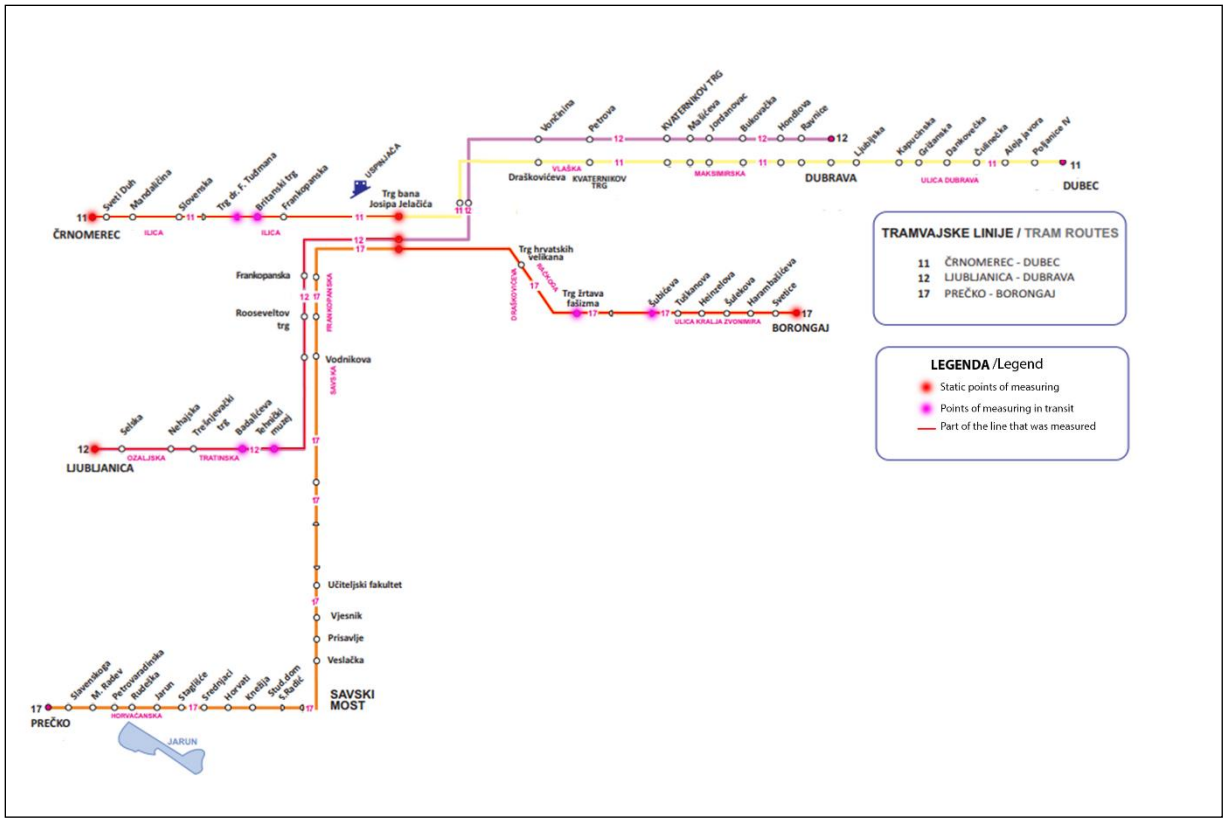


Figure 1 – Tram routes where field measurements were carried out (acc. to [24])

The devices used for measurements were available smartphones *Blackview Arrow V9* and *Huawei P9 Lite*. The devices were selected because of the difference in generation, technical characteristics and in order to test the functionality of the network on essentially different smartphones, taking into consideration the average age of mobile terminal devices in users / passengers of PUPT. The device *Huawei P9 Lite* is compatible with 802.11a, 802.11b, 802.11g, 802.11n, 802.11n and 802.11ac. Moreover, the device supports dual band, *Wi-Fi Hotspot* and *Wi-Fi Direct*, whereas the device *Blackview Arrow V9* supports only 802.11b, 802.11g, 802.11n and *Wi-Fi Hotspot*.

4. WIRELESS TELECOMMUNICATION NETWORK USED ON BOARD PUPT VEHICLES

The basic premise in introducing and using a wireless telecommunication network is an economical and rational way of realising the service of wireless network, in this case the vehicles of PUPT (trams), for frequency bands 2.4 GHz and 5 GHz in a way that includes coverage by the mentioned signal of all parts of the vehicle where the passengers are, and networking of all vehicles into a single *Virtual Private Network* (VPN). The wireless telecommunication system of the network located on board the observed trams (ZETWifi[1]) has to support minimally 65 to 75 simultaneous system users. The existing wireless system has been designed with a minimum of one router of the network traffic, minimally with one access point for wireless connection (*Wireless Access Point*) and one LTE antenna. The wireless telecommunication system of the network positioned locally in trams has to provide a level of signal during the ride of minimally 75 dBm [24]. Besides, the coverage has to be distributed to all parts of tram where the passengers stay and move. By accessing the system, it is required that every user who wants to use the service of wireless Internet access, has to pass the authorisation process.

[1] ZETWifi as a free Wi-Fi wireless Internet in public urban transport of the city of Zagreb started in November 2018, and currently encompasses all low-floor trams and 213 in public urban transport [24].

The authorisation process is carried out in such a way that when the user connects to ZETWifi, the system redirects the user to the web page where the usage conditions have to be accepted. After agreeing to the usage conditions, the user can use Wi-Fi for a period of 30 minutes and then this process has to be repeated if one wants to continue using the services.

4.1 Logic architecture of telecommunication network

Mobile network is a communication network providing connection of terminal devices to the base station, and the network is distributed by using the concept of cells. A cell is the coverage area of one base station that transmits the signal for terminal devices, and the signal is related to the generations of mobile networks 2G, 3G or 4G. Logic architecture of the wireless telecommunication network on board ZET trams consists of elements placed locally in trams that have a system for the control and management of local elements, and the transmission telecommunication infrastructure, that consists of LTE/UMTS[2]/IP[3]/MPLS[4] elements. The network operates so that the network elements are used for connecting local elements of the system into a unique and protected virtual private network (VPN). The system organized in this way is capable of accessing the Internet, and also fibre connections are used and they are connected to data centres, and they serve as core part of the network, and as a management, control and security infrastructure of the system. The logic architecture of the wireless telecommunication network on board ZET trams is presented in Figure 2.

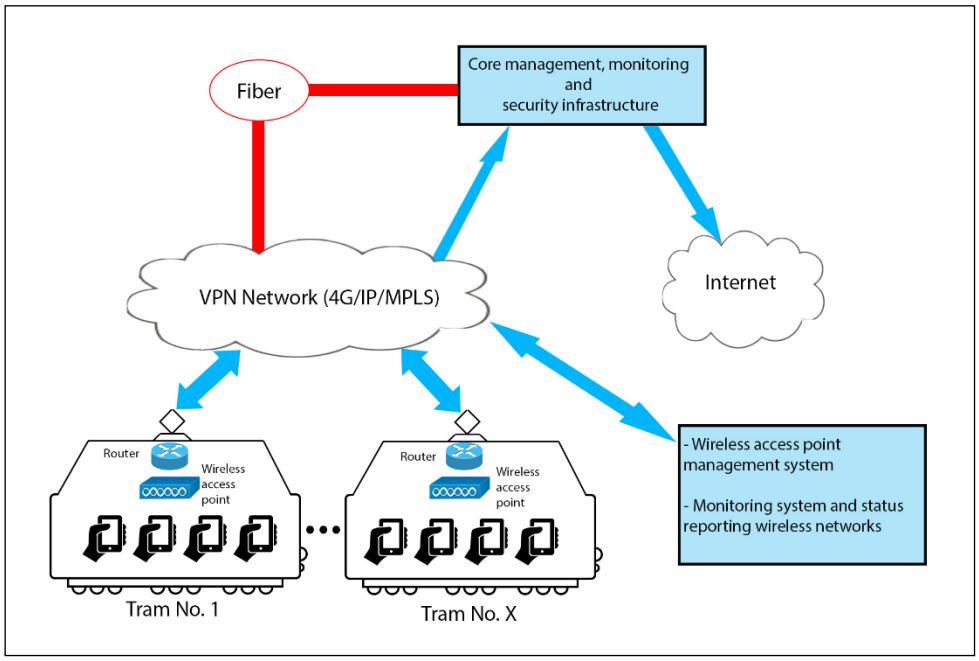


Figure 2 – Logic architecture of accessing Internet via wireless telecommunication network on board trams

The operation mode is simple, and it functions as any other wireless network that uses mobile networks for data transfer. As the observed vehicle moves, the network access is transferred from the coverage area of one cell to the coverage area of another cell, i.e. handover is performed. Therefore, the role of network elements located on board vehicles is to ensure the coverage by a signal in all parts of the tram where the passengers move and stay. They must also use the remote control system, and connecting to LAN network inside the vehicle towards the Internet is realised via routers located on board vehicle. They do not access the Internet directly, but the network traffic is first forwarded through security elements that are contained in the system core. The role of this architecture is to

[2] UMTS – *Universal Mobile Telecommunications System*
[3] IP – *Internet Protocol*
[4] MPLS – *Multiprotocol Label Switching*

unite all the system elements within the vehicle into a unique and protected virtual private network (VPN).

4.2 Network systems inside and outside the vehicle

As mentioned in subsection 4.1, the core of the system contains elements and equipment necessary for continuous operation method of the public wireless telecommunication systems for Internet access. This also means the equipment from the safety aspect which is centralized. It should be noted here that it is essential in the network part to ensure a space consisting of the core management and security centre owned by the service provider. Figure 3 shows the logic architecture of the management and security centre.

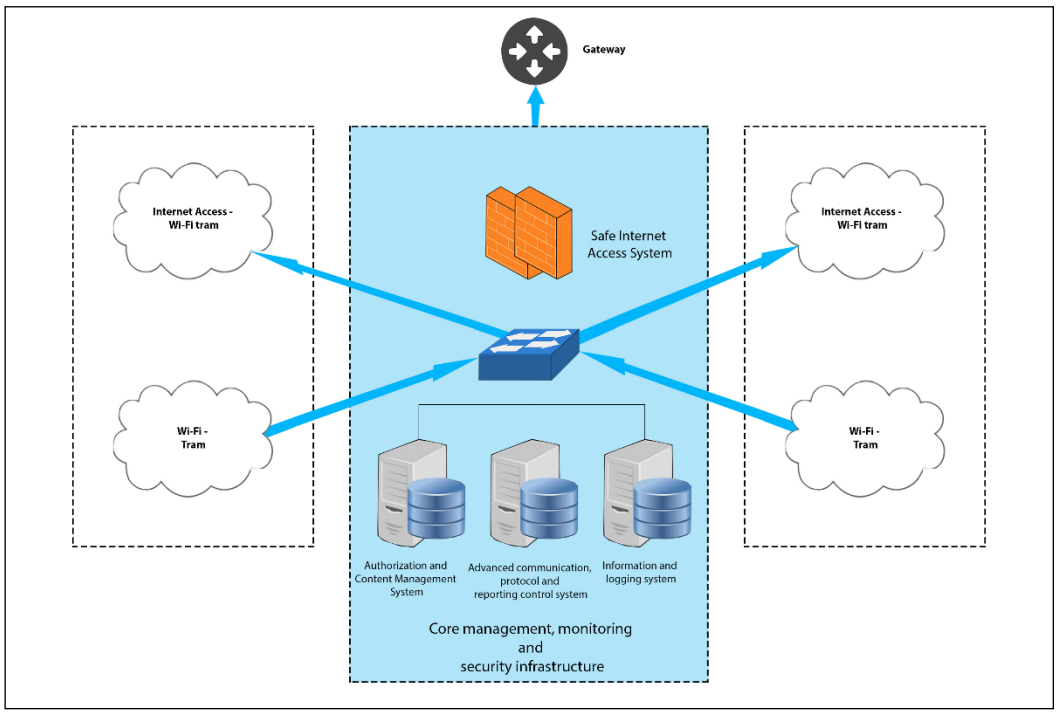


Figure 3 – Logic architecture of management and security centre

As presented in Figure 3, the logic architecture of the core system consists of the following crucial system elements [24]:

- Safe Internet access system;
- Advanced communication, protocol and reporting control system;
- Authorisation and content management system ("*Captive portal*"), and
- Information and logging system.

Safe Internet access system serves to secure protection and filtration of the network traffic having as the goal realization of a safety zone and preventing unauthorized and illegal usage of Internet access services. Since one of the elements of security and protection of wireless telecommunication network with public access by the users, there is a system of advanced control of communication, protocol and reporting. It has to allow control and analysis of the network traffic in order to provide the possibility of controlling whether the network is being misused. Malicious activities can occur with or without the awareness of the end users. Such a system is obligatory in order to provide the possibility for timely reaction should such a need arise. Then the authorisation and content management system is required in order to authorize the user and perform their authentication via "*Captive portal*". This means that every user prior to connecting to the Internet has to pass through the process of authentication and

authorisation. The last element, the information and logging system is used for the storage of users' information and log records.

5. RESULTS OF MEASUREMENT AND DISCUSSION

As indicated in the previous sections, the carried out research used two software tools i.e. two applications: *WiFi Monitor* and *Wifi Analyzer*. These applications enable an overview of the current state of the Wi-Fi network, overview of the list of available Wi-Fi networks and their parameters; then, the presentation of the strength of surrounding networks as well as the presentation of the access speed of the Wi-Fi network. Testing of these parameters has been carried out on the tram lines 11, 12 and 17, and the testing itself took three working days (in March 2019) at three different times of day. At 7 o'clock in the morning, at 3 o'clock in the afternoon and at 10 o'clock in the evening. Since two applications were used for testing, the applications were used consecutively, i.e. one after the other.

5.1 Results of measuring by means of software tools WiFi Monitor

The software tools / mobile application *WiFi Monitor* is free tools that enables the analysis of the state of Wi-Fi networks and monitoring of network parameters (e.g. strength of the signal, frequency, speed of transmission, etc.) [2]. The item within the mobile application "*Connections*" allows insight into the parameters of the wireless network such as the name of the Wi-Fi network (*Service Set Identifier*, SSID), MAC addresses (*Basic Service Set Identifier*, BSSID), maximum speeds ("*Link speed*"), current speeds ("*Speed*") etc. By viewing the item "*Networks*" it is possible to view the available Wi-Fi networks as well as their parameters, and item "*Channels*" allows insight into a spectrum of network signals. Item "*Speed*" shows *uplink and downlink* speeds, and this is being updated every second. Due to the space restriction of this paper, further in the text the data are presented that were obtained by measurement only at one selected location – tram terminal Ljubljanica, tram line No. 12 (*Figure* 4).



Figure 4 – Available networks at tram terminal Ljubljanica, a) in the morning, b) in the afternoon, and c) in the evening

By viewing the available networks at the tram terminal Črnomerec (tram line No. 11) at times during the day, one can observe that on channel number one, where ZETWiFi is found, there is a larger number of wireless networks that could cause interference, but in spite of that, ZETWiFi continues to have the highest transmission strength.

The difference that can be observed is that on the Ban Josip Jelačić Square there is the largest number of detected mobile devices. How the strength of signal behaves depending on the mentioned parameters will be explained in further sections. Field measurements on board trams on tram line No. 12 found that Wi-Fi signal is transmitted on the first and the eleventh channel. Besides, a difference in the strength of signal has been observed as the vehicle moves through the city, i.e. from Ljubljanica to Ban Josip Jelačić Square and this has been shown in Figure 4.

Looking at the measuring results on board tram (tram line No. 17) it has been observed that Wi-Fi signal is transmitted on the first and eleventh channel. Besides, a difference has been noted in the strength of the signal as the tram moves through the city, i.e. from the terminal Borongaj to Ban Josip Jelačić Square. As well as in the previous testing, by looking at the available networks at different times of day, one can notice that there is a large number of networks on channels one and eleven, where ZETWiFi is located, and this could lead to interference. In spite of this, the observed wireless network ZETWiFi continues to have the highest strength of transmission.

5.2 Results of measuring with software tools WiFi Analyzer

Like the previous mobile application, WiFi Analyzer is free tools that allows analysis of the state of Wi-Fi networks and monitoring of its parameters [3]. Thus, it offers an overview of channels, i.e. insight into the spectrum of network signals, strength of the signal, network parameters such as the name of Wi-Fi network, MAC addresses, type of encryption, etc. In the work it has been used in the same way as the previous application and the measuring was based on the frequency range, channel and strength of signal.



a) b) c)

Figure 5 – Available networks at tram terminal Ljubljanica, a) in the morning, b) in the afternoon, and c) in the evening

As in subsection 5.1, looking at the testing results it has been found that the vehicles that were tested, and that operate on Črnomerec – Dubec (tram line No. 11), transmit the signal via the first channel. Also, only the area of 2.4 GHz has been presented since this is the area in which the signal is transmitted. While checking the results of this part of testing it has been found that vehicles in which testing was carried out, on tram route Ljubljanica – Dubrava (tram line No. 12) the signal is transmitted on the first and the eleventh channel (Figure 5). Also, only the area of 2.4 GHz has been presented since this is the area where the signal is transmitted.

The last measurement was done on tram route Borongaj – Prečko (tram line No. 17), and it shows how the signal is transmitted both on the first and the eleventh channel, and the area is again 2.4 GHz. Further in the text there is the discussion related to the carried out measurements.

5.3 Discussion

This section analyses the parameters from the previous sections and the relevant values are presented in Figures 6 and 7, i.e. by graphs that show the fluctuations of strength and transmission speeds at certain moments as well as at different measuring locations. Figures 4 and 5 show the frequency bands, and Figures 6 and 7 show the correlation between the number of devices in the same frequency range and channel, signal strength and data transmission speeds – for one tram route (No. 12).

The strength at the tram terminal Črnomerec and on Ban Josip Jelačić Square is constant and no arithmetic mean has been calculated (tram line No. 11), whereas on the measuring location Britanski Square, the arithmetic mean was calculated due to the change in the strength value. Figure 6 shows the fluctuation of strength in dBm on tram route Ljubljanica - Ban Josip Jelačić Square (on tram line No. 12). The fluctuation of strength at tram terminal Ljubljanica and on Ban Josip Jelačić Square is constant and no arithmetic mean has been calculated (tram line No. 12) whereas at location at the Technical Museum the arithmetic mean has been calculated because of the change in strength value.



Figure 6 – Fluctuations of strength in dBm on tram route Ljubljanica -Ban Josip Jelačić Square

Data measured on other locations behave according to the same principle as the data shown in Figures 6 and 7 thus confirming the hypothesis about the impact of interference on the signal strength, including then also the transmission speeds.

The measured strength at the tram terminal Borongaj and at the location of Ban Josip Jelačić Square is constant and the arithmetic mean has not been calculated (tram line No. 17), whereas at the location of the Trg žrtava fašizma the arithmetic mean has been calculated because of the change in the strength value.

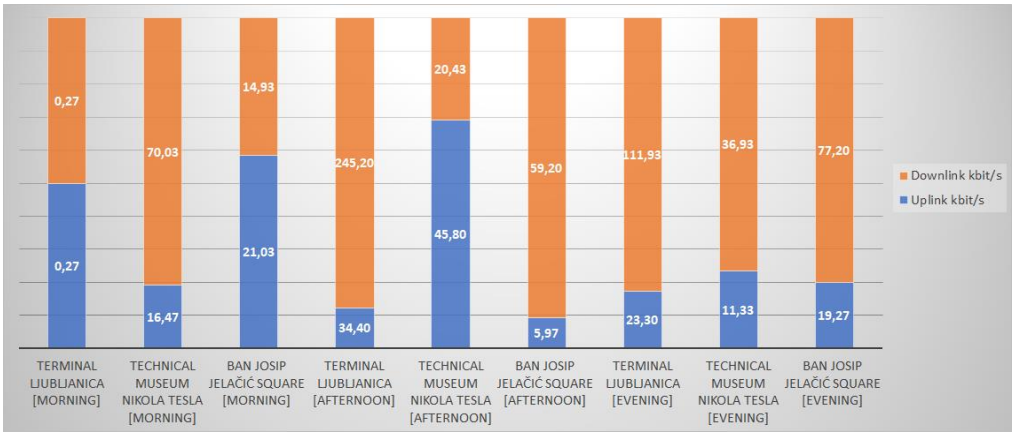


Figure 7 – Data transmission speeds on tram route Ljubljanica - Ban Josip Jelačić Square

At all measuring locations an approximately same behaviour of the wireless network system has been found, so that one may conclude that interference occurring due to different mobile terminal devices from the environment affect the signal strength, and thus the transmission speeds as well. The highest concentration of devices is, as expected, at the Ban Josip Jelačić Square (the main square in the city of Zagreb), as well as in the city parts where there is a greater number of residential / business facilities, as well as passers-by and users / passengers of PUPT. According to field measuring, carried out as part of the performed pilot testing, the expected future plans and guidelines in the planned research are given.

6. CONCLUSION

The carried out research had as its goal pilot testing of the current wireless telecommunication network (Wi-Fi) on board trams of public urban passenger transport as one of the initial phases of systemic testing of the Internet access service quality for end users of the public urban transport. Analysing the data obtained in different types of vehicles (trams), on different tram routes and measuring locations, at different times of day, the optimality of the current wireless telecommunication network (Wi-Fi) can be determined. Thus, from the available results of field measuring mentioned in this paper, it has been found that the signal strength is similar at all moments of measuring on all the analysed tram lines (from -30 dBm to -60 dBm), but the transmission speeds change with the fluctuations of the signal strength. Since the measurements have been carried out at the same position in every vehicle (tram), the position of the user / passenger did not affect the measuring results, unlike the number of passengers in the vehicles and the quantity of their mobile terminal devices that affected the occurrence and the level of interference. According to the available results of field measurements in this paper, it is clear that the oscillations in transmission speeds are great and that they depend on the time of measurement, i.e. the number of passengers/users on board vehicle. The signal interferences are highly present since the frequency range of 2.4 GHz is used by almost all mobile terminal devices in the environment of the observed tram network. It may be assumed that the speeds were more stable and the oscillations would be reduced if the signal of the wireless network ZETWiFi would transmit in the frequency range of 5 GHz. In order to be able to claim this with certainty, additional measurements in the mentioned band need to be carried out, as well as other expanded measurements and additional research. Besides, it is necessary to perform measurements using advanced software tools in order to discover potential omissions in the signal coverage and similar problems related to wireless telecommunication networks. The carried out pilot testing of the wireless telecommunication network on board vehicles of public urban passenger transport in the city of Zagreb will serve in the implementation of future research. The results of this research may be compared and used as the basis of launching future studies in order to facilitate the determination of the direction of research and the expected measuring results. Furthermore, the

theoretical base set while producing this paper, can be used as the basis of subsequent studies with the similar topic with the use of constant monitoring of the development of wireless technologies and the accompanying network infrastructure. The collected research results can serve the operator of the public urban transport as a base in making decisions on the improvement of the wireless telecommunication network system (Wi-Fi) on board their vehicles (trams).

The plans for future studies are related to the implementation of various mobile terminal devices (smartphones, tablets and laptops) and professional software tools (mobile applications) in the function of measuring the level and quality of the wireless telecommunication network (Wi-Fi) signal in tram and bus traffic, taking into consideration the implemented network equipment (access points). The field measurements would be closely connected to the frequency bands from 2.4 GHz and 5 GHz, and it is also necessary to carry out additional testing in the mentioned bands. In further studies the measuring should be carried out with advanced (professional) software tools in order to obtain better field data and result interpretation. According to the measured results the implementation of the measurements at peak hours is expected (in the morning and afternoon). Using the results of the carried out field measurements as the base, future research can concentrate on the omissions that have occurred in the interpretation of the results of the pilot testing.

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KRISTIJAN ROGIĆ, Ph.D.[1]
E-mail: krogic@fpz.hr
RATKO STANKOVIĆ, Ph.D.[1]
E-mail: rstankovic@fpz.hr
MARKO RUŽIĆ, dipl. ing. biol.-ekol.[2]
E-mail: marko.ruzic@gorica.hr
GORAN KOLARIĆ, M.Sc.[3]
E-mail: Goran.Kolaric@mzo.hr
[1] University of Zagreb, Faculty of Transport and Traffic Sciences
Vukelićeva 4, Zagreb
[2] City of Velika Gorica
Trg kralja Tomislava 34
[3] Ministry of Science and Education
Donje Svetice 38, 10 000 Zagreb

ANALYSIS OF WASTE TRANSPORT IN CITY OF VELIKA GORICA

ABSTRACT

As transport covers nearly 45 % of total logistics costs (transport, manipulation, warehousing, inventory management, distribution, etc.), and significantly influences the features of providing a complete logistics service, it is necessary to optimize the cost of that process. This paper analyses the collection of waste in the area of City Velika Gorica with an emphasis on the work performance of waste collection teams. As the separate waste collection in this area has just begun, the analysis was done on collection of mixed municipal waste. The paper presents the results of the research, thus achieved tons of kilometres per vehicle, the work performance per vehicle, and also the possibility of redefining the district and optimizing the layout of the vehicles by routes for the purpose of increasing efficiency was commented.

KEY WORDS

transportation waste; analysis; vehicle performance; optimization;

1. INTRODUCTION

Many authors have studied the routing of waste collection vehicles. Authors separated routing problems vehicles into:

- node routing and arc routing, where within waste management, the former is mainly used to model bring systems and
- the latter models curb side collection.

Authors [1, 2] consider collection of recyclable material using single and multi-compartment vehicles, respectively, while authors [3, 4] study collection of general waste.

Paper [5] impersonate the problem of district design, which is highly relevant to several real life problems of servicing street segments, including that of curbside collection of waste. Such districts form the basis of work to be performed between work teams or between weekdays and therefore workload need to be balanced between them. Furthermore, districts must have several attributes such as being compact, convex, and non-overlapping in order to be appealing in practice.

Authors [6] consider that the collection infrastructure (on-site curbside collection) and the collection policy (periodic schedules) of all systems are fixed, and concentrate on the variation in the combination level of collection, the characteristics of the col-lection vehicles, and the collection interval of each waste type. Paper impersonate four curbside waste collection systems:

- Collect to incinerate,
- Collect, then sort,
- Sort, then collect by single compartment vehicles,
- Sort, then collect by multi compartment vehicles.

According to [7] collection and haulage of transport in modern MSW management systems are accountable for the greater part of total costs associated with MSW management, so to manage these costs in this paper presents a model that optimizes MSW collection and haulage by means of dynamic scheduling and routing allocation. Authors [8] model the effect of three different options for MSW collection to reduce vehicle mileage while authors [9] discuss a model for choosing optimal waste collection and haulage to lower the transport cost associated with the collection and haulage of MSW. The cost associated with MSW transport accounts for the majority of total MSW management costs in the discussed case studies.

Authors [10] showed up comparative analysis of waste management in Croatia and other countries that have implemented certain waste management solutions. Paper also presented new technologies regarding waste management processes optimization will be presented as well.

The paper analyses the collection of waste in the area of City of Velika Gorica with an emphasis on the work performance of waste collection crews. Primary analysis is made for the collection of mixed municipal waste (MMW), as separate collection of waste at "home threshold" has only carried out for a short period (one to two years) and only for certain parts of the area of City of Velika Gorica, and there is not enough available data for making a complete analysis.

The analysis was made on the basis of available data for 2015, 2016, 2017 and 2018, and due to its inconsistency, some missing data for each period are approximated on the basis of known data from other corresponding periods. In this regard, the study includes the following elements:

- Overview of realized ton kilometres (tkm) per vehicle/crew for a specific time period
- Overview of performance per vehicle/crew
- After analysing per vehicle/crew analysis was performed by districts
- In conclusion there is a comment on the possibility of redefining districts and optimizing crew schedules in order to equalize the workload of the crews, which also creates the preconditions for separate collection of waste with existing resources.

Paper is based on the need and realistic possibilities for optimizing the work performance of waste collecting crews, while assuming preservation of jobs and increased efficiency.

Measures to prevent or reduce the harmful effects of waste on human health and the environment by reducing the amount of waste are regulated by the Act on Sustainable Waste Management (OG 94/13, 73/17), hereinafter referred to as the Act. In addition, this Act regulates waste management without using risk-based procedures for human health and the environment with the use of valuable waste properties. [11]

The statutory framework for waste collection and management, in addition to the above-mentioned Act, is further regulated by the Waste Management Ordinance (OG 117/2017), the Waste Management Plan for the period 2017-2022 (NN 3/2017), the Waste Management Plan of the City of Velika Gorica for the period 2018-2023 and the Decision on the manner of providing public services for the collection of mixed municipal waste and biodegradable municipal waste in the area of Velika Gorica (Official Gazette of the City of Velika Gorica No. 4/2018) and other documents related to the subject area. [12, 13, 14]

Waste management is of interest to the Republic of Croatia, and in this respect waste management and the efficiency of waste management are ensured by the Croatian Government and the Ministry of Environment and Energy and carried out by prescribing measures of waste management. Implementing bodies for waste management are the Croatian Agency for the Environment and Nature and the Environmental Protection and Energy Efficiency Fund.

Each local and regional self-government unit is obliged to ensure conditions and implementation of prescribed waste management measures in its area. [11]

The provisions of the Act establish: [11]

- The waste management system,
- Principles, objectives and method of waste management,
- Strategic and program documents in waste management,
- Responsibilities and obligations in waste management,
- Locations and waste management facilities,
- Waste management activities,
- Cross-border traffic of waste,
- Waste management information system,
- Administrative and inspection control over waste management.

2. BASIC INFORMATION

For the purposes of waste collection, the area of the City of Velika Gorica is divided into 23 districts. The district is a specific part of the collection area, and within the district routes are determined with respect to the type of waste collected (MMW, plastic and cans, paper). On the territory of the town of Velika Gorica, out of 23 districts, districts XXII and XXIII are specific, and are referring to the International Airport Franjo Tuđman, the Prison and the Educational Institution of Turopolje. Waste collection in these districts is performed by duty teams as needed.

In accordance with the above mentioned, in the districts where waste is collected separately, there are several routes (special route for each type of waste), and in areas where waste is not separated, there are certain unique routes for all locations in the area concerned. Districts of Velika Gorica represent a combination of urban and rural areas where waste is collected.

There are seven crews in the area of Velika Gorica for the collection of MMWs in 23 districts. The crew consists of a truck driver and two crew members, and in specific cases the crew consists of a truck driver and three crew members (cases involving amounts of waste larger than the usual average quantities). The seven crews mentioned have 10 trucks for waste collection. Vehicles/crews collect only one type of waste in a given period, and each vehicle/crew can collect the same waste at all types of waste sources (at all locations).

Vehicle/crew visits the district on a certain route, and after the waste is taken to the landfill, weighted and disposed (dumped), continues the tour at the location where the tour has been interrupted until the whole district or route is covered (most of the time one tour/disposal is sufficient).

All MMW collected is taken to the Mraclinska Dubrava waste disposal site near the Mraclin settlement. At the same location there is the Recycling yard Mraclinska Dubrava, where separate recycled waste is transported, while an additional recycling yard is located in Velika Gorica.

In order to control the disposal and collection of waste, in accordance with the Law, the priority of waste management is applied as follows:

- Prevention of waste generation,
- Preparation for re-use,
- Recycling,
- Other methods of recovering, for example, energy recovery and
- Waste disposal.

According to the Law on Sustainable Waste Management (OG 94/13, 73/17) [11]: "Waste must be recovered and waste recovery must be carried out in accordance with the principles and methods of waste management as defined by the Act. Waste management is carried out in a manner that will

not endanger human health and which does not cause adverse environmental impacts, and in particular to avoid:

- Risk of pollution of the sea, water, soil and air and endangering biodiversity,
- Occurrence of discomfort caused by noise and/or odor,
- Harmful impact on the areas of cultural-historical, aesthetic and natural values and other values of particular interest,
- Formation of an explosion or fire.

Waste classification includes the determination of the properties, origin and places of waste generation taking into account the composition of the waste and the limit value of the concentration of hazardous substances and hazardous waste properties, the determination of the group, subgroup and waste types in accordance with the Waste Catalog (OG 90/15). Waste Catalog contains: Waste Classification (except for cross-border waste classification), Waste Group and Subgroup List and Waste List. [15]

Waste Catalog divides waste into the following categories: [15]

- Waste generated by exploration, exploitation and physico-chemical treatment of mineral raw materials,
- Waste from agriculture, horticulture, aquaculture production, forestry, hunting and fishing, food preparation and processing,
- Waste from wood processing and production of wooden panels and furniture, pulp, paper and cardboard,
- Waste from leather, fur and textile industries,
- Waste from oil refining, purification of natural gas and pyrolytic coal treatment,
- Waste from inorganic chemical processes,
- Waste from organic chemical processes,
- Waste from production, formulation, supply and use of coatings (paints, varnishes and glass enamels), adhesives, sealants and printing inks,
- Waste from the photographic industry,
- Waste from thermal processes,
- Waste from chemical surface treatment and coating of metals and other materials; non-ferrous metal hydrometallurgy,
- Wastes from mechanical design and physical and mechanical surface treatment of metals and plastics,
- Waste oils and waste from liquid fuels
- Waste from organic solvents, refrigerants and propellant substances
- Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not specified otherwise,
- Waste not specified elsewhere in the catalog,
- Construction waste and waste from building demolition (including excavated land from contaminated sites),
- Waste resulting from the protection of human and animal health and/or related research (excluding kitchen and restaurant waste not derived from immediate health care),
- Waste from waste management facilities, sewage treatment plants outside the place of production and preparation of drinking water and water for industrial use,
- Municipal waste (household waste and similar waste from institutions and trade and manufacturing activities) including separately collected municipal waste
  - separately collected municipal waste (except packaging),
  - waste from gardens and parks (including waste from the cemetery),
  - other municipal waste.

Each local self-government unit is obliged to provide a public service in its territory for the collection of mixed municipal waste and biodegradable municipal waste; separate collection of waste paper, metals, glass, plastics and textiles and large (bulk) municipal waste. In addition, the local self-government unit must prevent waste disposal in a way contrary to the Act and remove such waste, implement the Waste Management Plan of the Republic of Croatia (OG 3/17), adopt and implement the waste management plan of the local self-government unit, conduct training-information activities in its area and have the ability to carry out waste collection activities. In addition, the local self-government unit is obliged to participate in the collection systems of special categories of waste in accordance with the regulation governing the management of a special category of waste. [13]

Waste disposal categories, procedures and other conditions for waste disposal, procedures and other conditions for receiving waste into underground landfills are laid down in the Ordinance on the methods and conditions for the landfill of waste, categories and operational requirements for waste landfills (OG 114/15). [16]

The structure of the vehicle fleet responsible for collecting waste in the area of Velika Gorica consists of a total of 10 vehicles. By type of vehicle, trucks with a load capacity between 6 and 7 tons are prevalent and a useful volume of 16 m3 cargo space. These vehicles are used by seven operating crews that collect waste, so that the organizational system is arranged in such a way that there is always a reserve vehicle(s).

From the technical point of view, vehicle equipment varies, only some vehicles have load cargo sensors (according to information from the VG Čistoća), which make the use and work of the crew easier.

3. ANALYSIS OF CREW PERFORMANCE

Work performance of crews by districts was analyzed according to the data and further clarifications were obtained from the company VG Čistoća d.o.o., which is responsible for collecting waste in the area of Velika Gorica. By looking at the data obtained and analyzing it with employees of VG Čistoća d.o.o., it was found that the established MCA collection model is repeated over time (months, years), while some data on waste quantities and team work are not consistent, and missing data for certain periods was approximated based on known data from other corresponding periods.

Table 1 – Collected tons of MMW during 2015, 2016 and 2017

Months	2015	2016	2017
1	1,062.12	990.66	1,009.24
2	935.66	1,025.84	962.84
3	1,106.60	1,116.16	1,160.00
4	1,174.48	1,087.88	1,041.12
5	1,138.24	1,190.02	1,241.80
6	1,102.34	1,178.22	1,154.76
7	1,196.16	1,087.96	1,130.14
8	1,087.42	1,213.70	1,191.20
9	1,178.48	1,171.30	1,182.33
10	1,230.50	1,174.26	1,271.95
11	1,142.70	1,236.78	1,173.12
12	1,178.12	1,094.78	1,139.70
Total	13,532.82	13,484.08	13,658.20
standard deviation	77.92231	75.81886	91.56265
average	1,127.74	1,130.63	1,138.18
coefficient of variation (CV)	7%	7%	8%

Source: created by authors

The schedule of crews by days i.e. MMW collection districts is given in Table 2.

Table 2 – Schedule of crews by MMW collection district

				Schedule of crews						
Team	**Driver**	**Vehicle registration**	**Vehicle type**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Team I	Dianežević	ZG 6843 AR	MB ATEGO	Districts III	Districts IX	Districts XIII	Districts III	Districts IX	Districts XXII duty crews	Districts XXIII duty crews
Team II	Galeković	ZG8506 FK	MAN TGM	Districts II	Districts VIII	Districts XIV	Districts II	Districts VIII		
Team III	Jović	ZG 6823 AR	MB ATEGO	Districts I	Districts VII	Districts XV	Districts I	Districts VII		
Team IV	Žugaj	ZG 2973 DJ	MAN TGM	Districts IV	Districts X	Districts XVI	Districts IV	Districts X		
Team V	Mrakovčić	ZG 1652 DD	MAN TGM	Districts VI A	Districts XII A	Districts XIX	Districts VI	Districts XII A		
Team VI	Zlodi	ZG 7640 BI	MAN TGA	Districts VI	Districts XII	Districts XVIII	Districts VI	Districts XII		
Team VII	Grdenić	ZG 8886 BH	MAN LE	Districts V	Districts XI	Districts XVII	Districts V	Districts XI		

Source: created by authors

Crews are deployed so that each crew collects waste in several different districts during the week (schedule by days) to compensate for the differences in the work required when collecting waste in a specific district (districts are formed so that the required amount of work per district is not the same). However, due to the characteristics of the districts themselves (larger rural areas or densely populated urban areas) the workload of crews is not sufficiently uniform.

In the further analysis 2016 was taken as the reference year, given that data for that year was the most complete.

Work performance of crews is shown in Table 3 and diagrams (Figure 1). Below average values are marked in red.

Table 3 – Collected quantities of MMW in tons (t) according to monthly average and annual total (2016)

				AVERAGE						TOTAL
Team	**Driver**	**Vehicle registration**	**Vehicle type**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**t/month**	**t/year**
Team I	Dianežević	ZG 6843 AR	MB ATEGO	26,32	34,83	29,87	24,59	26,38	142	**1.704**
Team II	Galeković	ZG 8506 FK	MAN TGM	24,53	27,51	39,82	28,42	22,98	143	**1.719**
Team III	Jović	ZG 6823 AR	MB ATEGO	20,79	25,21	34,51	24,78	22,35	128	**1.532**
Team IV	Žugaj	ZG 2973 DJ	MAN TGM	27,04	36,80	35,94	25,18	22,16	147	**1.765**
Team V	Mrakovčić	ZG 1652 DD	MAN TGM	19,02	28,62	26,57	28,34	20,00	123	**1.471**
Team VI	Zlodi	ZG 7640 BI	MAN TGA	28,24	28,19	29,87	32,91	29,92	149	**1.861**
Team VII	Grdenić	ZG 8886 BH	MAN LE	42,70	32,44	24,55	20,73	27,60	148	**1.776**
								average	139,96	1.689,63
								standard deviation	10,57	139,34
								coefficient of variation (CV)	8%	8%

Source: created by authors

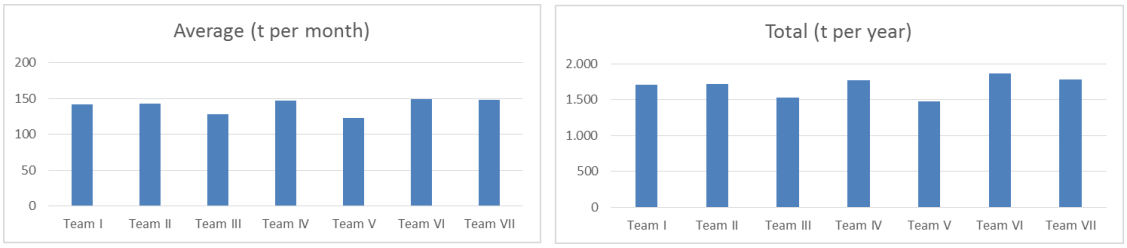


Figure 1 – Overview of collected tones (t) of MMW according to monthly average and annual total (2016)
Source: created by authors

In Table 4, the days were calculated by kilometers per crew, for monthly average and annual total (for 2016). Below average values are marked in red. Data from Table 4 are graphically shown in Figure 2.

Table 4 – Estimated kilometers (km) according to monthly average and annual total (2016)

				AVERAGE						TOTAL
Team	Driver	Vehicle registration	Vehicle type	Monday	Tuesday	Wednesday	Thursday	Friday	km/month	km/year
Team I	Dianežević	ZG 6843 AR	MB ATEGO	192	184	261	143	186	965	**11.583**
Team II	Galeković	ZG 8506 FK	MAN TGM	165	174	258	186	183	965	**11.579**
Team III	Jović	ZG 6823 AR	MB ATEGO	150	187	190	210	194	931	**11.168**
Team IV	Žugaj	ZG 2973 DJ	MAN TGM	148	353	347	268	299	1.414	**16.973**
Team V	Mrakovčić	ZG 1652 DD	MAN TGM	286	299	269	324	299	1.477	**17.718**
Team VI	Zlodi	ZG 7640 BI	MAN TGA	342	334	280	374	258	1.588	**19.060**
Team VII	Grdenić	ZG 8886 BH	MAN LE	359	257	216	439	273	1.544	**18.529**
								average	1.269,17	15.230,00
								standard deviation	300,29	3.603,49
								coefficient of variation (CV)	24%	24%

Source: created by authors

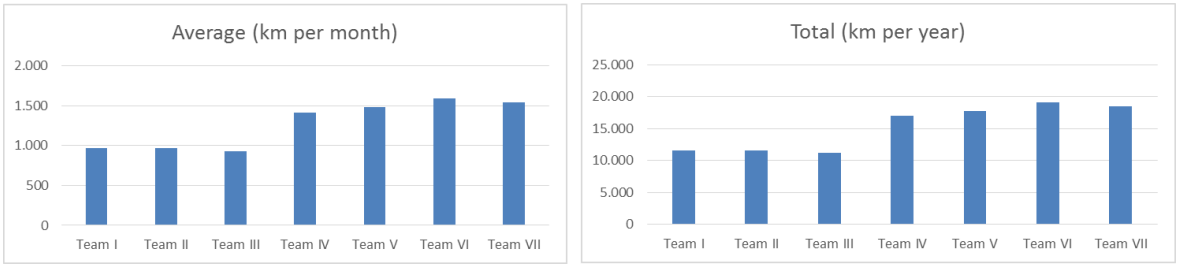


Figure 2 – Overview of mileage (km) according to monthly average and annual total (2016)
Source: created by authors

Overview of realized ton kilometers according to monthly average and annual total is given in Table 5, and the graphical representation in Figure 3. Below average values are marked in red.

Table 5 – Ton kilometers (tkm) according to monthly average and annual total (2016)

				AVERAGE						TOTAL
Team	Driver	Vehicle registration	Vehicle type	Monday	Tuesday	Wednesday	Thursday	Friday	tkm/month	tkm/year
Team I	Dianežević	ZG 6843 AR	MB ATEGO	5.046	6.420	7.790	3.510	4.898	27.663	**568.995**
Team II	Galeković	ZG 8506 FK	MAN TGM	4.044	4.784	10.259	5.275	4.201	28.564	**572.366**
Team III	Jović	ZG 6823 AR	MB ATEGO	3.118	4.725	6.547	5.198	4.331	23.919	**500.367**
Team IV	Žugaj	ZG 2973 DJ	MAN TGM	3.996	13.003	12.462	6.742	6.620	42.823	**874.929**
Team V	Mrakovčić	ZG 1652 DD	MAN TGM	5.433	8.550	7.159	9.180	5.975	36.297	**782.448**
Team VI	Zlodi	ZG 7640 BI	MAN TGA	9.651	9.428	8.351	12.322	7.724	47.476	**1.086.175**
Team VII	Grdenić	ZG 8886 BH	MAN LE	15.350	8.331	5.292	9.104	7.533	45.610	**1.052.134**
								average	36.050,44	776.773,45
								standard deviation	9.499,37	238.947,21
								coefficient of variation (CV)	26%	31%

Source: created by authors

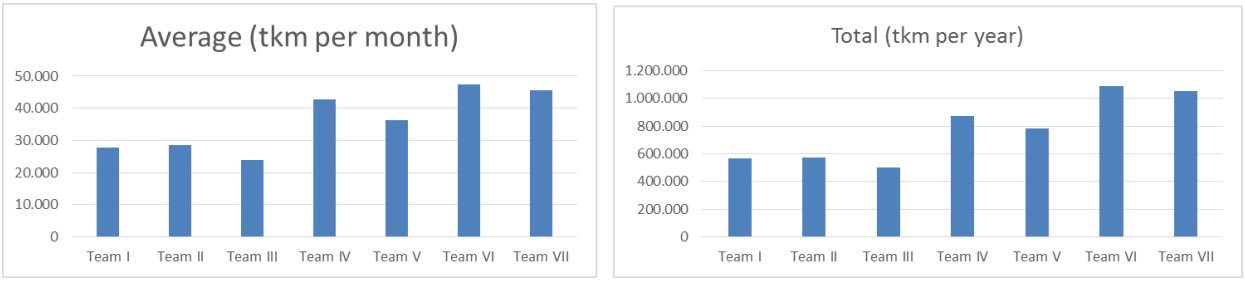


Figure 3 – Overview of realized ton kilometers (tkm) according to monthly average and annual total (2016)
Source: created by authors

Tables show the relevant figures for analyzing crew work performance; along with average values, standard deviation and coefficient of variation are also specified, and the values that are below average are marked in red. Significant deviations can be observed in work performance of individual crews, for example Crew III achieved 500.367 tkm/year and Crew VI 1.086.175 tkm/year.

The situation is such partly due to the specificity of the districts where individual crews collect the MMW, which is related to the density of urban or rural areas, the distance from the landfill site, and the graphs show the amount of collected MMW and covered kilometers, which results in a work performance in achieved ton kilometers (tkm). Analysis of the actual work performance, i.e. crew workload, opens up the question of possible reorganization of crews by districts.

4. ANALYSIS OF THE PERFORMANCE ACHIEVED BY DISTRICTS

Table 6 gives an overview of the work performance of crews by districts. Working hours of crews for individual days when crews collect the MMW are also given, so that data is separately provided for each day of the week, since in the same district a certain crew performs collection for two days a week, but not on the same route. Additionally, an overview of the vehicle's carrying capacity is given, enabling a detailed insight into the performance of a particular team in the above mentioned areas.

Table 6 – Overview of the performance achieved by districts

Districts	Team	Vehicle registration	Vehicle capacity (t)	Day	Working hours	Driving time	km per day	Average t per day	Average t per month	Average km per month	Average tkm per month
Districts I	Team III	ZG 6823 AR	6,82	Monday	6:22:39	1:09:38	29,52	5,19	**45,58**	**360**	**16.545**
				Thursday	7:49:31	2:39:32	41,29	6,70			
Districts II	Team II	ZG8506 FK	7,13	Monday	5:33:48	1:59:11	32,13	6,23	52,95	**350**	**18.794**
				Thursday	6:51:22	2:13:13	36,17	7,56			
Districts III	Team I	ZG 6843 AR	6,82	Monday	5:59:38	2:26:33	40,1	6,58	50,91	**334**	**16.979**
				Thursday	5:03:51	1:42:03	29,85	6,40			
Districts IV	Team IV	ZG 2973 DJ	6,18	Monday	5:23:43	2:39:14	28,56	7,58	52,22	**416**	21.765
				Thursday	6:06:37	3:37:55	51,74	7,29			
Districts V	Team VII	ZG 8886 BH	6,36	Monday	7:29:34	3:46:11	88,75	10,64	63,43	799	50.543
				Thursday	7:43:36	4:59:55	108,45	5,42			
Districts VI	Team VI	ZG 7640 BI	9,92	Monday	5:25:43	3:14:41	68,38	7,29	61,15	716	44.932
				Thursday	5:58:02	3:24:48	74,91	8,71			
Districts VI A	Team V	ZG 1652 DD	6,26	Monday	6:09:30	3:07:35	58,28	4,74	47,36	610	28.960
				Thursday	8:13:30	5:16:07	66,08	8,26			
Districts VII	Team III	ZG 6823 AR	6,82	Tuesday	6:11:16	2:11:36	36,90	6,73	47,56	**381**	**18.472**
				Friday	6:31:09	2:19:42	38,14	5,88			
Districts VIII	Team II	ZG8506 FK	7,13	Tuesday	5:28:17	2:01:20	33,89	6,86	50,49	**357**	**18.589**
				Friday	6:06:38	2:19:24	35,63	5,87			
Districts IX	Team I	ZG 6843 AR	6,82	Tuesday	6:11:51	2:47:03	38,55	9,35	61,21	**370**	22.711
				Friday	6:12:35	2:46:15	38,84	6,45			
Districts X	Team IV	ZG 2973 DJ	6,18	Utorak	6:24:10	3:37:41	68,28	9,07	58,96	652	38.624
				Friday	6:09:31	3:31:44	57,74	6,00			
Districts XI	Team VII	ZG 8886 BH	6,36	Tuesday	7:12:41	3:45:08	63,41	9,22	60,04	530	31.858
				Friday	6:57:21	3:59:06	67,39	6,75			
Districts XII	Team VI	ZG 7640 BI	9,92	Utorak	6:07:08	2:23:47	66,92	6,89	58,11	593	35.209
				Friday	5:14:40	2:42:03	51,66	7,91			
Districts XII A	Team V	ZG 1652 DD	6,26	Tuesday	7:47:23	4:29:45	60,94	7,57	48,63	597	29.096
				Friday	8:13:30	5:16:07	66,08	4,80			
Districts XIII	Team I	ZG 6843 AR	6,82	Wednesday	7:15:33	3:10:33	54,54	7,65	**29,87**	**261**	**7.726**
Districts XIV	Team II	ZG 8506 FK	7,13	Wednesday	7:01:04	3:48:20	50,21	10,90	**39,82**	**258**	**10.314**
Districts XV	Team III	ZG 6823 AR	6,82	Wednesday	7:11:08	3:29:42	37,35	9,57	**34,51**	**190**	**6.679**
Districts XVI	Team IV	ZG 2973 DJ	6,18	Wednesday	7:05:23	4:23:04	67,00	9,01	**35,94**	**347**	**12.521**
Districts XVII	Team VII	ZG 8886 BH	6,36	Wednesday	6:36:52	3:52:59	53,22	6,00	**24,55**	**216**	**5.277**
Districts XVIII	Team VI	ZG 7640 BI	9,92	Wednesday	5:40:26	3:18:56	55,94	0,00	**35,80**	**280**	**10.375**
Districts XIX	Team V	ZG 1652 DD	6,26	Wednesday	8:08:44	4:29:52	54,97	0,00	**26,57**	**269**	**7.148**
								average	46,93	423,06	21.577
								standard deviation	11,99	174,96	12.988
								coefficient of variation (CV)	26%	41%	60%

Source: created by authors

Table 6 show the relevant figures for analyzing crew work performance; along with average values, standard deviation and coefficient of variation are also specified, and the values that are below average are marked in red. In 12 districts less than average value of tkm was realized, which amounts to 21,577 tkm on average per month. In District XVII the realized tkm is only one quarter of

the average value. The situation is partly due to the specificity of districts where specific crews collect MMW (population density of the urban or rural areas, distance from the landfill site), which raises the question of possible reorganization of crews by districts.

Data from Table 6 are graphically shown in Figure 4, Figure 5, and Figure 6.

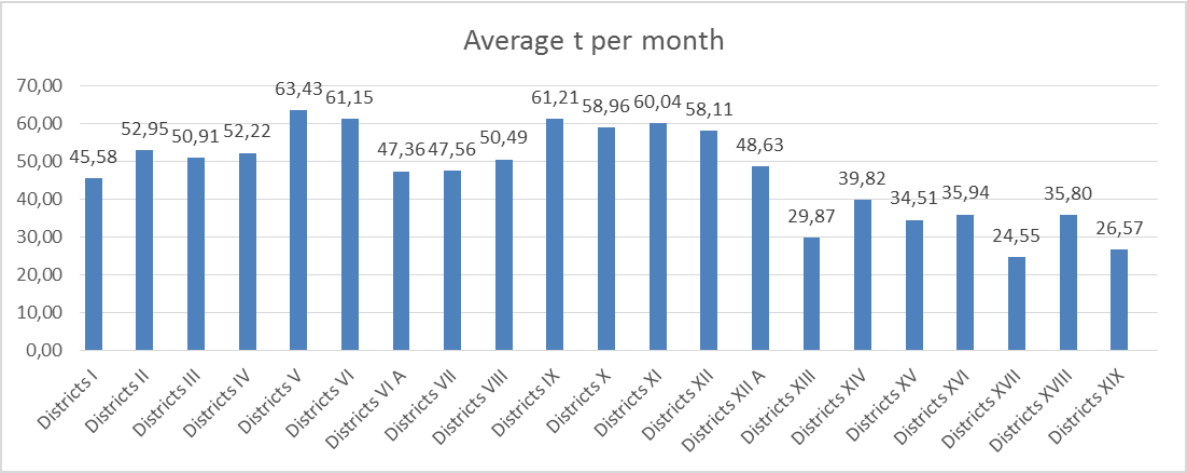


Figure 4 – Average monthly quantities of waste in tons
Source: created by authors

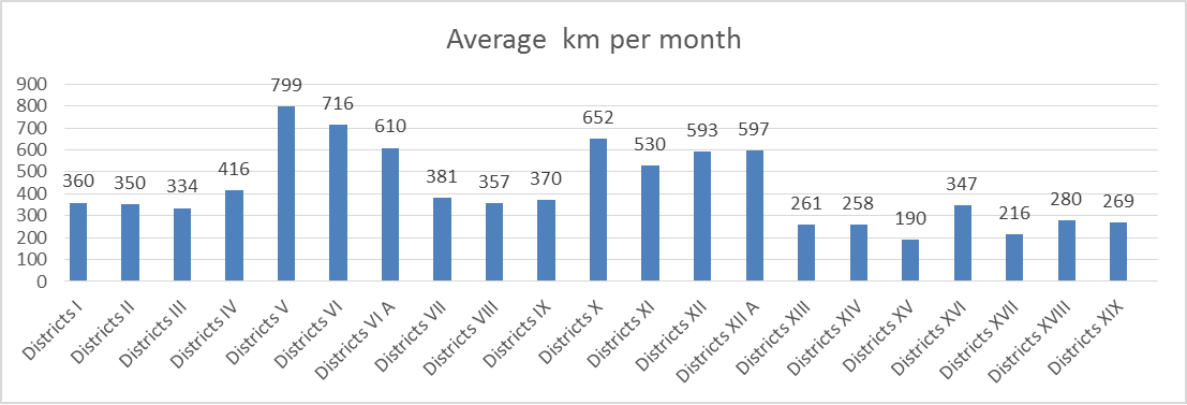


Figure 5 Average kilometers covered in a month
Source: created by authors

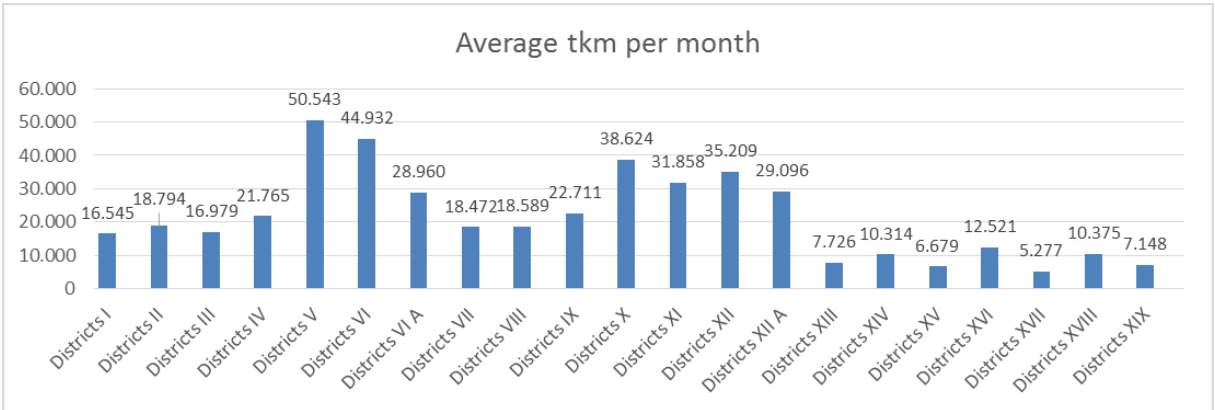


Figure 6 Average monthly ton kilometers achieved
Source: created by authors

5. CONCLUSION

Based on the results of the analysis of the existing state of the waste collection system in Velika Gorica, according to the available data and information obtained from the company VG Čistoća d.o.o. Velika Gorica, the following conclusions can be drawn:

Collected volumes of MMW by months for the year (2016) show a slight growth trend, which should be taken solely as orientational due to the high variation coefficient value (6% of 27%, depending on the district). In addition, data on the total amount of collected MMW, which in 2017 is 1.3% higher than in 2016, and 0.9% higher than in 2015. This should also be taken with a grain of salt because the period is too short to carry out statistically relevant conclusions about trends.

There is a noticeable inconsistency in the amount of work needed to collect MMW by districts (realized ton kilometers), ranging from 63,321 tkm/year in District XVII to 606,520 tkm/year in District V, with a variation coefficient of 60%. Such great differences are the result of different numbers, dispersions and user structures, and partly because of possible changes since the time the districts were defined.

The non-uniformity of the work required by the districts has been taken into account when arranging the schedules of crews that collect MMW by districts, and the existing schedule partly offsets that inconsistency. However, the work performance of crews in ton kilometers achieved during collection of MMW is still not sufficiently uniform, ranging from 500.367 tkm / year (Team III) to 1.086.175 tkm/year (Team VI), with a variation coefficient of 31 %.

Taking into account the expected reduction of MMW quantities due to separate collection of waste, redefining the districts/routes and optimum allocation of crews would open the possibility of separate collection of waste with existing resources (or with minimal additional resources).

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BERNHARD RÜGER, FH-Prof. Dr.[1]
E-mail: bernhard.rueger@tuwien.ac.at
NORBERT OSTERMANN, Univ.Prof. Dr.[1]
E-mail:norbert.ostermann@tuwien.ac.at
[1] Vienna University of Technology
Karlsplatz 13/230-2, 1040 Vienna, Austria

EFFICIENT PASSENGER TRAINS

ABSTRACT

In order to be "competitive" as a railway, operating efficiency counts as an important imperative. In the context of railway carriage interior planning this is often made subordinate to other substantial aspects such as for example, expediency. This leads in practice to the opposite wished for result. Misunderstood operating efficiency concepts such as a maximal utilization of space for seating can in reality lead to a decline in operating efficiency, operational problems and in incidents to serious safety risks.

KEY WORDS

efficient rail vehicles; baggage handling; passenger flow; dwell time reduction; high occupancy rate

1. INTRODUCTION

The railway finds itself, especially in long-distance travel, in an area of tension between both of its competitors, road travel and air travel. People who travel by air have or at least see no alternative to air travel. This leads to an acceptance by air travellers of comfort constraints which arise due to economic pressures on the airlines. Airlines can afford to arrange the seats in the passenger cabin to achieve a maximum of seating. Since in airline travel reservations as well as the check-in of luggage are compulsory, all seats can therefore actually be used and sold.

For the railway such restrictions or drastic loss of comfort are not common and are therefore seldom implemented. Depending on travel duration and distance at least half of railway passengers could use the alternative of auto or air travel. Over 50% of travellers on ÖBB long-distance trains say that they have a driving license and have an auto available at any time. Also, because airline tickets are to some extent inexpensive, the cost argument regarding this mode of transportation is often eliminated. This in turn makes air travel more attractive.

The railway cannot afford to (and should not) ignore the demands and needs of travellers. In order to achieve the high proportion of railway travellers wished for in transport policy, which as a rule also actually contains economic benefits, the railway must bring into play the advantages which it has over other modes of transportation.

However, the tendency in recent years to equip vehicle interiors with the highest possible number of seats contradicts these considerations. This leads not only to a loss of comfort, which approximates the comfort level of air travel, but also in a number of ways constitutes serious operational problems. These problems are often not considered especially in the purchase of vehicles. The often applied evaluation criterion of the highest possible number of seats and thereby expected lower purchase- and operating costs per passenger is one-dimensional and therefore inadequate since it clearly contradicts reality in more ways than one. The consequences are elucidated in this paper.

Especially in long-distance train travel but also on many local routes particularly in the service of cruise ship ports and airports the volume of luggage is often underestimated and not taken seriously

in sufficient measure as an influence factor on the criteria of station dwell time, achievable seat occupancy rate, comfort, customer satisfaction and ultimately safety.

2. DATA BASIS

For nearly 20 years The Research Centre for Railway Engineering at the Technical University of Vienna has been intensively involved in cooperation with netwiss OG with questions on a scientific level related to the optimization potential of railway carriages. The core of all research and development projects as well as the resulting scientific work is the serious examination of the needs and wishes of travellers as well as with their problems and difficulties in using the train. A substantial contribution to the objectification of the findings is the data collected over a decade concerning passenger behaviour, which has been and will continue to be collected through observation. The goal thereby is to capture the real behaviour of passengers under different marginal conditions uninfluenced by possible personal sentiments which may affect the results of surveys. Surveys formed an additional basis for the scientific analysis.

Thus far, over ten years, data has been collected on the following areas:

- **Passenger flow analysis:** The boarding and deboarding of approx. 20,000 passengers in approx. 50 different boarding areas and vehicle types were observed. Through video analysis precisely to a tenth of a second it was ascertained how long on average a person needs for boarding and deboarding. Above all, in addition to knowledge about individual time requirements, crucial insight can be gained into the extent to which the entire vehicle design concept affects passenger flow.
- **Passenger surveys:** Approximately 40,000 passengers in just under 10 different countries were surveyed concerning their problems and difficulties as well as their needs and wishes in all phases of travel in a railway vehicle. This related to boarding as well as movement in the train, the search for seating, stowing of luggage and requirements during the trip itself.
- **Passenger behaviour analyses:** The behaviour of approx. 200,000 passengers in more than 60 different vehicle types was analyzed with regard to choice of seats, storage of luggage and use of time. From the data, depending on the parameters of age, gender, occupancy rate in the vehicle and space design, information was accurately derived concerning which seats or seating areas were preferred, how and where luggage was stowed as well as the activities passengers performed.
- **Luggage data collection:** In combination with surveys, the exact anticipated luggage types and volumes per person, per vehicle or per train depending on travel purpose, age and gender as well as group size was determined through counting, exact measurements and weighing of several thousand pieces of luggage

In terms of new vehicle design concepts the data provides exact conclusions on how the envisaged space design will be used, how the design will affect passenger behaviour regarding seat selection, storing of luggage and performance of activities, and what impact the behaviour will ultimately have on the parameters of passenger boarding and deboarding, proper stowage of luggage and actually achievable seat occupancy

3. LUGGAGE VOLUME

Type, size, weight and number of particular pieces of luggage depend substantially on the parameters of travel purpose in combination with travel duration, age, gender and present group size of the travellers.

More than ten years of intensive observation shows that the volumes of individual pieces of luggage tend to be larger. This is due to an increase in comfort during transport particularly attributable to the fitting of luggage with rollers. For example, pieces of luggage which weigh 14 kilos

and are meant to be carried feel as though they are the same weight as pieces of luggage which weigh 21 kilos but are equipped with two rollers. Fifteen years ago 50% of suitcases taken along on rail travel were not equipped with rollers and therefore had to be carried. Five years ago this percentage amounted to about 5%. In the meantime, nearly 100% of suitcases, so-called trolleys, are equipped with rollers.

In accordance with the comfort enhancement provided by rollers increasingly larger pieces of luggage are being manufactured and used by travellers. This has led not only to an increase in the size of individual pieces of luggage but also to an increase in weight. Meanwhile, the tendency can be seen in luggage manufacturers to equip more and more trolleys with four wheels. As a result, in many transport situations an additional increase in comfort has been achieved. The assumption is that these pieces of luggage will be felt to be even more comfortable and in weight comparison even lighter; therefore, in the near future a further increase in luggage volume and pack weight is to be expected.

Both the increase in weight as well as in size present the rail operator with corresponding challenges. Namely, in the case of boarding the train over steps as well as the frequently necessary lifting of luggage in stowing, the rollers provide no support and accordingly increase the difficulties for travellers.

In order to construct adequate and efficient luggage storage areas, as a first step, knowledge of luggage volume in terms of type, size, weight and number of pieces per person is important. With regard to an efficient overall interior design statements on this cannot and must not be generalized. It appears that there can also be a regionally specific difference in the accompanying luggage. In particular the total volume to be reckoned with for each carriage is highly dependent on respective routes and their passenger or travel purpose mix. However, due to the existing amount of data very specific remarks can be made about this.

For example, in holiday travel on statistical average 50% of travel luggage pieces are medium and large trolleys (see Figure 1). At the same time it can be said that on average one piece of luggage per person is taken on holiday. On short trips on statistical average each traveller takes 0.8 pieces of luggage which are 35% medium and 10% large trolleys (see Figure 2). Relevant to necessary luggage accommodation is the most exact knowledge possible of the travel purpose mix which particular vehicles in their area of operation can expect. From this the actual expected average luggage volume per person and thus the corresponding total volume per vehicle can be determined.

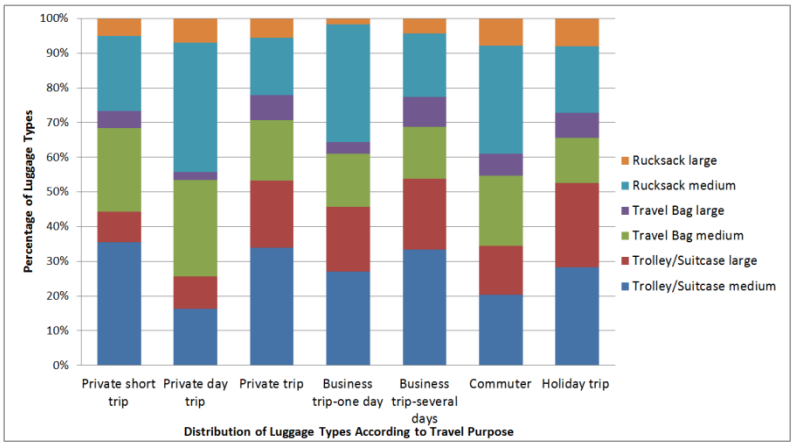


Figure 1 – Average Luggage Distribution per Travel Purpose (Source: Plank)

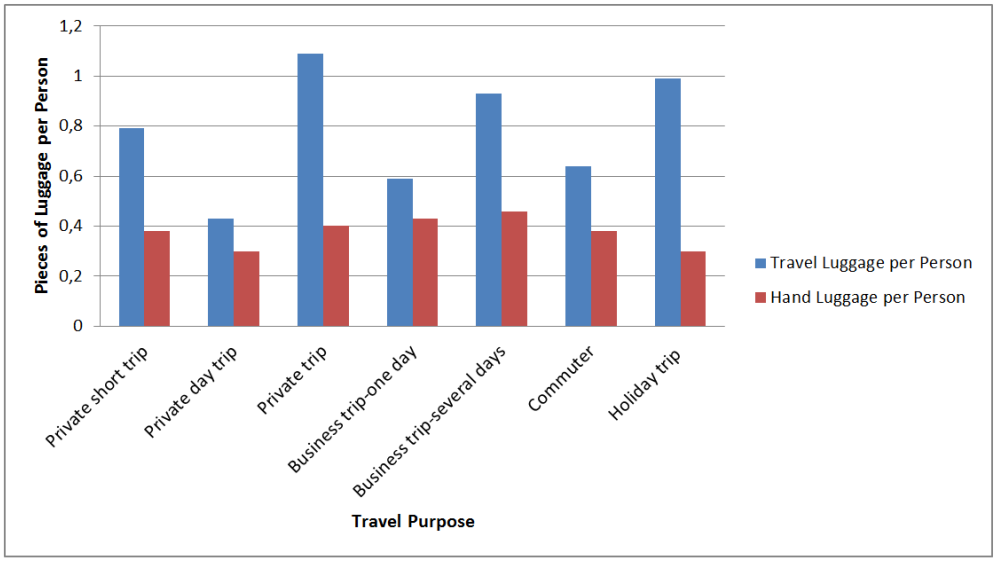


Figure 2 - Average Luggage Volume per Person per Travel Purpose (Source: Plank)

For air travellers who use the train for arrival an approx. 20% higher luggage volume is shown than for plain holiday train travel. This fact should be taken into account especially for all trains which eventually serve airports.

As an example of luggage volume, the average travel purpose distribution in Germany was used in a fictional carriage with 84 seats and a 100% occupancy, which led to the luggage volume represented in table 1.

Table 1 – Fictional Example: Luggage volume for an average travel purpose distribution in Germany with 84 people per carriage (Source: Rüger)

Luggage type	Dimensions (cm)	Number with 84 People
Trolley large	approx. 80x50x35	13
Trolley medium	up to 70x50x30	23
Travel bag/Rucksack large	approx. 90x40x35	9
Travel bag/Rucksack medium	up to 70x35x35	29
Hand luggage	up to 55x40x25	32

On average travel days an average of 36 medium and large trolleys and 38 medium and large rucksacks or travel bags were stowed. With regard to luggage accommodation the total volume of luggage must subsequently be superimposed on the wished for or actual passenger behaviour concerning the accommodation. For example, to believe that the luggage volume can be accommodated in overhead racks is a fatal mistake. Even if the calculated luggage volume could be stored in overhead racks the majority of travellers would not use the overhead racks. This means in practice much of the luggage would be stowed disruptively (see below).

4. LUGGAGE ACCOMMODATION

4.1 Passenger Behaviour

Regarding luggage accommodation there are two fundamental principles. Travellers do not want to have to lift their luggage; and for security reasons they want to have visual contact with their luggage at all times. If these two criteria are not sufficiently taken into account from the very beginning of planning, inefficient and in an "incident" quite dangerous conditions in the vehicles can be expected.

For 88% of passengers visual contact to their luggage is important or very important. This means that luggage must be able to be stowed in close proximity to the traveller. If there is no adequate possibility for this, and the luggage must be stowed at a greater distance, such as in luggage racks near the entrance, for most travellers this results in a corresponding uneasiness and loss of comfort. However, from an operational viewpoint the risk is even greater from luggage which due to a lack of visual contact has been stowed disruptively. Seventy-five percent of travellers indicate explicitly that they are prepared to stow their luggage disruptively in order to meet the need for visual contact.

As a result, luggage is placed on or in front of seats or in aisle areas. This leads to an increase in unusable seats and obstructions to passenger flow.

The second important criterion with regard to planning appropriate luggage racks is the willingness to lift luggage. For example, only 20% of travellers are prepared to lift heavy luggage into the overhead rack; over 50% are under no circumstances ready to do such lifting. With medium sized luggage at least 50% are prepared to lift it into the overhead rack. With regard to luggage racks, at least 50% of travellers are prepared to lift heavy luggage up to waist level (see Figure 3). These specific values make it clear that it is pointless to provide overhead racks with no exception or alternative. Also, the existing number of luggage racks must be adequately dimensioned!

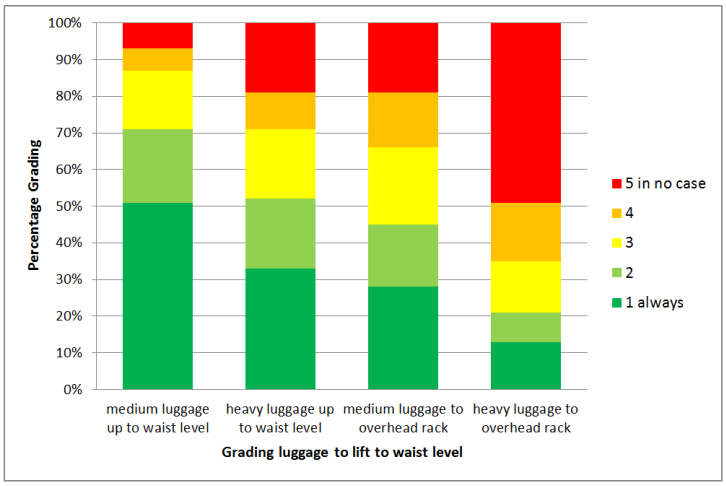


Figure 3 – Readiness to Lift Luggage (Source: Plank)

The sampled readiness regarding luggage accommodation has been confirmed by extensive objective observations. Although in some cases up to 50% of the overhead racks are not used, a variety of pieces of luggage are placed on the floor, in front of seats, in the aisle or on seats.

At lower occupancy rates of up to 35%, thirty percent of medium and large trolleys are placed on or in front of seats or in the aisle. Even at high occupancy rates of over 70%, by which making seats free can be expected, up to 20% of large and medium sized trolleys are placed in these positions. With rucksacks and travel bags nearly the same behaviour has been observed.

4.2 Possibilities for Accommodation

The basic possibilities for luggage accommodation are: overhead racks, luggage racks and spaces between the seat backrests. In part, areas under the seats can also be used. However, as a rule these areas can be used only for those pieces of luggage which fall under the category of hand luggage.

In order to design luggage storage space so that even with a very high occupancy rate all luggage can be properly accommodated, the following principles must be observed:

- Above mentioned principles "not lifting" and "visual contact"
- Determination of the actual luggage volume

- Reliable knowledge of the shape of the luggage

In order to efficiently design the most popular storage spaces between the seats and in the luggage racks, knowledge of the shape, size and volume of the luggage is by all means essential. Experience shows that luggage racks which are only a few centimetres, often only 5 cm to 10 cm too narrowly dimensioned, or whose shelf heights are too high or too low, can hold up to 50% less luggage than suitably dimensioned shelves!

The same applies to the space behind or between the seat backrests. Here 10 cm to 15 cm of too little usable space can lead to 70% less storage space.

In addition to the appropriate sizing of luggage racks and seat spacing, it is also important to ensure a well considered distribution of luggage storage possibilities in the vehicle. These must be distributed as evenly as possible over the vehicle to allow good visual contact to luggage from each seat and not impair the flow of passengers.

5. CONSEQUENCES OF UNSUITABLE LUGGAGE ACCOMMODATION POSSIBILITIES

If the important basic principles of luggage storage space design are not respected, two serious operational consequences can be expected. The passenger boarding and deboarding time in stations will be prolonged and the actual available occupancy rate will decline up to 80%.

5.1 Passenger boarding and deboarding time

There are many factors which affect passenger boarding and deboarding time. These include passenger related factors which manufacturers and operators have no control over. These factors include age, gender, accompanying luggage and any kind of mobility limitation.

However, the vehicle-side factors are important. On one hand, by correct planning the passenger-side factors can be correspondingly reduced; on the other hand, by improper planning these can be exacerbated. These factors include for example, the entry height and door width, potentially any existing level entrances, location and number of entrances, the suitability of entrance spaces as collection areas, any restrictions to passenger flow and the overall design of the vehicle interior.

From the perspective of passenger boarding and deboarding time the difference between the best and the worst vehicles currently in use is at a ratio of 1:4. This means in concrete terms that with an assumed passenger boarding and deboarding time of one minute in the best case, the time for the same number of passengers in the worst case can be up to four minutes! It should be noted here that with some exceptions younger generation vehicles which are currently in operation tend to produce higher values.

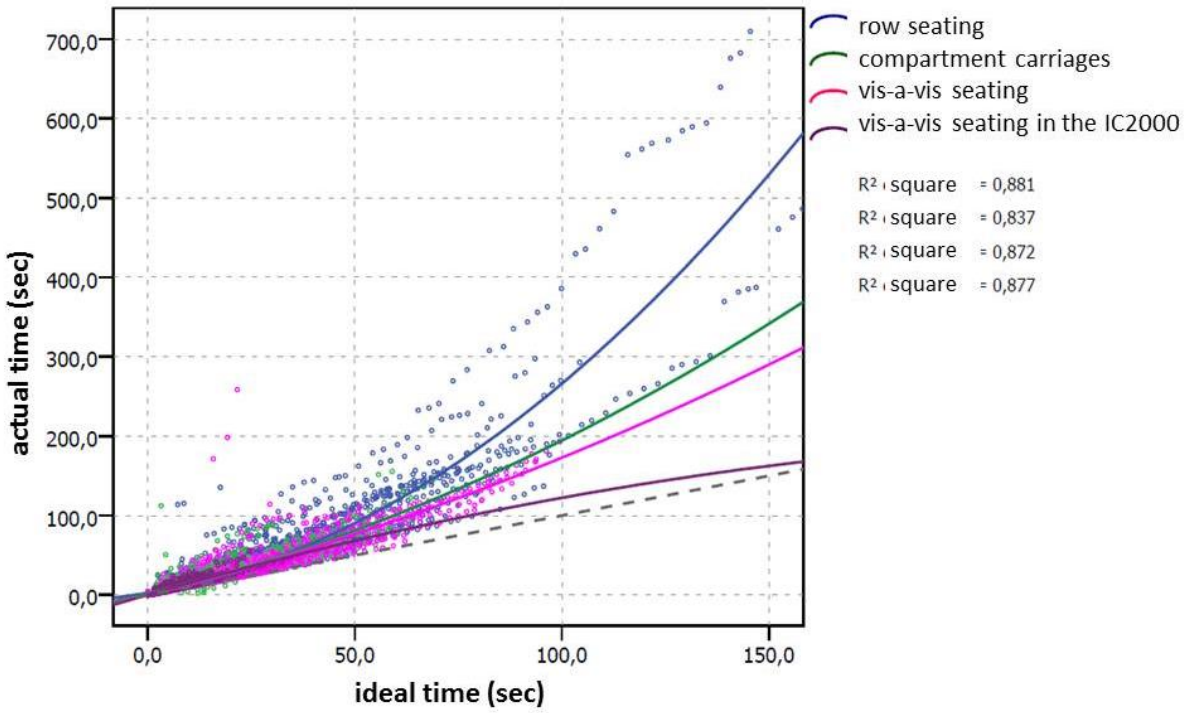


Figure 4 – Time required for the boarding and deboarding process in different interior designs (Source: Tuna)

The influence of interior design between the best and worst case already produces an affect with a ratio of 1:2 (see Figure 4). This means for example, in the best case at a high rate of passenger exchange in conventional vehicle constructions, a passenger boarding and deboarding time of two minutes can be achieved. Whereas, in the worst case it requires four minutes.

In Figure 4 fundamental concepts are presented; in such a way whereby in this example in row seating practically only overhead racks are available and in vis-a-vis seating luggage can be well stowed between the seat backrests. There is similar data from approximately ten basic vehicle interior categories. All findings show the clear correlation between time demand and luggage storage. The more suitable the design of luggage storage areas, the less time is needed for boarding and deboarding.

5.2 Occupancy rate

From an operational point of view, the second relevant effect of well planned or vice versa insufficiently thought out luggage storage areas, is the actual occupancy rate.

In long-distance traffic the only significant occupancy rate is the seat occupancy rate. With unsuitable and insufficiently designed luggage storage possibilities, even this can decline noticeably. In conventional passenger carriages with a length over buffers of 26.4 meters, a maximum of 80 seats for standard days and 78 seats for travel days are provided (see Figure 5). This number is achieved if the remaining areas are used in suitable form for luggage storage. If this is the case, up to 100% of the seats can be occupied. If there are more seats over these limits, it is at the expense of customer-oriented luggage accommodation; and the actual number of available seats as well as the occupancy rate sink drastically. Previous studies by the Research Centre for Railway Engineering at the Technical University of Vienna show that the average achievable occupancy rate in comparable vehicles with 88 seats is only about 80%. This means that on average only 70 of the 88 installed seats can be used (see Figure 5)!

The reason for the sharp decline in occupancy is that there is not enough luggage accommodation capacity available and the existing areas are frequently unsuitably designed. This leads to the fact that part of the luggage is stored not only in the aisle but also on and in front of the seats.

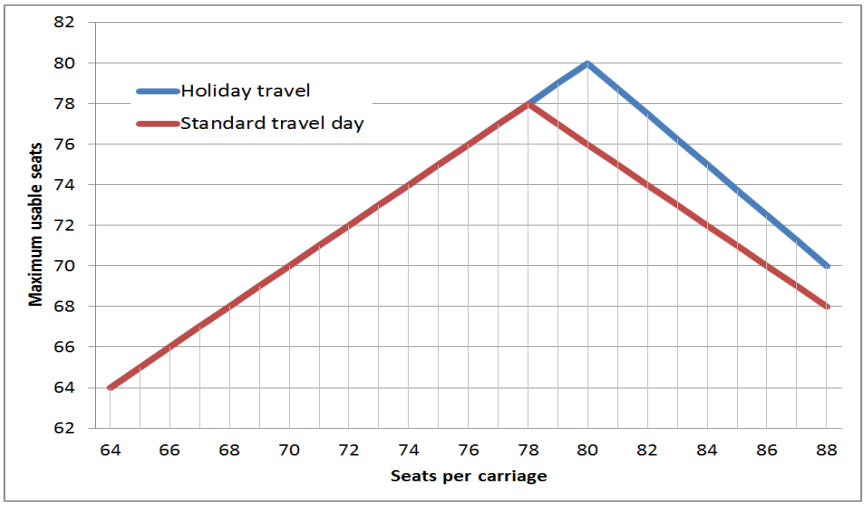


Figure 5 – Maximum possible number of seats in passenger carriages with a length of 26.4 meters over buffers
Source: Rüger

5.3 Operating efficiency

The consequences of falsely planned luggage storage possibilities presented so far ultimately have significant operating efficiency impacts. The hope or goal to also be more efficient through a greater number of seats is transformed as a general rule into the opposite. Under the premise that the goal is to want to take advantage of the highest number of available seats, the following circumstances always prevail:

Delays: Vehicle interiors following the idea of seat maximization inevitably lead to long station stop times. With a high passenger exchange, four to six minutes per station are the result. Whereas, ideally designed vehicles require only one to one and a half minutes. This fact in the case of a close sequence of stations leads to corresponding delays.

Declining operating quality: When they cannot be made up for, the aforementioned delays lead to a decline in operating quality. This is especially important if delays are carried over to connecting or opposite trains, or if the results are missed connections.

Higher energy consumption: If it is at all possible to make up for the delays, it is only possible by constant use of maximum line speed, which means a significant additional energy consumption especially at a high rate of speed.

Lower occupancy rate: There are seats installed which in practice are not available. At the same time the achievable seat occupancy rate declines up to 20%!

Declining passenger satisfaction: The declining seat occupancy rate causes a correspondingly high number of standing passengers, which accordingly reduces passenger satisfaction. Comfort is significantly reduced by the in part "chaotic" conditions in "overcrowded" vehicles. For nearly 18% of travellers high occupancy together with the already mentioned associated effects means a high stress factor!

5.4 Safety

The most important criterion which is often overlooked in insufficiently estimated operating efficiency considerations is safety. If in an emergency a train has to be evacuated, a large number of

seats at a high occupancy rate in combination with the aforementioned effects presents a high safety risk. In air transportation a maximum evacuation time of 90 seconds must be proven before the certification of an aircraft.[1] In railway transportation there are no such known provisions. However, it is understood that in most vehicles this time cannot be met. In a fully occupied carriage with 88 seats, the absolute exit time of all passengers under ideal conditions (no luggage during the exiting process, no backup because of crowding at the entrance door, only two steps) with the best carriage designs approx. 120 seconds is required and with the worst constructions, approx. 160 seconds.

In an incident, rising panic must be considered in which case an orderly exiting process cannot be expected. Above all, in this case improperly stowed luggage would lead to a corresponding safety risk! For this reason alone it must be ensured that for every installed seat there is also a suitable luggage storage space.

6. FUNDAMENTAL PLANNING ERRORS

From past experience, both on the part of the purchaser as well as on the part of the manufacturer, fundamental errors which lead to the inefficient conditions described above can be identified in the planning and ordering process.

Error 1: Volume calculation: Every cuboid-like object has a volume and also three definite dimensions. As a rule In tender documents there is only information on the total volume required for luggage accommodation. For cuboids the volume is known as the product of width, length and height. This means that an often called for volume of approx. 0.125m³ per passenger can either correspond to the dimensions of a midsized trolley with dimensions of 50x70x35 cm, or at the same time, a trolley with dimensions of 1x4160x30 cm! Accordingly, it is also common practice to multiply every small cross-sectional area by the available depth and to sum the resulting volumes to a total volume! As a rule, in practice a maximum of 50% of the calculated volumes are available. It is therefore necessary to have precise knowledge of the statistical distribution, shape and dimensions of the luggage!

Error 2: Disregard of passenger behaviour: If the principles of "not lifting" and "visual contact" with regard to luggage storage construction are disregarded, the planned storage areas will be only in part accepted by the passengers. In practice this leads to the condition that up to 50% of all storage areas remain unused and yet a larger amount of luggage is stored disruptively.

Error 3: False awareness of luggage volume: The actual luggage volume has to be calculated for each route and expected passenger or travel purpose mix. Frequently blanket assumptions are made, or days are taken as a basis for calculation on which only a below average luggage volume can be expected.

Error 4: False dimensioning: Meanwhile, luggage accommodation is increasingly being taken into account in vehicles with regard to the installation of luggage racks and the space between the seat backrests. However, here it must be noted that the dimensions of luggage racks are often oriented to seat spacing resulting in very inefficient dimensions. The same can be observed in the spaces between the seat backrests. When dimensioning the respective storage areas it is advantageous to take into account the forms and dimensions of the luggage as well as the storage behaviour of passengers. Seat spacing and luggage racks are often dimensioned a few centimetres to small, which can lead to an actual storage loss of 50% or more.

Error 5: False evaluation criteria for orders: In vehicle orders it can often be observed that evaluation criteria are applied which are not logically understandable. A popular evaluation criterion in tenders is to define the minimum number of seats. Usually this involves specifications which can be classified as a psychological perception; and thus, they often jump to increments of 100. If for

[1] http://de.wikipedia.org/wiki/Evakuierungssimulation

example in the tender as a fictitious number it is predetermined that a train must have 500 seats, then the hands of the manufacturer are already bound in the tender phase; and from the outset actually efficient solutions are not possible. These figures are usually based on a previously calculated maximum number per vehicle and thereby disregard reality. With the fictitious example mentioned it can be expected that a maximum number of 450 seats will actually be available in the train. Thus, it would be much more efficient to make no such requirement, but rather to allow the manufacturers to search for efficient overall solutions. With appropriate solutions it can be expected that vehicle design concepts can be found which in the example mentioned offer approx. 470 seats. Seats, which in the end can actually be used!

7. CONCLUSION

Fifteen years of research and development as well as participation in numerous vehicle plans make it clear that at all times with vehicle development and orders an overall optimum for vehicle interiors should be sought. Many negative examples make clear that the exclusive pursuit of a maximum number of seats can in practice lead to inefficient and dangerous situations. In particular, luggage storage possibilities must be precisely and thoughtfully planned in order to contribute to efficient overall systems. Experience further shows that it is very critical to lay aside blanket assumptions about design. Each vehicle must be assessed individually in terms of attainable overall efficiency which ultimately leads to an actual maximum seating occupancy.

Requirements for luggage storage must be thoughtfully formulated in the tender. Furthermore, in order achieve the greatest possible degree of efficiency, where and which luggage storage areas can be installed must be precisely considered in the beginning phase of vehicle planning. Later changes are usually achieved only with great difficulty or with little effect.

Fortunately, in recent times one can discern an awareness regarding these problems. Numerous recent projects confirm that both on the part of the operators as well as the manufacturers, interest in and willingness to develop efficient overall systems have emerged; and that some efficient overall solutions can be developed with negligible additional cost.

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ANDREAS SCHÖBEL, Priv.Doz. Dipl.-Ing. Dr. techn. [1]
Corresponding author
E-mail: andreas.schoebel@opentrack.at
CHRISTIAN SCHÖBEL, Dipl.-Ing.[1]
E-mail: christian.schoebel@opentrack.at
JOHANN BLIEBERGER, Univ.-Doz. Dipl.-Ing. Dr. techn.[2]
E-mail: blieb@auto.tuwien.ac.at
MARK STEFAN, Dipl.-Ing. Dr. techn.[3]
E - mail: stefan.mark@ait.ac.at
[1] OpenTrack Railway Technology GmbH
Kaasgrabengasse 19/8, 1190 Vienna, Austria
[2] Vienna University of Technology, Institute of Computer Engineering, Automation Systems Group
Treitlstraße 1-3, 1040 Vienna, Austria
[3] Austrian Institute of Technology, Center for Energy, Electric Energy Systems
Gieffinggasse 2, 1220 Vienna, Austria

BENCHMARK OF DELAYS SIMULATED BY OPENTRACK AND CALCULATED BY KRONECKER ALGEBRA ON ZAGREB-RIJEKA LINE

ABSTRACT

Within the project GoSAFE RAIL, funded by the H2020 Shift2Rail programme with focus on achieving Single European Railway Area (SERA), one work package is dedicated to the development of an integrated rail network model that will incorporate both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement) data. Furthermore, the existing OpenTrack model of Zagreb – Rijeka line is used as an input for optimization algorithm based on Kronecker Algebra. Therefore, infrastructure topology is exported in IVT format to cover infrastructure attributes like speed limit, gradients and main signals (home, exit, block). Additionally, the annual timetable is exported in OpenTrack format to create for each train the Kronecker operations. Finally, the simulated output from OpenTrack is compared to results from Kronecker algorithm. Main indicator is the graphical timetable as well as delays of trains in their final destination.

KEY WORDS

rail traffic flow optimization; scheduling; Kronecker algebra;

1. INTRODUCTION

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

Moreover, with OpenTrack [4] micro-simulation modelling tool, traffic model will be developed that will use multi-criteria optimization algorithms to address complex requirements, for both passenger and freight transport. Using Kronecker algebra, which showed good results in dealing with optimization scenarios in railway traffic flow, especially avoidance of deadlocks, simulation of the line between Zagreb and Rijeka in Croatia has been performed as well as an optimization based on Kronecker Algebra.

2. KRONECKER ALGEBRA FOR RAILWAY OPERATION

One of the constantly present problems in railway systems is the problem with deadlocks especially on single track lines or during rehabilitation work [5] on a double track line and around dead end hubs. Since there were no applicable solutions in the middle of 20th century, computer scientists tried to solve this problem by implementing Kronecker algebra in the analysis [3].

Before going into solving deadlock issue, a proper definition is needed. Stallings [6] defines Deadlock as 'an impasse that occurs when multiple processes are waiting for the availability of a resource that will not become available because it is being held by another process that is in a similar wait state'. There are four preconditions for a deadlock to occur according to Coffman [1]; in other words, if one of these conditions is not met, there will not be a deadlock. There is a mutual exclusion, where a resource can only be used by one process at a time. Second, hold and wait includes processes already holding resources and requiring additional resources held by other processes. Third, the so called no preemetion, no other than the process itself can release the resource. Finally, the circular wait that requires at least two processes to form a circular chain in which each process waits for a resource that is being held by the previous process in the chain. Clearly, these four conditions can be applied to railway systems.

After defining conditions for deadlock occurrence, possible ways to deal with deadlocks can be identified. These are deadlock prevention, or removing one of the above mentioned conditions in order to prevent deadlock from even occurring; deadlock avoidance, or decision about resource allocation in advance; and finally, after deadlock detection, termination and restart of the process. For the railway systems, only deadlock avoidance is applicable [3].

Kronecker algebra is a mathematical model that consists of Kronecker Sum and Kronecker Product. For the explanation of these two operations, set of matrices (1) is defined

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

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

$$\mathrm{Zn} = (\mathrm{zi,j}) \text{ where } \forall \text{ i,j:zi,j} = 0 \tag{2}$$

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

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

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

$$\mathrm{A} \oplus \mathrm{B} = \mathrm{A} \otimes \mathrm{In} + \mathrm{Im} \otimes \mathrm{B} \tag{4}$$

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

Application of Kronecker algebra in optimization of railway traffic flow lies in its functionality to detect and avoid any deadlocks within the whole analysed railway system, not just on one section. To put it differently, it can is represented as a matrix that includes all possible train movements in a system. In other words, deadlock-free solutions are overall best calculated solutions that take schedules, delays and different types of restriction on the tracks into account [7]. Whereas Kronecker Sum calculates all possible interleavings of all trains not using the same track section, Kronecker

Product ensures that those using common track sections can sequentially enter only free sections, namely, sections previously released by another train. Kronecker Algebra delivers results as a matrix. However, these can be represented as a graph, especially time-speed diagram.

3. CASE STUDY ZAGREB – RIJEKA LINE

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

Figure 1 shows planned timetable (black lines) and simulated timetable (pink for fast trains and green for regional trains) for all passenger trains on Zagreb – Rijeka line.

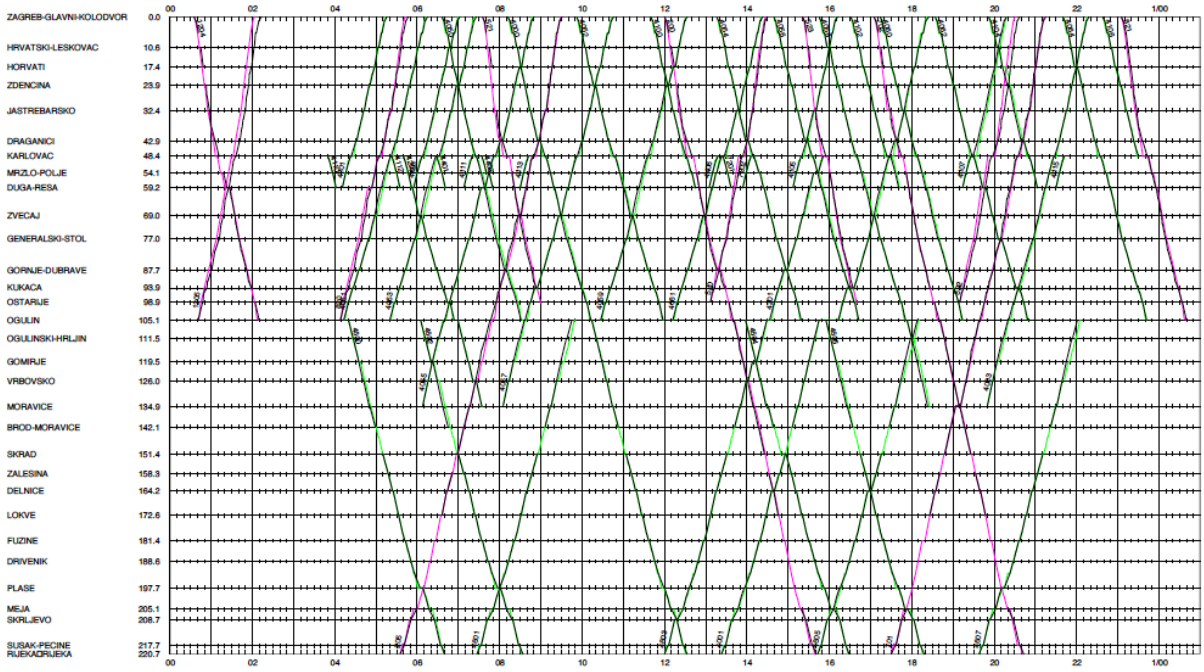


Figure 1 – Train graph of all passenger trains on Zagreb – Rijeka line
Source:[2]

As a benchmark for the Kronecker algorithm delays of all passenger trains are used according to figure 2. Delays are indicated by train ID and station ID in seconds. Obviously, majority of trains has a lot of reserve in running times and therefore arrive earlier at their final station. Of course, crossings with cargo trains are excluded in this simulation which require additional time. On the other hand, maximum delays are below 5 minutes.

Table 1 – Benchmark of earliness and delays simulated in OpenTrack and calculated by Kronecker Algebra [2]

Position	Earliness in OpenTrack	Earliness in Kronecker	Delays in OpenTrack	Delays in Kronecker
Sum of Delays in Seconds	-3143	-2779	1407	514
Number of Trains causing Earliness or Delay	42	35	14	19
Average Value in Seconds	-75	-79	101	27

Table 1 compares earliness and delays from simulation in OpenTrack of all 57 daily passenger trains using the entire or parts of the Zagreb-Rijeka line with calculated values by Kronecker. While trains

arrive earlier in sum in OpenTrack simulation, delays are reduced by application of Kronecker in sum and in average. Further investigations will be carried out on the level of each single train run to validate the calculations of Kronecker by simulations of OpenTrack. Additionally, all daily cargo trains will be included as well. Thereby, the recommendations from Kronecker can be used as input for the actual performance of each single train.

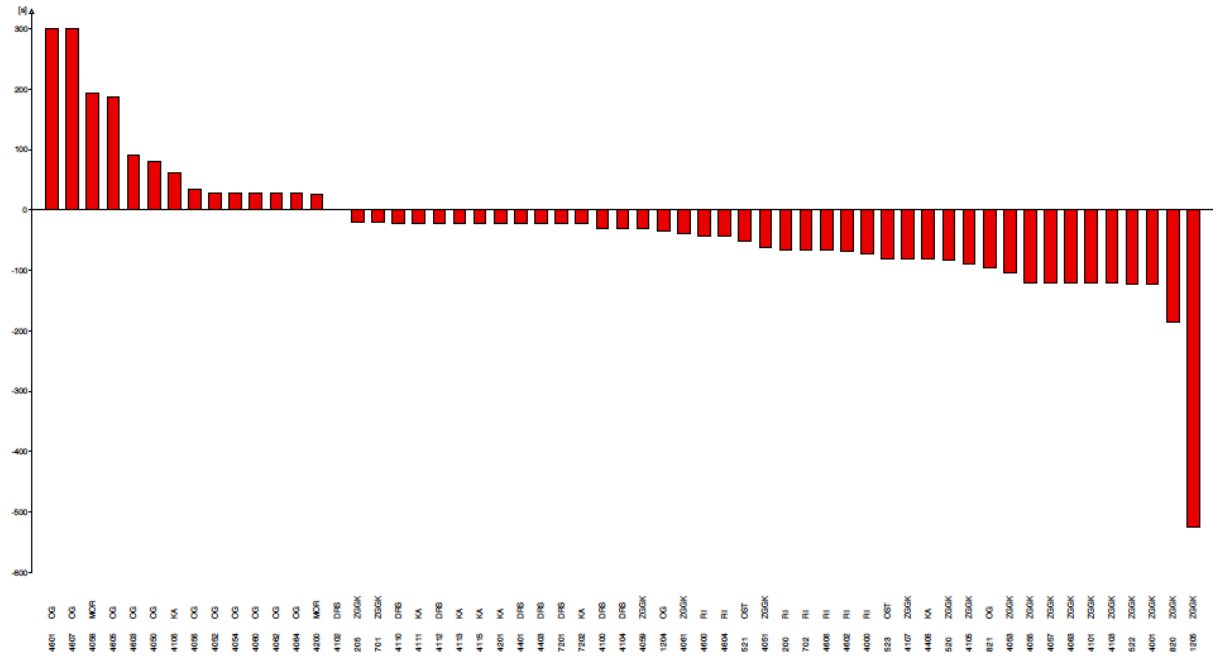


Figure 2 – Delays of all passenger trains on Zagreb – Rijeka line at their final destination
Source:[2]

5. CONCLUSION

OpenTrack, being a sophisticated micro-simulation model allows the determination of impact of safety decisions on operational network performance. Thus, by incorporating both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement), effective delivery of maintenance or new works while maximising the connectivity and adaptability of the overall surface system will be enabled. As a performance indicator for Kronecker Algebra the delays of trains at their final station are used as a benchmark criteria. Latest test runs on the railway line from Zagreb to Rijeka show a reduction of delay of more than 60 % in sum and 70 % in average. Therefore, results from Kronecker Algebra are suitable for reducing delays. Furthermore, these recommendations should be implemented into daily operation.

ACKNOWLEGMENT

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MARKO SLAVULJ, Ph.D.[1]
E-mail: marko.slavulj@fpz.hr
JULIJAN JURAK, mag. ing. traff.[1]
E-mail: jjurak@fpz.hr
MARKO EMANOVIĆ, mag. ing. traff. [2]
E-mail: marko.emanovic@gmail.com
IGOR JELIĆ, mag. ing. traff. [3]
E-mail: igor.jelic@scp.hr
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, Zagreb
[2] The Center for Vehicles of Croatia
Capraška 6, 10000 Zagreb
[3] Highschool for road traffic
J.F. Kennedy square 8, 10000 Zagreb

INCENTIVE MEASURES FOR ACQUISITION OF ELECTRIC AND HYBRID VEHICLES IN EUROPEAN UNION

ABSTRACT

Environmental pollution along with traffic accidents is the main negative transport product. Road transport in this sense is most represented and confirmed as one of the largest pollutants of harmful gases in the air. An increasing emphasis is placed on the development of new electric and hybrid vehicles in the automotive industry. The main drawback of that vehicles is the relatively high purchase price for private individuals and companies. The European Union as one of the main goals has indicated the use of electric and hybrid vehicles on roads in Europe. Certain measures to encourage the purchase are attempting to achieve a greater number of such vehicles on roads. This paper will present the impact of such measures on increasing of electric and hybrid vehicles in countries in European union.

KEY WORDS

Measures; Electric; Purchase; Hybrid; European Union.

1. INTRODUCTION

Caring for the environment and maintaining a healthy environment is the task of every individual but also of society. Developing the economy and increasing of population activities leads to increasing the needs for mobility. Increased mobility leads to the need to increase the number of means of transport and the distance at which such vehicles travel but leaves unwanted and unpredictable consequences for people and the environment. A large share of traffic is made up of transport vehicles that use fossil fuels as a plant. The unfavourable impact of traffic is manifested in air, water and soil pollution, noise and vibration, reduction of green areas, degradation of the urban space and increased danger to life and health. Traffic pollutes the environment with exhaust gases, smoke, dust, waste oils and fuels. This is particularly noticeable in urban environments and cities. In order to reduce the negative impacts, one of the key measures is increasing number of electric and hybrid vehicles on roads.

The aim of the paper is to determine the impact of purchase measures to stimulate the procurement of electric and hybrid vehicles.

The hypothesis of paper is will number of electric and hybrid vehicles increase if there exist measures to encourage their procurement. The work consists of 6 main chapter:

- Introduction
- Literature review
- Methodology
- Electricity and Hybrid Vehicles Market in Europe
- Review and discussion

2. LITERATURE REVIEW

According to the authors (Xingping Z, Jian X, Rao R, Yanni L) in work named: Policy Incentives for the Adoption of Electric Vehicles across Countries, it is about encouraging the purchase and increasing of the market for electric vehicles. The purpose of this paper is to explore policy mechanisms that are effective and applied in several countries. Three aspects of development policy are considered: financial resources (incentives - subvention), technological support and infrastructure for electric vehicles. A qualitative approach to adopting policies for the development and promotion of the use of electric vehicles in the United States has been demonstrated by the fact that the largest number of electric vehicles sold in that country is numbered on roads close to the desired target of one million electric vehicles.

The analysis has shown that proper policy in terms of financial incentives and technological support can significantly affect the increase in the number of electric vehicles. In this paper, the authors presented the advantages and disadvantages of different countries and their frameworks in the process of developing the use of electric vehicles. A review of China, as the largest manufacturer of CO_2 in the world, is considered and measures are considered necessary to accelerate the development of the number of electric vehicles on the roads. It is stated that China's measures of traffic control and the introduction of subventions in the purchase of electric vehicles seek to encourage the development of electro-mobility. It also faces obstacles in terms of subsidies and cannot be obtained for any vehicle, and as an example it cites the city of Beijing and ten types of vehicles for which it is possible to receive subsidies. In addition to subventions, there are also issues of infrastructure that China faces, so it should consider and practice the good examples and models used in the United States and the European union. The Government should, in cooperation with other competent authorities, develop a strategy for infrastructure development and subsidies, which would encourage the purchase, use and trust of electric vehicle users [1].

According to the authors (Sierzchula W, Sjoerd B, Kees M, Bert V W) in work named: The influence of financial incentives and other socio-economic factors on electric vehicle adoption it is about electric vehicles that represent innovation with the potential to reduce greenhouse gas emissions and can help and mitigate the causes of climate change in the world.

Based on existing literature, authors have identified several socio - economic factors that are important for increasing electric vehicles. Using linear regression analysis, the relation between certain variables and electric vehicles was investigated in 2012. The results indicate that from all the observed factors, the most important infrastructure in the form of electric vehicle fillers. The purpose of this study was to investigate the relationship between financial incentives and other socio - economic factors important for the development of electric vehicles in several countries. It was found that the financial incentives, the number of fillers for vehicles and the power generation plant have significantly and positively impacted the predictions of electric vehicles' rates in the observed countries [2].

According to the authors (Tsakalidis A, Thiel C) in work named: Electric vehicles in Europe from 2010 to 2017: is full-scale commercialisation beginning? - An overview of the evolution of electric vehicles in Europe, there is a study on the development of electric vehicles in Europe between 2010 and 2017.

Since 2010, the number of electric vehicle models, the number of registered vehicles, the share of electric vehicles on the market and the available infrastructure in the form of fillers are increasing significantly, but there is still a slight shift to be characterized as complete. Although the number of registered electric vehicles is still smaller than conventional vehicles, it is still increasing in Europe. Regardless of the increasing number of electric vehicles on the market, there appear to be obstacles that arise when buying a vehicle, namely: vehicle purchase costs, vehicle driving distance, infrastructure - availability of vehicle charging, model choice, maintenance costs, performance vehicles and driving experience. It is important to develop a proper policy for the procurement of electric vehicles. The authors argue that in countries where buyers offer subventions in the form of subsidies, there is an increase in the demand for electricity, while in countries with low incentives or where there is not a small number of registered electric vehicles, as well as the demand for the same. Different types of incentives and levels of support have already been tested in most European countries and provide useful experiences that support the implementation of the national policy framework and further development [3].

3. METHODLOGY

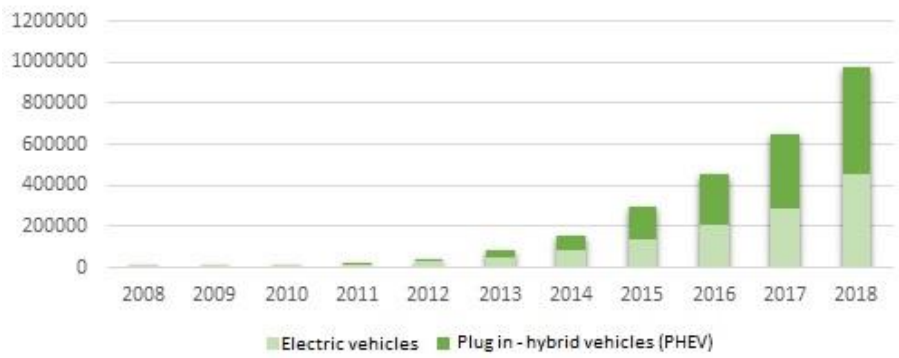
According to statistical databases such as Eurostat, European Alternative Fuel Observatory (EAFO), the European Automobile Manufacturers Association (ACEA) and Knoema, the status of electric and hybrid vehicles in the European The Union has been reviewed. The vehicle category considered in this analysis is a passenger vehicle (M1). Graphs shows the statistics for the observed vehicle category (electric and hybrid) on the roads in the European union, the number of new registered vehicles by type of fuel and number of vehicles (electric and hybrid) individually by country. Regarding to data, incentives and subsidies for the purchase of electric and hybrid vehicles will be compared to number of registered electric vehicles (M1 category) in the European union.

4. EUROPEAN MARKET OF ELECTRIC AND HYBRID VEHICLES

Transport in total energy consumption has a share of 30%. In the EU, total greenhouse gas emissions from transport is about 25%, of which 71.3% generates road traffic. In accordance with the EU's goals for reducing greenhouse gas emissions and air pollution, it is important to emphasize the cleaner transport vehicles, energy efficiency in transport, and encourage projects that increase energy efficiency of transport systems and the use of more efficient vehicles [4].

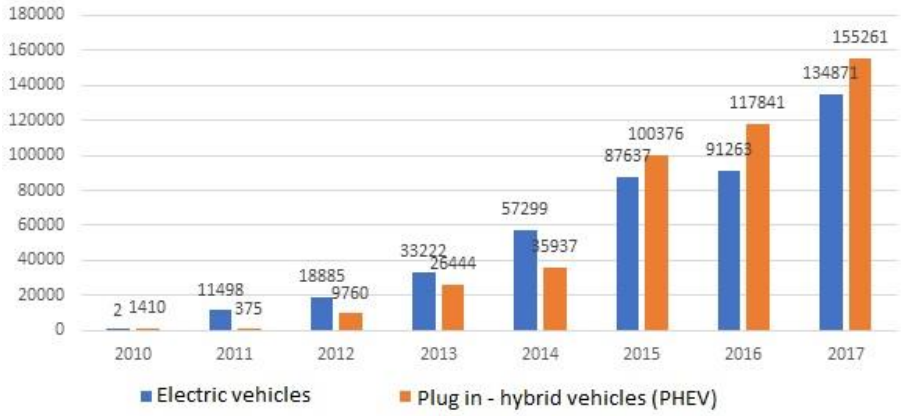
4.1 Review of electric and hybrid vehicles in the European union

Histogram 1. shows the status of electric and hybrid vehicles in the EU from 2008 to 2018.



Histogram 1 – Number of electric and hybrid vehicles in the EU from 2008. to 2018.

Furthermore, Histogram 2 shows an overview of personal vehicle status (M1 category) in the form of electric and "plug-in" hybrid electric vehicles. According to the European Agricultural Alternative Fuels Observatory (EAFO), the 882.081 electric vehicles (M1 category) is registered in Europe in the period from 2010 to 2017. Data from the same source indicate that in the total number of registered electric vehicles 436.085 were electric (BEV - Battery Electric Vehicle) and 445.996 was registered as "plug - in" hybrid electric vehicles (PHEV - "Plug in" hybrid electric vehicle [5].



Histogram 2 – Number of first time registered electric and hybrid vehicles in the EU from 2010. to 2017.

4.2 Review of electric and hybrid vehicles in the Republic of Croatia

Figure 1 shows the data on personal (M1 category) electric and hybrid vehicles for the period 2007 – 2018 in the Republic of Croatia. It is apparent from the accompanying note that the beginnings of the use of vehicles that use electricity as a source or a combination of electricity and diesel or gasoline were in 2007, when 1 electric and 71 hybrid vehicles were recorded. Growth trend has continued throughout the next years. Since 2013., the data on the hybrid vehicle with external charging has begun to be recorded with 12 vehicles in that year. In 2018 the highest number of hybrid vehicles (3.552), electric vehicles (452) and hybrid vehicles with external filling (230) [6] were recorded.

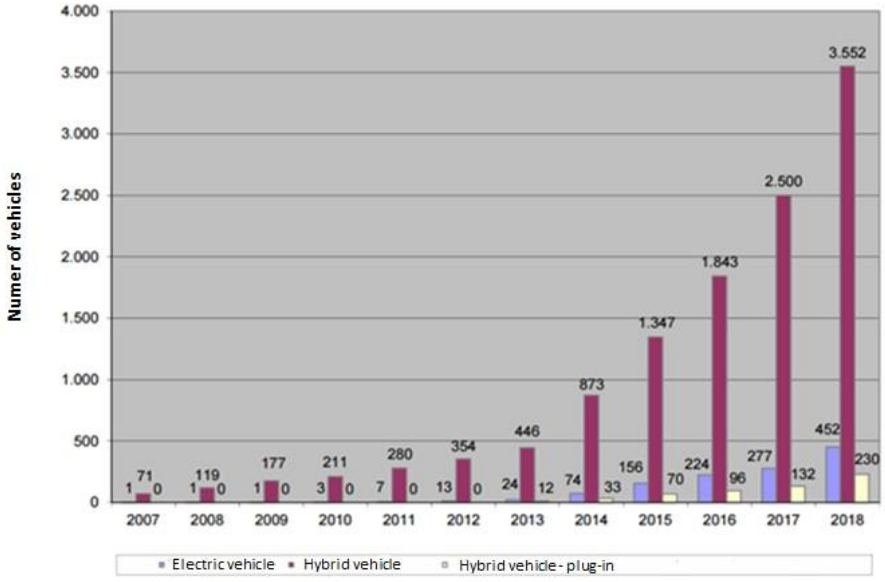


Figure 1 – Number of electric and hybrid vehicles (M1 category) in Republic of Croatia from 2007. until 2018.

4.3 Co-financing acquisition of electric and hybrid vehicles in the Republic of Croatia

One of the key measures to promote energy efficiency in traffic is to encourage the use of hybrid and electric vehicles. According to the Hrvoje Požar Energy Institute data, CO2 emissions in total domestic traffic is about 5.6 million tons, of which about 3 million tons are product of road traffic [6].

Today, more than 2 million road vehicles are registered in Croatia, of which almost 1.5 million personal cars. The average age of a passenger car is over 12 years and the average personal car in the Republic of Croatia emits about 3 tons of CO2 every year. For illustration, a hybrid vehicle emits 1 ton of CO2 annually, while electric vehicles do not have emissions or pollute the noise environment. In order to encourage cleaner transport in Croatia and reduce air pollution, the project "Vozimo ekonomično" is launched in 2014, through which citizens and companies are given grants to buy energy-efficient vehicles. From 2014 to 2017, the 50 million HRK, Environmental and Energy Efficiency Fund co-financed buying of .1425 electric, hybrid and hybrid plug-ins. According to the data of The Center for Vehicles of Croatia, there has been an increase in electric and hybrid vehicles over the last few years. In 2012, there were only 13 electric cars in Croatia, in 2014 they were recorded 74 and in 2017 277 [6].

In 2018, the Environmental Protection and Energy Efficiency Fund announced a new Public Call for Co-financing, which provided HRK 12 million of non-refundable funds to citizens. Co-financing was available for the purchase of a maximum one vehicle, and the amount of incentives depended on the type of vehicle. Potential gains were obtained for the purchase of the following vehicle categories [6]:

- Electric bicycle - up to 5.000,00 HRK
- Electric vehicle L1-L7 categories - up to 20,000.00 HRK
- M1 category vehicle with hybrid "plug-in" drive - up to 40.000,00 HRK
- M1 category electric vehicle - up to 80.000,00 HRK

4.4 Co-financing acquisition of electric and hybrid vehicles in the European Union

Chart 1. shows the total relationship of tax relief for all EU countries. The relationship shows the existence of tax reliefs according to the available data.

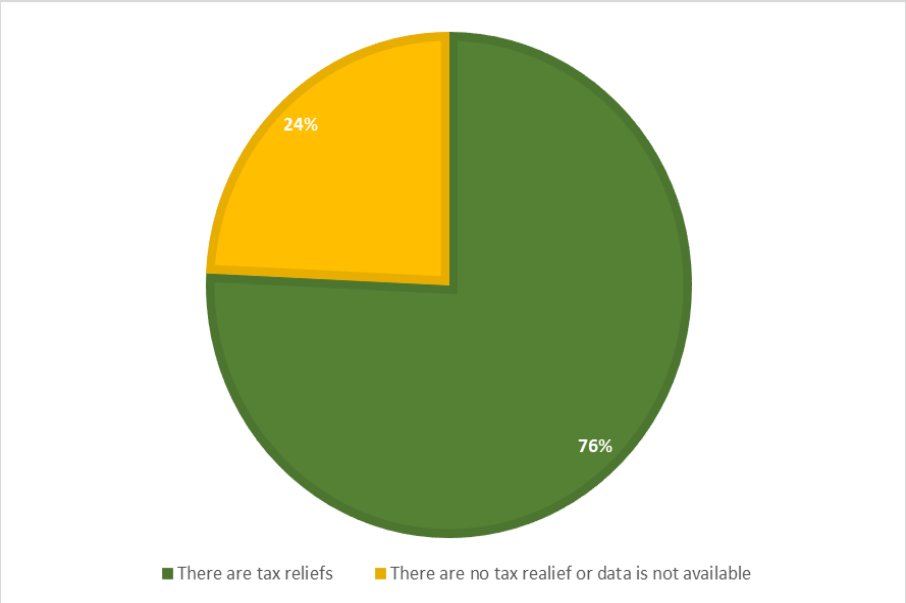
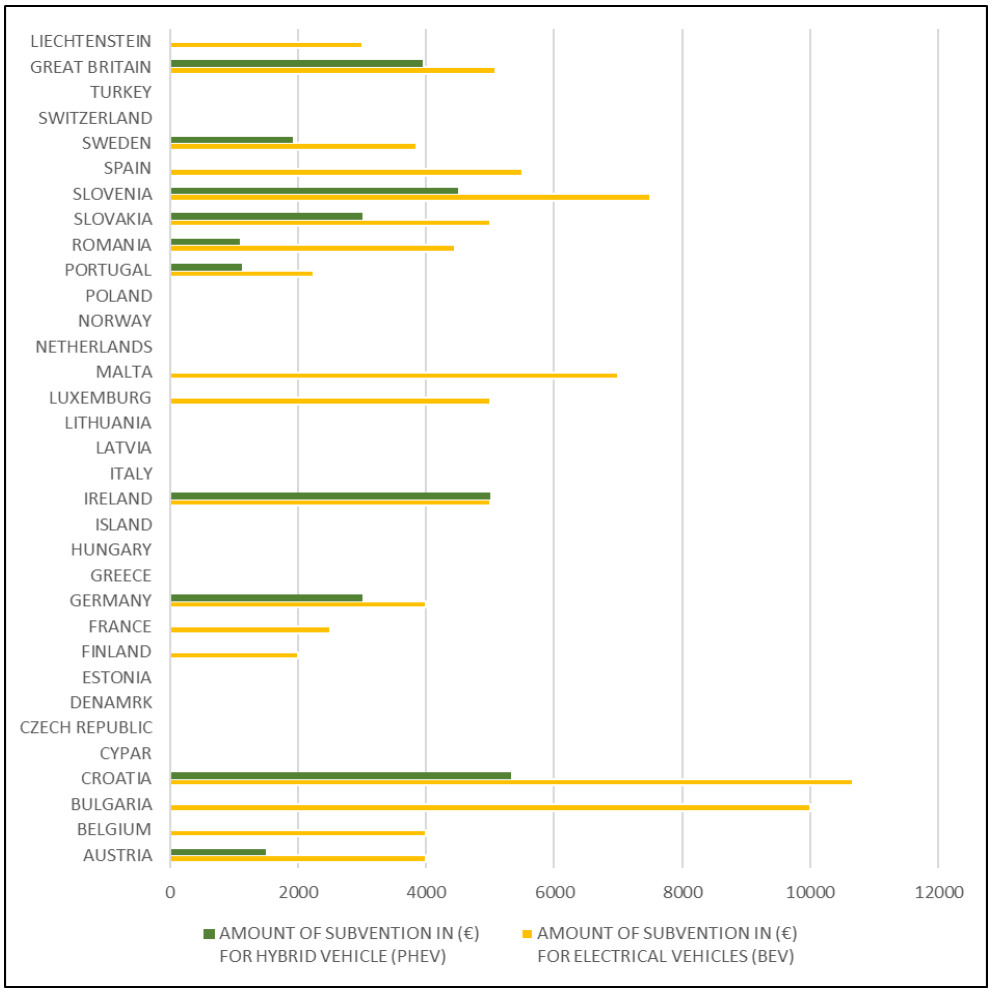


Chart 1 – The relationship between the number of countries with tax reliefs and without them in the EU

Histogram 3. shows the value of subsidies to European Union countries for electric and hybrid vehicles (M1).



Histogram 3 – Comparison of subsidies for electric and hybrid vehicles in the EU

5. DISCUSSION

Certain conclusions can be estimated based on the data processed in the previous chapter regarding the number of registered, newly registered electric and hybrid vehicles and charts representing values of procurement subsidies for electric and hybrid vehicles and the existence of tax reliefs according to the European Union states. The number of newly registered electric and hybrid vehicles is constantly increasing and a certain form of exponential function can be outlined from the data. Subsidies and tax reliefs for procurement of electric and hybrid vehicles show that the majority of the European Union states have both forms. A certain dependence between the number of newly registered electric and hybrid vehicles and the subsidies and tax reliefs in the EU states can be estimated.

6. CONCLUSION

The introduction describes the influence of vehicles that use fossil fuels as energy source, have many damaging consequences on the entire system, and are necessary to be replaced by vehicles using alternative propulsion. Literature review shows the issue with stimulating purchase of electric and hybrid vehicles, which is possible to resolve by means of harmonized traffic policy and incentives in the form of subsidies upon procuring such vehicles. Furthermore, the method of processing

available statistical data is described by means of working methodology. The chapter on electric and hybrid vehicles' markets in Europe shows the number of electric and hybrid vehicles in the period from 2008 to 2018, as well as the number of newly registered electric and hybrid vehicles in the period from 2010 to 2017.

Also, the available data show the co-financing status of electric and hybrid vehicles in the Republic of Croatia as well as other member states of the European Union. The chapter on review and discussion comments results and connection of the measures (subsidies and tax reliefs) with the number of newly registered vehicles. The set hypothesis is proved through the data regarding the constant increase in the number of vehicles in parallel with subsidies and tax relief measures. Further research will going to determine exactly how much influence do the subsidies and tax reliefs as financial incentives have on choosing and purchasing electric or hybrid vehicle.

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SANJA STEINER, Ph.D.[1]
E-mail: ssteiner@fpz.hr
TOMISLAV MIHETEC, Ph.D.[2]
E-mail: tom@integra.dk
ZVONIMIR REZO, Ph.D. student[3]
E-mail: zvonimir.rezo@gmail.com
[1] Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia
[2] Integra Consult A/S
Trørødvej 63B, 2950 Vedbæk, Denmark
[3] Croatian Academy of Sciences and Arts, Traffic Institute
Kušlanova 2, 10000 Zagreb, Croatia

RESOLUTION OF OPERATIONAL CONSTRAINTS IMPOSED BY FRAGMENTATION OF EUROPEAN AIRSPACE

ABSTRACT

The development of new concepts aiming to increase flight efficiency represents one of the main guidelines for the future European Air Traffic Management (EATM) system development. Future EATM system design is driven by the development and implementation of various technical and operational solutions which are based on collaborative and coordinated airspace and air traffic flow management. European airspace fragmentation is recognized as one of the most prominent problems which limit improvements in terms of flight efficiency. This primarily relates to the fact that EATM system is organized and operated at national scale. This research was carried out with the purpose to signify two concepts which have significantly improved flight efficiency level. Free Route Airspace and Flexible Use of Airspace concepts particularly distinguished as good examples of how it is possible to improve flight efficiency regardless to fragmented European airspace design. Hence, the research resulted by analysis of concepts designs, characteristics and their deployment benefits to airspace users. Also, an issue which limits further flight efficiency improvements at European scale have been identified.

KEY WORDS

Air traffic management; European airspace; fragmentation; Free Route Airspace; Flexible Use of Airspace

1. INTRODUCTION

Nowadays, due to increasing air traffic demand in the Pan-European region, many airspace management problems arise. Hence, air traffic and airspace planning and management functions can no longer be based on meeting of the demand foreseen only for the near future. There is no doubt that the manners in which the European airspace will be organized and managed in the future will play a vital role. Current airspace management design is extremely vulnerable and influenced by different external and internal factors. Hence, different EATM stakeholders are trying to minimize as much as possible both kinds of influential factors so the airspace users do not even notice them. Such an approach is necessary in order to enhance future improvements in terms of flight efficiency.

Fragmented design of European airspace is considered to be one of the hardly overcoming factors which negatively influence flight efficiency. During last two decades various initiatives, regulations and concepts implementations, with greater or smaller effects, tried to reduce negative impacts associated with fragmented airspace design.

The need for implementation of new operational concepts which will be able to overcome fragmented airspace design has been recognized as one of major challenge of future EATM development. Hence, in 2004 the Single European Sky (SES) initiative was formally launched with a goal to improve the overall performances of EATM system. It is supported by a technological modernization programme SESAR (Single European Sky ATM Research) whose purpose is to enable defined goals by modernising and harmonising ATM systems through the definition, development, validation and deployment of innovative technological and operational ATM solutions [1].

This paper presents referent samples of ATM concepts, which on national level maps changes occurring within the ATM system at European and regional level. Therefore, this paper presents a synthesis of effect of two Europe-wide applicable concepts - Free Route Airspace (FRA) and Flexible Use of Airspace (FUA), which managed to overcome operational constraints due to fragmented European airspace design and improve flight efficiency.

2. EUROPEAN AIRSPACE FRAGMENTATION STATUS

It can be defined that current fragmented design of European airspace is result of historical relationship between Air Navigation Service Providers (ANSPs) and European states. Over the last twenty years, as the most obvious EATM system's weakness was recognized problem of decision-making at national levels [2]. Considering that still nowadays European airspace is highly fragmentary designed with regard to the existing number of ANSPs, it can be concluded that this problem continues to exist. Figure 1 shows airspace of 19,507,200 km^2 divided between 37 ANSPs.

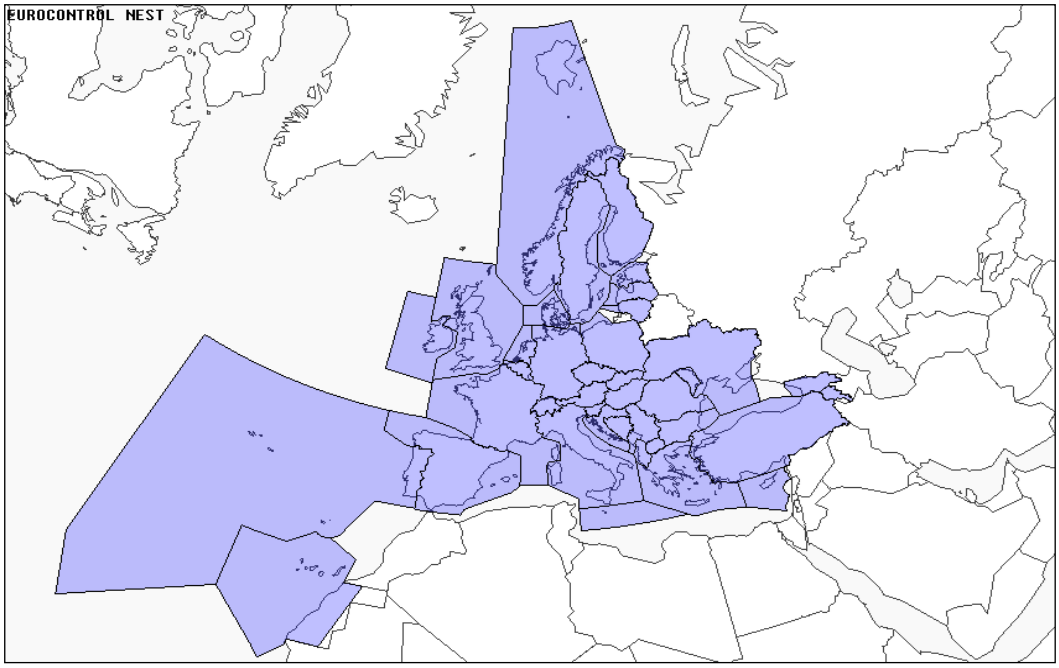


Figure 1 - Spatial overview of European airspace division between 37 ANSPs

There is no doubt that fragmented design of European airspace negatively influences safety and environment, reduces airspace capacities and increases operational costs. The European Commission, various representatives' bodies, as well as many experts and scientists recognize fragmentation as one of the causes of EATM system's inefficiency and dysfunctionality. For example, EUROCONTROL, the European Organisation for the Safety of Air Navigation, considers that it is difficult to overcome fragmentation due to the existence of different interest groups in Europe. They expect that the European airspace will be fragmented as long as Europe does not have an integrated European defence

system. Otherwise, their opinion is that, the states will continue to oversee and operate airspace through its ANSPs to protect their national sovereignty [3].

Undoubtedly, inefficiency has its cost and since fragmentation represents a quite significant issue, then, the size of the inefficiency related cost is even higher. By reviewing the literature, it can be concluded that there is no consensus about what is the real cost of airspace fragmentation. Even the European Commission itself lists different information within its publications. In 2015 within "An Aviation Strategy for Europe" it estimated that the cost of the EU's fragmented airspace design represent at least EUR 5 billion a year [4], while in 2017 it defined that the European airspace fragmentation costs at least EUR 3 billion a year [5].

An analysis of consequences of fragmented design of European airspace is precisely specified within European Court of Auditors' (ECA) report titled "Single European Sky: a changed culture but not a single sky" [6] which identified that Functional Airspace Blocks (FABs) - by which it have been tried to reduce airspace fragmentation level, eventually only fostered cooperation forums and did not airspace defragmentation. Report also indicates that the SESAR has fostered a common vision but has become detached from its initial schedule and is now open ended, as well as that the charging and performances measurement schemes are affected by different shortcomings. Hence, it is possible to identify several repercussions of fragmented design of European airspace. The most obvious ones are that Area Control Centres (ACCs) operate below optimal economic size, multiplication of systems, unsynchronized adaptation of technologies and infrastructure, higher maintenance, training, research and development (R&D) and administrative costs etc. [7]. Furthermore, even though the planning of the SES initiative is based on the collaborative implementation of ATM Master-plan defined concepts and projects, the real implementation is fragmented and based on national levels thus aggravating European airspace unification [8].

3. EUROPEAN AIRSPACE MANAGEMENT DESIGN

In general, airspace management function can be described as a process by which the airspace is being organized and managed in accordance with airspace users' requirements. Although European airspace management function does not represent an exception in this regard, during past decades the existence of certain deficiencies has been noticed. Hence, in order to achieve further improvements of flight efficiency, it was necessary to harmonize different EATM system's operational units. This primarily refers to the need of strengthening the link between interconnected operational units and procedures of airspace management (ASM), Air Traffic Control (ATC) and Air Traffic Flow Management (ATFM) functions. Figure 2 depicts the current interdependent design of operational units affecting flight efficiency level.

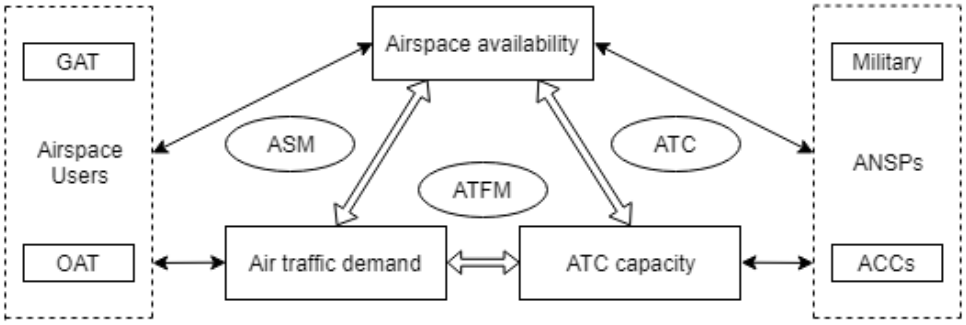


Figure 2 - Overview of operational units affecting flight efficiency level [9]

European airspace management design is based on a model that includes three functional levels: strategic, pre-tactical and tactical level where each level has a direct impact on other levels. Strategic level consists of definition of the national airspace policy and establishment of pre-determined airspace structures. Pre-tactical level includes day-to-day allocation of airspace structures according to

airspace user requirements while third (tactical) level is characterised by a real-time use of airspace structures simultaneously ensuring safe Operational Air Traffic (OAT) and General Air Traffic (GAT) operations.

Strategic level starts one year and lasts up to one month before planned event occur. Pre-tactical level starts just after strategic level ends and lasts up to one day before planned event occurs. Final, tactical level includes time gap lasting from one day before and ends up with few hours before planned event occur. Hence, although they are separated, specified levels are closely interdependent management phases which need to be performed coherently to ensure efficient use of airspace and booster flight efficiency level.

Such a systematic design aims to improve European airspace management performances and consequently EATM system's efficiency, i.e. to reduce flight inefficiency. By reviewing literature, it can be found that there are several different definitions referring flight inefficiency. In such a status quo different stakeholders involved in strategic air traffic planning and management have various perceptions of flight inefficiency. Reynolds [10] defines that flight inefficiency can be defined as anything that causes an aircraft to fly a path different to its optimum trajectory. Furthermore, it is well known that the potential causes of flight inefficiency significantly differ in accordance with different flight phases. According to Mihetec et al. [11], it is possible to express flight inefficiency by the agreed performance indicators including distance difference (NM), duration difference (min), fuel combustion difference (kg) and CO_2 emission (t). Bearing that in mind and in addition to many European ATM Master Plan-defined projects, two concepts have particularly distinguished and managed to overcome operational constraints due to fragmented European airspace design. Therefore following two subsections put a focus and defines how FRA and FUA concepts did improved flight efficiency on a Europe-wide level.

3.1 Flexible Use of Airspace concept

According to Huang [12], the issue of civil and military coordination in the context of airspace management have been discussed since 1996. Cook [13] concludes that such a situation was imposed by the need to better accommodate the changing needs of the military and markedly increased traffic congestion. FUA represents an airspace management concept described by the International Civil Aviation Organisation (ICAO), developed by EUROCONTROL and regulatory supported by the European Commission. European Commission (EC) Regulation No 2150/2005 defined that within FUA concept airspace should not be designated as either purely civil or military airspace, but should rather be considered as one continuum in which all airspace users' requirements have to be accommodated to the maximum extent possible [14]. The FUA concept implementation enabled the maximum shared use of airspace through enhanced civil/military co-ordination. It is based on dynamic airspace management design from which the most distinguished elements are Temporary Reserved Area (TRAs)/Temporarily Segregated Areas (TSAs) and Conditional Routes (CDRs). On the one side, TRAs/TSAs represent a manageable structures established in response to the need for civil, military, R&D, training, test-flights or activities of a temporary nature [15]. On the other side, it is necessary to emphasize that there are more applicable CDR types. Considering foreseen availability, flight planning possibilities and the expected TRA/TSA activity time, it is possible to divide CDRs into the three categories: CDR1 (permanently plannable CDRs), CDR2 (non-permanently plannable CDRs) and CDR3 (not plannable CDRs). Their spatial distribution is shown by Figure 3.

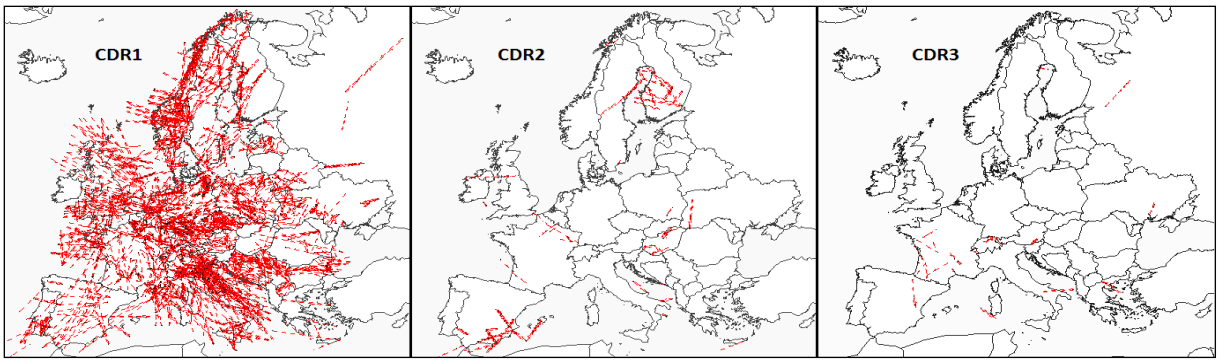


Figure 3 - Spatial overview of CDRs distribution

Unlike to the TRAs/TSAs - which are defined within national Aeronautical Information Publications (AIPs), CDRs are non-permanent parts of the published ATS route network. The CDR activation is published by an Airspace Management Cells (AMC) in a form of Airspace Use Plan (AUP) and Update Use Plan (UUP). Furthermore FUA concept is also defined by Reduced Coordination Airspace (RCA) and Prior Coordination Airspace (PCA) procedures used for flexible airspace management and few more airspace structures, e.g. Cross-Border Areas (CBAs), Danger (D) and Restricted (R) areas which are subject to pre-tactical or tactical allocation under the Temporary Airspace Allocation (TAA) process.

The concept of Flexible Use of Airspace is more detail explained in EUROCONROL's ASM Handbook [15]. Its purpose is to provide additional descriptions of the ASM functions and EATM system related processes and procedures referring FUA concept. In general, it can be defined that an idea behind FUA concept is that CDRs supplement the existing ATS route network and lead aircraft through TSAs. In such way FUA concept allows GAT to fly shorter, to use more direct routes and so save time, fuel and money. Thereby, a shift from permanent airspace structures into dynamically manageable military airspace structures significantly reduced operational constraints due to fragmented European airspace design.

3.2 Free Route Airspace concept

Second important concept which managed to operationally overcome constraints due to fragmented European airspace design is Free Route Airspace. The idea of Free Route Airspace concept originates from 1998 and creation of "Eight-State Free Route Airspace Project" involving following eight countries: Belgium, the Netherlands, Luxembourg, Germany, Denmark, Norway, Sweden and Finland. Ten years later EUROCONTROL actualized coordinated development of new and comprehensive FRA concept Europe-wide. New concept development and later on implementation was also politically supported by European Commission, i.e. by Commission implementing Regulation (EU) 2019/123 of 24 January 2019 laying down detailed rules for the implementation of air traffic management (ATM) network functions.

According to definition, Free Route Airspace concept includes an specified airspace within which users can freely plan a route between a defined entry point and a defined exit point with the possibility of routeing via intermediate (published or unpublished) waypoints, without reference to the air traffic services (ATS) route network, subject of course to availability. Within such airspace, flights remain subject to air traffic control [16]. Figure 4 shows an example of how FRA concept implementation in form of South East Common Sky Initiative Free Route Airspace (SECSI FRA) reduced number of required cross-border waypoints. Consequently such an approach made flying more direct and increased flight efficiency.

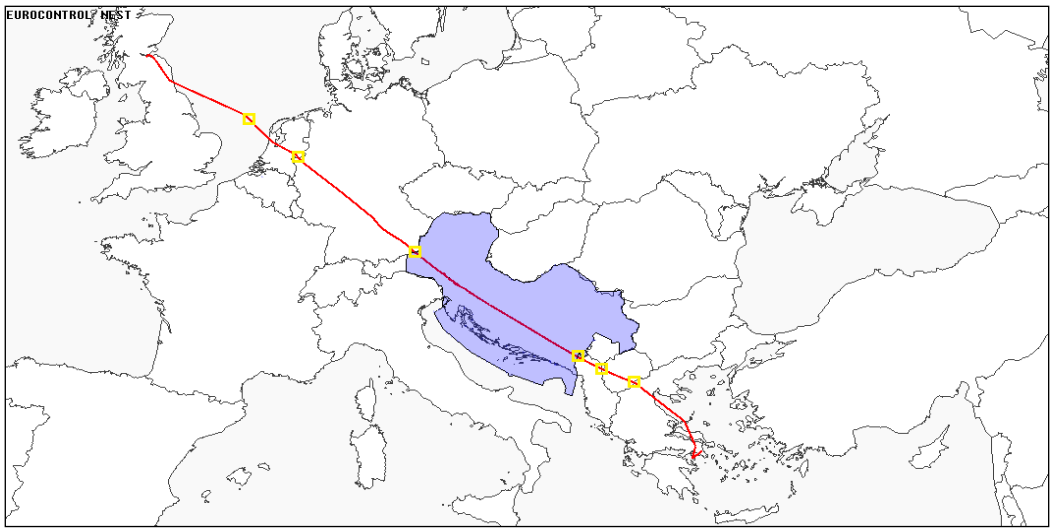


Figure 4 – Spatial overview of South East Common Sky Initiative Free Route Airspace (SECSI FRA)

Nowadays, FRA concept implementation is still underway and is scheduled to be Europe-wide completed above Flight Level (FL) 310 by Jan 1, 2022. Considering that EUROCONTROL has initiated FRA concept deployment, as the Network Manager (NM) - it is responsible for further coordination, development and concept implementation. In addition, involvement of a large number of different stakeholders, such as civil and military experts in airspace design, European Civil Aviation Conference (ECAC) Member States, ANSPs, airspace users, flight planning organisations and other relevant international bodies, witnesses comprehensiveness and significance of FRA concept in European ATM development.

In the regions where FRA concept is already deployed, airspace users can fly any preferred trajectory between a defined entry and exit points. Unlike conventional Air Traffic Service (ATS) routes, FRA concept implementation enables a reduction in route length (NM), flight time (min) and consequently fuel consumption (kg) as well as carbon dioxide (CO_2) and nitrogen oxide (NOx) emissions reduction. According to EUROCONTROL, since 2014, due to deployment of FRA concept airspace users have saved of around EUR 500 million of additional fuel costs [17].

4. DISCUSSION

Due to the increasing density of air traffic in Europe, the availability of airspace capacities becomes more important issue. The anticipated growth of air traffic over the next twenty years requires the implementation of innovative methods, solutions and procedures with an aim to improve the current flight efficiency level. In an ideal world, aircraft would fly directly from point of departure to point of arrival. Between these two points ATM system would manage flight operation, continuously trying to minimize any potential constraints influencing flight efficiency level. Taking into account the current state of the European ATM system, it can be concluded that it is still far away from ideal design.

Undoubtedly, it is possible to single out European airspace fragmentation as one of the most apparent causes jeopardizing improvements in terms of flight efficiency. European airspace fragmentation represents a condition which disables complete European air traffic market's development potentials. It limits airspace capacity, adversely affects the environment, increases operational costs and above all, potentially affects safety.

Nowadays different development strategies, initiatives and projects within European ATM system aim towards creation of more efficient system. SESAR, as the technological pillar of the SES initiative, seeks to harmonise and modernise ATM systems and procedures across Europe. Since its establishment, it has been gradually releasing technological and operational improvements which

usually had to pass "three steps approach" including definition phase (drawing up the plan for modernisation), development phase (the establishment of the necessary technological bases) and deployment phase (installation of the new systems and procedures). Although different concepts are frequently defined as the main driving forces for the realization of the Single European Sky, in terms of improvements achieved by operational harmonization of EATM system, it is undisputed that FUA and FRA concept are the most distinguished examples.

SESAR Joint Undertaking (JU), which is responsible for managing the development phase of SESAR, proposes a new initiative to reorganize the European airspace. Within its document titled "Proposal for the future architecture of the European airspace" [18] as the key element of the proposal it highlighted airspace optimisation process that includes both, further extension of Free Route Airspace and Flexible Use of Airspace, as well a progressive re-sectorisation based on dominant traffic flows. Although it hasn't been yet Europe-wide applied, the effects of the FRA concept implementation can already be noticed. As it can be seen by Figure 5, in past few years, NM and ANSPs efforts have led to the successful FRA concept implementation in a large part of North, South-East and Central South-East Europe. By the end of 2017, 51 ACCs have either fully or partially implemented Free Route Airspace concept, which exceeds the target of 35 ACCs set by the Network Manager Performance plan [19]. Hence, airspace users are already adapting their flight planning systems to fully exploit potentials enabled by FRA concept. The shift from fixed ATS routes to free airspace offered significant opportunities to airspace users in terms of flying time and distances reductions. Consequently, less fuel is burnt what enables financial savings to airspace users and reduces amount of emitted emissions. To be more precise, EUROCONTROL defines that by implementation of FRA concept flying distances could be reduced by approximately 7.5 million NM that represents the equivalent of 45,000 tonnes of fuel saved, or a emissions reduction of 150,000 tonnes of CO_2 or EUR 37 million [15].

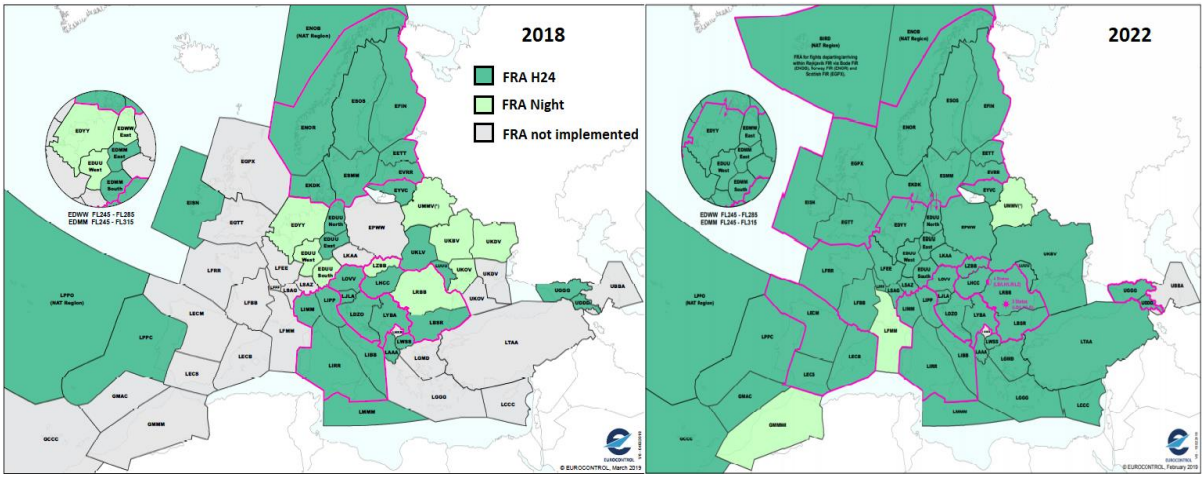


Figure 5 – Temporal and spatial overview Free Route Airspace concept implementation [20]

Effective and harmonized application of flexible use of airspace includes clear and consistent rules for civil-military coordination which takes into account all airspace users' requirements. Bearing that in mind, it is important to point out that different airspace users are driven by different objectives and business models. Consequently, they have different requirements for airspace allocation. On the one side, civil aviation (GAT) wants to develop trajectories with the most cost-efficient aircraft routing options. On the other side, military aviation (OAT) wants to use the airspace structures in such way that they enable the most effective aircraft routing with a goal to enhance execution of missions' objectives. Figure 6 shows an example of flight route between London (ICAO: EGGW) and Naples (ICAO: LIRN) in dependence of spatial allocation of TRAs and TSAs.

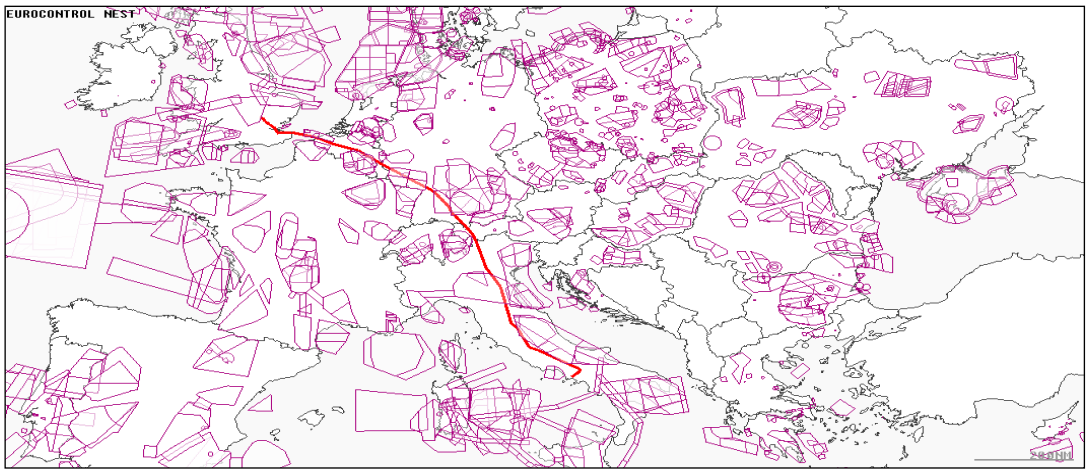


Figure 6 – Spatial overview flight routeing in dependence of TRAs/TSAs allocation

Until the introduction of the FUA concept, airspace structures were H24 per day unavailable for commercial air transport [21]. Although military airspace structures were closed for commercial airspace users, frequently they were not H24 operational. Such a situation made European airspace management more complex and civil-military cooperation more difficult. Consequently, it affected increase of en-route delays, lack of airspace capacity and increase of operational costs. The implementation of FUA concept has given a big growth in the general level of flight performances, including efficiency, capacity, reduction in distance and time [22-23]. Also, FUA concept implementation enabled higher utilization level of military airspace structures which could be no longer operational H24 and unevenly used. In such way prerequisites have been made to further increase the flight efficiency. According to EUROCONTROL [24], the implementation of the Flexible Use of Airspace concept delivered benefits to both civil and military aviation. It increased flight efficiency offered through a reduction in distance, time and fuel, enabled more efficient ways to separate OAT and GAT, enhanced real-time civil/military coordination, reduced need for airspace segregation and finally enabled higher airspace utilisation level.

Analysed two concepts' implementation certainly improved flight efficiency and managed to overcome fragmented European airspace design. In this way operational improvements reduced negative impacts associated with airspace fragmentation. Jointly they enabled higher flight efficiency by facilitating airspace management (less aircraft rerouting and more direct flight routes), financial saving to airspace users (less fuel burnt), better civil-military coordination (higher airspace utilization level) and minimized negative environmental effects (reduction of NOx and CO_2 emissions). But despite achieved improvements in terms of flight efficiency, still there is one thing to be considered. If we consider the relation between current flight efficiency in regard to opportunities enabled by implementation of two analysed concepts, it can be concluded that full potentials have not been yet utilized in proper way. Also, it can be frequently seen that opportunities enabled by two concepts implementation are being abused by airspace users. This primarily refers to the fact that certain factors impacting flight efficiency level are outside of a ANSPs' control and that they do not significantly depend on improvements achieved by optimization of the airspace structures as much as they depend on a current charging scheme for air navigation services. The best examples could be found in flight planning practices of GAT operations, their route choices and used models of routes cost-optimisation. Bearing in mind mentioned, it is important to point out horizontal en-route flight efficiency indicator which reflects flight efficiency elements which are beyond the control of ANSPs, but does not specify their share in overall value. Indicator captures the difference between the planned or actual trajectory against the shortest route. According to Performance Review Body of the Single European Sky [25] for 2018 the average horizontal en-route flight efficiency of the actual trajectory (KEA) was on average 2.81% longer than the great-circle distance while in regard of the last filed flight plan (KEP) it was on average 4.73% longer than the great-circle distance. Figure 7 shows level of flight inefficiency during

2014 and 2018 on the example of Republic of Croatia (ANPS: Croatia Control Ltd; FIR Zagreb) where both analysed concepts were implemented.

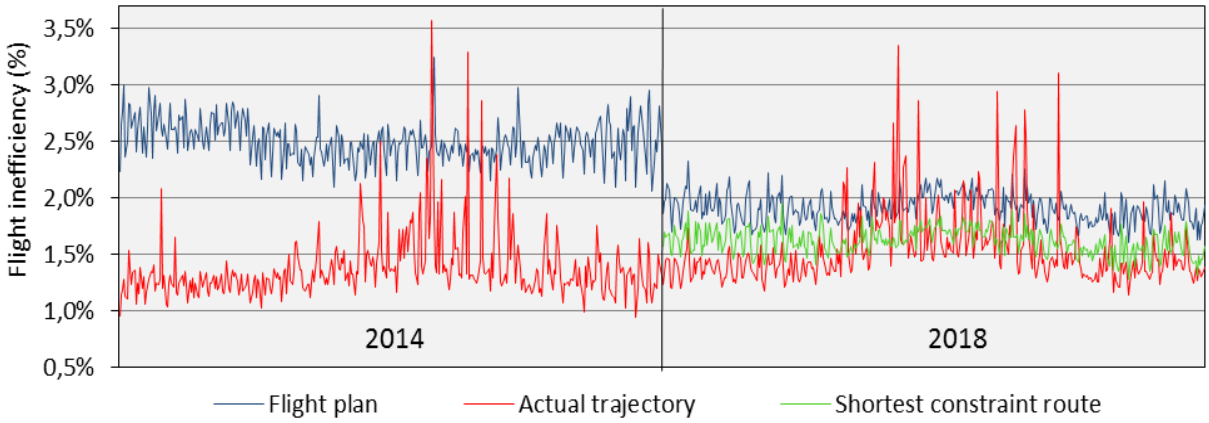


Figure 7 – Comparative overview of flight efficiency improvement at FIR Zagreb [26]

From the figure above, except from the fact that horizontal en-route flight efficiency is quite variable indicator, it can be seen that two concepts improved flight efficiency. Also, 2018 data indicates that during pre and post summer time, flight efficiency level was deteriorated. Hence, it can be concluded that although two analysed concept improved flight efficiency level, nowadays there is an issue arising how to further improve flight efficiency by managing the flights in most optimal way.

5. CONCLUSION

The need to improve the airspace management system was yet recognized at the end of the 1990s. Nowadays, it is quite debatable how much really significant work has been done so far. Since the European airspace is as fragmented as 20 years ago, there is a rhetorical question arising what have been done ever since and was it possible to do it better?

Although airspace represents a limited resource, air traffic volume continuously increases over the Europe. Such a situation made airspace management more complex and civil-military cooperation more difficult. To prevent further system's dysfunctionalities at the operational level, it was necessary to reduce negative impacts arising from fragmented airspace design. Later on FRA and FUA concept were developed and their implementation phases started. Nowadays benefits from their deployment are notable to airspace users on daily basis. Due to fact that they have possibility to execute flights on more direct routes improved flight efficiency level.

Although different airspace fragmentation types can be found in other areas of EATM system, operational improvements - in terms of implementation of FRA and FUA concepts are seen as a the most distinguished efforts how to overcome fragmented design of European airspace. Hence, it can be concluded that during last two decades the most noticeable effort to overcome airspace fragmentation was made in terms of operational improvements which also led to an improvement in flight efficiency level.

Furthermore, despite opportunities enabled by two analysed concepts, it is recognized that the airspace users continue to execute flights in a way to maximize their financial benefits. This primarily refers to the fact that airspace users choose to utilise benefits of FRA and FUA concepts in way to maximise financial savings by flying on a most economic instead on the shortest routes. Considering that airspace users are primarily driven by business models which will enable them grates cost efficiency, frequently it is achieved at the expense of flight efficiency. Such an approach results in lower utilization possibilities of maximum benefits enabled by FRA and FUA concepts. Hence, it can be concluded that although FRA and FUA concepts already did improve flight efficiency, their maximum

benefits won't be noted until airspace users start to rather fly on shorter instead of more economical routes.

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ADAM SZELĄG, Prof. D.Sc. Ph. D. El. Eng. [1]
E-mail: adam.szelag@ee.pw.edu.pl
MIROSŁAW LEWANDOWSKI, D.Sc. Ph. D. El. Eng[1]
E-mail: miroslaw.lewandowski@ee.pw.edu.pl
MARCIN STECZEK, Ph.D. El. Eng. [1]
E-mail:marcin.steczek@ee.pw.edu.pl
TADEUSZ MACIOŁEK D.Sc. Ph.D. El. Eng. [1]
E-mail: tadeusz.maciolek@ee.pw.edu.pl
[1] Warsaw University of Technology Power Electrical Institute Electric Traction Division
ul.Koszykowa 75; 00-662 Warsaw, POLAND

FROM TRAMS TO HIGH-SPEED TRAINS AND ELECTROMOBILITY – 140 YEARS OF DEVELOPMENT OF ELECTRIC TRACTION

ABSTRACT

In the current world, electrified transport constitutes one of the main modes of mass transport. Individual transport is dominated by cars with an internal combustion engine (ICE), even though the first electric cars had appeared before an ICE was invented. Electric traction that depends on a catenary is characterized by restrictions imposed by dedicated, electrified routes, which reduces its availability. Development of economy in the world causes increased demand for transport, in particular the cars become more available, which presents a higher risk for the environment. We witness development of energy storage technology that reduces its price and increases energy capacity, but the range of battery electric vehicles (BEV) is still too low for long-distance travels. The perspectives for the wider use of BEVs are in the cities, where shorter distances of travel allow for e-vehicle applications with overnight charging. Increasing the number of BEVs technology creates a need for a network of chargers and requires higher power supply capacity for energy delivery to millions of e-vehicles. The paper presents the issues associated with undertaken activities for electric transport development, especially electromobility in the world and perspectives for Poland.

KEY WORDS

electric traction; electric trains; electromobility, e-vehicles, e-buses

1. INTRODUCTION

Electric traction is understood as an application of an electric drive in a vehicle's drive (object in motion). The type and parameters of a motor applied in a drive influence the traction characteristic of a vehicle, its performance, and operating costs. These costs are related not only to the vehicle, but also to the elements and cooperating systems of electromechanical and power electronics systems of energy conversion and supply, systems of automatics, control and signaling. In a solution with an external supply of electric energy into a vehicle, using a special set of conductors – a catenary, such a system is called a system of traction dependent on catenary power supply (Fig. 1). When the source of electric energy is placed on the vehicle, such a solution is called independent traction. The common type of independent traction is Diesel - electric traction, where electric energy is produced on board of a vehicle due to the application of a Diesel engine that is coupled with a generator supplying energy to electric motors of a vehicle's drive. A diagram showing connections between subsystems forming the system of *electrified transport system* is presented in Fig. 1. Application of electric traction in drives of on-ground vehicles or vehicles in tunnels is the most common solution. The idea behind using electric energy in vehicles' drive emerged at the dawn of electrical engineering development. This was connected with improvement of electrical machines and devices for energy conversion. The first practical application of an electric drive in land transport appeared as early as in the 19th century

(Berlin, 1879 - Werner von Siemens), the first electric tram was launched in 1881, in Lichterfelde, underground in London (1890), railway in Switzerland (Burgdorf-Thun, 1893). First road electric vehicles (EV) using independent traction appeared at the end of the 19th century. They were developed in Europe and in the U.S. in the late 19th and 20th century to reach worldwide speed records (105.9 km/h – Renault car) at the beginning of the 20th century. The 19th century was a "golden age" of railway, which developed rapidly, due to the construction and use, first for mining transport purposes, of vehicles with iron wheels moving on iron rails. Historical traces also point to the previous attempts with similar vehicles. The beginning of the twentieth century witnessed peak development of railway, with steam locomotives reaching speeds above 200 km/h (213 km/h in Germany, in 1903). Further development of railway became possible due to the rapid growth of electric traction. However, upon improvement of an internal combustion engine (ICE), in the twentieth century railway faced strong competition from the road transport and air transport. It caused that in the second half of the twentieth century, in the cities, rail ground transport was superseded (disposal of tram lines), by buses and individual transport means (cars), while the consequence of expansion of road and airport networks is the reduction of importance of railway in long-distance passenger transport.

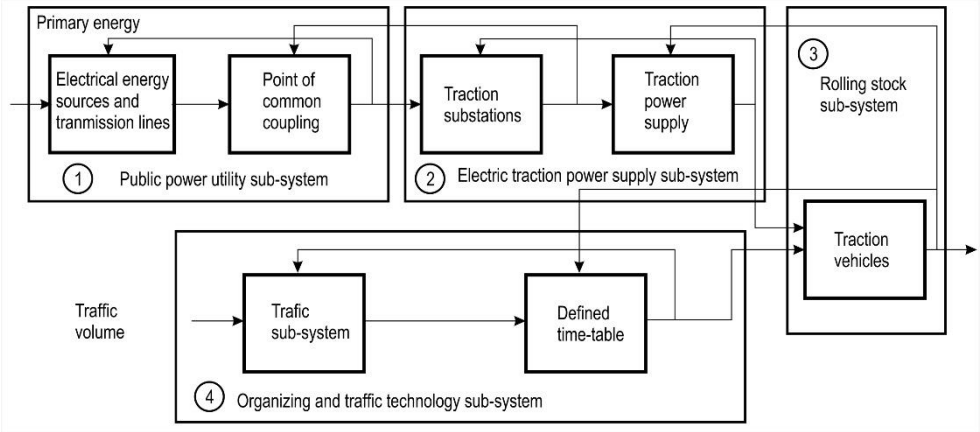


Figure 1 – A diagram of connections between subsystems forming the system of electrified transport system

In the Europe, share of rail transport in passenger transportation acc. to statistics has declined from 10% (1970) to 6% (2000), while the share of freight transport declined from 21% to 8% over the same period of time. Road congestion and environmental pollution, along with difficult access to petroleum and increase in petroleum prices, resulted in increased interest in electric traction. In the 1990s, legal regulations aiming at stopping the decline of rail transport started to be introduced. In Europe, it was connected with the desire to deepen European integration by creating a Trans-European rail network. Establishing a network of rail connections between the European countries, large cities in particular, became a priority. Since the beginning of 21th century, the EU policy aimed at:

- Increasing the share of rail transport in passenger and freight transport,
- Reducing the energy consumption and fossil fuels use in transport,
- Reducing the negative influence of transport on environment (enhancing preference for alternative fuels, specifically electrified transport.

Of high significance was Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance.

2. ELECTRIFIED TRANSPORT- CURRENT STATE

In the current world, electrified transport constitutes one of the main modes of mass transport. Individual transport is dominated by cars with an internal combustion engine (ICE), even though the first electric cars had appeared before an ICE was invented. Due to the large number of solutions and

systems used in the electrified transport, depending on the type of a vehicle's route, the following classification is applied:

- road transport: public (trolleybuses, commercial vehicles and buses) and private (cars, bikes, scooters, skate-boards, etc.),
- rail transport (railway, urban underground railway, light rail transport, trams, industrial railway),
- unconventional transport systems (maglev, suspended rail system, automated transport systems on dedicated routes, industrial transport).

2.1 Advantages of electrified transport

It is well known that in comparison to other modes of transport, electrified transport is characterized by a number of advantages:

- it allows for mass transport at a low level of energy consumption;
- it is environmentally friendly (requires less area, has a lower level of air emissions).

Furthermore, the advantages of rail transport include:

- greater safety, rail transport can also be characterized by a greater level of safety than other modes of transport, only aviation has more strict safety rules;
- smaller area of occupancy;
- – lower sensitivity to weather conditions, because electric vehicles are less susceptible to disturbances from weather conditions (temperature, precipitation, fog);
- electrified transport relieves congested roads, because shifting traffic from roads;
- Construction of new highways is not a solution to the problem of entering city centers by cars, while, on the other hand, by using rail transport passengers can reach city centers very easily, since this is where the stations are located.

From a technical point of view, application of an electric motor allows achieving better parameters of vehicles with an electric drive in comparison to the vehicles with an ICE. It is due to the fact that:

- an electric machine can be transiently overloaded (so power higher than the rated one is obtained). It allows for attainment of a greater drive force during, for instance, start-up. Degree and duration time of overload depends on the cooling properties; a fuel engine lacks this property;
- an electric drive allows for easy application of a multi-motor distributed drive (more driven axles with motors of smaller power) and multiple control in traction units (sets of several wagons with a drive).
- an electric machine can operate reversibly, i.e. as a motor propelling a vehicle (conversion of electric energy into mechanical energy) or as a generator (conversion of mechanical energy into electric energy during braking);

It allows for energy recovery (recuperative braking) and decrease of its consumption by 15-30%, provided that during braking there will be a regenerative energy consumer of this energy. It results in smaller wear out of mechanical brakes, but also in a lower level of environmental pollution. However, effectiveness of implementing recuperation needs not only technical, but also law changes. Why not to include recuperation energy to the renewables? If energy received from wastes (waste to energy process) is treated as a renewable one, recuperation energy which, if not reused, will be lost (wasted) should be treated in the same way. In some EU countries (Spain, UK, Sweden) legal regulations are being introduced for sending back energy from a traction system to the power utility system, including relation between energy taken from supply and return energy. It is important, as energy distribution companies are not always willing to allow for transfer of recuperation energy to the public system due to its quality parameters (harmonics, dynamic changes). Many documents have been devoted to these aspects, including Commission Regulation (EU) No. 1301/2014 of November 18, 2014 on the technical specifications for interoperability relating to the ‘energy’ subsystem of the rail system in the Union.

2.2 Development of rail electric traction

The data outlined above clearly point to the ecological advantages of rail transport, especially of the electrified network transport. Electrification, i.e. the use of network electric traction, currently constitutes an alternative for transport, which uses liquid fuel as energy sources. Usually, technical and economic viability of such a process is a decisive factor in electrification of a particular line.

Currently, the main reasons for constructing new lines of electrified transport are as follows:

- high external costs of road transport in the cities,
- inability to obtain appropriate transport capacity of road transport (number of passengers and speed of travel),
- effective competition with air transport (high-speed railway lines in inter-city relations at distances up to 500 km).

For several years now, one has witnessed an intensive development of traction vehicle drives. One of the main causes is the constantly growing and more diversified need for improvement of the transport mode as well as technical possibilities resulting from material technology development, mainly from significant development in semiconductor technology.

Current traction vehicles should meet a number of criteria and requirements for ecology, operation, energy and material consumption. It relates, in particular, to high reliability and durability levels, serviceability, i.e. maintenance and repair technology, required adjustments for diagnostics. Vehicles should be ergonomic, for both, service staff as well as passengers, environmentally friendly (no air, soil or water pollution, lack of vibrations and noise limitation), but also provide comfortable (air-conditioning) as well as safe transport.

Urban traffic uses trams, trolleybuses and underground trains (metro, tube), which usually operate underground. It is possible to run a metro line on a track on the aboveground area, but also to partially run the trams in a tunnel. The line routing depends on the local area conditions.

Currently, electric traction vehicles are technical objects with complexed mechanical, electric, electronic and pneumatic systems that can reach high speeds and acceleration. These vehicles, used especially often in rail traffic, are conventionally divided into separate generations, depending on the maximum speeds and equipment. Dependent electric traction also enables, due to energy supply from an external supply network and high power of motors, attainment of higher speeds (record: 574 km/h in 2008 – AGV train in France, in regular traffic – 380 km/h in China) than independent from catenary, diesel traction (maximum speeds above 200 km/h) as well as provision of higher travel comfort by application of a range of additional devices that require supply, such as: air conditioning.

2.3 Electromobility as a new era of road electric traction

Economic development is responsible for increased demand for freight and passenger transport service. Dependent on catenary supply electric traction, applied in public transport is characterized by limitation only with respect to the defined routes, which reduces its accessibility to passengers. So more flexible road vehicles are widely used, with their large increase – in 1998 there were approx. 700 million of cars in the world, in 2012 over 1 billion (10^9), while prognosis for 2050 is 2 billions) and as a result of environmental pollution [1,2]. Road transport is responsible for 90% of energy used for transport, with 64% share of cars. As a response to commendations regarding sustainable transport became rather rigorous. According to “White Paper: European transport policy for 2010: time to decide, EC 2001” sustainable transport should:

- assure availability of transport services in a safe, not creating danger to health of people or environment for current and future generations;
- be effective and offer opportunity for choice of transport means in order to maintain economy and development, locally and globally;

- limit emission and waste in a way that it could be absorbed by the earth/ground, uses amount of renewable resources, uses amount of non-renewables, which could be exchanged by renewable substitutes, with minimizing noise and land occupation.

Particularly relevant for such issues is Directive 2014/94/EU of the European Parliament and of the Council of October 22, 2014 on the deployment of alternative fuels infrastructure.

Practically, it means requirements for development of electric public transport and exchange of ICE cars with electric ones (e-vehicles) or other forms of electric transport (including sharing of e-cars, e-bikes, e-scooters, etc.), which induce passengers to resign from private cars. However, one should still take into account an electric road transport share in congestion and smog creation due to PM10 emissions, caused by brake and tyre wear. Another disadvantages of usage of e-vehicles are observed when taking into account materials and energy spent and emission provided during manufacturing and recycling of batteries. According to [3], the estimated share of emissions not related to exhaust emissions is as high as: 16-55% (brake wear), 5-30% (tyre wear) and 28-59% (road dust resuspension), so public rail transport has advantages in this case; however it is as available as individual road transport that in the form of electromobility creates an opportunity for decrease of environmental problems in the cities. Due to the costly infrastructure of rail electrified transport, in smaller towns without rail lines, electric buses (e-buses) should be put into service. The still significant limit of spread of e-vehicles is energy capacity and short life-cycle of energy storage devices (ESD) applied on-board, which causes low range. High cost of ESD is a dominant factor in a price of an e-vehicle; however, in last few years battery cost has been significantly reduced (cost of 1 kWh energy capacity in a battery in 2019 makes only 17% of the costs in 2010) [4]. While exploitation costs of e-cars in 2019 in the U.S. were twice lower comparing to ICE cars (underlining low process of gasoline in the U.S. comparing with Europe) [4]. Of course this comparison relates to a ratio of electrical energy to gasoline price in a specific state. Generally, it may be stated that the prices of electrical energy increase slowly, while crude oil prices fluctuate significantly.

For instance, the price of electrical energy for householders in Germany increased between 2010 and 2018 by 24% (in 2018 – 0.3 euro/kWh) [5], while crude oil barrel prices in the world market fluctuated from 17.3 USD/barrel in November of 1998 to 162 USD/barrel in June of 2008 and 54 USD/barrel in January of 2019 [6]. All of it may influence e-vehicle market significantly.

According to statistics of 2018 sell of PEV (plug in electric vehicles-PEV) (70% – BEV- battery electric vehicles, 30% –PHEV - hybrid electric vehicles with ICE) exceeded 2 million (half of them in China), which makes 2% of share in the car market [4]. Governments in many countries are introducing law regulations, which should encourage clients to buy e-cars, as subsidies, which are operating in 17 European countries (among others in Germany, France, UK, Spain, Romania, Slovenia, etc.) and in China. The majority of e-cars is registered in China [4], a global number of PHEV CARS (in China called NEV – new energy vehicle) exceeded 2.2 million in 2018. Next region with a high number is Europe – over 1.3 million units and the U.S. (half of them in California) – nearly 1.3 million cars. In Europe, the highest number of electric cars is registered in Norway, by the end of 2018 – nearly 300, 000 (10% of passenger cars), which means over 55 cars per 1,000 of inhabitants of the country [4]. High selling rates of e-vehicles in China, Norway and California results from the proper pro e-vehicle policy of the governments.

The Chinese government is currently introducing strategy titled ”energy saving and electric vehicles” to assure energy security and reduce environmental impact based on domestic production and being the biggest manufacturer in the world [7]. It results from the fact that the Chinese government has started introducing a policy promoting technological innovations and a new energy automobile industry, which requires creation of an industrial system (chain) starting from raw materials acquisition, key emerging technologies to new vehicle assembling and marketing. In [8], the long-term and short-term strategy for NEV industry in China has been discussed. The long-term strategy should include the use of local advantages by cost control competition, while the short-term

strategy should accelerate construction of vehicles, increase development of new technologies (important, due to high demand for specific raw materials used in high-tech batteries) and create new business operation models. It was highlighted that the most significant factor is the government support.

In Norway, policy towards e-mobility is the most advanced one. In [2], it was stated that from among measures and initiatives undertaken in Norway to promote EVs, the most effective included: VAT exemption (25% rate), access to bus lanes and free toll roads. E-car users motived their decision to drive e-cars by: environment (38%), economy (29%) and practical (28%) reasons. In some cities no-ICE car zones are imposed, while in other countries, it is planned to stop selling new ICE cars by 2025 - Norway, 2030 – India, 2040 – France and UK [4]. At the same time, we should have in mind that in most countries, the majority of electrical energy is generated in fuel power plants, which produces emission to the air. Development of preferred renewable energy sources gives a chance for real environmental friendliness of e-vehicles.

Observed improvement in the technology of ESDs increases the range of e-vehicles year after year, but their frequent charging is still required when covering longer distances (currently the most popular BEVs have ranges from about 340 km as Nissan Leaf to 539 km - Tesla Model S [4]). A more perspectival solution is the implementation of e-vehicles in populated areas with shorter travels, where e-vehicles, charged overnight could be used. It is worth assessing the opportunity for use of a power supply network of rail transport to create a network of charging points, as traction substations typically have power reserves [9]. It will be a real problem with availability of stationary charging points and capacity of the power utility network for millions of e-vehicles. It may be difficult to introduce "mobile charging", as it requires special infrastructure (with catenary or contactless one) and technical solutions applied in cars. For example, the concept of a mobile charging system for e-cars was presented in [10].

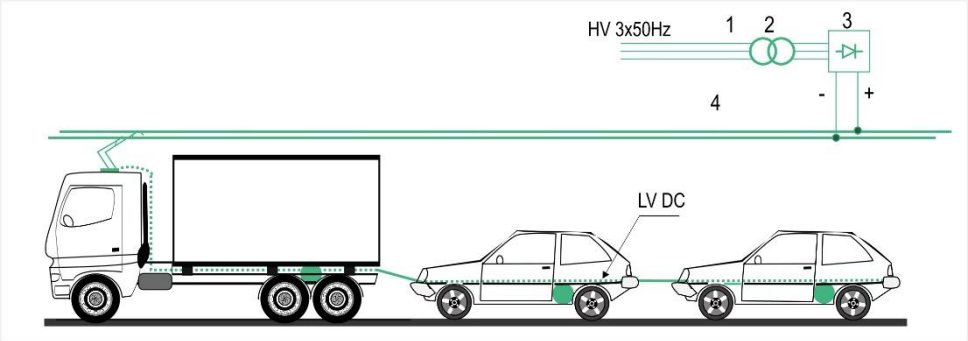


Figure 2 – Proposed in [13] Mobile Catenary Power Supply Convoy Cars System
Source: [10]

In this system [10] (Fig.2): "cars are composed into a road train via DC automatic electric couplers. Connecting and disconnecting of the cars forming a convoy is possible during driving with a maximum speed. Any car in a convoy may leave it at any point of road. The convoy is headed by a Pilot – a vehicle equipped with current collectors and power connector allowing energy transfer from a catenary to cars connected to the Pilot. The Pilot is a truck or a bus with a central unit controlling the whole convoy and cars as well data transmission between the Pilot and cars, and it sends information about availability of 'space' for another car to connect the convoy. All cars in a convoy must have unified connectors in front and at the back.

The proposed MCPSCC system has the following advantages in comparison with individual traffic of cars: - lower energy consumption, - increased driving range, - longer lifecycle of batteries, - higher safety, - higher traffic capacity of a road lane, - decreased fatigue of drivers, - lower unitary costs of transport, - lower environmental load, with flexibility of individual car transport maintained. However, some drawbacks are evident: - the road must have at least one lane equipped with an overhead

catenary, - equipment of cars must be unified (automatic power connectors allowing connection/disconnection at maximum drive speed), - due to close distances between cars (<1 m) an automatic operation of vehicles during connection to/disconnection from a convoy is a must. - central control unit in the Pilot vehicle must be used, - continuous wireless data transmission between cars in a convoy is required, - continuous data wireless transmission between a central control unit in the Pilot vehicle with an external data transmission network is necessary to enable localization of a specific convoy for connection".

3. STRATEGIC ROLE OF ELECTRIC TRACTION IN COUNTRIES WITHOUT OWN CRUDE OIL RESOURCES - POLISH EXAMPLE

The strategic role of electric traction in countries without own crude oil resources, as Poland, results from [11]:

- the opportunity to assure economy running in a case of shortage of delivery of crude oil (electrical energy in Poland is mainly generated in coal power plants), a wide network of electrified railways (over 12,000 km from over 19,000 km being in use in 2009), covering the whole Poland (Fig. 3), however not uniformly, more than 90% of railway transport in Poland is performed by electric traction. This is an important point for greater usage of railway electric traction, which consumes electric energy from own mineral fossil fuels as coal or renewables, while there is a need to import liquid fuels for Diesel traction and road transport, in particular;
- 15 tram systems, 3 trolleybus systems in different cities and 2 lines of metro in Warsaw;
- well-developed electric rolling stock (Polish companies: PESA, NEWAG, Solaris) and fixed installation industry;
- application of new technologies and solutions in electrified transport;
- ecological and energy saving character of electric traction, which allows for wide use of EU funds.

3.1 Catenary supplied traction

Overhead catenary still constitutes the most effective way of electrical energy delivery to high power vehicles and speeds up to 350 km/h. In Poland, important issues concerning catenary traction are as follows:

- increasing use of the existing 3 kV DC railway network with speed up to 200-230 km/h at CMK line;
- undertaking research and study works preparing railway operators and industry in Poland for introduction of a new 2x25 kV 50 Hz traction power supply system on new lines or not electrified lines (LHS – wide gauge line between Ukraine and Silesia, Rail Baltica section, new high speed lines).

Introduction of above requires:

- relevant development of the power plants, power utility system and transmission lines,
- construction of a test section of 2x25 kV 50 Hz supplied line,
- support of Polish railway industry,
- development of new methods and devices for diagnostic, monitoring and exploitation of traction substations, catenary and current collectors,
- application of energy efficient solutions.

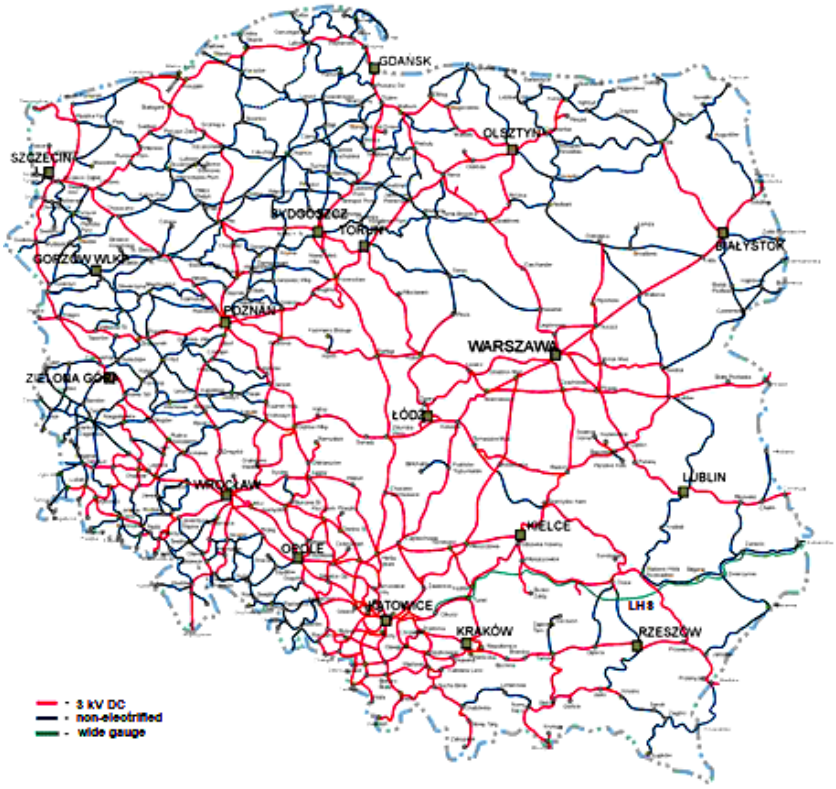


Figure 3 – Map of railway lines in Poland (red lines - electrified ones)
Source: PKP PLK S.A.

Due to the increase of power and speeds of trains, the following is needed:

- development of new types of catenaries for DC and AC power supply,
- implementation of new solutions with higher load capacity, reliability, serviceability, but lower vulnerability to weather conditions (temperature, precipitation) or theft and devastations.

For the significant demand of electrical energy used by non-traction needs (signaling, command and control systems, illumination of stations and stops), it is important to assure reduction of energy consumption and quality of such power supply, including protection against overvoltage and thunderclaps. Due to the safety reasons reliability should be high, so quite apart from classical solutions of supply from public utility lines power supply by a catenary or from smart grids with multi-mode energy sources.

3.2 Electric traction in urban transport

In urban transport, it is expected that trams, being in service in 15 main towns, will still dominate, in some areas, in a form of high speed tram or a pre-metro. It results from the fact that subsides from the European Union support significant investments in tram rolling stock and infrastructure [9].

In order to reduce energy consumption energy storage devices (ESD) are to be installed either on-board of vehicles [12] or in a power supply system. Installed on-board ESDs allow to move on sections without a catenary or in case of emergency. Inverters in DC tram traction substations have been tested. In Warsaw Metro supercapacitor energy storage devices (ESD) has been installed in 750 V DC power supply, which provides daily savings in the amount of over 2.0 MW energy (Fig.4) [13].

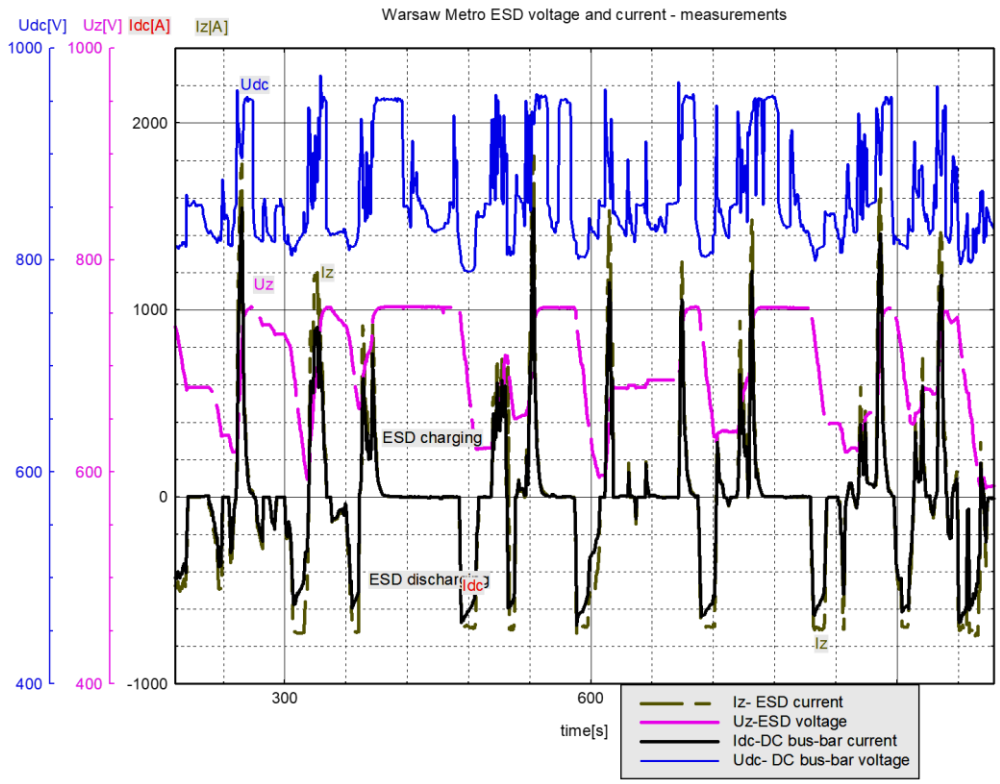


Figure 4 – Results of measurements of voltage and current of an energy storage device (ESD) installed in 750 V DC power supply of II line of Warsaw Metro

Data received from Warsaw Trams , where some of Pesa trams in service are equipped with ESDs of 1 kWh energy capacity, have shown a reduction of the total energy consumption by 8÷9% due to the ESD installation, while recuperation energy sent back to the catenary amounted to 24% of energy taken from the power supply network [12][14]. Modern trams with recuperation allow for 108,000 MWh/year and reduction of coal use in power plants by 31,800 t and CO_2 emission by nearly 120,000 t.

All the aforementioned pro-energy saving activities are associated with intensive exchange and modernization of rolling stock in urban and railway electrified transport, significantly supported by the EU funds. However, Polish law still lacks clear regulations concerning: a definition of 'recuperation energy', treatment of rolling stock with recuperation operators from the point of view of energy consumption and generation, taxes and tariffs for recuperated energy, benefits stimulating pro energy-saving activities. Estimations have shown that modernization of the entire tram rolling stock in Poland provides savings.

Trolleybuses constitute a niche being in service in 3 towns only. But development of battery technologies allows making of them bi-modal vehicles operating under a catenary and off a catenary for tens of km. So, it may be a solution in some cities to install a catenary in some areas, covering 30-40% of the transport service, and allowing e-buses equipped with pantographs mobile charging.

Metro lines will be developed slowly, in Warsaw, IIIrd metro line is planned, Cracow is performing an analysis comparing between metro and high-speed tram systems [14].

In some areas, the existing non-electrified railway lines could be modernized to create a kind of urban railway. It is important to have non-typical solutions, different, according to a specific region, transport demands (other in big, other in small cities) [15].

3.3 Road electric traction – towards electromobility in Poland

The Polish Government announced a Program for Electromobility Development [16] (Act on electromobility and alternative fuels announced in Journal of Laws of 2018 item 317 of January 11,2018). It is expected that by 2025, in towns, 1,500 e-buses will be in service, while on roads, will drive 1 million e-vehicles. This is to be achieved in stages – in 2020, 50 BEVs will be used in 32 selected urban areas, and they will be charged by 6,000 typical chargers and 400 high power chargers. Electromobility is to be based on manufacturing vehicles in Poland. A specially dedicated company ElectroMobility Poland was established for this purpose. In March 2019, a technical partner – an engineering company EDAG was selected to integrate preparation for manufacturing process of 100,000 BEVs yearly. Batteries will be manufactured in Poland in factories of the world's leading companies- for example LG Chem is constructing the biggest Li-Ion battery factory in Europe, with target year production of 100,000 batteries with 40÷60 kWh energy capacity. The defined areas of activity [16] of this electromobility policy include: changes of mentality of potential users for e- vehicles, defining a set of benefits for e-vehicles users, development of electromobility industry, law changes, reconstruction of the public utility system with a distribution of smart charging points allowing V2G operation. The last one could pose a significant problem, as increase of power demand when assuming 1 million of cars being charged only by 3 kW power chargers will give 3 GW, which covers over 10% of current peak-power demand in Poland (in February 2018 at the level of 26 GW). On the other hand, batteries installed in e-cars, when shared in a public utility network in the peak-power demand period may be used as a distributed reserve power source.

In the last year, half a million of new cars has been registered, among them only over 600 BEV [17]. The Act on electromobility introduced, as an advantageous solution for e-vehicle users, the possibility of free parking at the metered parking lots and use of bus-lines free of charge. In order to increase interest in e-vehicles that are still very expensive, the government plans subsidies for e-vehicles, higher than in Germany (EUR 4,000), France (EUR 6,000) or UK (GBP 3,500), but lower than in China[7] (USD 10,000 USD). Most of the Polish car owners are buying cheaper second-hand cars (total price EUR 4,000). However, it is expected that prices of new PEV and ICE cars will be similar (mainly due to the significant price drop of batteries in years 2026-2029 [17]. The subsidies (not for buyers, but for the dealer to reduce the price) will concern not only PEV, but also new alternative fuel vehicles (gas, H) [16], including vessels with drives supplied by bio-fuel, gas or electrical energy. The amount of subsidies will be as follows:

- for e-cars up to 30% of costs (maximum EUR 8,400),
- for e-vehicle for communal services up to 30% of costs (maximum EUR 35,000),
- for vehicles using natural gas or hydrogen up to 30% of costs (maximum EUR 17,400),
- for 'eco' yacht or other vessel, propelled by bio-fuel, gas or electrical energy au to 30% of costs, no more than EUR 232,000.



a) *b)*

Figure 5 – E-bus (a) equipped with overhead fast charging system (b)

Important part of the e-mobility plans are e-buses (Fig.5). Due to the mature market of e-buses manufacturers as Solaris, Ursus BUS and Volvo with manufacturing 178 e-buses (January 2019), perspectives for fulfilling the number of 1,500 e-buses up to 2023 are more probable [17,18]. The last tender in 2019 for delivery of 130 articulated e-buses to Warsaw was won by Solaris with the price of EUR 772, 000 each.

Additionally, in 3 trolley-bus systems (Lublin, Tychy, Sopot) some of trolley-buses (85 in January 2019) are equipped with battery allowing to drive outside a catenary.

Unfortunately, the majority of electrical energy in Poland (77%) is generated in coal power plants, so effective reduction of CO_2 due to the use of PEV is low, comparing with countries where renewable energy sources are intensively used.

Another problem is the increase of energy prices, as in 2019, which could significantly reduce interest in transferring ICE based transport into e-vehicles. So, the Ministry of Energy is preparing regulations giving opportunity for energy distributors to create a special tariff for road public transport, unfortunately excluding rail transport. The prices of electrical energy increased in 2019 by 50-60% for trams and metro. Similarly, the increase of energy costs for private owners of e-cars could result in making comparable costs of travel by ICE cars and PEV cars, which reduces operational savings due to e-vehicles use. Assuming average petrol consumption of 7 l/100 km with 1.2 euro/1 liter of petrol makes 8.4 euro per 100 km trip and assuming for e-car energy consumption 20 kWh/100 km with 0.15 euro / 1 kWh when charging at home makes nearly total of only 3 euro, while 10 euro (assuming 0.5 euro/ 1 kWh when charging by a commercial charger). Fortunately, the Ministry finally blocked 2019 year energy tariff increase by making some compensation of costs to energy distributors, but the prices in the future must be higher, due to the European emission allowance prices increase (over 23 euro/1 t of CO_2 on February 13, 2019). This component of costs is important in Poland, where coal is the main primary energy source for power plants.

4. CONCLUSIONS

Electric traction started its history by the end of the 19th century with development of electrical engineering and makes a response to the increase of demand for transport services for industry and in widespread populated areas of cities. Later, due to the restriction of electric traction traffic to a catenary electrified line, because of the low capacity of available batteries and development of the flexible vehicles with the ICE engine role of the electrified transport was significantly reduced. It was not until the 1970s, due to the sudden increase of the crude oil price, that the interest in electrified transport means returned. Increase of mobility of societies and availability of road vehicles with ICE led big cities to the edge of environmental and transportation catastrophe. It looks like as if it was a kind of return to the situation in the 19th century, where the use of horse traction was expected to stop development of towns, because of pollution with horse excrements. In such cases electric traction was the solution. And electromobility – road electric traction seems to be a solution allowing for the exchange of ICE vehicles and stopping of pollution and congestion in towns. Wide development of: rail electric traction, public e-vehicles, individual e-vehicles (e-cars, e-bikes, e-scooter, etc.) is an answer, finding an alternative may be difficult. However, transition to electromobility constitutes a costly and long-term process requiring application of a proper global strategy in many areas. In particular, technology innovation in energy storage devices (with possibly low availability of proper raw materials) and alternative fuel as well as construction of vehicles is crucial. In the area of exploitation, it is necessary to develop a wide network of smart charging points giving opportunity for Vehicle to Grid (V2G) operation. This should be supported by smart data transmission for control and automatics to make it easy for a transport service client to find the most convenient means of e-transport, from public long-distance railway, e-bus to e-car, e-bike or e-scooter sharing to make the last mile travel by personal, but shared e-vehicle.

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SIMONA ŠINKO, teaching assist.[1]
E-mail: simona.sinko@um.si
MATJAŽ KNEZ, assoc. prof.[1]
E-mail: matjaz.knez@um.si
MATEVŽ OBRECHT, assist. prof.[1,*]
E-mail: matevz.obrecht@um.si
[1] University of Mariboru
Faculty of logistics
Mariborska cesta 7, 3000 Celje, Slovenia

ARE WE READY FOR AUTONOMOUS VEHICLES?

ABSTRACT

Vehicle technology programed for autonomous driving without human interactions is becoming more and more developed. Because they are changing the classical concept of personal transportation, this topic requires examination of public perception and readiness for such new technology. Therefore this paper focuses on knowledge, awareness and opinion of general public on autonomous vehicles. It also discusses possible future development of autonomous vehicles as well as economically perceived value including willingness to buy it, potential benefits and risks, that reflecting their integration on roads and evaluating most important benefits which were identified: energy efficiency and road safety. Paper is focused on autonomous vehicles in Slovenia and the results were cross-compared with data on China, Japan, India, UK and USA. Results have shown that even if Slovenian survey was carried out 2 years after survey in other countries, smaller share of Slovenians know autonomous vehicles and are in general less positive about them. Less people were interested in purchasing them in the near future and pay extra fee for autonomous vehicle. Perception on autonomous vehicles in Slovenia is in general not as positive as in other comparable countries. A significant share of participants believes that the autonomous vehicle will become the dominant transport mode in the next ten years and will enable us to reduce transport related environmental impacts and improve time management as well as road safety.

KEY WORDS

Legislation; Slovenia; autonomous driving; consumer perspective; autonomous vehicles;

1. INTRODUCTION

Autonomous vehicles (AV) are vehicles with special technology, programed to be able to control and manage a vehicle by itself without active human interaction and cooperation (1). The idea is that computer is more reliable as human can ever be because it does not make mistakes, therefore positive consequences of AV integration should be less traffic accidents, less traffic jams, improved fuel economy, smaller need for parking spaces allowing more green spaces and increased mobility of people unable to drive conventional vehicles (2). In general AV can be seen as a technology enabling transition towards more sustainable transportation sector. When discussing the idea of sustainable transportation, social dimension, including public perception of AV plays a vital role.

Idea of autonomous driving without human cooperation with completely computer managed functions of a car is already almost one hundred years old, since the idea was first published almost one century ago in the Scientific America journal (3). Even if the idea is not as new as most people believe, the use of AV is still under development and not yet widely used. Study of Cohen (4) forecast that approximately 45 million AV will be in use by 2035 and that AV will replace all men controlled vehicles by 2050.

Future of AV integration, especially with existing road infrastructure is related to three important issues: first is legislation that allow or forbid AV. AV is currently allowed only in some states of USA - Florida, California, Michigan and Nevada (1). Slovenia as a small country within the EU must be consistent and in accordance with the EU legislation, that means that AV must first be allowed on the EU level. The first step towards it was "Amsterdam Declaration on autonomous driving" signed in Amsterdam in April 2016 (5).

The second factor for efficient integration of AV is road infrastructure that must be at least partially adjusted to AV and be able to notify AV to adapt to any threats on their way (6). This can be very cost intensive or quite cheap (7). Slovenian road infrastructure is currently not suitable for safe driving with AV (as well as other infrastructures across the EU) especially due to dilapidation and deterioration of some roads as well as sometimes lacking signalization.

The last but not least is public opinion on AV and decision of each individual to use AV. It is believed that public opinion is extremely important factor for future commercialization because if different stakeholders, including general public do not trust new technology, they will refuse to use it (8). Therefore, even perfect infrastructure and modernization of legislation with the new and more sustainable technology would be meaningless without positive public perception of AV. Behavioral changes can also be expected and should be studied in details (9).

Casley, Jardim and Quartulli (10) found out that people are afraid of what would happen if AV would malfunction. Nonetheless, public perception is that AV would increase general safety and reduce tension and tiredness that consequent on long term driving. However, some studies (11,12) revealed that approximately one third of general public would never consider AV as an alternative to conventional vehicles. Mainly because most of them believe that their driving capabilities are better than a computer system in AV could ever be. The public is also afraid of possibility of AV to collect sensitive personal data when using them. One of the studies, carried out in the USA in year 2012, also revealed that physical condition of potential AV users plays significant role on AV perception. The study revealed that people would be more willing to use AV when going on a road tired than when going on a road rested (13).

Terwilleger (1) made interesting conclusions based on research carried out in 109 countries. Research revealed that there is a strong correlation between personal income and willingness to buy new car. Because AV's are supposed to be more expensive (at least at the beginning of commercialization), wealthier segment of consumers will play a crucial role of AV's expansion. On the other hand, one other research (14) found out that 75 % of respondents in American survey are afraid of AV because of technology systems integrated in them. Main findings of research carried out by Abraham et al. (15) are that younger generation is more susceptible for AV use and integration and that they are also prepared to pay some extra fee for AV technology. Contrary, older generation is not prepared to pay additional fee for AV and is less susceptible to it. Abraham et al. (15) also revealed that trusting car manufacturers that produce specific AV is also very important when considering an AV as a possible future vehicle choice.

AV could also enable significant energy savings with optimized driving routes, smart accelerating, cruising and on time communicating with other vehicles and with infrastructure to avoid congestions, consequently cheaper and more efficient driving and greater fossil fuel independence could be expected. Greenblat and Saxena (16) believe that reduction of fossil fuel will be almost 100 %, and possible reductions of peak consumption, more efficient use of time and better road safety should also be systematically integrated in AV debate on political, technological and R&D level. Ethics and liability of AV is another important issue that AV developers and policy makers must aware as pointed out also by many authors (17–19). Another issue is current understanding of car manufacturing. Due to specifics of AV car manufacturers will have to significantly redesign the concept of vehicle, according to customer demands and it is possible that car manufacturers will be completely divided from system software developers like in case of mobile phones or computers.

Schoettle and Sivak (20) made a wide survey about AV perceptions in six distant countries. This survey was used also for cross comparison with our primary data. Contrary to other researches carried out before 2013 Schoettle and Sivak found out that almost one third of the general public is very interested in AV. Public perception and opinion on AV is improving with development and media coverage on AV as well as with more and more car manufacturers announcing their future development of AV features.

In this paper results on public perception on AV, general knowledge of AV and its technology, willingness to buy and pay an extra fee for AV in the future as well as study of factors that influence development, commercialization and integration of AV are presented in case of Slovenian public. In addition, these results are cross compared with secondary data gathered from the study of Schoettle and Sivak (20) on public perspective of AV in India, China, Japan, Australia, UK and USA. A comparison of our data with this survey was chosen because it was more comprehensive than others and is also still actual and up-to-date, however, it does not cover economic issues that were also included in our study. The hypothesis was that public opinion on AV in Slovenia is in general lower than in other countries due to lacking knowledge of AV as well as a quite conservative society, sceptical about new technologies and especially because Slovenians mainly buy used cars therefore new technologies will be interesting for Slovenia with a slight delay. Future development of AV is also examined to foresee the dynamics and integration of it in the transportation sector.

2. METHODS

Research on public perception on AV was carried by with web-questionnaire combined of 22 closed and four open type questions. For closed type questions Likert scale was used. A questionnaire was carried out on the web and in classical form. For web questionnaire QuestionPro platform was used. With classical questionnaires distributed at the same time as web survey, it has enabled to study perspectives on AV also in older population that is not used to carry out web based questionnaires as the younger generation. 291 completed questionnaires were gathered within online and 258 questionnaires were gathered with classic questionnaires (549 completed questionnaires all together). Research was carried out from March 2016 until July 2016. When designing questions for this survey questionnaire of Schoettle and Sivak (20) who carried out similar research in six different countries was used, modified and partially expanded on economic issues to achieve the possibility of more objective cross comparison afterwards. Their survey was chosen because it was more comprehensive than others and is also still actual and up-to-date, however it was extended also on economic factors relating AV, willingness to pay extra for AV and its dependence with respondents' personal income. Collected data were statistically processed in SPSS (Statistical Package for the Social Sciences) software. Descriptive statistics was used for the analysis. Analyzed results are discussed to propose possible reasons for data distribution and future development of AV.

Research structure can be divided into three parts: demography, vehicle ownership/access and AV perception. Different demographic characteristics important for segmentation of results were included. Questions on current vehicle ownership/access and features as well as acceptance were included because it was believed that opinion on AV can differ between different car owners as well as within different car classes/categories. Third and most important part was related on AV acceptance, public opinion and willingness to purchase AV as well as to evaluate activities people would carry out when driving with AV as well as to identify reasons for and against AV integration. Survey structure is presented in Table 1.

Table 1 – Survey structure

Survey parts	**Indicators / gathered data**
Demographical characteristics	▪ gender ▪ age ▪ education ▪ employment

	▪ average annual net income ▪ acquisition of driving licence
Data on current vehicle (access)	▪ ownership/access to vehicle ▪ vehicle class ▪ value of the vehicle ▪ age of the vehicle ▪ integrated systems for greater autonomy of driving
Perception of autonomous vehicles	▪ knowing AV ▪ perception and opinion on AV ▪ forecasting leading role on domestic roads ▪ barriers for integration of AV ▪ possible areas of AV integration ▪ reasons for purchasing/using it ▪ reasons against purchasing/using it ▪ evaluation of time spent while driving ▪ worries related with car driving ▪ impacts of driving with AV ▪ factors influencing decision to buy/use it ▪ readiness for purchasing/using AV

This paper focuses especially on knowing AV and comparing general knowing and acceptance of AV in Slovenia with other countries. Detailed results reveal also activities that people would carry out when driving with AV, willingness to buy and pay extra fees for AV as well as to identify reasons for and against AV integration. Those respondents who never heard of AV (answering with answer under 1 on the Likert scale) were excluded from the secondary analysis made in the third part of the survey because they were unable to evaluate AV features, pros and cons if they do not know them at all. Results of this research were also cross-compared with results of Schoettle and Sivak (20) to assess core similarities and differences.

3. RESULTS

Results of public opinion on AV in Slovenia are presented, analysed and discussed hereafter. Where possible, Slovenian data are compared with data from foreign countries (20).

3.1 Demographical data and car ownership

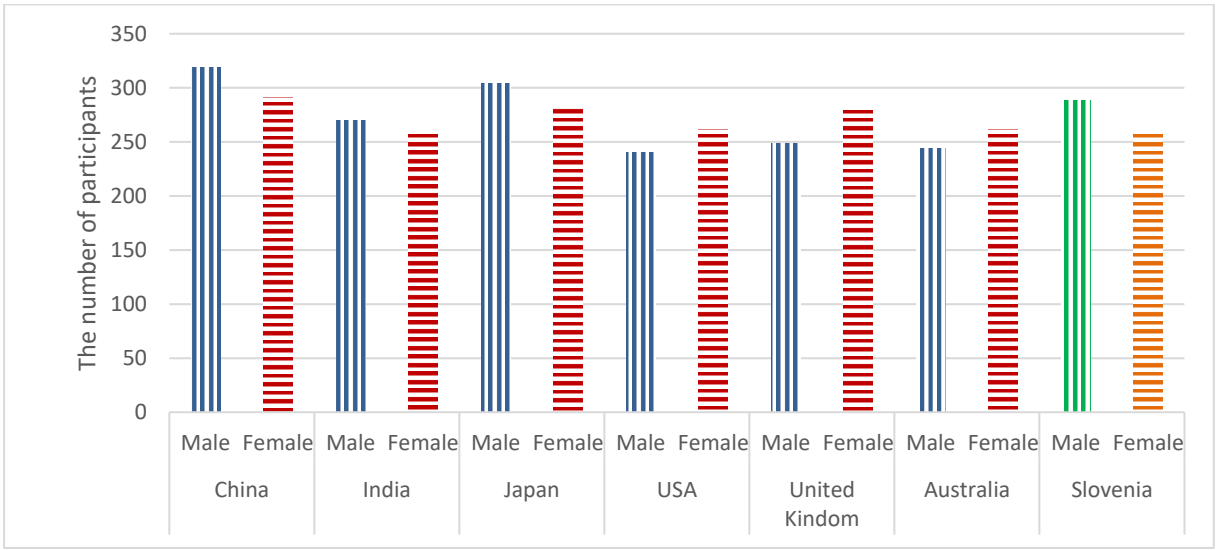


Figure 1 – Number of respondents by countries
Source: (20), own results

As presented on Figure 1 Similar number of respondents were included in survey in comparable countries. The highest number of respondents were in China and the smallest in the USA. In all countries included in this paper the number of respondents is between 500 and 610. In Slovenia sample included 5 % more men – similar also with the gender distribution in other countries. According to survey topic which is autonomous vehicles that are subject of technology this was expected since the topic is more interested for men. Most respondents (over 86 %) were in the age group between 19 and 59 years old. This segment was also the most interesting in this survey and was carefully chosen since members of this segment are main participants in traffic as car drivers and users and are therefore most relevant for public opinion on new transportation technologies such as AV. In Slovenia driving license for individual driving can be obtained with 18 years of age and 16 years of age for driving with a supervisor. The majority of respondents (over 90 %) responded that they have a valid driving license.

Slightly less than half of respondents in Slovenian survey were employed. The segment of employed respondents was followed by students, retirees, unemployed and self-employed respectively. 82.9 % respondents have net annual income below 20,000 €, followed by segment with net annual income between 20,000 and 30,000 € (12.4 %), group with income between 30,000 and 40,000 € (1.5 %) and 3.3 % of them have annual net income above 40,000 €. This was examined since net income of an individual is usually correlated with status of employment which affect the possibility of purchasing a vehicle in the future. Segmentation is consistent with Slovenian statistics on net income and average salary in Slovenia which is 1,077 € (21).

It was assumed that perspective on AV can vary also if respondents own/access a car or not. Slovenia has surprisingly the highest share of respondents who own personal vehicle (over 90 %). This is in accordance with data from national statistic. Ownership instead of leasing, renting, sharing etc. is still prevailing and is strongly anchored in the mind of Slovenians especially for assets like cars or houses. Analysis revealed that there are differences between car owner and non-owners, between men and women as well as between different age groups and different income segments. Among those that own personal vehicles, most of them are senior men with higher income.

Most respondents in Slovenian survey drives cars from class A and B (mini and small cars – 29.8 %), class C (lower middle class cars – 33.1 %) or class D (higher middle class cars – 23.2 %). Only minority of them have class S cars (large limousine – 1.2 %). Among car owners of lower classes (class A, B and C) results revealed that they are mostly respondents with lower income, women and younger respondents. Employed respondents own more class E and F cars (high and luxury class). Almost half of Slovenian respondents drive a car that is worth up to 5,000 €. Owners of more expensive cars are usually men. It was assumed that respondents with cheaper cars will be less interested in AV because AV are supposed to be more expensive and not yet on the market as used vehicles. In Slovenia market of used cars is flourishing therefore interested users will be able to get AV with delay, when first users/owners will start to sell them a few years after launched on the market.

When reviewing literature and analyzing results from this survey, it was revealed that public perception on AV is significantly dependent also on systems for partially autonomous driving integrated in their current vehicle. More than half of respondents do not have integrated any system that could be related to autonomous driving. 40.0 % of them already have integrated cruise control, 13.5 % have active parking systems and sensors, 12.9 % have systems for maintaining driving lane, 7.4 % have systems for accident prevention with pedestrian detection systems and 1.2 % of them already have integrated systems for detection of traffic signs and signalisation. As expected vehicles older than seven years have less such systems integrated.

3.2 Awareness and recognition of autonomous vehicles

On Figure 2 average knowledge and awareness on AV in compared countries is presented. On average 70.3 % of respondents already have some knowledge and awareness about AV before cooperating in the survey, which is evaluated to be relatively high share. It can be assumed that this

share would be even higher in new survey like this due to media coverage and attention on topics related to AV and unfortunate accident of real life testing of AV (e.g. Uber, Volvo).

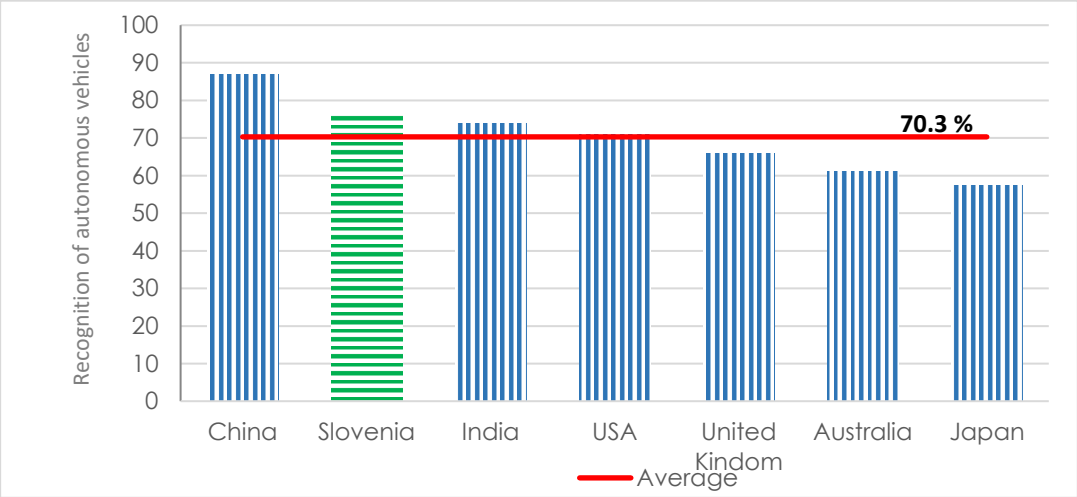


Figure 2 – Recognition (awareness and knowledge) of autonomous vehicles by countries
Source: [20], own results

As seen in Figure 2 the highest share of respondents have already heard about and knew AV in China (87 %) followed by Slovenia, India and USA which were above the average of 70.3 % share of respondents. Share in Slovenia might be high also because the survey in Slovenia was carried out in 2016 and in other countries in 2014 when AV were not so frequently addressed by professional and general media. When analyzing data, the correlation between sex and age of respondents on their opinion on AV was identified. As expected, more men know AV than women. However surprising was that older respondents know AV in greater extent and are more familiar with AV technology than younger generations (younger than 29 years of age). 46.8 % of respondents in age group up to 29 years of age evaluated their knowledge and recognition of AV with grade 1 (do not know anything about AV) or grade 2 (have heard of AV but do not know them well) on Likert scale from 1 to 4.

Total 42.1 % of female respondents evaluated their knowledge and recognition of AV with grade 1 (never heard of AV) and only 7.3 % of male respondents. On the other hand 77.8 % of male respondents and 22.0 % of female respondents evaluated their knowledge and recognition of AV as well (graded with grade 3 or grade 4)

In table 2 average public perception and knowledge of AV is presented as well as shares of answers by particular grades.

Table 2 – Comparison of public opinion and perception on autonomous vehicles by countries

	Very positive	Positive	Neutral	Negative	Very negative	**Average value**
China	49.8	37.4	9.8	2.3	0.7	**4.3**
India	45.9	38.3	12.5	3.0	0.2	**4.3**
Japan	10.1	32.8	50.3	6.2	0.7	**3.6**
USA	22.0	34.3	27.3	12.4	4.0	**3.6**
UK	13.9	38.3	34.2	11.2	2.5	**3.5**
Australia	16.2	45.7	26.7	8.3	3.0	**3.5**
Slovenia	**10.3**	**33.5**	**38.0**	**12.4**	**5.8**	**3.3**

Source: [20], own results

Even though general recognition of AV is relatively high in Slovenia as presented on Figure 2 (and higher as in most other comparable countries except China), results in Table 2 revealed that general opinion on AV in Slovenia is less positive and is on average the lowest among all studied countries. The

highest share of all respondents by all studied countries answered that they have very negative opinion on AV (5.8 %) which reflects fear of technical innovations in car industry. It is assumed that news about fatal accident of Tesla testing AV might influence such distribution of evaluations since the accident happened during the study. AV are one of the emerging technologies and can receive distrust of public when launched on a global market and public opinion can be changed significantly on the basis of positive or negative daily news therefore AV promotion with all benefits like energy savings, cheaper driving, greater fossil fuel independence and possible reductions of peak consumption, more efficient time management, increased road safety etc. must be systematically addressed instead led by media.

Results of Slovenian survey revealed that there is significant correlation between knowing AV and opinion about AV. Those who have better knowledge of AV also have more positive general opinion on AV. On the other hand, data analysis also showed that respondents from countries with more positive general opinion on AV (China, India, USA) are also more concerned about AV integration because they aware their pros and cons. According to comparative analysis between studying countries, it can be concluded that more positive opinion on AV also means greater concern on all factors related to them.

3.3 Forecast of future AV development

The study focused also on possible integration of AV on Slovenian roads. Over 60 % of respondents evaluates that AV will be implemented, but its implementation and commercialization will take more than 10 years. Approximately 15 % of them believe that AV will never take the leading position among transport technologies on Slovenian roads. Approximately the same percent of respondents believe that conventional vehicles will keep their current advantage vs. AV. Main reasons for such beliefs were also investigated. They were divided on objective and subjective factors and are presented in Table 3.

Table 3 – Factors against AV integration

Objective factors	Subjective factors
-Possible higher price of AV	-Joy of driving and controlling a car
-Risk of intrusion in AV software	-Greater confidence in human capabilities than in computer's
-Incomplete legislation and legislation violations	-Becoming boring if not included in driving
-Bad conditions of Slovenian road infrastructure	-Fear of computer managed reactions in unpredictable situations
	-Lacking computer interpretation and reactions in unusual situations

Most of them forecasted that possible higher price of AV technology could block faster implementation of AV. Specific for Slovenia is also road infrastructure. Having good highways, but rather bad and unmaintained local roads might be risky for AV implementation as well as for AV development. Another very important factor against AV implementation revealed by the participants was also the joy of driving and controlling a car by yourself which was not expected to be so important. This might be a serious issue for car manufacturers to enable maybe some driving simulations for AV users. Having greater confidence in people than in AV technology, performance and algorithms is something that might be avoided with AV development and increasing performance, however risk of intrusion in AV software will always remain a serious risk of AV.

Only 7.7 % of respondents are convinced that AV will be commercialized and implemented on Slovenian roads within the next 10 years (up to 2026). All participants that have positive opinion on AV are also convinced that AV will take the lead and contrary, those that have negative opinion on AV believe that leading role will always be reserved for conventional vehicles driven and managed by a man. Female respondents are more convinced that AV will take the lead than male respondents. It was also examined where AV will be implemented first. Respondents believe that AV will be first implemented within large close systems such as large factories, airports etc. followed by public

transportation (taxis and buses) as well as military units since military units are not that related on technology costs but more on performance and man safety. Personal transportation was evaluated to follow after integration in all above mentioned transport systems and was ranked in the fourth and last place. It must be noted here that trolleys with autonomous control systems with electric battery powered drive already exist in warehouses and production halls and AV are being tested within airports (22) therefore these forecast are, even if made by general public, relevant for predicting future of AV. Hussler et al. (23) actually came to paradoxical conclusion that non-expert judgements is less stable but not necessarily less accurate.

3.4 Economic perspective and willingness to buy an autonomous vehicle

Share of respondents prepared to purchase AV was identified to be in correlation with average values of knowing AV and consequently also with public opinion on them. Most of respondents will be ready to buy AV in the near future in China – app. 95 % of respondents (which also have the most positive opinion on AV), followed by India with 1 % smaller share of respondents prepared to buy AV in the future (second best opinion on AV). Slovenia is ranked as the country with the smallest share of respondents willing to purchase AV in the near future – only app. 24 % of them would be willing to buy an AV, which is consistent with the lowest average grade of public opinion on AV which was also identified as the lowest among studied countries. As mentioned before, this was surprising since Slovenian survey was performed two years after surveys in the other comparing countries therefore we expected better public opinion on AV and more willing potential AV owners and users in the near future. Again media attention on death accident of Tesla AV testing can be one reason for that as well as traditionally conservative Slovenian public. When analyzing Slovenian data the correlation with knowing and recognition of AV was identified. Higher the knowledge and recognition of AV is, the higher is the willingness for purchasing AV in the near future.

This study was extended also on economic issues relating AV. It was studied how high could be the expected additional fee for complete AV (phase 4 AV) and how personal income impacts willingness to buy AV and pay extra for it.

Because AV will most probably cost more, at least at the beginning of their integration, it was expected that respondents with higher income will be more willing to buy an AV and pay extra for it because a) they could afford to pay any extra fee, b) they have more expensive cars with more integrated systems related with autonomous driving. These systems may already enable much more comfortable and already partially autonomous driving than economy class vehicles. As presented in Table 4 there is no strong correlation between personal income and willingness to buy an AV.

Table 4: a) Willingness to buy AV (by personal income classes) and b) readiness to pay extra for AV

a) Personal income	Willingness to buy an AV
Up to 10,000 €	25.0 %
10,000 – 20,000 €	23.7 %
20,000 – 30,000 €	18.9 %
30,000 – 40,000 €	20.0 %
Over 40,000 €	13.3 %

b) Willingness to pay extra for AV	Share of respondents (cumulative)
Up to 10 %	65.3 %
Up to 25 %	28.5 %
Up to 50 %	5.3 %
Up to 75 %	0.7 %
Up to 90 %	0.2 %

As seen in Table 3 majority of respondents is also not ready not pay much extra for AV features. In average men are more willing to pay the extras. Regarding income structure respondents with lower annual income are surprisingly more interested to pay larger premium for AV than others. No matter the demography of respondents, respondents who know AV better and have better opinion on them are more willing to pay extra premium for them. That means that car manufacturers must inform and

educate their potential customers about AV features to be able to charge extra for AV features, but also insurance companies will have to adapt because completely autonomous driving will decrease the risk for potential accidents and damage (24). The highest identified premium for an AV between all respondents was 142,500 EUR which means that economic factor is extremely important here, especially for car manufacturers to get higher premium for product with higher added value as well as to replace some of their income if ownership of cars changes according to predictions of trends from personally owned to shared ownership and shared economy as studied by Fagnant and Kockelman (25). Owners of vehicles are also more interested in AV that respondents that do not have their own car and those that have their driving license for a longer period of time are also more interested in AV.

3.5 Benefits and risks of autonomous driving

More than half of respondents identified that the main reasons for interest in AV is more relaxing drive and being more relaxed when reaching destination, followed by more efficient time management (time to attend other activities than driving e.g. reading, working, phone calls) as well as increased traffic safety. Some also evaluated that AV would react better than themselves and that they do not enjoy in driving and managing a car and evaluate it as an effort. Most important reasons identified not to buy an AV is not being ready to give control to computer managed system and losing the control of managing vehicle by themselves. These are followed by fear of computer managed technology and boring driving as well as predicted high price of AV with the investment higher than potential benefits for individuals. Risks and worries related to autonomous driving are presented in Table 5.

According to the relatively low average public opinion on AV in Slovenia it was expected that there would also be high share of respondents who would not be willing to sit and drive with AV managed by a computer. However, comparison with other countries revealed that this is not necessarily right. The highest share of respondents who would not be willing to sit in the AV and drive with it was identified in Japan and the smallest in China (as expected according to average grades). When analyzing activities to be carried out while driving with an AV, very small share of respondents in Slovenian survey stated that they would be watching the road and follow the driving of AV (app. 7 %) when the average of other comparable countries was above 32 %. Most respondents would be watching the road and follow the driving in the UK and the least in India, however the share in India is still for 23.5 % higher than in Slovenia. That could mean that people in Slovenia are not that freighted of AV and concerned about their safety features after all. Other activities to be carried out were reading and using the mobile phone, sleeping and working (more relevant for Slovenian users than for others) followed by watching TV/movies and playing computer/video games (note interesting for Slovenian users). It was quite surprising that working was ranged on the 4th place in Slovenia and on the 7th place in average for other comparable countries.

When analyzing data, differences between male and female population was also identified. The men answered most often that they would follow the driving of AV and would watch the road. In the second place it was reading, followed by working. Women, on the other hand identified reading as most frequent activity to be carried out when driving with AV, followed by watching the TV and working on the computer. Men were also more concerned about what could go wrong than women. Differences occur also between different age groups. Younger respondents would spend more time for sleeping and resting as well as communicating with smart phones and older respondents would watch the road and follow the driving. It was also revealed that respondents who are using newer and better cars with more already integrated systems for partially autonomous driving (cruise control, lain maintaining system, etc.) are less concerned about possible negative consequences that those who drive older cars.

Table 5 – Worries and risks factors related with autonomous driving

	China	India	Japan	USA	UK	Australia	**Slovenia**	**AVG**
Safety features and consequences related with system failure or malfunction	3.63	3.43	3.04	3.29	3.23	3.19	**2.91**	**3.25**
System reliability in unexpected situations	3.46	3.26	3.04	3.31	3.05	3.10	**3.06**	**3.18**
System safety (risk of hacking in vehicle control system)	3.42	3.35	2.85	3.02	2.89	2.95	**2.93**	**3.06**
Legal responsibility of vehicle driver/owner/user	3.47	3.27	2.86	3.11	2.95	3.00	**2.63**	**3.04**
Safety features (physical breaking into vehicles)	3.42	3.35	2.82	3.02	2.85	2.90	**2.42**	**2.97**
Data security and privacy (e.g. tracking device. cameras)	3.34	3.28	2.64	2.98	2.71	2.75	**2.94**	**2.95**
Interaction of AV with conventional vehicles	3.19	3.06	2.83	3.08	2.89	2.88	**2.57**	**2.93**
Interaction with pedestrians and cyclists	3.24	3.12	2.87	3.10	2.94	2.92	**2.64**	**2.98**
Learning how to drive with AV	3.25	3.13	2.45	2.74	2.42	2.54	**1.99**	**2.65**
System reliability in bad weather	3.52	3.25	2.70	3.06	2.59	2.74	**2.47**	**2.90**
Not being as reliable as human drivers	3.14	3.09	2.78	3.05	2.76	2.86	**2.32**	**2.86**
AVG	***3.37***	***3.24***	***2.81***	***3.07***	***2.84***	***2.89***	***2.63***	

Source: [20), own results

Questionnaire also included an open question about risks and worries related to autonomous driving. The most frequent answer was fear of electronics failure (17.5 %) and safety features (13.4 %). Less important, but still evaluated as relevant risks were inability to take control of the vehicle and legal responsibility of a driver in case of accidents as well as cyber security and risk of hacking in the AV control system. This was pointed out also by Schellekens (19). 6.9 % of respondents stated that they do not have any concerns related on driving to AV. Concerns of risks and worries related with AV are again correlated with knowing AV – people that know them better, are less worried about possible risks and men are in general more concerned about AV related risks than women.

Study also examined impacts of AV on environmental issues such as greenhouse gas (GHG) emissions and fuel economy; safety features and optimization of traveling and information technology. These issues are pointed out as significant issues regarding automatization by different studies (26,27). Results are presented in table 6.

Table 6 – Comparative evaluation of potential impacts and benefits of AV

	China	India	Japan	USA	UK	Australia	**Slovenia**	**AVG**
Less accidents	3.18	3.13	2.95	2.84	2.87	2.90	**2.89**	**3.0**
Better fuel economy	3.17	3.30	2.68	2.87	2.99	2.84	**2.96**	**3.0**
Less serious injuries in accidents	3.21	3.16	2.95	2.83	2.88	2.91	**2.67**	**2.9**
More efficient accident handling	3.32	3.34	2.73	2.97	2.69	2.85	**2.59**	**2.9**
Decreased GHG emissions	2.98	3.18	2.59	2.74	2.84	2.69	**2.86**	**2.8**
Less traffic jams / congestion	3.00	3.02	2.61	2.51	2.47	2.47	**2.65**	**2.7**
Shorter travel time	3.08	3.04	2.39	2.46	2.34	2.43	**2.33**	**2.6**
Cheaper insurance	3.01	2.94	2.63	2.57	2.62	2.55	**2.21**	**2.6**
AVG	***3.12***	***3.14***	***2.69***	***2.72***	***2.71***	***2.71***	***2.65***	

Source: (20), own results

Respondents with more positive opinion on AV also believe that impact of AV on environmental issues such as GHG emissions and fuel economy; safety features and optimization of traveling are much higher. Men again assessed that impact of AV on factors mentioned in Table 5 will be higher. In

Slovenian survey, we also investigated which studied factors and impacts would be the most relevant for respondents to motivate them to buy an AV in the near future. The highest impact was detected by shorter traveling time, less accidents and better fuel economy. Surprisingly, less congestion and traffic jams was evaluated as a less important factor, however it is assumed that from a consumer's mind-set this is already included in "shorter traveling time".

In Slovenian survey respondents believe that the highest impact of AV will be detected in fuel economy. Fuel economy should be significantly improved since AV enable more efficient route planning, adapting to road situation, communication with other vehicles and infrastructure, enabling more efficient acceleration, driving as well as calculating and predicting the right speed for catching green wave in cities and areas with frequent and dense traffic lights. This is also in accordance with other studies that evaluate that AV could directly improve fuel economy from 5 to 15 % (5,28).

4. DISCUSION ON CORE FACTORS FOR AV DEVELOPMENT

It was found out that Slovenia is not yet fully prepared for the integration and commercialization of AV since it has obstacles in legislation, on road infrastructure development and in the low average public evaluation of AV acceptability. These obstacles were similar to other countries.

Probably the most important obstacle in the beginning of the integration of AV is identified in legislation on road transportation. In most of the EU Member States road transport legislation is based on the Geneva Convention from 1949 and legislation from 1968 that both require complete control over the vehicle from the person driving the vehicle (29). Slovenian legislation is based on the same foundations. However the idea of AV is completely contrary to such legislation since it enables autonomous driving without human interaction.

When reviewing four Slovenian laws related to road transportation it was found out that it should be completely changed if AV integration would be implemented. For the beginning vehicle »driver« and vehicle »user« should be separated as two different concepts. Both concepts should be integrated in existing laws to fulfil the legal requirement for responsibility of drivers of regular and autonomous vehicles. If AV should replace conventional man driven vehicles only concept of AV would remain as a part of traffic legislation.

Second obstacle was identified within the interpretation of legal and personal responsibility for accidents in which AV would be involved. Experts as well as majority of leading AV manufacturers and developers (e.g. Volvo, Google, Tesla and Mercedes-Benz) believe that responsibility should be on a site of car manufacturers and AV software producers. However, some car manufacturers disagree. It is also very complicated to determine the penalty for such responsibility since it cannot be related to anyone's freedom as it is now (imprisonment in case of causing traffic accident on purpose: causing traffic accident with injuries or death, etc.). Some professional as well as scientific literature appears to be more favorable to the idea that users of AV should take the responsibility because they chose to purchase and use AV therefore they should also be completely sure about their AV safety features as well as possible interactions with other autonomous and conventional vehicles and traffic accidents. The authors believe that one solution is that responsibility of the AV that can be controlled by a person could remain partially on that person, but responsibility for any traffic accidents related to AV without e.g. steering wheel, throttle, gas and brake pedals and therefore without possibility to manually control it should not be connected to a user because car manufacturers should not promote and sell AV if it is not completely safe and well tested also in unpredicted situations. This solution seems to be the only one where car manufacturer could not avoid complete responsibility for possible accidents. Development of consistent legislation therefore remains a crucial issue strongly correlated with AV commercialisation.

A third factor is road infrastructure that in Slovenia and many other countries with underdeveloped or inadequately maintained road infrastructure does not allow integration of AV. The basic framework

for AV is many times seen in road markings that should be visible and well maintained. Holes and uneven roads, etc. could represent a serious issue in this case. Traffic signs should also be considered and well placed to be always visible and not even partially covered by trees, bushes or fences. Snow or ice on roads is another problem that must be solved before integration of AV. It can be proposed that road infrastructure monitoring and maintenance should be more frequent and systematic to allow efficient integration of AV. This issue is important especially for transportation policy designers and infrastructure designers.

Due to changing the way of managing vehicles as well as changing drivetrain (of internal combustion towards electric vehicles) energy efficiency will also play a vital role. AV will enable fast and efficient route planning and adapting to road situation based on real time data and communication with other vehicles and infrastructure. Authors also believe that fuel economy will be one of the main drivers for faster integration of AV as well as electric vehicles in the transportation sector. Because electric vehicles currently have a lower range as internal combustion vehicles, more efficient route planning, communications and more efficient use of energy will also enable the expansion of the range of electric vehicles. AV technology simultaneously with electric vehicle technology could make an efficient breakthrough towards sustainable mobility within the sector of personal vehicles (30).

For improvement of public opinion on AV authors propose test driving with AV as a good solution for increasing acceptability of AV and willingness for future purchases. Authors believe that general public would gain trust in AV if they would be able to personally test it and convince themselves that AV are safe for use. However, recent fatal accidents of Tesla AV testing or Uber AV testing show us that AV technology is not yet completely reliable especially in unpredicted situations. Complex products such as AV require systematic solutions combining different levels of development, therefore the vehicle itself, AV software and accompanying algorithms must be carefully developed (31).

5. CONCLUSION

Driving in a car autonomously without human interaction is becoming highly topical issue and AV technology is developing rapidly. Experts believe that AV will change current conventional vehicles completely in the next 30-35 years. However, numerous obstacles exist such as legislation, road infrastructure and public acceptance. In this paper main findings on knowing and recognition of AV in Slovenia are presented as well as public perception of AV in Slovenia and its comparison with public perception in Japan, China, India, Australia, UK and USA.

An assumption that knowing AV influences the opinion about AV and willingness to buy and use them was confirmed. Even though relatively high share of participants already heard of AV and knows them. Not many of them will be willing to purchase such a vehicle in the near future. Main reasons for this were identified in joy of driving and controlling a car as well as fear for AV system malfunctions. Due to relatively conservative Slovenian society assumption that Slovenian car drivers are in general more negative about AV implementation than in other compared countries was also confirmed even though research in Slovenia was carried out 2 years later than in comparing countries. Slovenia also does not have suitable legislation for AV integration as well as it does not have appropriate road infrastructure.

The findings of this research can be of great help to understand general opinion on AV and can influence significantly to AV integration into road transportation, adapting design and production of vehicles from car manufacturer's perspective (e.g. added value and consequently market price) as well as proposing some ideas for legislation changes regarding legal responsibility. The most significant advantages are recognized by more efficient energy use and possible reduction of traffic accidents because AV would be better informed about traffic situations and could communicate with smart infrastructure and make their own predictions about traffic situation, best route, the most appropriate speed, etc. This is useful especially in case of fog, traffic jams or congestion when such predictions would mean significantly higher fuel economy and faster journey. However, current technology of AV

has many obstacles that should be examined for AV integration such as safety features in unpredicted situations, legal and personal responsibility for possible accidents etc.

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SEBASTJAN ŠKERLIČ, Ph.D.
E-mail: sebastjan.skerlic@fpp.uni-lj.si
University of Ljubljana
Faculty of Maritime Studies and Transport
Pot pomorščakov 4, 6320 Portorož, Slovenia

ANALYSIS OF LOGISTICS AND WAREHOUSING ERRORS BY TYPE OF WAREHOUSING TECHNOLOGY USED IN THE SLOVENIAN MANUFACTURING COMPANIES

ABSTRACT

The introduction of modern technological solutions into warehousing requires a substantial financial investment, but at the same time, it does not a guarantee a successful integration process. Since various authors suggest that automation also comes with potential setbacks, the aim of the case study is to analyse logistics and warehousing errors, according to the type of warehousing technology used. The study sample consisted of Slovenian manufacturing companies that are suppliers to the international automotive industry. The research analyses the use of basic and modern warehousing technology. The research has shown that the use of advanced warehousing technology affects the logistics errors measured by the PPM indicator and does not affect the errors in the warehouse. Recommendations for improvements in warehouse process management and better utilisation of warehouse resources are provided. The results can thus help researchers as well as warehouse managers in understanding the use of automated warehousing solutions.

KEY WORDS

warehousing; warehousing technology; logistics errors; warehouse errors; case study;

1. INTRODUCTION

The warehousing function within the supply chain is constantly evolving, due to the highly competitive environment. Customers expect suppliers to be able to manage a wide range of products in small quantities and require customised, value-added services and, above all, timely delivery. Fulfilling customer orders represents the biggest challenge for the warehousing function, as it involves satisfying customer needs in terms of responsiveness, cost competitiveness and flexibility. Warehouse operations management is also affected by the potential risks that may arise in logistics operations [1].

The risk of damage to materials is the greatest among these risks. In addition to this, the warehousing process itself reduces the value of materials and creates the costs of maintaining inventory. In order to improve the quality of the services provided throughout the entire supply chain, these negative factors must be examined and eliminated. Therefore, warehousing seems to be important for the quality of services in the supply chain due to the broad spectrum of possible adverse events and errors that may occur in warehouses [2]. Errors in the process of warehousing are either classified as internal or external, depending on the company's system of operation. The first type of errors is most often the result of human error, objective lack of efficiency, lack of coordination between technology and tasks, lack of capacity and random events. External errors, from the point of view of warehousing, arise exclusively from random causes connected with changes in the supply structure. The nature and scope of these changes are not reviewed at the warehouse level, but are the subject of supply chain planning [2]. The number of errors can be reduced by the automation of warehousing processes, which usually reduces labour costs and increases the accuracy, reliability and performance of the system. Automated warehousing systems require large investments, which is why many issues

related to their integration should be resolved in the most optimal way. This is how we can achieve significant advantages through automation [3].

In recent years, the use of modern warehousing technology has become focused on reducing and eliminating manual handling. In this context, Warehousing management system (WMS), Radio-frequency identification (RFID), Pick by Voice, Pick-to-light, Automated guided vehicles (AGV) and Automated storage and retrieval systems (AS/RS) are the most widely used solutions. However, as the number of manual handling operations and related errors has been reduced, there has been an increase in the number of potential errors that can occur as a result of processing a large amount of information.

That is why various authors state that the automation of warehousing processes also presents some challenges that can arise as a result of the inefficient use of warehouse technology [4, 5]. The purpose of the present study is therefore to compare logistics and warehousing errors according to the type of warehousing technology used. The study sample consisted of Slovenian companies that are suppliers to the international automotive industry. The case study analyses the use of basic and advanced warehousing technology. Recommendations for improvements in warehouse process management and better utilisation of warehouse resources are provided. The results can thus help researchers as well as warehouse managers in understanding the use of automated warehousing solutions.

2. LITERATURE REVIEW

The purpose of using modern technological solutions in warehousing is to increase productivity and quality of work. Warehousing management system (WMS) is a useful tool for every warehouse. An automated warehousing system ensures less effort and more efficient and reliable results, compared to manual handling systems. WMS is designed to help reduce costs through efficient warehousing processes [6]. The key objectives of WMS are [7]: eliminating order fulfilment errors by product identification; sending and receiving critical customer/warehouse information with minimum lead time through electronic transmission; maximising labour productivity by managing and prioritising tasks; maximising space utilisation by selecting a proper warehouse location and reducing inventory and handling requirements through a continuous flow of information. The use of modern technological solutions in warehousing also includes the use of radio-frequency identification (RFID), pick by voice, pick-to-light, automated guided vehicles (AGV) and automated storage and retrieval systems (AS/RS).

In order to highlight the benefits of RFID technology for reducing inventory inaccuracies, most researchers [8, 9, 10, 11] take into account three main sources of inventory inaccuracies: shrinkage, product misplacement and transaction errors. RFID technology uses radio frequency waves to transmit information between RFID tags and readers. A typical RFID system consists of three main components: tags, readers, and software. The tags are attached to entities (items) and contain information about the entities. The readers are used to read and write data on the tags. The software is used to display and enter RFID data into business applications. RFID is mainly used to search for, identify and track items, such as products, containers and vehicles. RFID does not only provide a product identification number, prices and costs, but can also include information on the product, such as manufacturing date, location and available stock. More importantly, RFID information is collected and available in real time. Unlike barcode technology, RFID does not require line of sight for reading data on the tags [12].

In addition to RFID, the material handling industry has introduced technology tools that facilitate the picking process. Examples of these tools are PtL and PbV, which are commonly used in many warehouses around the world and help companies make significant improvements in the process of managing orders [13]. Dujmešić et al. [14] highlight the following benefits of these technological solutions: increased accuracy, increased productivity, reduced costs and reduced training, since verbal prompts are easier to understand and the warehouse worker can easily learn all the commands in a short period of time.

The most common automated cargo transport technology in the warehouse is the automated storage and retrieval system (AS/RS), which has already been integrated into many warehouses and distribution centres. The main purpose of AS/RS is to automate the process of storing and retrieving the load in the warehouse, thereby reducing labour costs, human error rates and increasing the system's performance and storage capacity [15]. The traditional single-shuttle AS/RS is equipped with a rack construction, a stacker crane with a shuttle to handle the racks, a connection to another system in the warehouse via input/output transporters and a control system for planning AS/RS operations [3].

Automated guided vehicles (AGV) have had a significant impact on the field of warehouse management. They are being extensively used for intelligent transport and distribution of materials in warehouses and autoproduction lines due to their attributes of high efficiency and low costs. Such vehicles travel along a predefined route to deliver desired tasks without the supervision of an operator [16]. Given the large number of operations, AGVs offer a wide range of different technical and exploitative solutions and they have a very large estimate of the significance of factors when it comes to physical labour reduction. The investment in installing AGVs is amortised much faster provided that the service robots work 24 hours a day. The investment in service robots for logistics is repaid within 2-3 years, and such a system works for about 15 years, operating costs are around 2-4 % annual investment, operation availability is approximately 98.5 %, a high productivity, optimised costs and processing time [17].

The reasons for using modern technology in logistics are also dictated by trends [18]: the need for forecasting is increasing (accurate business forecasts reduce wastes and errors); the quantity and quality of data are increasing (technologies such as POS – point of sale, RF – radio frequency, barcode scanning and RFID enable processing of large amounts of data); the need to analyse the profitability of individual products or services is increasing, and the use of modern technology facilitates the participation of participants in the supply chain (suppliers, manufacturers, customers).

On the other hand, various authors [4, 5] emphasise the potential setbacks of excessive automation, as the need for a faster, stronger and more accurate system is increasing; its poor ability to adapt to existing work processes and technologies, the fact that it requires additional training and the fact that it comes with new weaknesses that previously did not exist. Reason [5] also identifies additional weaknesses, as technology has made the more demanding tasks even more challenging, by taking over less demanding work operations that were once handled by humans. High-tech systems require operators only to supervise their operations - this raises the problem of maintaining vigilance for longer periods of time. He also stresses that the skills of operators are becoming more difficult to update and, above all, the high investment costs are not always justified, given the expected benefits.

3. METHODS

The analysis carried out is part of a larger-scale study, conducted in cooperation with the Slovenian Automotive Cluster (ACS), in which various areas within warehousing in the Slovenian automotive industry were studied. The ACS is an association based on the economic interest of its members uniting Slovenian suppliers to the automotive industry and motor vehicle manufacturers. The ACS carries out the following activities [19]:

- Enhances and maintains communications among members who produce components, modules and systems for original manufacturers of personal vehicles, commercial vehicles and special motor vehicles and for after-sales activities.
- Encourages research and development of more complex products and systems with greater added value.
- Provides links between members who are important suppliers of machines and tools, as well as providers of research, development, manufacturing, logistics and other services to the automotive supply and automotive industry.

- Promotes joint members' activities to improve their products and operations in research and development, manufacture and quality, and to maintain business excellence.
- Stays up to date with any new developments in the automotive industry and in the automotive supply industry and forwards any new information to its members.
- Establishes, develops and maintains information, educational and other infrastructure for its members' needs.
- Represents the interests of its members and promotes their activities at home and abroad, with a special focus on motor vehicle manufacturers.
- Monitors the systemic, legal and economic issues in the industry and proposes appropriate measures to improve the economic environment and to enable its members to adapt to the constant development challenges of the automotive industry.

Previous studies have placed special emphasis on the topic of employing modern warehousing technology and the implementation of risk management in warehousing. For this purpose, a comprehensive online questionnaire was designed, which was mainly completed by warehouse managers.

For the purposes of the present study, logistics and warehousing errors were analysed, according to the type of warehousing technology used. Logistics and warehousing errors are defined by parts per million (PPM), which in the logistics sector refers to the number of errors per one million products supplied. This way of evaluating errors is a constant practice in the international automotive industry, where suppliers are also evaluated on the basis of this criterion.

Two groups of warehousing technology were analysed based on the classification proposed by Richards [20]. The first group includes the basic warehousing technology, which is intended for manual handling. The second group includes modern warehousing solutions, which involve automated handling in the warehouse.

Mann-Whitney U test was used to test the difference in distribution between two independent samples. Statistical analysis was performed by IBM SPSS version 22.0. Significance level was set to $\alpha = 0.05$ (two-tailed).

4. RESULTS

The purpose of the present study is to compare logistics and warehousing errors according to the type of warehousing technology used. Based on the Richards classification [20], two groups of warehousing technology were analysed. The first group includes the following basic warehouse technology: hand and motorised pallet jack, stacker crane, horizontal and vertical carousel, gas, hybrid and electric forklift trucks and barcode technology. The second group includes modern warehousing technology, such as: automated guided vehicles with navigation system - AGV, automated storage and retrieval systems - AS/RS, radio frequency identification technology - RFID, voice picking technology, light picking and warehousing management information system - WMS.

As distribution of logistic and warehouse mistakes PPM is highly skewed to the right, Mann-Whitney test was used to compare the two groups of companies in this characteristic. Companies using advanced technology statistically significantly differ from companies using basic technology in the number of logistics errors made. Companies using advanced technology make more logistics errors than companies using basic technology. At the same time, companies using advanced technology are larger than companies using basic technology ($p = 0.001$). Among companies using advanced technology there are 9 (90%) companies with over 250 employees, while in companies using basic technology only three (21.4%) are large companies.

A multiple regression model with usage of modern technology as the independent and company size as the control variable and the number of logistics errors as the dependent variable was built. To normalise the dependent variable, its natural logarithm was used in the regression model. No

statistically significant association between modern technology use and the number of logistic errors was found, when controlling for company size (data not shown). No statistically significant differences in the number of warehouse errors between companies using advanced and those using basic technology were found.

Table 1 – Comparison of number of logistics and warehousing errors PPM by type of warehouse technology used

Use of warehouse technology	n	Median (range)	P-value
Logistics errors			
Basic	14	1 (0 – 22)	0.013
Modern	10	10 (0 – 800)	
Warehousing errors			
Basic	14	1 (0 – 20)	0.201
Modern	10	5 (0 – 500)	

Source: Author.

5. DISCUSSION AND CONCLUSIONS

The results of measuring the number of logistics errors PPM (part per million delivered) point out that companies using advanced technologies are statistically significantly different from companies that use basic technology. Companies using advanced technology create more logistics errors than companies that use basic technology. At the same time, companies using advanced technologies are larger than those that use basic technology. This can be attributed to the fact that PPM logistic errors are not explicitly related to the use of modern technological solutions in warehousing. On the other hand, no statistically significant differences were found in the number of warehousing errors between companies using advanced technology and those using basic technology.

Since the study sample does not include many companies that use advanced technological solutions and the companies that are included have a higher number of logistic errors, it is possible to draw on the integration problems identified by researchers. Dekker [4] states in his study that the introduction of modern technology does not reduce the number of potential errors, but only changes them. In certain situations, it can also increase the number of work tasks and thus the number of opportunities for a new type of error. Reason [5] arrives at the same conclusion and stresses that, in their efforts to ensure greater reliability of work processes, the designers of automated systems have unwittingly created opportunities for new types of errors that may be even worse than the errors they were trying to avoid.

McBride et al. [21] view this subject in a more positive light, recognising that automation has the potential to help operators perform various tasks. In addition, automation provides support for the overall performance of the system. However, since the problems that come with the use of modern technology have not been completely eliminated and are not completely understood, they state that operators have to be actively involved in the process of detecting, understanding and correcting errors. That is why Grosse et al [22] stress that not every manual operation in the warehousing process should necessarily be automated. In certain circumstances, the automation process must take into account the level of adaptability of the warehouse operators. How successful automation is thus largely depending on how efficiently the operators are able to use modern technological solutions.

Hancock [23] therefore highlights the key questions related to this context, namely: What is the appropriate degree of use of modern technologies? Do operators require automation in all areas of operation? What large-scale benefits of automation can be expected? Questions such as these are becoming increasingly relevant, because operators apparently prefer to complete simple tasks manually, rather than completing them twice as fast in a completely automated way [24].

Similar questions are left open by the present case study, although it was carried out on a small sample of companies. From this perspective, the results obtained cannot be generalised to a wider context. Nevertheless, this analysis helps to understand the use of warehousing technology in Slovenian manufacturing companies that are part of the international automotive industry. We believe that a similar study should be conducted in comparable countries in central and eastern Europe, and that the results of both studies should be compared.

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MARKO ŠOŠTARIĆ, Ph.D.[1]
E-mail: marko.sostaric@fpz.hr
DIJANA BEGANOVIĆ, mag. ing. traff.[1]
E-mail:dijana.beganovic@fpz.hr
MARIJAN JAKOVLJEVIĆ, mag. ing. traff.[1]
E-mail:marijan.jakovljevic@fpz.hr
MARKO ŠVAJDA, mag. ing. traff.[1]
E-mail:marko.svajda@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10 000 Zagreb

ELECTRIC VEHICLES IN THE FUNCTION OF MODELLING PARATRANSIT FOR AREAS WITH SIGNIFICANT DEVIATION BETWEEN CYCLE TIME – CASE STUDY OF JASTREBARSKO (CROATIA)

ABSTRACT

The attitude of the European Union is to ensure sustainable mobility for each populated area, along with the environment friendly traffic system [23]. The most common need for mobility is the reason for the redistribution of regular public transportation lines. Such approach does not meet the requirements for mobility in rural areas there is no high demand for public transport. The problem is to define bus schedules because of the deviation on a daily and weekly basis. Paratransit (transport on demand), can be solution for this problem. This type of transport is flexible regarding the timetable, capacity and bus stops. Electric vehicles can be used for this type of transport. According to previous studies, paratransit is very benefitial, especially in rural and island areas. In case study of the City of Jastrebarsko, the survey method was defined by user requirements for mobility which can be solved by using the paratransit with electric vehicles. The purpose of this study is to show paratransit as a solution for flexible bus schedules in the case of demand for transport by high school students. Electric vehicles can be used as a solution between the morning and afternoon school cycle.

KEY WORDS

paratransit; public transport; mobility; electrical vehicle

1. INTRODUCTION

The first use of paratransit in public transport has appeared in 1959 [1]. The dynamic mode of paratransit (transport on demand) is taking place over the last few decades through a taxi transport and car-sharing system. Previous researches suggests that future generations of autonomous vehicles will increase the trend of urban mobility development on demand and accordingly create a redistribution of public transport and passenger cars [2, 13, 16]. In the paratransit organisation there is a need for interaction between the users and transport service providers. Development of mobile devices and applicable traffic solutions have led to alignment of passenger needswith demand for drivers in the central dispatch system [3]. Paratransit can be defined by income groups, which is common for low and middle income areas. It is often associated with land use and housing [4, 6, 7, 8, 9]. Some researches has also shown the connection with historic cities which has led to the different approaches to public transport development. Focusing on the availability of healthcare facilities for all users can also be analysed as a potential for defining a demand for paratransit [6] and provide mobility in city edges [12, 14, 17].

The research methodology was mostly based on the study of travel time, calculation of accessibility and comparison of housing zones [6, 7, 8, 9], income analysis [6, 8, 16], providing accessibility to users [8] and determining differences between modal share and length of travel [9, 15]. The necessity of systematic data collection is key to organization, and data can be collected through Google Maps service [18]. Investigations of the security risk in the paratransit are devastating for certain parts of the country in Asia, precisely because of poor organization and interoperability with other public transport systems [10, 11, 18].

Paratransit organization is most often privately owned [6, 11]. The most frequent recommendations for funding this type of transport are political decisions related to the financing of public transport [4, 15, 16, 17, 18]. Low-end users are most likely to walk [9, 15].

Previous studies have, to a lesser extent, paid attention to the semi-formal public transport system, such as paratransit or transport on demand. It is this system that enables mobility for less populated areas. In such areas, demand for mobility does exist, but not daily. A custom-made system with custom timetables, capacities and bus stops can be a solution for such areas [6, 12, 13, 14, 17].

Electric vehicles are becoming generaly accepted in urban areas and are also eligible for subventions [20, 22]. The electric automotive industry achieves better results through time to the extent where minibus battery can be charged while passengers are boarding the minibus[21].

The purpose of the study is to prove the necessity of paratransit for less populated areas by using electric vehicles. Because of the high time deviations in peak and over time hours, there is enough time for minibus battery to be charged. In the case study of Jastrebarsko, customer requirements have been defined as the basis for organising the paratransit transport. The target group of users are high school students. User requirements are defined by the survey method [19].

2. METHODOLOGY

The growing need for mobility in rural areas is a problem due to the lack of access to any potential user. The problem is present through a continuous gap between supply and demand in typical days and significant deviations of demand for public transport in urban and rural areas. Case study of the City of Jastrebarsko was used for this project. Tests were conducted by online surveys of high school students and their needs for going to school and coming back home from the school.

The online survey method is financially acceptable for implementation and the data is automatically digitalized. The collected data were processed using QGIS software to determine space and time demand. The goal was to have visible space and time demand deviations depending on the target user group. The target group of users were high school students who have two shifts. One part of them go to school outside the place of residence. The mode of transport to the city is also analysed. Thisata was collected for the purpose of integrating the existing public transport system with paratransit. Paratransit means an M1 (personal car with a maximum of 8 + 1 seats) or a M2 class (a passenger car with a minimum of 8 + 1 seat weight not exceeding 5 tonnes). By the field analysis, two car chargers were located in the city centre (22kW AC).

3. RESULTS

Using the online survey methodology of high school students and using the QGIS program, the requested results were obtained. The aim of case study is to achieve mobility for high school students.

The area of research includes the northeastern part of Jastrebarsko. Taking into consideration the urban area of Jastrebarsko, northeastern part is considered rural. Collected data and their processing need to suggest a model for mobility that will be financially and ecologically acceptable. Data collected through online surveys and insight into the existing public transport system shows space and time deviations in public transport demand. The space-time view of demand is given in Figure 1.

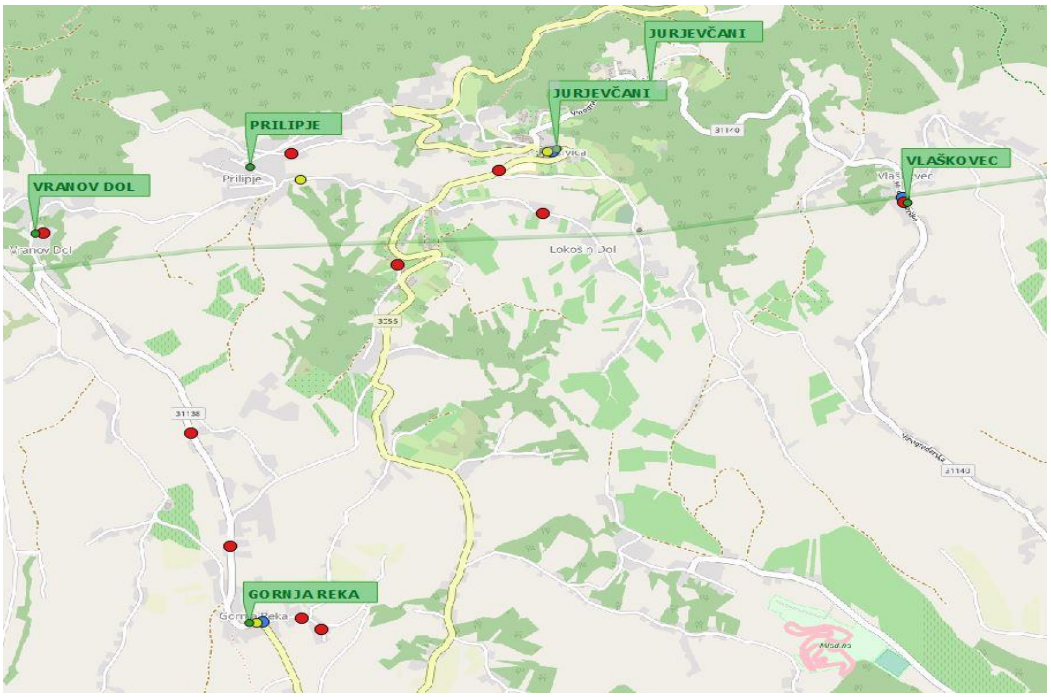
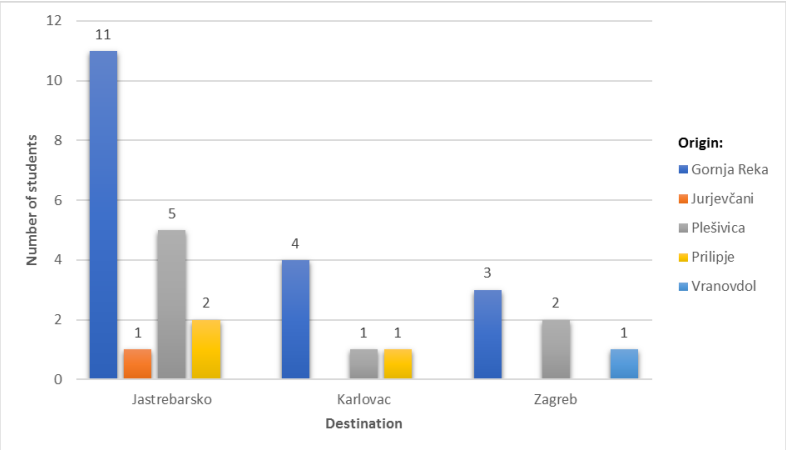


Figure 1 – Space-time view of demand in area of research
Source: [19]

According to the mentioned space coverage, there is demand for mobility for high school students in each village, with a total of 31. The demand is different depending on the hours and is present in the morning when students who have classes in Jastrebarsko and in the surrounding area, 20-40 km further. Demand also exists in the afternoon school hours for high school students in Jastrebarsko and surrounding areas. Duration of travel deviates for about an hour for high school students who are going to school in city of Jastrebarsko and surrounding areas, because this time is needed for travel to Karlovac or Zagreb.

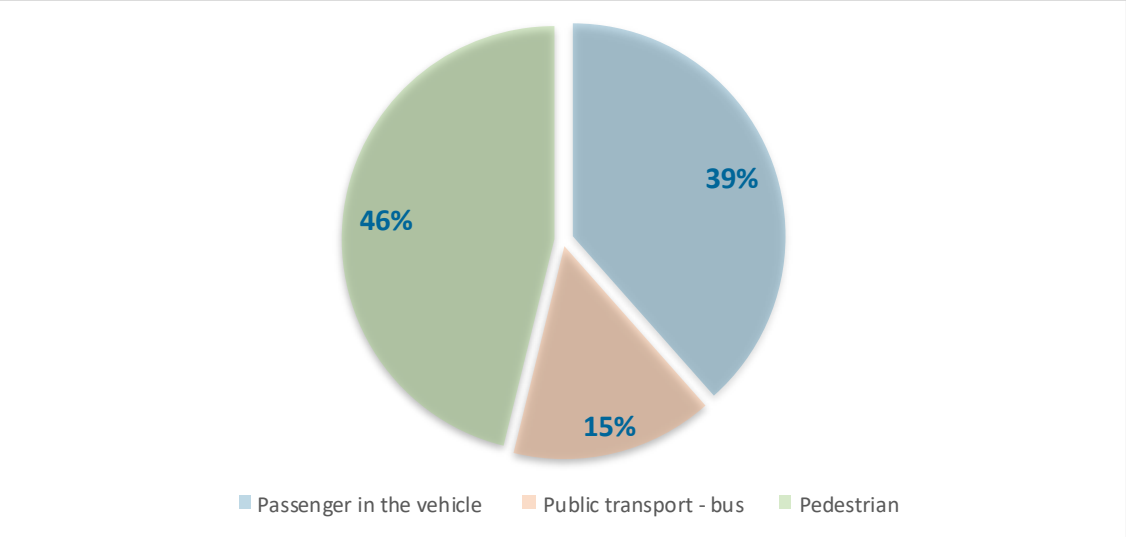
3.1 Survey

Survey results taken by high school students in the coverage area shows significant deviations in time when school starts. Deviations are displayed according to the settlements and location of the school. Students who go outside of Jastrebarsko school also have double school hours shifts, but their additional requirement is to get to the public bus / train one hour before.



Graph 1 – Student Travel
Source: [19]

In the area of research, the existing road infrastructure is not satisfactory. It is restricted to passenger cars and vehicles of categories M1 and M2. The respondents mostly walk to the school, 46% of them, 39% of them traveling by car, and 15% are using public transport for those with high school students in Zagreb or Karlovac. The structure is shown in Graph 2.



Graph 2 – Method of transport to school
Source: [19]

These requirements have resulted in two variants that have bus stops in settlements where demand exists. Demand could be satisfied with a total of eight cycles during the working day of the school year. With eight cycles per day, the demand for mobility for high school students is met during school hours in both shifts of the beginning of classes and for the inner and outer Jastrebarsko area.

According to the number of proposed circles per day, the maximum number of passengers that can be transported is calculated. There are also a number of kilometres assuming that the offer of the transport lasts 8 hours a day. Calculation is given below.

- **Number of circles = 8 circle/day**
- **number of kilometres = 19 km/ circle**
- **Time =8 h/day**
- **Maximum capacity = 26 trip/circle**

3.2 Annual Costs

According to the mentioned inputs, annual costs for a minibus, 18 + 1 (M2), are calculated. Variants for a classic minibus for diesel and electric propulsion are calculated. Calculations for savings were also made for the use of an electric minibus.

The calculation below shows the costs that may vary depending on the types of vehicles chosen. Costs may also be affected by certain discounts of providers of various types of insurance, depending on the number of vehicles registered in the same period.

Annual costs for a minibus on a diesel engine (M2)

- Amortization of the new bus (10 years) = 70,000,00 HRK
- Regular technical inspection = 1,436,11 HRK
- Obligatory auto insurance = 5,000,00 HRK
- Casco Insurance = 6,500,00 HRK

- Extraordinary maintenance = 30,000,00 HRK
- Regular maintenance = 20,000,00 HRK
- Gross II. mobile staff = 100,000,00 HRK
- Tires = 15,000,00 HRK
- Average specific consumption = 77,976,00 HRK
- Administration (tachograph, permissions, material costs) = 2,500,00 HRK
- Ticket issuance = 7,000,00 HRK
- Other material costs = 5,000,00 HRK

Total cost 340,412,11 HRK

According to the same demand inputs, annual costs for electric minibuses are also calculated. The biggest savings are visible on fuel costs.

Annual costs for electric minibus (M2)

- Amortization of new bus (8 years) = 50,000,00 HRK
- Regular technical inspection 1,436,11 HRK
- Obligatory auto insurance = 5,000,00 HRK
- Casco Insurance = 6,500,00 HRK
- Extraordinary maintenance = 30,000,00 HRK
- Regular maintenance = 20,000,00 HRK
- Gross II. mobile staff = 100,000,00 HRK
- Tires = 15,000,00 HRK
- Average specific consumption = 1,000,00 HRK
- Administration (tachograph, permissions, material costs) = 2,500,00 HRK
- Ticket issuance = 7,000,00 HRK
- Other material costs = 5,000,00 HRK

Total cost = 243,412,11 HRK

Assuming that we only analyse fuel costs and note that at yearly level the electric vehicle allocates about 1,000.00 HRK to control the battery and then the savings are significant and are shown in Table 1.

Table 1 – Minibus Fuel Costs on Electric and Diesel Propulsion

Type of engine	Fuel costs
Diesel	77,976,00 HRK
Electric	1,000,00 HRK

Source: [19]

The total fuel savings on the annual level using the electric drive is 76.976,00 HRK. Charging the battery is possible at the power outlet at the centre of the city between the cycle. The charging time is enough to perform the next circles. In such demands, the demand for cross-subsidies allows for flexibility, using electric vehicles and maximum savings. When charging the battery, the vehicle does not require additional parking charges. Due to geographical constraints, the minibus is the optimum solution because it provides flexibility for stops. For such users the requirements are changed every school year. The vehicles can also have bicycle mounts, which would further encourage sustainable mobility.

3.3 Subsidies

Public transport revenue is most often achieved through monthly surveys. The following are legal regulations concerning secondary school subsidies and monthly card revenues.

Monthly ticket price

Assuming a monthly ticket price for 31 students is 200,00 HRK, the annual ticket income would be 62.000 HRK. Monthly high school earnings are too low to finance the entire line. The solution is to rent a minibus for a weekend, which could cover part of the cost. With the assumption of using a vehicle on an electric drive, the costs would have been considerably lower, and hence the amount of subsidy from the local self-government unit. Savings can also be achieved by electronic ticketing, which would save you around 7.000 HRK. In addition to electric vehicle selection, work on reduced insurance policies and regular maintenance, including the replacement of special tires and reduced depreciation. Specially adapted tires for electric vehicles are with a faster torque and reduced noise emission

Legislation

According to the new regulation, public transport should be organized as a public service [24]. The problem that arises is the co-financing of public transport lines. Local LGUs are expected to undertake funding for securing mobility. Given the views on the necessity of mobility in all areas, it is assumed that by such approach many cities and municipalities might have even greater financial problems. By use of electric vehicles in the public transport system, especially in paratransit model, significant savings can be made.

4. DISCUSSION

Significant savings can be achieved by introducing electric vehicles into the public transport system, which has significant time deviations between the cycles. Savings are achieved in fuel at the annual level and the time the vehicle does not perform the transport service. Paratransit, as a model of public transport is a good solution to meet the demand for mobility with deviations in daily demand. It is also a good solution for high school students who change their demand for teaching on a weekly basis.

Quality solutions to meet demand in these areas are also vehicles on classic engines. The advantages of paratransit in the function of public transport are the adaptation of the timetables and stops. Bicycle mounts can also be introduced in the system for the purpose of promoting sustainable ways of traffic system.

The benefits of fleet electronically-valued solutions include: reduced exhaust emissions, savings at the parking lot, time-consuming battery charging time, reduced noise emissions and a good capacity with respect to existing infrastructure and demand.

The research results are inspired by pilot projects of areas with significant deviations in space-time demand. The use of electric vehicles in the public transport system encourages further research into the benefits that such a system can offer. Continuous development of electric vehicles results in increasing demand for their use. Local and state authorities, as well as the European Union, encourage their purchase by offering suventions. The future development of the transport system is closely related to environmentally friendly models of transport and mobility. Such a proposal is certainly part of this approach.

5. CONCLUSION

Due to its adaptability, paratransit is a good solution for areas with unequal economic development. In addition to economic disparities, it is good to meet the demands of mobility in areas with deviations in time-space demand requirements.

In the case study of the city of Jastrebarsko, research was carried out on the function of the mobility of high school students in the rural part of the city. Users have shown discrepancies in space and time demand requirements. Infrastructure analysis has defined limited options for choosing a fleet of vehicles.

Based on input data, the choice of paratransit organization was defined. Due to adjustments in the timetables, stops and the use of M1 and M2 vehicles, the requirements defined by demand are met. Because of the size of the existing demand, annual maintenance costs for the vehicle have been defined for the classical and electric vehicles. Significant deviations between the anticipated expenditures and revenues concludes that a better choice of the electric fleet of vehicles needs to be made. In addition to fuel cost savings, savings can also be made in a parking lot which is free of charge for electric vehicles while they are charging. The time to charge the battery between the cycles is enough to provide the afternoon service.

By applying the proposed solution, higher mobility for rural areas is possible. In addition to mobility, positive benefits are ecological contributions and financial savings on an annual basis. The use of electric vehicles in the public transport system encourages further research into the benefits that such system can offer. Continuous investments in the quality of electric vehicles and their use in the public transport system are a contribution to a sustainable transport system.

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JURAJ VERTLBERG, mag. ing. traff.[1]
E-mail: jvertlberg@fpz.hr
IVICA KRAJNOVIĆ, mag. ing. traff.[1]
E-mail: ikrajnovic@fpz.hr
MARKO ŠEVROVIĆ, Ph.D.[1]
E-mail: marko.sevrovic@fpz.hr
[1] University of Zagreb,
Faculty of Transport and Traffic Sciences
Vukelićeva 4, 10000 Zagreb, Croatia

METHODOLOGY FOR DETERMINING CONCEPTUAL LOCATIONS OF PARK&RIDE TERMINALS IN THE WIDER ENVIRONMENT OF THE CITY OF ZAGREB

ABSTRACT

Number of cars in the majority of the world's large cities is increasing year by year, resulting in traffic congestions. The solution to this problem should be sought in optimizing the parking system and the system of public transportation as well as constructing infrastructure for sustainable modes of transport, like cycling and pedestrian traffic in particular. The Park&Ride system is one of the possible solutions for traffic problems in modern cities. It combines usage of personal cars, motorcycles, bicycles and public transportation. There is no universal method to determine exact locations for the Park&Ride terminals, due to the difficulties of defining the size of cities' gravity zone. The purpose of this article is to examine existing methodologies for determining Park&Ride locations by other authors, and to determine conceptual locations for Park&Ride terminals in the wider environment of the city of Zagreb.

KEY WORDS

traffic congestion; sustainable mobility; Park&Ride terminals; gravity zone

1. INTRODUCTION

Park&Ride facilities are parking lots with public transport connections that allow commuters and other people heading to city centres to leave their vehicles and transfer to a bus, rail system (rapid transit, light rail, or commuter rail), or carpool for the remainder of the journey. It can be said that the first forms of P&R systems date back to 1920s in the USA if spontaneously generated P&R systems are to be taken into account. Since then, there has been a planned approach which has been applied for decades, but American cities are not limited by special issues to the extent experienced by many European cities. In Europe, P&R systems have been implemented in variety of different ways and forms.

In recent times, there is an increased number in concerns regarding sustainability of transport, and congestion is one of the most important problems in modern cities. One of the solutions to this problem are P&R facilities which should encourage users to switch to public from private transportation which then leads to reduction in urban congestion. This way, the number of cars is reduced in the city centre, or the area of high congestion, the air pollution is lowered, economical expenses are lower, and travel times are much lower.

But locating the exact locations of P&R terminals is a challenge because it involves multiple factors and there is often limited number of possible alternatives in terms of available space for terminal locations. The analysis of terminal locations, public transport reliability, parking supply, user demand,

economic impact must be considered. P&R facilities are expensive, and they take up a lot of urban land, so the construction should be rationally planned.

In this article, conceptual locations for P&R terminals were selected. Due to insufficient data, only relatively larger localities with surrounding villages have been considered. The proposed locations of P&R terminals were selected by experience, and the fulfilment of the proposed criteria due to the lack of a common methodology that can be applied to most cities. This article is organised as follows. Section 2 presents P&R as a sustainable mobility system and gives an overview of P&R facilities across Europe as well as the data of capacities and parking fees. Section 3 discusses professional literature on different methodologies used to find an optimum conceptual location for a P&R terminal. The case study of city if Zagreb is presented in Section 4. Finally, research conclusions are discussed in Section 5.

2. PARK&RIDE AS A SUSTAINABLE MOBILITY SYSTEM

The P&R system today represents one of the indispensable measures to resolve traffic problems in urban environments. It first appeared in the 1920s in some US and Canadian cities, later in Europe, when users of the traffic system began to use it spontaneously. Traffic engineers started to introduce it methodically as it showed as an advantage [8].

P&R is an extremely simple intermodal system, which can reduce the number of vehicles that come into inner parts of the cities. The system functions in a way that parking lots on the strategic, peripheral parts of cities are created, side by side with the public transportation terminals (train, underground, bus, tram, etc.) where car drivers, bikers or cyclists can park their vehicles and use means of public transportation to continue their trip to the desired location.

Positive effects of the P&R system are reduction of traffic congestions, fuel consumption, exhaust gasses emission, and noise, shorter travel times, fewer casualties, as well as freeing of spaces that can be used for sustainable forms of transport (pedestrian walkways, bicycle lanes) [9, 8->12]. In order for a city traffic system to be sustainable, external traffic costs need to be as low as possible. The most common external costs incurred by the traffic system are traffic accidents, traffic congestions, air pollution, climate change, noise, etc.

In Europe, external costs were €530 billion in 1995, €650 billion in 2000 [11] and €524 billion in 2008, traffic congestion costs excluded, which then amounted 4% of total European GDP [10]. The most of external costs take part in road traffic (around 83%[1]).

The implementation of the P&R system aims to reduce the aforementioned costs caused by traffic. In order to do this, an alternative must be offered. Rather than a passenger car, a fast, efficient, comfortable, frequent, reliable and economically acceptable public transportation can be a more acceptable form of transport [8]. High quality public transportation and strategically well-located P&R terminals can significantly reduce the number of passenger cars in city centers, thus downsizing external costs.

In many developed cities in Europe, implementation of P&R systems increase the use of public transportation. Data on the P&R system in Europe is shown in Table 1.

[1] Data for year 2000 [11]

Table 1 – Characteristics of P&R system in Europe [12]

CITY	NUMBER OF INHABITANTS	NUMBER OF P&R TERMINALS	NUMBER OF P&R PARKING SPACES	PUBLIC TRANSPORT FARES €(ROUND TRIP 1 ADULT)	NUMBER OF FREE OF CHARGE PARKING SPACES	PARKING FEES € (MAX PER DAY)
BERLIN	3.422.943	44	4.947	4.20 - 5.60	ALL	-
HAMBURG	1.773.218	49	9.409	3.30 - 5.20	ALL	-
COLOGNE	995.397	28	5.570	4.60 - 6.40	ALL	-
MUNICH	1.314.350	24	7.128	4.60	7120	1.50
HELSINKI	568.146	27	3.163	4.40	2908	2
PARIS	2.166.200	28	5.849	3.20	1.700	12.50
SHEFFIELD	530.300	8	1.754	*	750	4.50
ROME	2.708.395	31	12.880	2	260	3
LUXEMBOURG	86.329	5	4.116	3	ALL	-
AMSTERDAM	743.104	5	1.278	**	NONE	6
OSLO	565.653	5	3.000	5.20 - 10.40	2.330	14
VIENNA	1.681.469	6	6.226	3.40	NONE	3
STOCKHOLM	795.163	22	3.000	6-12	NONE	3
GENEVA	1.314.350	19	4.854	4 - 7.60	NONE	29.10
LJUBLJANA	278.638	1	217	*	NONE	1
PRAGUE	1.194.407	17	3.196	1.50	NONE	1
BUDAPEST	1.696.128	25	3.384	2	2.682	1

** included in parking fee for the driver*

*** round trip for up 5 persons included in parking fee*

The above Table 1 shows that on more than 50% of the P&R parking spaces parking is free of charge. Furthermore, in the cities of Sheffield, Amsterdam and Ljubljana a public transportation ticket is included in the parking fee. For those reasons, direct financial profitability of the P&R system should not be expected, however, the system could provide many social benefits by reducing the previously mentioned external costs (traffic accidents, traffic congestions, air pollution, climate change, noise, etc.) [8, 9].

3. METHODOLOGY FOR DETERMINING CONCEPTUAL PARK&RIDE LOCATIONS

The common methodology, which can be applied to most cities for determining P&R terminal planning, has not yet been developed based on the experience gained in the P&R terminal planning in Europe and North America. Various criteria and methods are used nowadays for realization of P&R terminals.

3.1. Analysis of the professional literature

AHP (Analytic Hierarchy Process) methodology is one of the most common methods used in transport planning in cases when pure economic criteria cannot be considered sufficient for final decision making. It provides a good basis for multicriteria ranking and evaluation for P&R terminal locations [1]. The AHP method is even considered to be the best method for all transport projects by some authors [2]. The AHP method has been found to greatly reduce the possibility of making a mistake in locating the P&R terminal by selecting the lowest cost alternative. It has also enabled the consistency in decision making of the significance of individual criteria and in potential P&R terminal location ranking [3].

Evaluation based on Distance from Average Solution (EDAS) multiple-criteria decision-making method is another methodology that has been found for successfully locating the P&R terminal locations. The authors found this methodology to be easily applicable, does not demand large amount of data which is not easily obtainable and it's applicable in other cities despite the geological, population and transport system differences. The main and most important criteria in this method is the frequency of the public transport on the P&R terminal, followed by the advantages of public transport in regard to cars (it's faster, more comfortable etc.) and free parking spaces in city center [5].

Some authors [4] say that an attractive P&R terminal should be located in a neighborhood in which several factors exist to motivate car users to switch to P&R and that it should also impact the bus operator, existing parkers and surrounding stores. The author proposes several tasks to evaluate potential terminal locations:

1. Site location analysis
2. Bus system reliability analysis
3. Parking supply and usage analysis
4. Mode choice model
5. User demand and ridership estimation
6. Cost estimation and economic impacts analysis

The six-step analysis approach may be repeated for the design year and for any future year and is not a detailed engineering study [4].

Author Cvathe recommended in her PhD thesis [6] the guidelines for the selection of conceptual locations of the P&R terminals which are also a good way to determine the sensibility of the implementation of P&R system. It was concluded that if the city has got little or none daily migrations to the city center, P&R system will be inefficient and its implementation not sensible and inappropriate. Recommendations that were provided for successful implementation of the P&R system are that parking spaces have to be located on the edge of areas where traffic reductions are needed and have to be easily accessible from major roads, leading into the city. It is also said there must be as few parking spaces as possible in the city as a measure of discouragement. Cameras that broadcast a live signal should be implemented and public transport routes must be insured, connecting P&R parking lots and the city center, are as fast as possible. Regularity and high frequency of public transport services are crucial as well as the pricing which should be as low as possible, and it should be considerably more affordable than the car travel option [6].

3.2. Applied criteria for the P&R terminal locations

Previous analysis of the professional literature and the aforementioned methodologies and guidelines for the determination of P&R locations, the following criteria has been used and applied in this article. The location must generate a large number of people that gravitate towards Zagreb and needs to have an existing public transport connection. Building a parking lot near the public transport station must be possible, and the travel time needs to be equal or shorter than the car travel time.

4. DETERMINING CONCEPTUAL LOCATIONS OF PARK&RIDE TERMINALS IN THE WIDER ENVIRONMENT OF THE CITY OF ZAGREB

Based on the analysis of the previously elaborated methodologies and guidelines for determining locations of P&R terminals for the purpose of determining the conceptual locations of the P&R terminals in the wider environment of the city of Zagreb, the conditions according to which locations of the P&R terminals were determined were selected:

- Location from which a large number of people gravitate to Zagreb;
- Public transportation exists between the location and the city;
- Possibility to build a parking lot near the railway or bus station exists;
- Travelling time by means of public transportation is equal to or shorter than by passenger car.

Based on the above stated conditions, and due to insufficient data, only relatively larger localities with surrounding villages have been considered. The proposed locations of P&R terminals are (Figure 1):

Location 1. Velika Gorica (next to the railway station)

Location 2. Podsused (next to the railway station)

Location 3. Hrvatski Leskovac (next to the railway station)

Location 4. Zagreb - bellow the Domovinski most

Location 5. Zaprešić (next to the railway station)

Location 6. Dugo Selo (next to the railway station)

Location 7. Westgate Shopping city parking lot

Location 8. Sesvete (next to the railway station)

Location 9. Zagreb - with the embankment next to Savski/Jadranski most

Location 10. Samobor (next to the railway station)

Location 11. Vrbovec (next to the railway station)

Location 12. Zabok (next to the railway station)

Location 13. Jastrebarsko (next to the railway station)

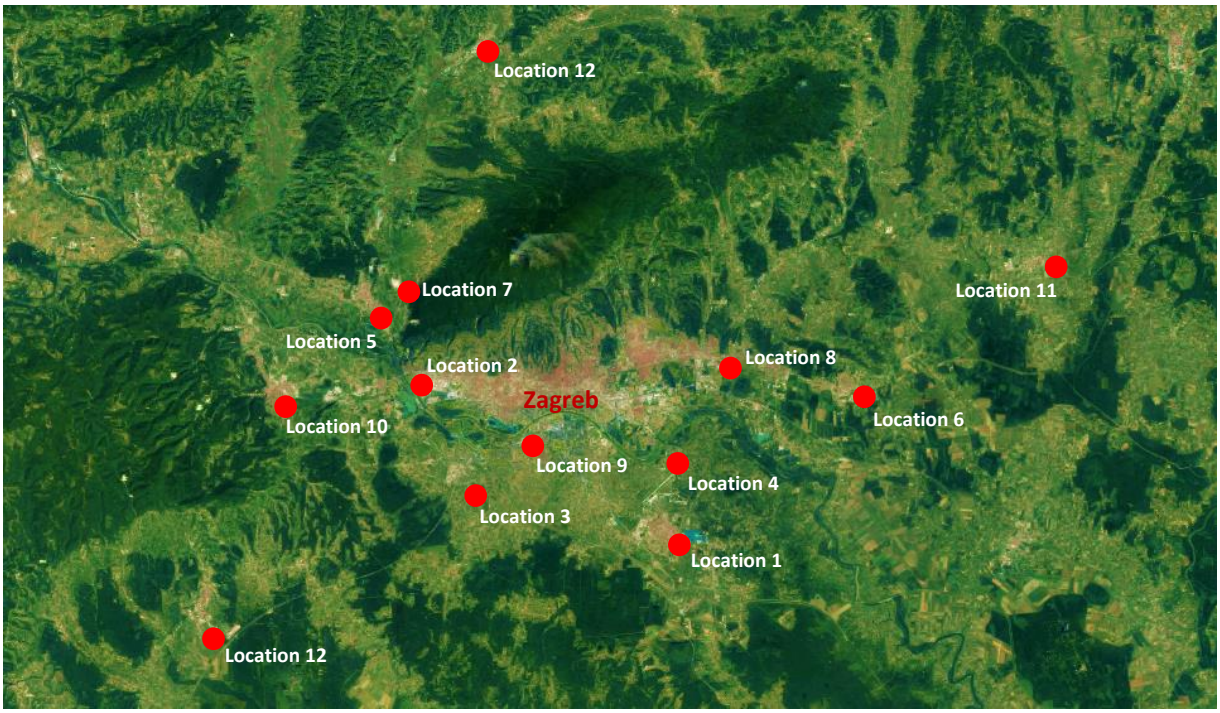


Figure 1 – Proposed locations for P&R terminals

Proposed locations are selected by experience, and the fulfillment of the terms of each proposed location is shown in Table 2.

Table 2 – Proposed locations with selected conditions

PROPOSED LOCATION	1. A location from which a large number of people gravitate to Zagreb	2. Connection between the location and Zagreb by public transport	3. Potential to build a parking lot near the railway or bus station	4.1. Travel time from the location to Zagreb by passenger car [min]	Travel time from the location to Zagreb by public transport [min]
Location 1. Velika Gorica (next to the railway station)	YES	YES - Railway connectivity	YES	41	37
Location 2. Podsused (next to the railway station)	YES	YES - Railway connectivity	YES	40	35
Location 3. Hrvatski Leskovac (next to the railway station)	YES	YES - Railway connectivity	YES	34	17
Location 4. Zagreb-bellow the Domovinski most	YES	YES - Bus connectivity	YES	**22**	**26**
Location 5. Zaprešić (next to the railway station)	YES	YES - Railway connectivity	YES	47	22
Location 6. Dugo Selo (next to the railway station)	YES	YES - Railway connectivity	YES - Parking lot already exists	38	20
Location 7. Westgate Shoppingcity parking	YES	YES - Bus connectivity	YES - Parking lot already exists	**33**	**39**
Location 8. Sesvete (next to the railway station)	YES	YES - Railway connectivity	YES	20	14
Location 9. Zagreb-with the embankment next to Savski/Jadranski most	YES	YES - Railway, bus and tram connectivity	YES	24	20
Location 10. Samobor (next to the railway station)	YES	YES - Railway connectivity	YES	58	43

Location 11. Vrbovec (next to the railway station)	YES	YES - Railway connectivity	YES	68	52
Location 12. Zabok (next to the railway station)	YES	YES - Railway connectivity	YES	71	57
Location 13. Jastrebarsko (next to the railway station)	YES	YES - Railway connectivity	YES	69	42

As seen from the table, all proposed locations fulfill the first three conditions, however, locations 4 and 7 do not fulfill the fourth condition. The data shown in the last two columns is measured and represent the average travelling time of car or public transportation at peak hours.

In this article, the best 3 locations for P&R terminals are determined out of all 13 proposed locations. Those locations that fulfill most of the conditions are considered as the best ones. Since proposed locations 4 and 7 do not fulfill condition 4, the best three locations are selected from the remaining 11.

The remaining 11 proposed locations entirely fulfill all four conditions, and the best 3 locations are determined according to the fourth condition. Considering that, according to condition 4, not all of proposed locations have the same relative difference in travelling time by car and public transport, the three determined conceptual locations of the P&R terminals are those with largest relative travelling time difference (Table 3, Chart 1).

Table 3 – Proposed locations – difference in travel time

PROPOSED LOCATION	**Travel time from the location to Zagreb by passenger car [min]**	**Travel time from the location to Zagreb by public transport [min]**	**Relative difference of travel time by public transport in relation to passenger car**
Location 1. Velika Gorica (next to the railway station)	41	37	**9,76%**
Location 2. Podsused (next to the railway station)	40	35	**12,50%**
Location 3. Hrvatski Leskovac (next to the railway station)	34	17	**50,00%**
Location 5. Zaprešić (next to the railway station)	47	22	**53,19%**
Location 6. Dugo Selo (next to the railway station)	38	20	**47,37%**
Location 8. Sesvete (next to the railway station)	20	14	**30,00%**
Location 9. Zagreb-with the embankment next to Savski/Jadranski most	24	20	**16,67%**
Location 10. Samobor (next to the railway station)	58	43	**25,86%**
Location 11. Vrbovec (next to the railway station)	68	52	**23,53%**
Location 12. Zabok (next to the railway station)	71	57	**19,72%**
Location 13. Jastrebarsko (next to the railway station)	69	42	**39,13%**

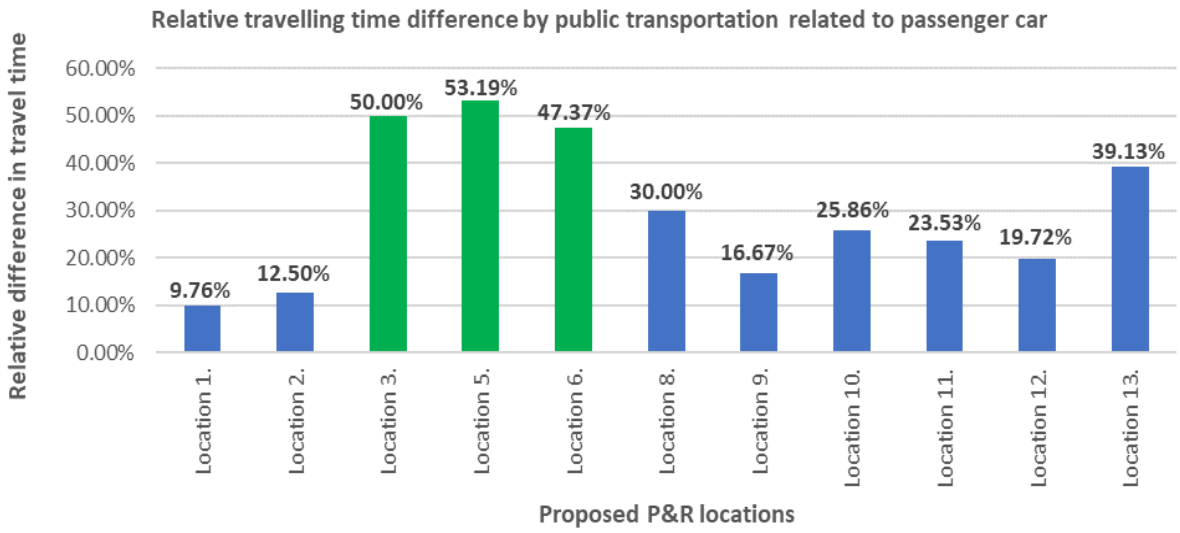


Chart 1 – Relative travelling time difference by public transportation related to passenger car

From the Table 3 and Chart 1 it is evident that the best 3 locations (where P&R terminals are proposed to be implemented) are locations 3, 5 and 6; Hrvatski Leskovac, Zaprešić and Dugo Selo.

4.1. Design P&R location in Hrvatski Leskovac

Hrvatski Leskovac is a small town which is a part of the City of Zagreb. It is surrounded by villages - Gornji Stupnik, Donji Stupnik, Brezovica and Demerje - from where people commute to Zagreb every day. It is connected by railway with the Zagreb Main Railway Station, to which the average travelling time is 17 minutes (Figure 5), whereas by passenger car in peak hour averages 34 minutes.

Suggestion is to form a car parking lot of approximately 400 parking spaces (Figure 2) with the assurance of a free car parking at the terminal with the presentation of a public transportation ticket.



Figure 2 – Proposed P&R terminal next to railway station in Hrvatski Leskovac

4.2. Design P&R location in Zaprešić

Zaprešić is a town in the northwestern part of Croatia, within the Zagreb County. It has about 25,000 inhabitants. Nearby are villages of Brdovec, Šibice and Lužnica, from where many people commute to Zagreb every day. Zaprešić is connected by railway with the Zagreb Main Railway Station, to which the average travelling time is approximately 22 minutes (Figure 5), and by passenger car in peak hour averages 47 minutes.

Suggestion is to form a car parking lot of approximately 400 parking spaces (Figure 3) with the assurance of a free car parking at the terminal with the presentation of a public transport ticket.



Figure 3 – Proposed P&R terminal next to railway station in Zaprešić

4.3. Design P&R location in Dugo Selo

Dugo Selo is a town in Croatia, located in the Zagreb County, 20 km east of the center of Zagreb. Dugo Selo is a satellite city of Zagreb with about 17,500 inhabitants. A large number of people from surrounding villages (Andrilovec, Donje Dvorišće, Kopčevec, Kozinščak, Leprovica, Lukarišće, Mala Ostrna, Prozorje, Puhovo and Velika Ostrna) commute to Zagreb every day. Dugo Selo is connected by railway to the Zagreb Main Railway Station, to which the average travelling time is approximately 20 minutes (Figure 5), by passenger car in peak hour about 38 minutes.

Suggestion is to form a car parking lot of approximately 400 parking spaces (Figure 4) with the assurance of a free car parking at the terminal with the presentation of a public transport ticket.



Figure 4 – Proposed P&R terminal next to railway station in Dugo Selo

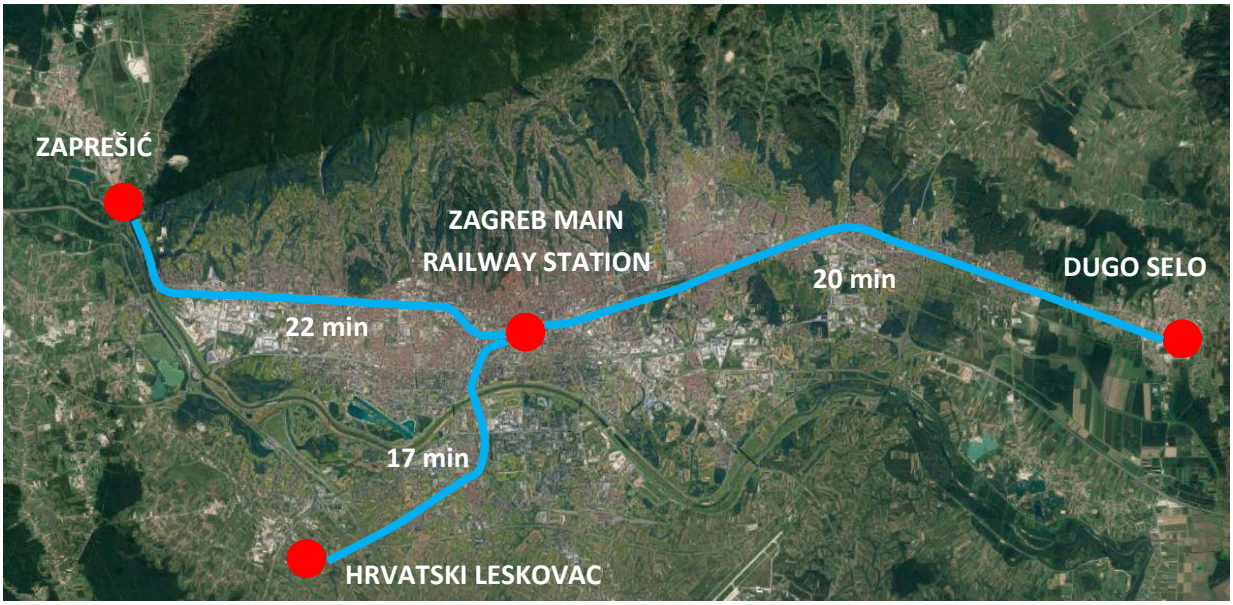


Figure 5 – Railway routes from Zaprešić, Hrvatski Leskovac and Dugo Selo to Zagreb Main Railway Station

5. CONCLUSION

The traffic network is a foundation for a functional city and the economical growth. To avoid unneccesary social losses and to reduce the negative impact of traffic, we must approach the strategic development of the traffic system with the sustainable mobility as the main goal.

In Croatia, very little attention was given to creating the optimal traffic solutions in the process of planning, which results in the wrongly situated roads. This leads to the increase of traffic volumes on the rest of the traffic network while the badly placed roads are not exploited to the fullest. This problem leads to the need for finding the optimal solutions for congestion problems and the problems it produces. One of those solutions for the reduction of external costs is the P&R system implementation. Apart from the social benefits, P&R also has an impact on the development of

sustainable forms of traffic to enable the conversion of traffic areas for the development of sustainable forms of transport. Accessibility and quality of public transport services is also increasing by the P&R system implementation.

The professional literature has shown that many different approaches regarding the P&R terminal location finding are used. Existing examples of P&R parking lots, practical rules, expert experience and knowledge, and multi-criteria approach, all could be used to make a decision regarding the location of a P&R terminal. But most of those methodologies lead to many potential terminal locations.

Based on the analysis of the methodologies and guidelines for determining locations of P&R terminals in the wider environment of the city of Zagreb, the following criteria was used to locate the P&R terminal locations. The location must have a large number gravitating towards Zagreb, there must be an existing public transportation link with Zagreb, there must be a possibility of building the parking lot near the railway or bus station exist and the travelling time by means of public transportation is equal to or shorter than by passenger car. Thirteen possible locations were taken into consideration, but only three were selected as they fulfill all of the criteria and have the largest relative travelling time difference. The selected P&R terminal locations are location 3 (Hrvatski Leskovac), location 5 (Zaprešić) and location 6 (Dugo Selo).

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GORAN VOJKOVIĆ, Ph.D.[1]
E-mail: goran.vojkovic@fpz.hr
MELITA MILENKOVIĆ, mag. iur.[1]
E-mail: melita.milenkovic@fpz.hr
ROMINA JOVANČEVIĆ, mag. iur.[1]
E-mail: romina.jovancevic@fpz.hr
[1] University of Zagreb
Faculty of Transport and Traffic Science
Vukelićeva 4, 10000 Zagreb, Croatia

NOVELTIES IN PASSENGER ROAD TRANSPORT IN THE REPUBLIC OF CROATIA

ABSTRACT:

In May 2018 the Croatian Parliament passed a new act in the urgent procedure, an Act on Road Transport. Significant changes were introduced in the area of road transportation of passengers, particularly regarding market liberalization of passenger taxi transportation, introduction of micro transport and regulation of the integrated passenger transport. This paper attempts to present the basic changes introduced by the new legal framework and the opportunities that it has opened on the market.

KEY WORDS:

road transport; passengers; taxi transport; micro transport; integrated transport

1. INTRODUCTION

At its session on 27 April 2018, the Croatian Parliament passed a new Act on Road Transport (further: Act) [1], which fully substituted the same act from the year 2013 [2]. In the explanation of the draft of this Act [3] it was stated that the road transport sector has been experiencing constant technological and technical development, primarily through the use of advanced information technologies. In compliance with the European Union transport policy documents and the strategic development documents of the Croatian transport system by 2030, it is necessary to take into account the real circumstances in the transport supply and demand on the transportation market and further deregulate and liberalize the transportation market in road transport, and facilitate the access to this market.

The implementation of the European traffic law into the national legal framework has imposed the need for further regulation of certain issues that had not been adequately resolved by previous regulations (e.g. taxi transport, car rental with driver, occasional transport, transport of cargo and persons for personal needs, etc.), primarily regarding the emergence of new forms of transportation, resolving of the problem of the fluctuating increase of the transport demand during the summer season, and the organization of accompanying activities in the road transport sector.

The adaptation of the Croatian legal framework in the form of the Act is interesting because it is not just an adjustment to the EU framework, but also an attempt to resolve the two major transport problems in Croatia, which have emerged in recent years:

- Changes in tourists behaviour - while once a tourist was located at one single destination for couple of weeks, today it is exceptionally popular to visit several destinations during the holiday, which significantly increases the need for a taxi during the season in tourist areas, the need for a taxi ride increased even in smaller seaside resorts where it has by so far been neglected;

- the depopulation of large parts of Croatia (Slavonia, Banovina, Lika) has made classic local liner transport unsustainable and not even cost effective, therefore the legislator tried to solve the issue by introducing a completely new category of micro transport.

These changes in the Croatian legislative framework only improved the adaptation to the European legal framework and became interesting as an example to other Mediterranean countries.

The fact to which only a passing reference has been made in the explanation, was the big pressure on the legislator to address the issue of using the globally popular Uber service. As written in the Telegram in 2015: "The idea and the basic purpose of the Uber application is simple. The program that can be installed on any smartphone allows the user to order transport that is not necessarily a standard taxi ride. After the application receives the request and finds your location, the call is forwarded to the nearest Uber registered driver, whose travelling towards you can be tracked on your phone display. Upon arrival to your desired destination, the amount of money you need to pay is deducted from your bank account, and Uber takes its part and the rest is forwarded to the driver." [4] UBER has organized its business operation in Croatia by using the legal lease option with the driver, and this has caused several years of disputes with the competent Ministry. However, the expansion of the transport ordering system through an application that has huge benefits (the same application for the entire world, direct card payment, obtaining of the map with the travelled route) required legal adjustment. The existing taxi service framework was actually outdated, and additionally new models that prefer card payment are ideal in the view of financial control of service provision.

Another novelty is micro transport, which is defined as a form of public passenger transport by M1 category passenger car or M2 category bus, carried out in the areas where there is no organized public transport of passengers, i.e. in the areas characterized by low level of transport demand. According to the explanation of the proposal of the Act, micro transport as a new legal institute, offers the local self-government units the possibilities of solving the issue of public passenger transport in the conditions of reduced transport demand, by concluding contracts and by arranging the model of financing such transport thus providing minimum transport provision by using personal cars and minibuses. [3] In short, this is a transport for poorly populated rural areas.

The third novelty is the organization of integrated passenger transport. Negative demographic movements have caused the development of micro-transport model, but as stated in the explanation of proposal of the Act, "integrated passenger transport as unique organizational, technical, technological and tariff transport system". All public transport vehicles (trains, buses, trams, ships…) have been united in a common passenger transport system in a certain region, and the service is intended for all citizens.

The Act was adopted in an emergency procedure. Among the reasons for such a move it is stated: "Special reason for the adoption of this Act through emergency procedure is a complete reform of the county regular passenger transport, by transition from a system of transport permits to the system of transport as an economic public service, pursuing precisely the Regulation (EC) 1370/2007 on public passenger transport services by rail and by road [5], and the reform of the passenger taxi transport, which reduces the previous administrative and financial barriers and liberalizes the access to the transportation market."

2. TAXI TRANSPORTATION

One of the fundamental changes in the Act is the substantial liberalization of the taxi transport. The existing legal model was very rigid and, in some cases, allowed almost monopolistic position of the existing taxi carriers. There were a few taxi drivers in the big cities, and transportation was expensive. There was a special emphasis on limiting the number of licenses for taxi vehicles by local self-governments.

Taxi transport was considered something "for the rich" and not as in most of the world: another form of public transport. Due to high prices, the number of rides was small, and therefore tax revenues from this activity. In addition, as most of the rides were charged in cash (unlike new models preferring card payments), tax evasion possibilities were great. And finally, particularly high night-time driving prices reduced the effects of promotional actions, such as: not to drive after consuming alcohol, but rather to call for public transport.

2.1 Reasons for Liberalization

The possibility of performing taxi transport has been already partially liberalized by the old Road Transport Act. The older regulations mentioned, namely, that taxi transport is performed based on the licence or a concession, and the concession model can be regarded legally as a complex. [6]

Article 56 of the old Act stated that taxi transport is performed on the basis of the acts and regulations that in compliance with this Act are brought by the competent body of one or several local self-governments, in this matter the City of Zagreb, having a status of a city and county. Taxi transport was performed on the basis of a permit, if thus stipulated by the stated regulation. The permit was issued by the competent body of the City of Zagreb to a legal or natural person who fulfills (hence cumulatively) the following conditions:

- owns a valid permit to perform taxi transport,
- passed the exam, i.e. has an employed driver with a passed exam referred to as in the Article 59 of the respective Act.

The mentioned Article 59 of the Act defined that the Taxi vehicle driver shall have a passed exam on the basic knowledge about cultural, economic, tourist, traffic and other significant facilities and sights in the area of their respective transport services provision. Furthermore, the competent body of the City of Zagreb, provides the exam program and the knowledge testing method.

What did it look like in practice? For instance, the Ordinance on Special Exam for Taxi Vehicle Drivers with the Exam Program for the city of Sisak [7] required knowledge about the urban and historical development of Sisak, Lonjsko polje Nature park, significant facilities, as well as trade fair dates. The comprehensive Zagreb handbook Materials for the Preparation of the Oral Exam for Taxi drivers [8] published on the web pages of the City of Zagreb, contained also a text such as e.g.: ‘’Petrova gora – once this mountain was called Gvozd which means forest. After a great battle between the Hungarian army on the one side and the Croatian army led by the King Petar Svačić, on the other side, Croatian King Petar Svačić was killed on that mountain, and thus this mountain was named after him, Petrova gora.”

In the time of today’s smartphones where the user finds such information without any problem (and updated as well), and for the navigation through the city even the natives use Google Maps because it indicates traffic jams, it is obvious that these regulations were outdated. Interestingly, no foreign language knowledge was assumed here.

2.1 Liberalization in the new act

The new Act on road transport primarily defines taxi transport much more precisely, and in its glossary it says: taxi transport is an activity of public passenger transport which is performed by a passenger car of M1 category, if one passenger or a connected group of passengers board on one or several places, and disembark at only one place, and such transport is performed based on one order and with one payment of the total charge for the performed transport determined by a taximeter or an electronic application, providing the passenger with in-advance visible maximum price and the travelling route is planned according to in-advance known conditions, with the transport order being realised by a call, electronic application or directly with the driver, and which has no characteristics of other forms of passenger transport. [1]

It is interesting that the legislator (probably in order to prevent Uber and similar services[1] to attempt to circumvent the taxi transport rules) now defines extensively also the vehicle renting with a driver: "renting of vehicle with a driver is an activity of a special form of passenger transport in the road traffic, in which, based on a written contract the lessor (the carrier) shall make available to the lessee (tourist or travel agency, hotel, road transport agent) a high-class passenger car of M1 category, which apart from the driver's seat has maximally four passenger places (vehicle of at least E segment) with a driver, in order to perform a special purpose transport service (limousine transport, transport of the VIPs, transport of groups of persons for tourist purposes, emergency passenger transport, etc.), where drivers and vehicles have to satisfy special conditions stipulated by a regulation brought on the basis of this Act, which has no features of taxi transportation, and with the service being calculated on the basis of a time unit (hour or day), and the charging is done through cashless payment". It is interesting that this service has been available in Croatia already for years, through the Blacklane Company [9] specialized for VIP service of collecting passengers at airports (the driver waits at the exit gate, takes over the luggage, with a high class vehicle), but there were no disputes about it.

However, according to the actual Act (Art. 5) the drivers who manage vehicles for the taxi transport of passengers and who perform the activity of renting vehicles with drivers as a special form of transport in the road traffic, which requires a B-category driving permit, have to acquire the initial qualification according to a special program for the B-category drivers. Pursuant to the Article 10 the Minister stipulates by the Ordinance a program and contents of the exam for acquiring of the initial qualification for handling taxi vehicles and vehicles used to perform renting of vehicles with a driver.

Taxi transportation is now being performed through a licencing procedure. Pursuant to the Article 14 of the Act a legal or natural person – tradesman is allowed to perform the activity of public road transport of passengers or cargo in inland road traffic if he has been registered at the court register, i.e. tradesmen register for performing the activity of road transport. Also, if they own a licence for inland transport issued by the office of the state authority in the county, i.e. the body of the City of Zagreb which is competent for the business of transport, according to the carrier's headquarters / residence. Those who are obliged to have a licence include also taxi carriers. Furthermore, according to the Art. 18 a natural person – tradesman performing taxi passenger carriage, prove their financial capability /solvency/ by a valid insurance policy of all the passengers in the vehicle performing taxi transportation, and which has been concluded in accordance with the special regulation which defines the obligatory insurances in road transport (which are simpler conditions from other forms of transport).

Taxi passenger transport in inland traffic has been especially regulated by a comprehensive Art. 47 of the Act, out of which we focus on: Taxi passenger transport in inland road transport is performed on the basis of licences for taxi passenger transport and permits for taxi transport of passengers.

Legal and natural persons – tradesmen who perform taxi transport, exclusively for stopping in order to embark and disembark passengers, can use the stops intended for public transport vehicles and taxi stands, and for driving they can use specially marked traffic lanes that provide priority of passage. The licence for taxi transport from the para. 1 of this Article is issued by a decision of a competent administrative body for traffic of the City of Zagreb.

Also, important is the provision according to which a legal or natural person – tradesman can obtain a licence of several units of local self-government if they meet all the conditions stipulated by this Act.

It will be issued to a legal or natural person – tradesman who has a valid licence for taxi transportation in inland road transport at the moment of applying for the licence issue.

[1] Uber is used here only as an example of a typical global computer platform, since there are others as well, such as Lyft, Waymo and the other platforms which operate on a very similar principle.

Especially significant is the provision according to which the City of Zagreb cannot limit the number of issued licences in its region. The past possibility of limiting the number of issued licences was a potential generator of possible abuses.

It is also important to emphasise that the maximum charge for issuing of the licence cannot be higher than one tenth of the average monthly payment of a net income in case of legal persons in the City of Zagreb for the last month for which the data have been published, and which precedes the application for issuing of the licence.

Let us mention also the Article 49 of the Act according to which taxi transport of passengers is carried out in such a way that the carrier performing the taxi transport activity may embark the passenger and start transport only in the area of the City of Zagreb for which they are licenced. If the carrier provides passenger taxi transport service using a taxi-meter, during the provision of the service the taxi-meter has to be switched on, and there has to be a price list in a visible place.

The taxi transport price list is determined independently by the carrier, and it has to contain at least a price per one travelled kilometre. This provision significantly facilitates the market competition among the carriers.

It should also be noted that if the carrier provides the service of passenger taxi transport by means of electronic application where the maximum price and the planned travelling route are visible in advance, the application has to be switched on in the vehicle during the entire time of service provision.

These changes have made the essential liberalization of taxi transport in the Republic of Croatia; they have enabled competition, and it is also possible to use global applications such as UBER. The result is not only the price reduction of the travelling but a much larger usage of taxi services, that have stopped to be an exotic service for the “rich”. Card payment preferred by the advanced models of service provision are certainly favourable from the tax point of view.

With this move, Croatia has significantly liberalized the taxi services, but it does not allow the drivers without a special licence and permit to occasionally perform taxi services (UberPOP) as for instance possible in Norway. [10] Since this service has been restricted in the meantime also in the mentioned Norway, it may be concluded that the Croatian legislator has chosen correctly. [11]

3. MICRO TRANSPORT

According to the Act’s Art. 50, para. 9 Contract on the provision of micro transport services may have the character of a contract on the provision of public services. [1]

Therefore, Regulation (EC) No 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public passenger transport services by rail and by road states in the Art. 1. The purpose of this Regulation is to define how, in accordance with the rules of Community law, competent authorities may act in the field of public passenger transport to guarantee the provision of services of general interest which are among other things more numerous, safer, of a higher quality or provided at lower cost than those that market forces alone would have allowed. [5]

Micro transport is a new, special category of passenger transportation in the Republic of Croatia, which is used to try to mitigate the very bad demographic movements in the Republic of Croatia. Thus, the newspaper Večernji list published on 23 February 2019 brings a statement made by the demographer Prof. Anđelko Akrapa, Ph.D., the head of the Chair of Demography at the Zagreb Faculty of Economics: “In my opinion, we have now about four million inhabitants since a large number of the emigrated have not unregistered. However, more significant than the number of citizens is the poor age structure of the population in Croatia, a decreasing ratio of the youngsters, up to 14 years of age compared to those older than 65. This is accompanied by difficult economic and social issues and consequences on the pension and health-care system. According to the ratio of the youngsters, it is

to be expected that many schools will have to be closed, which is obvious even without the assessments of the Croatian Bureau of Statistics, since many district schools in rural places have already disappeared." [12]

It is precisely these smaller rural places in, e.g. Slavonia, Lika or the islands, that need public transport – the majority of the population there are of senior age and lower income and they depend on the public transport. The disappearance of district schools means that they cannot use the legal possibility (Art. 44 of the new Act) according to which the carrier performing special regular passenger transport (usually schoolchildren to and from school, with the part of the contract including a list of passengers) can perform, with a special permit, also the transport of passengers who have not been included in the list of passengers both to a place or from a place where there is no organized regular public passenger transport service. This makes it possible, if there is a carrier who would obtain the appropriate permit, for the citizens from these smaller places to reach the bigger centres at least during the school year. This possibility, as mentioned, exists also now – but the number of places not reached by a school bus is increasing.

Apart from the definition stated in the introduction, micro transport is primarily regulated also by the Article 50 of the new Act. Micro transport can be performed by a carrier owning a licence for passenger transport in inland road transport or a licence for taxi transportation or a licence for the activity of renting a vehicle with a driver or a licence of the Passenger Transport Association, based on the provisions of the decision made by the local self-government about micro transport based on the provision of this Act.

The carrier performs micro transport by vehicles of category M1 or by vehicles of category M2, under the conditions stipulated by the decision of the local self-government on the micro transport. The categories are described in Annex I of the Ordinance on Vehicle Categorization. [13] Accordingly, category M are road motor vehicles that serve for the passenger transport and that have at least four wheels, and they are further divided into:

- Category M1: motor vehicles for passenger transport that apart from the driver's seat have a maximum of eight (8) seats.
- Category M2: motor vehicles for passenger transport that apart from the driver's seat have more than eight (8) seats, with the maximum allowed mass not exceeding 5 t.
- Category M3: motor vehicles for passenger transport that apart from the driver's seat have more than eight (8) seats, with the allowed maximum mass greater than 5 t.

Thus, micro transport involves also the usage of passenger cars and vans up to eight (8) passengers as well as small buses. The person proposing such a solution obviously considered that these vehicles due to lower maintenance costs can be profitable where the profitability of classic vehicles cannot be expected. Moreover, since M1 vehicles require only B category for the drivers (with additional education, according to the Art. 5 of this Act), this allows employment of drivers who do not have D category for buses, and these are at the which are currently deficient and according to the market conditions require much higher salaries.

According to the Art. 50, the carrier performs micro transport in order to meet the transportation demands of the population in rural and poorly inhabited areas, where no public regular passenger transport is organized, according to a schedule adapted to the persons seeking transport. Micro transport is performed on the basis of a contract signed between the transport customer and the carrier, in compliance with the provisions of the decision made by the self-government about micro transport.

The decision of the self-government about micro transport defines the needs for micro transport and the method of covering the transport costs.

The micro transport customer can exclusively be a state authority body, a unit of local or district (regional) self-government, a legal person founded by a state authority body and/or unit of local or

district (regional) self-government and a legal person entrusted by the state authority bodies and/or local or district (regional) self-governments with the organization of micro transport in their respective area based on a special decision or contract. Additionally, if the self-government is not being at the same time the transport customer, it has to provide its written consent to such a contract.

Furthermore, micro transport service provision contract can have the character of a contract on the provision of public services. Micro transport can be organized also on relations with an existing public regular transport on the days when the regular public transport does not operate (e.g. during school holidays, on weekends, holidays, etc.).

Since it has been less than a year since this Act was implemented, it is difficult to say much about the effects in the practice of introducing micro transport.

4. INTEGRATED PASSENGER TRANSPORT

Section V of this Act is titled "Integrated Passenger Transport in Inland Traffic". According to the Art. 52 of the Act, the service of integrated public passenger transport is a service that includes interconnection of the public passenger transport services within a certain geographic area with a unique information technology service, unique ticket, i.e. tariff system and a unique schedule.

According to Art. 53 of the Act, for more economical and efficient operation of public passenger traffic and in order to increase the quality of the transport service for the users, the operators of the transport service of various kinds of transport can provide services of integrated passenger transport. Further, (Art. 54) the services of integrated public passenger transport, in view of this Act, can be provided:

a) only within the region of a single district (regional) self-government or a single local self-government, or
b) in the region of several units of local and/or district (regional) self-government within a certain pilot-region, and
c) if the operator of the public passenger transport service has a signed contract on the provision of the service of integrated public passenger transport with the competent body, i.e. local competent body.

The contract of the provision of the service of integrated public passenger transport is concluded between the public passenger transport operator and the unit of local, i.e. district (regional) self-government with the consent of the Ministry, in case the Ministry is not at the same time the competent body (Art. 55).

The objectives of such a contract are also defined (Art. 56):

- defining of mutual rights and obligations among operators of passenger public transport service and competent body, i.e. local competent body regarding provision of infrastructural preconditions for service operation;
- determining of the area, i.e. pilot-region of integration;
- determining of the traffic network of lines included in the integration;
- defining of the obligations regarding public service provision;
- defining of quality standard;
- determining of the charge for the provision of the service of public interest; and
- defining of the obligations of delivering data to the competent body, i.e. local competent body on service provision.

Pursuant to Art. 57 of the Act, the obligatory annexes to the Contract on providing the service of integrated public passenger transport include:

- general terms of transport,

- price list and bill of costs of the transport, and
- a unique schedule (in the glossary defined as an act which contains mutually harmonised schedules of different interconnected types of public transport).

Let us mention also Art. 60 of this Act according to which the following is applied to the provision of integrated public passenger transport service:

a) to the public passenger transport service by road included in the integrated public passenger transport – provisions of this Act that regulate the municipal passenger transport, county passenger transport, inter-county passenger transport and micro transport;
b) to the public passenger transport service by the sea included in the integrated public passenger transport – provision of the Act that regulates the transport in regular maritime coastal transport;
c) to the public passenger transport service on inland waterways included in the integrated public passenger transport – provisions of the rules that regulate the transport on inland waterways;
d) to the public passenger transport service in railway traffic included in the integrated public passenger transport – provisions of regulations that regulate railway transport;
e) to public urban passenger transport included in the integrated public passenger transport – provisions of this Act that regulate the municipal transport of passengers and provisions of regulations on municipal economy; and
f) to the issues of the protection of rights of the integrated public passenger transport users – provisions of the regulations that regulate the protection of the consumers' rights and the protection of passenger rights.

The fact is that integrated transport had not been legally restricted until now – it had only not been legally regulated in such detail. The obligatory law is not a "closed structure" like property law, but it recognizes also the contracts that have not been specially regulated by law, and in legal theory these are called non-named (innominate) or atypical legal business activities. [14]

Already, for years Zagreb has been using a combination of a unique ticket for suburban train and bus/tram, as part of the contractual business cooperation of HŽ Passenger Transport and Zagreb Electric Tram (ZET) [15], and on the Croatian islands the local bus transport has been adapted to the ferry transport for decades, (however, separate traffic documents have to be purchased as a rule).

5. CONCLUSION

The new Road Transport Act represents a good example where the legislator follows the technological applications, particularly in the segment of liberalization of taxi transport. Liberalization, apart from reducing the prices, significantly expanding the services, possibilities of facilitated business operation without personal car ownership, also has a direct safety correlation – it is common in Croatia that people going out at night usually (and too often) consume alcohol, and the affordable taxi price, now also with the possibility of simple cost sharing among several users, reduces the number of drunk drivers on the roads. Simply, driving four persons across the city costs even at night tariffs 20-25 kunas per person, so that fewer people will opt for the risk of illegal and dangerous driving under the influence of alcohol. This has been observed when Uber was still operating in the "grey" zone. [16]

Regarding micro transport, it is a welcome novelty useful in more efficient connecting of the parts of the country that had been previously less well connected by public transport. Along with the already mentioned problems and difficulties encountered by the inhabitants of "more remote" places, especially those of senior age, as well as workers who have no possibility of personal car travelling, the benefits of making micro transport as a form of public transport legally possible, are obvious.

As mentioned earlier, integrated transport has been already previously known, but the expansion and detailed legal regulations have certainly contributed to a higher level and modernization of the transport services in the Republic of Croatia. With the modernization of services and connecting of

different branches of passenger transport, Croatia can benefit from the development of this type of transport not only regarding the provision of an easier life for the citizens, but also in promoting tourism which is restricted today only to big tourist resorts.

Naturally, it is not to be expected that the legal regulation can significantly change the negative demographic and other changes because of which certain parts of Croatia stay empty. It can help the existing population and it is certainly welcome, and it can help also to the modern research tourism that is becoming increasingly present, but for the revitalization of Croatia other numerous measures, outside the transport segment, are of great necessity.

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PAWEL ZAJAC, dr eng.[1]
E-mail: pawel.zajac@pwr.edu.pl
OLEG A. GAVRISH, Prof.[2]
E-mail: dekan_fmm@kpi.ua
MATEUSZ ZAJAC, dr eng.[3]
E-mail: mateusz.zajac@pwr.edu.pl
[1] Wroclaw University of Science and Technology
27 Wybrzeże Wyspiańskiego st., 50-370 Wrocław, Poland
[2] National Technical University of Ukraine, Faculty of Management and Marketing
Проспект Перемоги 37, 03 056, Kiev, Ukraine
[3] Wroclaw University of Science and Technology
27 Wybrzeże Wyspiańskiego st., 50-370 Wrocław, Poland

INLAND TRANSPORT, TECHNICAL AND ECONOMIC ANALYSIS, ON THE EXAMPLE OF THE ODRA RIVER

ABSTRACT

The article discusses the issue of inland water transport in Poland, on the example of the Odra River. It is incomprehensible why this type of transport for the last eighty years has not been developed in Poland equally with other basic transport branches - which was in contradiction with the economic policy of other European countries. In 2018, the reconstruction of this transport branch in Poland began, taking into account the need to integrate transport systems (called eurologistics) with the technical conditions of transport in such countries as: Germany and the Czech Republic, which are adjacent to Poland. The process of modernization and expansion of the Oder is long-lasting - it can be estimated for several dozen years. The Odra River is a special river in comparison to the rivers of the already mentioned countries, because it is to a small extent canalised, which is why there is a long section of the freely flowing river. Hence, it is impossible to import indicators from Germany or the Czech Republic, so the question arises what assessment indicators of the transport system to take, what determines profitability - whether getting a constant depth of a river can improve the remaining indicators. The paper presents these relationships, verifying them with the results measured on real objects. The calculations were made using programs that are part of the doctoral thesis [5].

KEY WORDS

transport; logistics; costs; waterway parameters; energy consumption;

1. INTRODUCTION

The Polish network of inland waterways, according to [2], has 3813 km, of which 2722 km are exploited. In line with European Union policy, inland waterways are an equal and important component of pan-European transport networks [5]. The TINA report of 1999 [1] takes into account the key importance of Polish waterways in two strategic directions; North - South and East - West. The Oder is the only Polish waterway that has a connection to the Western European waterway system.

The maximum transport by inland navigation on the Oder reached in 1980 in the amount of 14.1 million tons decreased in 1991 and 1992 to the level of 5.5 million tons and in the driest, 1993, navigation on the Wroclaw - Szczecin section was virtually stopped. Currently, inland navigation carries approx. 10 million tons per year, of which a large part of the transport is carried out in the waters of Western Europe. If we accept the fact that the Odra is the backbone of the Szczecin-Świnoujście port complex, in this team in 2001, about 8 million were reloaded. tons of coal, 2.5 million tons of ore and almost 2 million. tons of other bulk cargoes. To these given amounts should be added about 10 million

tons of coal burned annually by power plants located along and on the Oder. In addition to typical bulk cargoes, which are the cheapest to transport by water, a whole range of other cargoes can be transported, such as dangerous, oversized cargoes and motor vehicles.

On the Oder, the use of the fleet depends on the possibility of swimming across the entire river. Practice proves that in the case of the possibility of swimming along the whole Oder with a minimum draft of 1.5 m for a period of at least 2 months, the entire Polish fleet is used. In 2017, about 2.5 million loads were abandoned on the Oder due to the impossibility of transporting them. It was about 30 sets of transports of oversized elements, steel constructions and aluminium products, steel products (steel sheets and profiles), cement, artificial fertilizers, cereals and processed cereals as well as ore and coal. Not all loads were transported by other transport modes. Around 20% were not transported at all, there are no contracts concluded.

The whole Odra River is divided into: The Gliwicki Canal, Sealed canal, Oder flowing freely from Brzeg Dolny to the estuary of Nysa Łuzycka, Oder flowing freely from the mouth of the Nysa Łuzycka River to the mouth of the Warta River, Oder flowing freely from the mouth of the Warta River to Szczecin. Taking into account only the hydro-technical conditions of the ODW section, which limits and decides on transport, is the section between Brzeg Dolny and the mouth of the Nysa Łużycka River. Here there are the lowest transit depths, which actually make it impossible to operate along the entire waterway. The basic shipping facilities on the Oder are ports and transhipments. Currently, 11 public ports and 18 ports and factory transshipments operate on the Odra waterway, with very different technical equipment and utilization levels.

2. COSTS OF TRANSPORT COSTS

In general, the total transport costs can be divided into:

- investment costs
- operating costs
- external costs

The investment costs will relate to the purchase costs of the new fleet. These costs constitute a significant item in total costs. This may be the main cause of the long life of the inland waterway fleet. In many cases, it is more cost-effective (for a shipowner) multiple repairs than buying a new unit. The amortization period of the fleet ranges from 10 to 20 years. It depends primarily on the type and use of the ship. In practice, the life span of the fleet exceeds significantly the depreciation period. This is a common phenomenon which is confirmed by statistics defining the age of the fleet.

Operating costs are directly related to the operation, i.e. the performance of transport work. Part of these costs do not depend in principle on whether the fleet is used. These are the costs of maintaining the fleet in a state of readiness to perform their tasks. This group includes costs such as:

- of equipment
- of depreciation
- for renovation and maintenance
- for crew costs
- about insurance
- for general administrative costs

Only renovation and maintenance costs from this group of costs have a significant impact on total costs, others can be omitted. These costs depend to a large extent on the requirements that each ship must meet in order to be allowed to operate. In principle, the more specialized a ship, the more expensive its equipment will be.

The next group of costs are costs directly related to the performance of transport work. The technical and hydrotechnical conditions have a decisive influence on the amount of these costs. These costs include:

- fuel costs,
- costs of oils and greases,
- costs of channel fees, locks, port fees,
- handling costs.

This group of costs in Polish conditions constitutes approx. 80% of total costs. The main part of these costs are the costs of fuel and lubricants. In Polish shipping companies, these costs are 40 - 45% of the total cost. The second group is the cost of the crew (about 25%). In EU countries, these costs are slightly different. Fuel costs are lower, crew costs are higher. This is due to preferential fuel prices and higher personnel costs. Other costs do not have a significant impact on the total costs.

Technical and hydrotechnical conditions have a direct impact on transport costs. A significant impact on costs is:

- length of the navigation season,
- permissible transit depths and durations of these depths

These costs also depend on the size of the fleet and the stability of the navigational conditions. The fuel consumption is affected by the navigation speed and the associated power of the main propulsion engines. The increase in the size of the ship causes an increase in navigation resistance, and therefore also the power of propulsion engines. However, the unit consumption (per unit of workload) clearly decreases with the size of the ship.

External costs are not directly related to the costs of transport work. They are included in the so-called social costs that are not transferred to the user by the market. They are therefore costs or a part of the costs for which the entities creating this cost do not pay, but those who have nothing to do with its creation, and even have negative consequences. These costs are borne by the environment and not by the owner of the ships.

Transport does not pay full social costs, including environmental costs. This leads to significant distortions of competition in the transport market. An example of this is the phenomenon of the increasing importance of road transport, at the expense of rail and inland waterway transport, despite the fact that the last two systems are definitely more environmentally friendly than road transport.

3. INDICATORS FOR INSPECTION OF INLAND TRANSPORT

Taking into account the simple relationship between load capacity and the required propulsive power, and the ship's main dimensions, the following relationship (1) can be obtained on the transport rate [2].

$$TEN = \frac{\eta_L \cdot \eta_D}{C} \frac{\left(L \cdot B \cdot T \cdot C_B\right)^{\frac{1}{3}}}{V^2} \tag{1}$$

where L, B, T denote, respectively, the length, width and draft - of the vessel, C_B – coefficient of integrity, C - admiralty coefficient used for approximate determination of navigation resistance. For a given class of ships, it has a constant value, η_D – drive efficiency, η_t- block coefficient (of a ship's hull).

For a given class of ships (motor barges, pushed sets) the admiralty factor and block coefficient (of a ship's hull) change in a small range with the value of TEN decide:

- load factor. Depends on the weight of the structure and dimensions of the ship. With the increase of the LBT product, its value increases.

- navigation efficiency. Using classical propulsion systems, this efficiency depends on the dimensions of the propulsor. This means that it grows with increasing immersion.
- ship's linear dimensions, the growth of which, apart from direct influence, indirectly influences the increase of the index through a positive impact on the load factor and efficiency. This also results in a more favourable power-to-load ratio.
- the navigation speed, the increase of which affects the efficiency index.

Increasing the amount of transported cargo can be obtained by increasing the navigation speed or dimensions of the ship. The last dependency clearly shows that increasing the speed is very ineffective. Other ways to increase the efficiency ratio are to reduce the vessel's weight, which leads to an increase in the load factor. As a rule, this treatment increases the construction costs and possibly the costs of renovations. Weight reduction by 20% increases the load capacity from 7 to 12%. It depends on the degree of use of the construction draft. The longer the service life of the ship with the maximum permissible structural draft, the lower the profit from the reduction in the weight of the structure. The drive efficiency η_{TD} is the product of the efficiency of the shaft line η_{TR} and the efficiency of the propulsor η_S. During the design and operation phase, the propulsor's efficiency can be significantly affected. It depends primarily on the linear dimensions (size) of the propulsor. This means that you should aim for maximum immersion. Another solution is the use of multi-propulsor systems.

A ship on a free-flowing river is operated at various immersion values. It depends on the currently prevailing hydrotechnical conditions. Already in the design phase there is the problem of choosing the optimal draft. Too low draft value means that you will not be able to use the existing depths of the waterway. The shipowners' experience shows that there is a minimum draft at which the shipping company is not yet suffering losses. The value of this draft depends on the length of the route, type of cargo and type of ship. Too high draft, it is not possible to use the design load capacity of the ship. This leads to "transporting" unnecessary mass of ship's construction and equipment. The indicator defined by equation (1) may only be applicable if navigational conditions are set on the waterway. It can not be applied to the efficiency analysis in the case of the Odra River flowing freely, where variable hydrotechnical conditions occur over time. The paper [2] presents the proposal of performance indicators in the form (2) index including only construction costs:

$$WB = \frac{Q}{K_B} \tag{2}$$

(3) an index including construction costs and operating costs determined on the basis of unit transport work costs; and (4) an index that takes into account construction costs and fuel costs.

$$WE = \frac{Q}{K_B + K_E} \tag{3}$$

$$WP = \frac{Q}{K_B + K_P} \tag{4}$$

$$WPP = \frac{Q}{K_P} \tag{5}$$

Equitation (5) defines an index that only takes into account fuel costs. It can be used to analyze the efficiency of the fleet built and when designing the rules for carrying out a transport task on a given waterway, where Q [t] – the amount of transported cargo on a given route, for a given construction draft T_K, taking into account the variable during immersion, T_i for a given number of pushed sets, motorboats and a given service life. K_B – construction costs depend on the ship's main dimensions. K_P – Fuel costs depend on current immersion and navigation speed. K_E – operating costs determined on the basis of unit transport work costs. Costs, regardless of how they are determined, depend on the

construction draft T_K and real immersion T_i which occurs during the analyzed period of time, with the condition that: $T_{min} \leq T_i \leq T_K$.

The presented principles of determining the effectiveness indicators enable the analysis of the impact of a number of technical parameters on the determination of transport efficiency. These parameters are:

- the number of barges in the set, while maintaining fixed fixed horizontal dimensions of the whole set,
- the width of the bar in the set,
- swimming speed,
- costs of building the fleet,
- operating and fuel costs.

The basis for any analysis is data specifying the transit depths on a given waterway for a given time interval. The specified time interval is the time to complete a specific voyage *TR* on a given stretch of waterway. Of the many possible cases, three can be distinguished as significant:

- cruise down the river on the route under consideration (G – D) -TR_D,
- cruise up the river (D –G) -TR_G,
- circular cruise down-up-down (D – G – D) - TR_O.

Each of these relations is the specified length of the route in [km]. In the pushed system, it can be assumed that there is no waste of time during loading or unloading. The duration of the relationship can be adopted based on the data of the shipowners who carry out transport on a given route or determine analytically, assuming:

- a specific operating speed,
- effective number of navigation hours for one day.

In this case, the duration is rounded up to full days. When defining it, you can include the so-called technological times, which result from the time wasted on the demolding of the set, its re-formation, or time lost for and for discharging. Examples of the duration of specific relations Wrocław - Szczecin - Wrocław are presented in Table 1, based on data [5]. The data refer to the pushed BIZON + 2xBP500 set. The duration of cruises in Table 1 has been rounded up to the full days.

Table 1 – Trade speeds and durations of Odra flows freely.

Draft T [m]	1.2	1.3	1.4	1.5	1.6
Driving time WR - SZCZ [hour]	38	40	43	46	50
Commercial speed [km / h]	12.63	12.0	11.16	10.43	9.6
Driving time SZCZ - WR [hour]	80	83	87	92	100
Commercial speed [km / h]	6.0	5.78	5.5	5.21	4.8
Time of technological operations [hours]	28	29	30	31	32
Duration of the cruise WR-SZCZ. [days]	3	3	3	4	4
Duration of the SZCZ-WR cruise [days]	5	5	5	6	6
Duration of the cruise WR - SZCZ - WR [days]	8	8	8	9	9
Trade speed in the WR-SZCZ-WR cruise [km / h]	8.14	7.8	7.38	6.96	6.4

If the durations of specific transit depths are known (admissible draft), it is possible to determine how many times a given vessel will perform cruises in a given navigation period. Individual cruises can take place in a certain range of dives:$< T_{min}, T_K >$. T_{min}, this is the minimum immersion at which exploitation is profitable, and T_K is a construction draft that cannot be exceeded. Statistically, it is possible to determine how much cargo a specific unit transports cargo on a given route.

4. EFFICIENCY OF TRANSPORT IN CONDITIONS OF FREE FLAMMABLE DRAINAGE

The analysis was based on data on existing transit depths on the Oder on the Brzeg Dolny section - the mouth of the Nysa Łużycka River in the period from 1980 to 2014. It was assumed that the transit depth in this section determines the draft along the entire length of the Odra River flowing freely. The results presented refer to a round trip on the Wrocław - Szczecin - Wrocław route. The length of this route is 960 km. The analysis was carried out for constant swimming speeds, independent of the current draft and variable speeds consistent with the data [5] (Table 1). This also applies to the duration of the voyage. The range of the analyzed construction dives was: T_{Kmin} = 1 m; T_{Kmax} = 1.7 m

A barge with a design immersion T_K = 1m can not be operated with a larger draft. A barge with a draft T_K = 1.7m can be operated in the range of dives from 1 to 1.7 m. It depends on the current permissible transit depth. Horizontal dimensions of the Bizon + 2xBP500 pushed set were adopted for basic horizontal dimensions. The impact of the following parameters on the performance indicators was analyzed:

- construction draft,
- navigation speed,
- width of the pushed barge,
- length of the pushed barge,
- shape of the pushed train formation and the number of barges in the set.

In the calculation of the efficiency indicators, it was assumed that the cost of 1 kg of the pushed barge construction is approx. 1.28 EUR and the fuel cost 0.303 EUR for 1 litre. The average unit fuel consumption for BIZON class pushers is approx. 250 g / kWh. The above parameters were changed during the test calculations. This did not lead to changes in the general nature of the dependencies obtained. Their impact will not be analysed here.

Figure 1 shows the influence of navigation speed and construction immersion of pushed barges. The calculation of the efficiency index included construction and fuel costs (WP indicator). Fuel costs have been determined based on known unit fuel consumption. At an average speed of 2 m/s, the duration of the circular voyage was 11 days and respectively 9 days at 3 m/s and 7 days at 4 m/s. A clear increase in efficiency with a decrease in swimming speed is obtained. The increase in fuel consumption as the speed increases is of decisive importance here. It is much faster than the increase in the number of cruises in the analysed period of time. The duration of specific dives in% of the number of days of the period considered (20 years) is shown in Figure 2. Duration of life determines the amount of transported cargo.

The amount of transported cargo increases with increasing navigation speed and construction immersion. However, fuel costs determine the efficiency. Hence, in the range of construction dives from 1.5 m to 1.7 m, the efficiency takes almost constant value. In this case, only the load quantity criterion may indicate the choice of the maximum possible draft for a given draft draft of the barges.

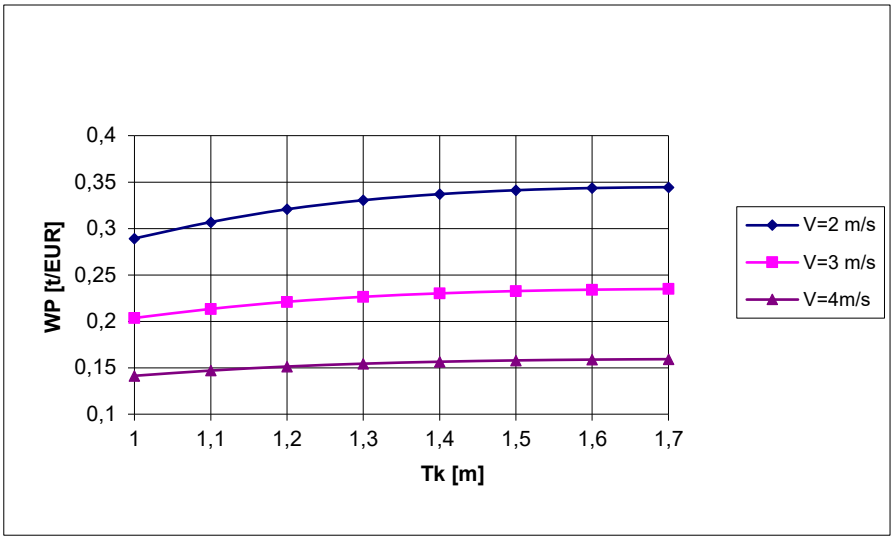


Figure 1 – Influence of navigation speed on transport efficiency (P+2BP, L=45m, B=9m).

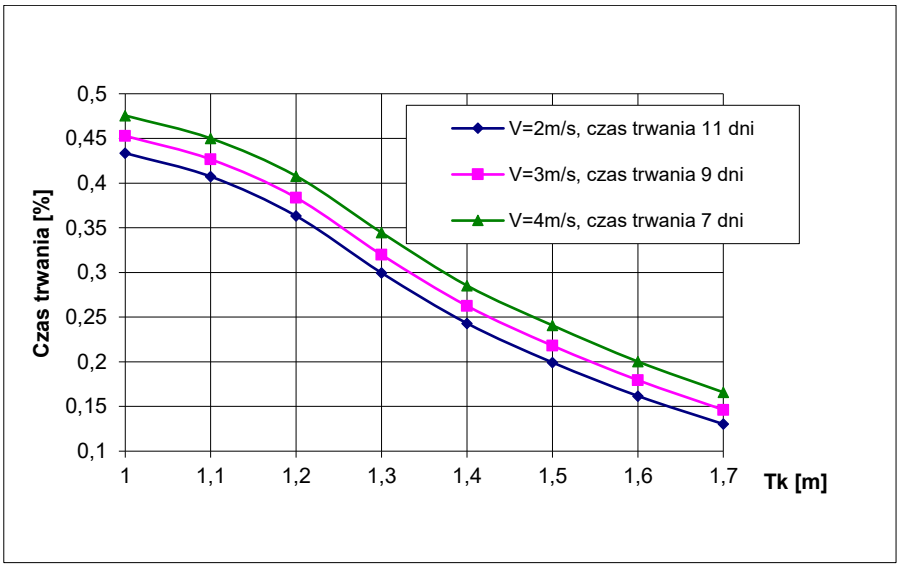


Figure 2 – Depth durations depending on the duration of the voyage and navigation speed.

The navigation speed can be reduced only to a certain limit. It results from the speed of the current of the river and ensuring safety during the movement of the ship. Too low speed causes a decrease in the effectiveness of the steering systems.

Fig. 3 shows the impact of the formation of the pushed set, dimensions of the pushed barge on the efficiency indicator. The indicator includes fleet construction costs and fuel costs. The results of the calculations indicate clear benefits from the use of maximum acceptable structural dives. It is also very advantageous to increase the length of barges in the set, with a fixed width. The prolongation of barges results in more favorable resistance relations as well as an increase in the capacity of barges. The impact of changing the width of the barges is no longer unambiguous. Increasing the number of barges in the set (while maintaining the same horizontal dimensions of the whole set) is not favorable. This is due to the reduction in load capacity which is the result of the LBD product decline (length x width x lateral height), and thus the increase in the weight of the structure and construction costs.

Using the operational data [5], calculations of transport efficiency were made considering the actual fuel consumption figures per flight and the duration of the voyage. These data are included in table 1 and are valid for the BIZON pushed set. They were determined based on operational data in 2014. The

calculations were made for the parameters of the BIZON + 2BP500 set. The results of the calculations are shown in Fig. 4. The obtained indicators (WPP and WP), assume maximum values at the construction draft of TK barges = 1.4m. These results indicate the possibility of obtaining a construction draft in which the transport costs calculated in the long-term can be obtained.

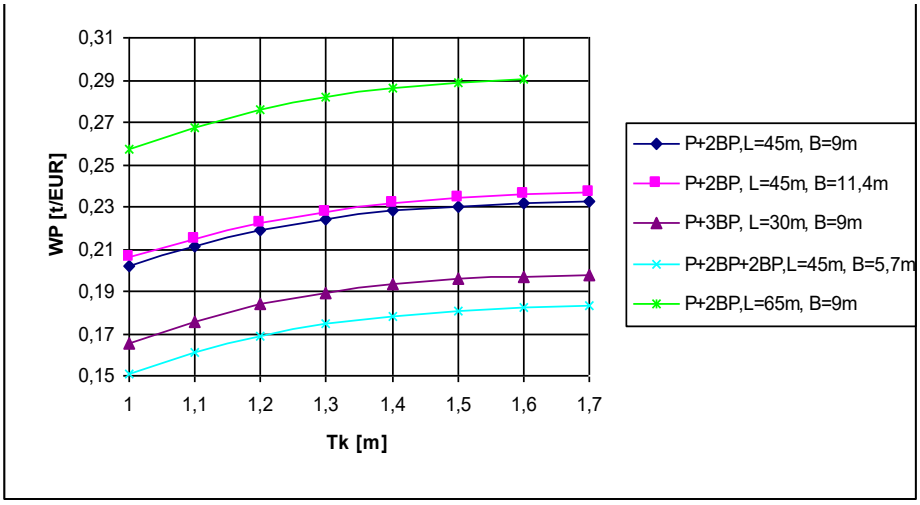


Figure 3 – The impact of the dimensions of the barge and formation of the set on the efficiency of transport.

To ensure the improvement of inland transport efficiency, it is necessary to ensure a constant transit depth. However, this requires modernization and constant monitoring of the technical condition of the waterway. Statistically, considering the transit depths on the Odra, one BIZON-class push-set, at the design immersion of T_K barges = 1.4 m, annually on the Wrocław - Szczecin - Wrocław roundabout, will transport approx. 13 200 tons of cargo. If it is possible to maintain such a set for a whole year with the immersion of T = 1.4 m, then the amount of transported cargo will amount to approximately 33,000 tons. Putting it differently, considering transit times, in the present conditions such a set on the Odra river will use its capabilities only in 26%.

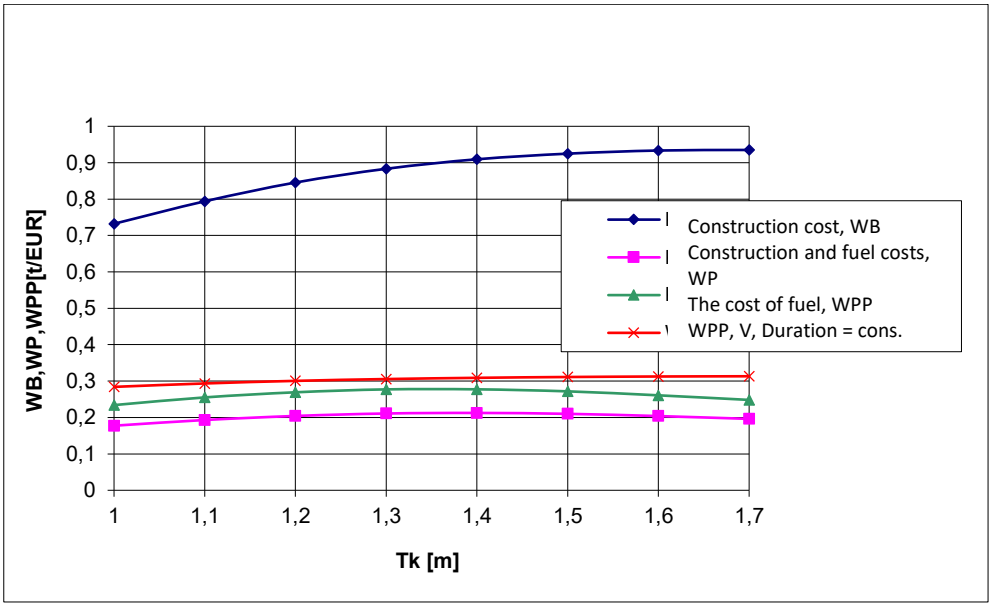


Figure 4 – Transport efficiency considering the actual duration of the relation and the amount of fuel consumption.

4. FINAL CONCLUSIONS

Considering the analyzes and calculations carried out, as well as taking into account the suggestions of shipowners, the essential factor that contributes to the increase in efficiency and competitiveness of inland waterway transport is the assurance of a constant unchanged transit depth at the time. The minimization of transport costs, and thus the increase in efficiency, can be achieved by using the fleet with its dimensions adjusted to the parameters of the waterway. The structural immersion and the length of the motorized barge, the pushed set, are of fundamental importance here. In designing a new fleet, one should strive to adopt maximum values for these parameters. Considering the above, the basic length for pushed berths on the Odra River should be around 60 m long and 70 m for motorboats. If you consider the planned parameters on the Oder connecting channels to the West European road system, the new fleet should have a draft of T = 2 m. ships should be adapted to container transport. For this reason, the wheelhouses of pushers and motorboats should be raised to a sufficiently high height. The structure of the barges should be a free-standing structure, with double sides.

In the case of long vessels, crossing the bend, the forward bow of the barge must be equipped with a bow rudder. At small radii, a solution that can significantly increase efficiency is the use of broken pushed sets. The concept is not new, but at the current level of technology its implementation is possible. This requires preliminary analysis of the behavior of such a set on the bend. This will allow development of a concept to control such a set, as well as the requirements for the construction of connection solutions between the components of the set. Due to the connections with Germany and the Czech Republic - the recommended width should be B = 9 m, and a draft of at least 2 m. The prediction of the quantity and type of cargo that weighs heavily on waterways in this direction is of great importance here

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MARGARETA ŽIVIČNJAK, M.Sc.[1]
E-mail: mzivicnjak@fpz.hr
IVONA BAJOR, Ph.D.[1]
E-mail: ibajor@fpz.hr
MARIJA MATIJEVIĆ, B.Sc. student[1]
E-mail: marija.matijevi@gmail.com
FILIP BUTURIĆ, student[1]
E-mail: filip.buturic@gmail.com
[1] Faculty of Transport and Traffic Sciences, University of Zagreb
Vukelićeva 4, 10000 Zagreb, Croatia

PICK-BY-VISION IN WAREHOUSE USING AUGMENTED REALITY GLASSES

ABSTRACT

In modern highly competitive business environment, the efficiency of warehouses can be critical for the efficiency of the overall supply chains they belong to, because warehouse storage accounts for significant part of logistics costs. As a result, new technologies are being tested and adopted in industry to improve the performance of warehouse operations. Order picking is the typical work pattern in warehouses and its optimization can help boost their efficiency. In this paper, we explore the opportunities arising from the usage of augmented reality in warehouses to support the order picking process as well as the barriers for its industrial implementation.

KEY WORDS

Warehouse; Order picking; Augmented reality; Pick-by-vision; Head-worn display; Smart glasses;

1. INTRODUCTION

Warehouse is part of supply chain where goods or products are stored. The prime goal of the warehouse is to control the flow of products or items. The products must be managed carefully otherwise it may reducing on space, time, and cost. The warehouse storage different types of products to maintain seasonal production, seasonal demand, quick supply, continuous production, price stabilization. The warehouse management system (WMS) is a requisite approach for every warehouse. A computerized warehousing system provides warehouse system less effort. More efficient and stable results are correlated with hand held manual system. The urge for automating the warehouses originates from the fact that manual handling systems may lead to human errors which may affect the warehouse utilization. [1]

According to [2, 3, 4] warehouse processes refer to loading, unloading, packing, order picking, outbound operations and include processes of reverse logistics and a mission of warehouse process to effectively process products at the right time, right place, and right quantity without damages or differentiation. Authors [5] indicate that every process, from receiving until shipping is as well vital, while also order picking is the one that accounts majority of warehouse operating costs and requires the most performing time. According to [6], it is necessary to approach to processes from where the deficiencies can be indicated to analyse and measure effectiveness warehouses processes

Order picking means that workers have to pick stock keeping units (SKU) in a warehouse, according to a work order. Order picking, takes 70 % of time and 55 % of total warehouse costs and that makes it significant process in a warehouse [4]. Considering that the picking as a warehouse process takes the great amount of time and cause the highest operational costs, this paper shows

optimization possibilities by implement solutions in form of the augmented reality smart glasses (ARSG) in warehouses using pick-by-vision technology. ARSG are essentially a head-up transparent display integrating a wearable miniature computer that adds virtual information to what the user sees. The overlaying of virtual information on the real worldview is called Augmented reality (AR) and applying this concept makes it possible to enhance a human's perception of reality. [7]

AR has proven to be useful for providing positioning instructions, both in maps navigation but also in large warehouse facilities for inventory management and package retrieval, facilitating the operators to efficiently manage large facilities with changing stocks (such as the case of logistics warehouses). It is intended to assist warehouse operators in the processes of storage, localization, relocation and collection of SKU - order picking process. The immediate advantage of displaying information on AR devices is a decrease in human errors and optimization the time which is associated with the warehouse processes. [8]

With the emergence of computers systems, the deployment of information and communication technologies has often been suggested as an effective solution for managing warehousing operations. Recently, AR is a technology that has caught the researchers and practitioners attention by its potential to support manufacturing and logistics processes. AR involves the combination of the physical and the digital world in real time through a wearable device and has been recognized as an enabler for industrial cyber-physical systems. [9]

2. ORDER PICKING AUTOMATIZATION

In recent years, with the rapid development of logistics industry and technological progress, automatized warehouse management has also begun to be put on the agenda. Automatic warehouses integrate multiple functions, such as, storage, transportation, delivery, and management, and have many distinctive traits, with mass storage capability, less inhabiting area, fast turnover speed, low dilapidation rate and easy management. They are widely adopted in material supply sections, commercial system, and have become the main components of modern logistic systems and parts of computer integrated manufacturing systems (CIMS). [10]

In the warehouses it is very difficult if the worker wants to locate any product, because worker have to do a detailed search manually in all the available warehouses zones. This requires a lot of effort, so to avoid this problem the WMS is very helpful because it maintains the detailed product information and gives information to the worker in which warehouse zone is the product situated. The automated WMS is an essential replacement for a manual management system. The main purpose of automating the warehouse system is to control the movement and storage of the products, together with the benefit of enhanced security and quicker handling. The warehouse system has become more reliable and efficient after implementing the WMS, simplifying the process for the operators, the supplier and the dealers.

Warehousing management system (WMS) is a necessary approach for every warehouse. An automated warehousing system provides less effort, more efficient, and reliable results compared to manual handled system. [1] WMS is designed to help reduce costs through more efficient warehouse processes.

The need for automating the warehouse arises from the fact that manual handling may cause human errors which may affect the warehouse utilization rate. In order to automate the process, a thorough study on the system should be conducted. The first step towards an automated warehousing system is identifying and reengineering the processes and procedures carried out in the warehouse, followed by identifying the processes that could be automated. Modelling the business processes and workflows helps seeing the process as a whole. [11]

Typically, the process of order picking begins with a paper picking list specifying the location of each type of item, the number of items to be picked, and sequence in which the items will be picked.

A worker collects the items from stock and transports the items to a specific location for later delivery to a customer or to an assembly line. Errors in order picking process can affect customer satisfaction or stop an assembly line. [12] Thus, while picking should be time efficient, it should also be accurate.

Authors [4, 12] define some activities of order picking process, so, 50 % of a picker's time is spent on traveling, 20% searching, 15% picking, 10% in setup, and 5 % performing other activities as indicated in the Figure 1. Research of manual picking systems focuses on optimizing travel time. Besides efficient path planning, orders requiring similar parts may be grouped together (proximity batching). Similarly, items that are normally picked together may be clustered on the shelves (family grouping). In order to avoid picker travel, automation may bring shelves of items to the picker based on the requirements of the order, resulting in a very small pick area. Authors [12] cliam that the picker's travel time has already been optimized. Instead, AR visual guidance (Pick-by-vision) of pick lists has great potential to improve setup, search, pick times and accuracy.

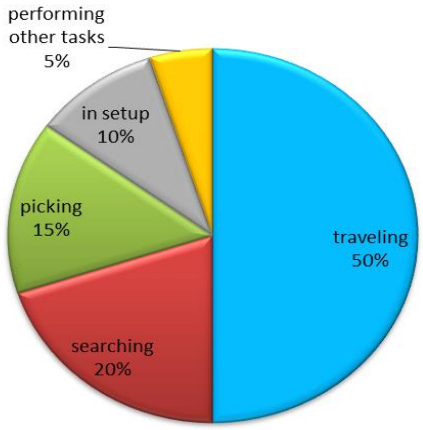


Figure 1 – Picker's activities spent time
Source: Made by the authors according to [12]

To reduce the time needed to pick items once the picker is at the correct storage rack, several task guidance systems are commonly used: text-only paper pick lists (pick-by-paper), illuminated bin indicators (pick-by-light), and audio-assisted picking (pick-by-voice). [13]

Starting from simpler combinations on laser scanners and barcodes, contemporary warehouse operators try to integrate new technologies to facilitate managing available stock in warehouse and effective product localization, especially in larger facilities. Utilising wearables, such as smart watches and head-worn displays, the operators may easily report product input/output in the warehouse, while also retrieve the position of a stored product. Using advanced visualization techniques, such as augmented reality, the operators may intuitively be guided to find a stored product and easily report stock updates. [14]

Pick-by-vision is a new industry augmented reality (AR) task guidance system to visually support the order picking process. Authors [12] defines task guidance systems as "unsensored, computer-based systems which remind a user of the actions required to complete a task." Pick-by-vision system uses head-worn display (HWD), typically AR glasses. The use of a head-worn display showed significant picking speed gains as compared to a traditional text-based pick list, a paper-based graphical pick chart, and a mobile pick-by-voice system. [13]

4. AUGMENTED REALITY

Augmented reality (AR) is a method to add virtual elements, items or information in real time in the physical world. In other words, AR is a technology that can enrich physical reality by overlaying computer-generated information atop the real environment and/or annotating objects and

environments, and which has been suggested as having substantial potential for occupational applications. [15] Augmented reality needs the environment and uses a camera integrated in devices such as Smartphone, tablets, PCs. The term is not constrained to the visual aspect, since it can also include audio or involve other senses of the user. [9]

In logistics in particular, even though the available literature is quite limited, augmented reality is seen as one of the technologies that could bring the "next big wave of change" in the industry. It has also been argued that it can improve the execution of several logistics processes. [9] These processes often require frequent data interactions to complete physical work tasks, for example when planning a work path, identifying item locations and quantities, and arranging goods. [15]

4.1. Smart glasses

A virtual control panel (digital user interface) can be superimposed on the smart product to be operated directly using an AR headset, hand gestures, voice commands, or even through another smart product. Tablets and smartphones were an improvement, but they can distract the worker's attention, needing their hands to operate the device when switching between instructions and the industrial process itself. Head-mounted display (HMD) or head-worn display (HWD) devices overcome such distractions by allowing users to view the information in a hands-free manner whilst simultaneously performing an operation. In addition, the glasses can make use of gestures, touch and voice recognition. [8]

AR head-worn displays (AR HWDs), or simply "smart glasses" (Figure 2), are a wearable AR hardware platform that is attractive for occupational applications, since workers can freely use both hands and move about and easily access task-relevant information in a head-up fashion using either one (monocular) or two eyes (binocular). The potential benefits of AR HWDs have been demonstrated in diverse industrial applications, including warehouse operations and maintenance or assembly. [15]



Figure 2 – Two representative head-worn display (HWD) types: binocular (Left; Epson Moverio BT-200) and monocular (Right; Vuzix M100) HWD
Source: Source: [15]

Augmented reality smart glasses (ARSG) are hands-free devices that present information at eye level, just where it is needed, making them an ideal user interface for an industrial operator. Furthermore, using camera based object recognition, ARSG can detect the specific object the user is looking at, providing context-aware information dynamically adjusted to the specific situation. Equipping operators with ARSG therefore makes it possible to automatically provide the exact information needed, at the right time and place, to handle a specific situation or work task optimally. [7]

It is worth mentioning that other authors [7], after performing a systematic review, point out five key characteristics that smart glasses should have when implementing applications for smart factories:

- The field of view should be as wide as possible, being 30◦ (horizontally) the recommended minimum for a good user experience.

- Since smart glasses are meant to be worn during the whole day, they should be as light as possible.
- Batteries should last through the working day.
- The video-based display technologies should be avoided, since they incur in delays that harm the user experience. Optical and retinal projection are then recommended.
- Voice-based interaction is recommended to free the operator hands, but it is currently a challenge to make it work properly in noisy industrial environments.

In addition, there are different techniques for image recognition. Some are based in traditional AR markers, which usually are square or rectangular markers that contain a high-contrast figure similar to a QR code. These type of markers are usually framework-dependent and the software is, in most cases, optimized to recognize them by means of specific algorithms. On the contrary, natural feature tracking (NFT) techniques extract characteristic points from images. Such points are then used to train the AR system to detect them in real time. NFT techniques have the disadvantage of being more computationally intensive and slower than other alternatives, and less effective at long distances, but they provide a seamless integration of the augmented information with the real world, since there is no need for placing an artificial marker visible in the scene. In order to mitigate the disadvantages of NFT, small artificial markers called fiducial markers are often added to the scene to accelerate the initial recognition, improving the performance of the system and reducing the algorithm computational requirements [8].

4.2. Software development tools for AR

Nowadays, there are many libraries for the development of AR applications, each implementing certain functionalities required in a specific scenario. In general, for the development of an IAR application it is necessary:

- 2D and 3D graphic libraries, which should enable real time visualization and overlapping of virtual elements in the field of view.
- Recognition mechanisms to be able to follow objects or to superimpose information on them.
- Speech recognition, which is very useful when the user is not able to interact with physical controls. Gesture recognition is also useful when ambient noise prevents voice recognition.
- Reconstruction of 3D environments to get an understanding of the surroundings.
- Overlapping 3D virtual elements (with or without AR markers).

All these features should be addressed by the different pieces of an industrial augmented reality (IAR) software development kit (SDK), which is responsible for interacting with the hardware of the device to obtain data from the environment in order to show contextual information to the user depending on the surrounding scenario. The most relevant SDKs for developing AR applications are compared according to several requirements. First, their license type: open-source (i.e., ARToolkit, ArUco, BazAr, UART, OpenSpace3D), free (i.e., ALVAR, Armedia, Vuforia, Wikitude), or commercial versions (i.e., Armedia, Vuforia, Wikitude, ZappCode Creator). Other criteria are the platforms supported (i.e., Android, iOS, Linux or Windows) and requirements about the marker generation, tracking or the overlaying capabilities. Beyond the general requirements explained, the SDK should be compatible with the chosen HMD device (i.e., Vuforia is compatible with Epson Moverio, ODG R-7 and HoloLens). Moreover, the compatibility with Unity should be considered. Unity is currently one of the most advanced game engines in the market and it is possible to use it for developing and deploying IAR applications. Examples of SDKs with this feature are UART, Vuforia, ARKit or ARCore.

4.3. Indoor navigation system for AR

The major technological challenges are the internal registration of the objects displayed by the system, the tracking of visual elements and features (SKUs), and the development of the information display system, a cloud that contains information about each element in real-time. In addition,

rendering (i.e., photometric registration, comprehensive visualization techniques, or view-management techniques) and real-time data processing are also challenging, since their performance is key when inserting graphic elements in the environment in a rapid, consistent and realistic way. Thus, accurate, fast and robust registration and tracking are required to develop AR techniques that allow for determining the position and orientation of the observer and the real or virtual objects. [8]

Internet of Things (IoT) is a vision that permits individuals and things to be associated in a perfect world utilizing any path or any service. The need or urge for this warehouse management system, it is very challenging to track, identify products or objects in big industries. To track any product in a precise span of time it is very difficult.

An indoor navigation system (INS) is a network of devices used to wirelessly locate objects or people inside a building. Instead of using satellites, an INS relies on nearby anchors (nodes with a known position), which either actively locate tags or provide environmental context for devices to sense. INS can be entirely local to your Smartphone (or other portable navigation device). INS, like GPS, can establish a location fix completely passively.

A satellite navigation is a system of satellites that provide autonomous geo-spatial positioning with global coverage may be termed a global navigation satellite system (GNSS or GPS). GPS has two fundamental problems. They don't work indoors and they only really operate in two dimensions. GPS are generally not suitable to establish indoor locations, since microwaves will be attenuated and scattered by roofs, walls and other objects.

GPS and INS are two systems that can complement each other very well. For instance, GPS will guide you from your home to the parking lot of an unfamiliar subway station. From that point, INS will take over and help you find the ticket counter and the correct platform to get where you want to go. Whilst GPS uses satellite technologies, INS is resolved leaning back on large number of available technologies.

Todić, Šimunović and Tomac [16] cited various types of technologies that could be used for locating purposes. Most commonly referred are:

- Infrared (IR)
- Ultrasound
- Bluetooth (BLE)
- Radio Frequency Identification (RFID)
- Ultra Wide Band (UWB)
- Wireless-Fidelity (Wi-Fi).

The IR technology makes it easy to locate devices based on the identification code. However, it is a short-term and requires maintenance, which is not suitable for the location system.

Ultrasound technology based on sound pulses is based on measuring the response time to determine the location but can not compensate for the problem of multi-path signalling and isolate the present noise.

RFID requires labels and readers, enabling fast read / write data communication, but does not include the right location and positioning.

Other option is bluetooth, which provides fast data transfer and has an acceptable range, however, the entire network is portable and location determination may be difficult.

UWB provides high capacity and data transfer rates and has features such as bluetooth and Wi-Fi. The advantage of UWB is that it allows a very precise localization (about 30 cm), but the implementation of such a system is very expensive.

Latest one is Wi-Fi positioning system (WPS). This system usually can be easily installed with the help of the existing Wi-Fi infrastructure. Its main advantage is a partial penetration through facilities which is a major advantage in industrial use.

Nowadays most common are the ones mentioned in the Table 1 shown below. RFID has a short distance range with less than one meter while UWB and Wi-Fi can compete with range of 150 meters at least. RFID is suitable for spot detection with very precise accuracy with astonishing 10 centimeters, UWB is not far behind with less than 30 centimeters, the least accurate is Wi-Fi with 15 meters.

Table 1 – INS technologies and their features

Technology	Area/Spot Detection	Accuracy	Range
RFID	Spot Detection	< 10 cm	< 1 m
UWB	Area Detection	< 30 cm	< 150 m
BLE	Area Detection	< 8 m	< 75 m
Wi-Fi	Area Detection	< 15 m	< 150 m

Source: Made by the authors

The one not listed above is simultaneous localization and mapping (SLAM). It has become a crucial technology in the field of robotics, automation and computer vision. Currently it has been used in such as augmented reality (AR), virtual reality (VR), unmanned ground vehicles (UGV), micro aerial vehicle (MAV) and autonomous driving. This technology is still not explored and developed enough to be used in a larger scale. [17]

So, before an AR system can display virtual objects into a real environment, the system must be able to sense the environment and track the viewer's (relative) movement preferably with six degrees of freedom (6DOF): three variables (x, y, and z) for position and three angles (yaw, pitch, and roll) for orientation. There must be some model of the environment to allow tracking for correct AR registration. Furthermore, most environments have to be prepared before an AR system is able to track 6DOF movement, but not all tracking techniques work in all environments. To this day, determining the orientation of a user is still a complex problem with no single best solution. {Formatting Citation}

Such techniques can be classified into:

- Techniques based on sensors (e.g., Inertial Measuring Unit (IMU), GPS, infrared, ultrasounds).
- Image-based techniques that make use of markers, which can be synthetic or natural.
- Sensor and image fusion techniques. [8]

5. OPPORTUNITIES AND BARRIERS OF AUGMENTED REALITY ADOPTION IN ORDER PICKING

In order picking tasks, workers collect sets of items from assortments in warehouses according to work orders. They deliver them to the next station in a precisely designed material flow process. The efficiency of such picking processes can be evaluated by measuring of four interleaved tasks: the base time for getting the next order information, the dead time during which a worker interprets and understands the order as a 3D navigation and picking task, the way time during which the user physically moves to the selected item and the picking time to actually grab the item. The base time, the way time and the picking time have already been subject to many process optimizations. The only time component which we can optimize with a Pick-by-Vision system is the dead time. [18]

Authors [9] define potential uses of augmented reality in the order picking process:

- Inform an operator about a new task allocated to him,
- Display picture and details of the item to be picked,
- Display the storage location of the item to be picked,
- Display picking route,
- Highlight the physical location with the item required Inform about errors and disruptions,
- Scan the item's barcode to assign to picking cart or to see more information,
- Highlight where to put each item on the picking cart for sorting while picking,
- Give information to prevent congestion in aisles Monitor picker's condition and performance.

In a simulated warehouse setting, Kim, Nussbaum and Gabbard [15] examined the effects of different HWD types and UI (user interface) designs (i.e., information modes and information availability) on job performance, workload, usability and visual discomfort. Their results suggest that job performance, workload, and usability were more affected by UI designs than the HWD type. An improvement in these outcomes was observed with specific UI design conditions, such as the graphic-based UI and/or the always-on condition.

Compared to the baseline paper pick list condition, using an HWD, especially with the graphic-based UI, led to improved job performance and reduced perceived workload, while causing increased discomfort (i.e., higher mean SSQ response values).

Information presentation mode and availability affected job performance, as measured by job completion time and/or the number of errors, regardless of HWD type (Figure 3). The graphic-based User Interface (UI) design reduced job completion time and the number of errors on average by 13% and 59%, respectively, as compared to the text-based UI design. In addition, using this design with information always-on (vs. on-demand) led to a 4% reduction in job completion time. These performance gains may be explained by: 1) a higher efficiency in confirming information on the screen, which is congruent with the physical work setting, compared to the text-based UI; and 2) the relatively lower perceived workload with the graphic-based UI design and the always-on display, excepting the NASA-TLX Physical Demand subscale (Figure 4). Responses to the workplace cognitive failure scale also indicated a lower risk of cognitive failure specifically with the graphic-based UI design with always-on display.

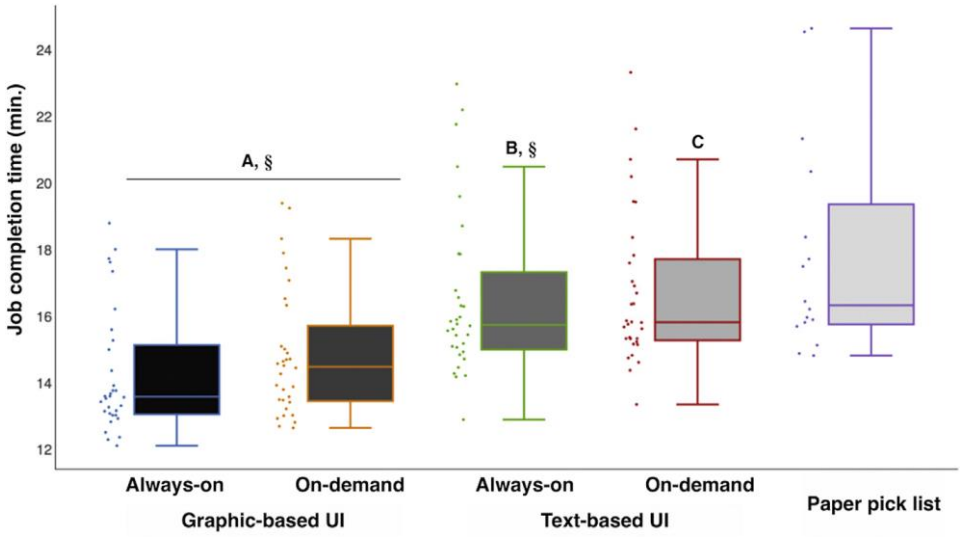


Figure 3 – Interaction effects of Info Mode (graphic-vs. text-based UI) and Info Availability (always-on vs. On demand display) on job completion time
Source: [15]

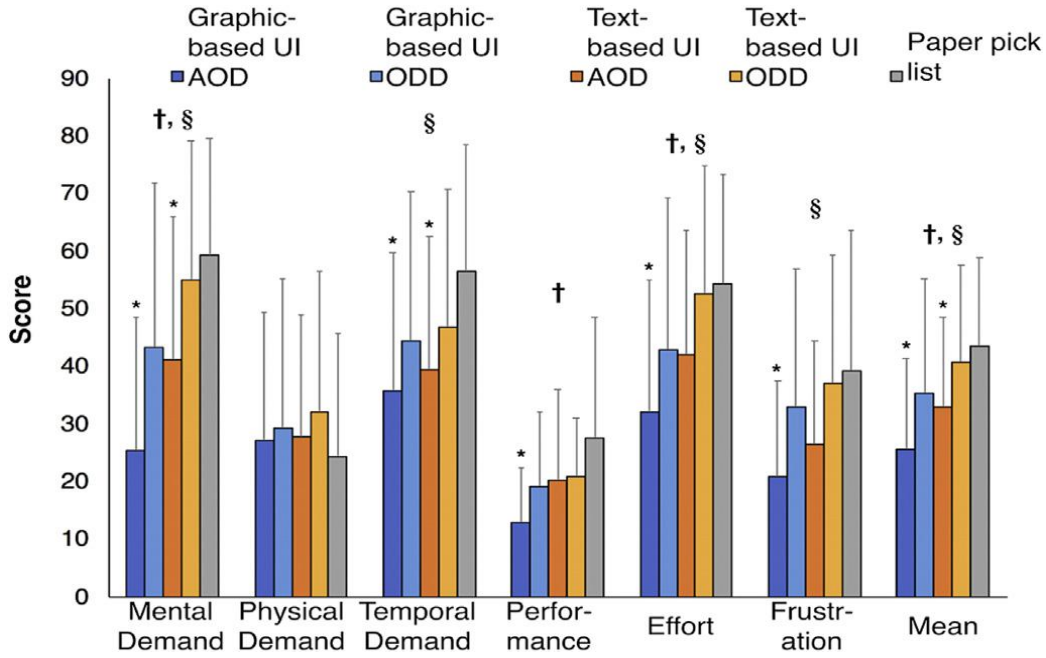


*Figure 4 – Summary of NASA-TLX subscale and mean scores. Note that error bars indicate standard deviations. For a given scale, † and § respectively indicate a significant difference between levels of Info Mode (graphic-vs. text-based UI) and Info Availability [Always-on (AOD) vs. on-demand display (ODD)]; * indicates a significant difference compared to the baseline condition for a given NASA-TLX subscale.*
Source: [15]

Different HWD types and User Interface (UI) designs (i.e., information mode and availability) may affect warehouse workers. A majority of users preferred having graphic-based information constantly visible on the HWD. This preferred condition led to increased job performance and reduced perceived workload as compared to the use of text-based information (particularly when that is visible upon request), or the use of a traditional paper pick list. While user feedback revealed relatively consistent opinions about information mode and availability, no such consistency was found regarding HWD types. Their results, however, support the potential for occupational use of HWD technology, while highlighting the importance of UI design practices in achieving this potential. However, walking while processing visual information presented via HWD or more generally distracted walking (e.g., performing a cognitive task, texting while walking) may cause gait adaptations such as using more conservative and hesitant gait, and more conservative obstacle crossing strategies. Thus, occupational HWD use may have important workplace safety implications given to the prevalence of slips, trips and falls-related injuries. Given this, and the limitations discussed above, future efforts are needed to investigate how different HWD types and UI designs may affect worker safety (e.g., gait adaptations, distracted behavior) and work performance with routine or frequent use in a workplace, and also to understand better the impacts of HWD use on diverse working populations over time. [15]

Syberfeldt, Danielsson and Gustavsson [7] identified five topics that particularly merit further examination to ensure the successful implementation of ARSG on the industrial shop floor:

- Extending the field of view (the natural human field of view is almost 180 degrees horizontally, but the widest field of view of today's off-the-self ARSG is only 46 degrees)
- Making the glasses wearable (reducing the weight, eliminating cables, and designing products usable by people with visual defects)
- Developing guidelines for user interface design
- Improving voice-based interaction in noisy environments (the most common way to implement hands-free interaction is through voice commands).

6. CONSLUSION

As indicated in the paper there are scientific researches on AR application in the logistics and warehouse processes. Because order picking takes 70% of time and 55% of total logistics costs this process need optimization. Order picking optimization is an ever existing challenge that highly affects the efficiency of the warehouse.

It is necessary to design and plan a warehouse, which initiates from inventory control and warehouse management. The capabilities of the warehouse management system have been upgraded ever since development of modern technologies had begun to increase rapidly.

Adopting AR technology in order picking has great amount of positive effects, such as accuracy, time improval and, as a result, cost decreasing. Picking times were significantly faster using the Pick-by-vision AR glasses over all of the other picking methods. The AR supports graphical hands-free guidance which allowed users to combine the benefits of the graphical paper and audio picking methods in a single device.

For future work, a more throughout analysis of the ARSG design has be done to insure secure, flexibile and ergonomical use. Also, software development tools and indoor navigation systems must be improved. This review reveals that considerable work remains to be done before ARSG are really ready for mass adoption in the order picking processes.

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