Трета Меѓународна Конференција
„Транспортот во денешното општество“

Зборник на трудови

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- Department of Traffic and Transport -

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Трета Меѓународна Конференција
"Транспортот во денешното општество"

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Почитувани колеги,

2020 беше година во која присуството на научните конференции од страна на истражувачите, лицата инволвирани во креирање на политики, како и колегите директно вклучени во праксата, беше нарушено.

Имено, поради пандемијата со корона вирусот и мерките кои се превземаа со цел да се намали ширењето на болеста, бројни научни конференции ширум светот беа откажани. Во такви услови, институциите бараа альтернативни начини за организирање на ваквите настани.

Следејќи ги правилата во однос на заштита од covid 19, конференцијата „Транспортом во денешно инженерство“ закажана за мај 2020 година, беше одложена за октомври 2021. При тоа, Техничкиот факултет во Битола се одлучи за дводневна конференција организирана на хибриден начин. Дополнително, тоа беше и добра пригона за обележување на много значаен настан во развојот на Факултетот, 60 години од неговото формирање.

Фокусот на Конференцијата беше насочен кон повеќење на истражувањата, креирањето на политики и праксата во транспортното инженерство. Во текот на првот ден, настанот беше организиран со физичко присуство, во просториите на Факултетот, додека вториот ден програмата беше реализирана во целост „online“.

Двајцата пленарни предавачи имаа голем придонес за Конференцијата. Почетокот на настанот беше означен со поздравниот говор на Дипл.инж. Sebastian Belz, Генерален Секретар на Европската Платформа за Транспортни Науки. Тој исто така го одржа пленарното предавање на тема „Дали дигитализацијата ја има клучната улога во државата мобилност?“ Со фокус врз дигитализацијата и нејзиното влијание врз подобрувањето на транспортната одржливост, во предавањето беше анализиран предизвиците кои се резултат на дигиталната трансформација во транспортот.

„Што претставува Европската Унија? Транспортните студии и истражувањата како мотор во интеграцијата“, е насловот на второто пленарно предавање, презентирано од Професор Laurent Guihéry од CY Cergy Универзитетот во Париз. Основна цел на презентацијата беше да се потенцира важноста на транспортните студии во процесите на пристапување кон Европската Унија.

Транспортното инженерство се сосочува со многу предизвици. Оваа Конференција беше посветена на тековните прашања, како и на најновите научни настани во транспортот. Основна цел на презентацијата беше да се потенцира важноста на транспортните студии во процесите на пристапување кон Европската Унија.

Вонреден професор Норберт Павловиќ од Сообраќајниот факултет во Белград, Универзитет во Белград, одржа предавање под наслов „Истражување на параметрите кои влијаат врз безбедноста на железничките премини“. Основната цел беше да се потенцираат грешките на возачите во железничките премини и одлуката за нивно преминување. Беше заклучено дека е потребно истражување на причините за настанатите грешки, како и анализа на едукацијата на возачите во обид да ги променат на начинод на работа на опремата и моделите за безбедност во железничките премини.

Вонреден професор Едоуард Ивањко, Факултет за сообраќајни науки во Загреб, Универзитет во Загреб, го презентираше предавањето „Развој на адаптивни сигнални системи за контрола во урбаните средини“.

При тоа беше посветено внимание на пентата генерација на адаптивни сигнални системи за контрола и потребата за вклучување на човечкиот фактор во управувањата и контролите во непредвидени околности.

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Миле Милковски, координатор за развој на партнерства од компанијата ToMToM, го одржа предавањето „Прецизни локациски технологии“, фокусиран кон начинот на подготоувка на податоците за анализи на патиштата, резултатите од производите, како и презентација на примери од клиентите.

Ваквите конференции претставуваат многу добра можност за поврзување на академскиот кадар, лицата вклучени во праксата, студентите и останатите чинители, (преку непосредна комуникација или на далечина), а со цел, дискусија за тековните и унапред забележани во одредено научно поле, како и начините за нивно решавање. Во таа насока, 55 трудови со две позитивни рецензии, (една од домашен рецензент и една од рецензент од странство), пријавени од колегите од различни држави во Европа, беа прифатени и вклучени во програмата на Конференцијата. Исто така, согласно нивната содржина, трудовите беа распределени во 9 области во рамките на транспортното инженерство.

Пријавените трудови обработуваат важни прашања од транспортното инженерство, а како последица на интеракцијата помеѓу социјалните, техничките и економските системи, заедно со нивната адаптибилна и одржлива интеграција во природната и дополнително изградената околина.

Присуството на студентите на конференција кои се однесуваат на нивното поле на студирање е многу важно. Тоа беше препознавено од страна на Технички факултет и посебна студентска сесија во рамките на Конференцијата беше организирана. Дадената можности беше искористена од страна на студентите од различни држави на Факултетот. Имено, 6 постери презентации поврзани со најновите сознанија и прашања во транспортното инженерство кое се предмет на настанот кои биле истражување, без претставени. Презентациите се исто така дел од Зборникот.

Успешната реализација на една конференција подразбира огромна работа и ангажирање на голем број на луѓе. Техничкиот факултет се заблагодарува на професорот и вклучување на професорите, лицата од праксата, студентите, колегите и гостите во организацијата на истата. Дополнително, изразуваме благодарност до целокупниот тим кој беше вклучен во нејзината подготовка.

Се радуваме на повторната средба на следната конференција „Транспортот во денешното општество“, која, се надеваме, ќе се одржи со физичко присуство, во услови во кои сме навикнати да живееме.

Во име на Технички Факултет Битола
Професор д-р Марија Маленковска Тодорова
Dear colleagues,

2020 was a year when attendance to scientific conferences by researchers, policymakers and practitioners was heavily disrupted. 
Namely, because of the coronavirus pandemic and measures undertaken to reduce the spread of the disease, numerous scientific conferences all over the world were cancelled. In a situation like that, the institutions were scrambling to find alternative ways for organizing such kind of event.

Following the new covid 19 rules, the “Transport for Today’s Society” Conference scheduled for May 2020, was postponed for October 2021. Therefore, the Faculty of Technical Sciences in Bitola has shifted the conference in-person to a two-day hybrid event. In addition, it was a good opportunity to celebrate an important milestone in the Faculty’s history, the 60th anniversary of the Institution.

The focus of the Conference was directed towards linking research, policy and practice in the field of traffic and transportation engineering. During the first day, the event was organized in “live”, on the premises of the Faculty, while the program on the second day was fully online.

Two keynote speakers have an outstanding impact on the Conference. The opening speech of the event was given by Dipl.-ing. Sebastian Belz, Secretary General of the European Platform of Transport Sciences. In addition, he held a keynote lecture, titled "Does digitization play a key role for sustainable mobility?" With a focus on digitization and its influence on improving transport sustainability, challenges regarding digital transformation in transport were addressed.

“What does the European Union mean? Transportation studies and researches as a motor of integration” is the title of the second keynote lecture, presented by Professor Laurent Guihéry from CY Cergy Paris University. The main goal of this presentation was to emphasize the importance of transportation studies in the processes of joining the EU.

Transport engineering is facing many challenges. This Conference is addressing current and future issues, and as organizers, we were fortunate to have such distinguished three guest lecturers from the region with us for these two days.

Associate Professor Norbert Pavlovic from the Faculty of Transport and Traffic Engineering in Belgrade, University of Belgrade, delivered the lecture titled “Research of parameters influencing the safety at level crossings”. The main goal was to emphasize the failures made by the road vehicle drivers in the process of approaching the level crossing and making the decision to cross it. It was concluded that it is necessary to investigate the reasons for making failures, as well as the drivers’ knowledge regarding the way of operating traffic safety devices at level crossings.

Associate Professor Edouard Ivanjko, Faculty of Transport and Traffic Sciences in Zagreb, University of Zagreb, presented the lecture “Development of Adaptive Traffic Signal Control Systems for Urban Environments”. The attention was given to the fifth generation of Adaptive Traffic Signal Control systems and the necessity for human supervision and intervention in unforeseen circumstances.

Partner development coordinator Mile Milkovski, from the ToMToM company, held the lecture “Precise location technologies”, focused on the way of building road analytics data, the outputs presented in products, as well as using cases of customers.

Conferences such as this, provide an excellent opportunity for academics, practitioners, students and others to come together, (in-person or remotely), discuss current and future challenges in a particular scientific field and how to address them in the best way. Therefore, colleagues from different countries in Europe submitted their papers and 55 articles with two positive reviews, (one from a domestic reviewer and one from abroad), were accepted and included in the Conference programme. In addition, according to the contents, they were divided into 9 topics within the field of transport engineering.
The submitted papers are addressing significant issues facing transport engineering, at the intersection of social, technical and economic systems, altogether with their adaptive and sustainable integration to natural and built environments. Such a kind of conferences is the bases for the professional development of engineers and scientists needed to meet the requirements of providing sustainable, smart and resilient transportation systems.

Attendance of conferences related to the study field is vital for students. This was recognized by the Faculty of Technical Sciences and special students’ session was organized within the Conference. The given opportunity was used by the students from different Faculty departments. Accordingly, 6 poster presentations related to the current state of the art and issues in transport engineering that should be further explored, were prepared and presented. They’ve been also part of these Proceedings.

It’s obvious that a huge amount of work by many people is needed to conduct a successful Conference. Therefore, the staff of the Faculty of Technical Sciences would like to express their gratitude for the personal interest and involvement of teachers, professionals, students, colleagues and guests in the process of realisation the Conference. In addition, thanks to the entire support team behind the preparation of this event.

Looking forward to seeing you at the next Transport for Today’s Society Conference which, hopefully, will be held in-person, in circumstances we are used to living in.

On behalf of the Faculty of Technical Sciences in Bitola
Prof. Marija Malenkovska Todorova, PhD
Организацијски одбор

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*ATTACHMENTS*
Транспортно планирање и политики
Transport Planning and Policy
How to determine KPIs in Multi-Annual Infrastructure Contract – Case Montenegro

Branislav Bošković¹, Mirjana Bugarinović¹, Nikola Stojadinović¹ and Milan Bankovic²

Abstract – The transition to a contractual relationship between government and Infrastructure Manager under Directive 2012/34/EU requires the possession of contract management skills and the development of key performance indicators (KPIs). Previous activities related to the Multi Annual Infrastructure Contract (MAIC) have been exclusively in the field of the Annual Infrastructure Maintenance Program implementation (railway maintenance, public procurement, and supervision of civil works implementation). However, under Directive 2012/34/EU it is necessary to introduce a system of performance indicators for upgrading/modernize infrastructure to obtain value for money. The paper presents a systematic approach in determining the KPIs and their merits on the example of a contract between the Government of Montenegro and the Railway Infrastructure manager of Montenegro (ŽICG JSC) with the aim to improve the operation and quality of services of ŽICG JSC and the condition of railway infrastructure in Montenegro as well.

Keywords – Key performance indicators, railway infrastructure Multi-annual contract.

I. INTRODUCTION

With publication of Directive 2012/34/EU, both the state and the infrastructure manager are forced to have a long-term view of the railway infrastructure by signing a multi annual contract (Multi Annual Infrastructure Contract - MAIC) [1]. The MAIC now becomes the central document (responsibilities, operation, management) of the infrastructure manager and the mechanism by which the Government provides the infrastructure manager with medium-term financing. Infrastructure financing must be in accordance with its operation, network size and maintenance requirements that correspond to traffic safety and user needs as well as to enable infrastructure modernization. With MAIC therefore are defined the level of financial assistance that a government allocates for the maintenance of public railway infrastructure and the regulation of railway traffic over a longer period. On the other hand, the infrastructure manager must provide value for the money received, ie. it is obliged to fulfill the specific conditions of the contract related to the business, performance (level of maintenance) of the infrastructure and the quality of services that provides [2].

The above said is defined through the so-called key performance indicators (KPIs) and their target values for each year of the contract separately. The subject of this paper is precisely the answer to the question which KPIs should be considered, how they should be defined on the example of infrastructure managers in Montenegro - Railway Infrastructure manager of MontenegroJSC (ŽICG).

In other words, the question arises as to how to determine the KPIs related to the performance of the infrastructure and the quality of services to be fulfilled by ŽICG for the money received through MAIC.

II. LEGAL FRAMEWORK FOR PERFORMANCE AND KEY PERFORMANCE INDICATORS

According to Directive 2012/34/EU, in Article 30 and Annex V of this Directive [1] and in the draft Railways Law on of the Republic of Montenegro [3] are defined all mandatory elements of MAIC as well as service quality performance for which it is necessary to determine criteria and indicators. These are the following performances:
- train performance, such as in terms of line speed and reliability, and customer satisfaction,
- network capacity,
- asset management,
- activity volumes,
- safety level,
- environmental protection.

For all these infrastructure performances, it is necessary to formulate key performance indicators and determine their target values. This is not easy because the KPU should be measurable, and their target values should be in correlation with the state of infrastructure, needs of infrastructure and allocated financial resources, and on the other hand to represent the work of ŽICG management (i.e., give an answer to the question of how well ŽICG meets the set operational and strategic goals of development of railway infrastructure of Montenegro).

III. KEY PERFORMANCE INDICATORS

To defining performance indicators, the authors were guided by the fact that KPIs, together with their relative importance, should represent the performance of infrastructure provided by the legal framework, consider the actual state of the railway network and its primary problems to be solved, user requirements in terms of performance, plans and possibilities of the state of Montenegro in financing the railway

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infrastructure, i.e. the needs and influential factors at this moment. The goal is that both sides (Government and ŽICG) through the given indicators, their target and realized values manage the railway infrastructure in accordance with the defined policy and strategy of transport and railway development [4], i.e. the needs of the economy and citizens of Montenegro.

As a result of the above guidelines in determining the KPIs, the following 4 groups of indicators have been defined (Table 1):

- availability, quality, and maintenance of railway infrastructure,
- utilization of railway infrastructure,
- safety, and
- productivity of infrastructure managers - ŽICG.

**TABLE 1: KEY PERFORMANCE INDICATORS FOR MAIC BETWEEN THE GOVERNMENT OF MONTENEGRO AND ŽICG**

<table>
<thead>
<tr>
<th>Associated area and key performances indicators (KPIs)</th>
<th>1. Availability, quality and maintenance of railway infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Ratio of planned and realized lost train kilometers due to line closure</td>
<td></td>
</tr>
<tr>
<td>1.2. Number of speed restrictions on main lines</td>
<td></td>
</tr>
<tr>
<td>1.3 Coefficient of length of speed restrictions on main lines</td>
<td></td>
</tr>
<tr>
<td>1.4 Number of interferences on signalling and telecommunication devices</td>
<td></td>
</tr>
<tr>
<td>1.5 Average duration of interference on signalling and telecommunication devices</td>
<td></td>
</tr>
<tr>
<td>1.6 Percentage of the railway network maintenance plan realization</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Utilization of railway infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Increase the volume of traffic</td>
</tr>
<tr>
<td>2.2 Efficiency of using international line Bijelo Polje – Bar and Podgorica – Tuzi</td>
</tr>
<tr>
<td>2.3 Efficiency of using regional line Podgorica – Nikšić</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Total number of train collisions and slippage</td>
</tr>
<tr>
<td>3.2 Number of accidents at level crossing</td>
</tr>
</tbody>
</table>

The following section will briefly describe the KPIs and reasons for introducing these KPIs.

**A. Key performance indicators for availability, quality and maintenance of railway infrastructure**

In this phase of development and condition of the railway infrastructure in Montenegro, which is characterized by many speed restrictions and interruptions in traffic due to the reconstruction and maintenance of the network, as well as system failure, six indicators have been defined in this group.

**Indicator 1.1.** - Ratio of planned and realized lost train kilometers due to line closure. The indicator refers to the ratio of planned lost train kilometers due to planned line closures (interruption of traffic) during the reconstruction and maintenance of the network and realized train kilometers due to the actual duration of line closure for one year. The goal of this indicator is to stimulate the improvement of traffic conditions during the execution of works at line and at the same time consistent execution of works according to the planned dynamics and deadlines, i.e. to increase the supervision and influence on the contractors, regardless of whether it is an external contractor or a ŽICG as a contractor (ongoing maintenance).

**Indicator 1.2.** - The number of speed restrictions on main lines is defined as the difference between the number of newly speed restrictions in one year and the number of eliminated speed restrictions by executing defined plans of all types of maintenance to reduce the number of speed restrictions on network.

**Indicator 1.3.** - Coefficient of length of speed restrictions on main lines. This indicator is complementary to the previous one, considering that not only the number of speed restrictions is relevant, but also their length on the main lines. It is defined as the quotient of the total length of speed restrictions and the total length of main lines.

The number of speed restrictions and the coefficient of speed restrictions reflect the current quality of infrastructure maintenance as well as the assets management (open track, station tracks and stations).

**Indicator 1.4.** - Number of interferences on signaling and telecommunication devices. This indicator refers to the number of train traffic disturbances caused by failures on signaling and telecommunication devices for traffic management as well as on traction facilities.

**Indicator 1.5.** - Average duration of interference on signaling, telecommunication devices or catenary. This indicator is complementary to the previous KPIs and refers to the time that...
elapses from fault detection to troubleshooting (average duration of interferences on signaling and telecommunication devices for traffic management as well as on traction facilities).

Indicator 1.6. - Percentage of the railway network maintenance plan realization refers to the % realization of the Annual program of construction, reconstruction and maintenance of railway infrastructure, organization and regulation of railway traffic. Execution of the maintenance plan requires from the top and operational management of ŽICG good organization and management of the maintenance process both in depth and in breadth of the organizational structure of the company. This indicator is very representative for the owner (Government of Montenegro) and indicates the capacities of human resources and organization of infrastructure managers. Also, the indicator indicates the degree of correlation between the plans, allocated funds and capacities of ŽICG and the measures that need to be taken in order to harmonize the funds, capacities and plans. The indicator will stimulate and at the same time force the management and employees of ŽICG in these jobs to dedicate themselves to increasing efficiency, better understanding of their own capabilities and places that are bottlenecks in the maintenance process, as well as better planning. Essentially, this indicator should be correlated with the indicators related to the number and length of interferences.

B. Key performance indicators of railway infrastructure capacity utilization

According to Directive 2012/34/EU, it is necessary to define performance indicators for "network capacity" and "activity volumes". Due to the closeness and close connection between these two performances, they are classified in one group called "utilization of railway infrastructure capacity". The following indicator is given for this integrated performance: the indicator of increase of volume of traffic (for the activity volumes) and the indicator of the Efficiency of using international line (for the network capacity).

Indicator 2.1. – Increase the volume of traffic. Having in mind that for the infrastructure manager the basic product that sells capacity (railway infrastructure) is measured in “train km”, this is the basic goal of increasing revenue from capacity sales. There are numerous reasons why the volume of income is not taken in any EU country as indicator, but the volume of traffic is, and it was proposed for ŽICG as well. It is calculated as the difference between the realized total train kilometers in the current year and the total train kilometers in the previous year divided by the total train kilometers realized in the previous year and is expressed in %.

Indicator 2.2. – Efficiency of using international line Bijelo Polje - Bar and Podgorica - Tuzi. This is an indicator that refers only to international lines i.e., Bijelo Polje-Bar and Podgorica-Tuzi, where it is possible to influence the competitiveness of railways by ŽICG in cooperation with operators. It is expressed in the number of train kilometers per 1 km of main lines.

C. Safety key performance indicators

In terms of safety, we proposed two indicators covering two types of extraordinary events: train collisions and train slippage as one category of emergencies involving exclusively railway vehicles, and second indicator - road crossing accidents which involving road vehicles. These are indicators which the responsibility is not only ŽICG, but also the state as the owner and as one of those responsible in the safety chain. The state level should interest in the trend in whole sector not by the participants.

Indicator 3.1. - Total number of train collisions and slippage. It is expressed by the ratio between the total number of collisions and slippage of trains and the total train km realized on the network.

Indicator 3.2. - Number of accidents at level crossing. It is expressed in the number of accidents per year per 1 train km with the aim of reduction.

D. Key performances indicators of ŽICG productivity

Indicator 4.1. – Productivity. Labor productivity is expressed by the ratio of total realized train km per year and the average number of employees during the same year with the aim of increasing. ŽICG's productivity should be an expression of the vision of what infrastructure manager the Government wants to see and wants to: stable with good financial and other business indicators, capacities that meet market needs, with competitive service, adequate organizational structure, etc.

Indicator 4.2. - Coverage of operation expenses by track access charges income. One of the basic objectives given in Directive 2012/34/EU is for infrastructure managers to manage their costs and to strive to cover operating costs with track access charges revenues. The goal of introducing this indicator is for ŽICG to have a look from that perspective, to manage the infrastructure in a commercial manner and take measures in that direction. It is calculated as the ratio between total track access charges income and total operating expenses. In addition to the mentioned KPIs that will be covered by the contract, it is proposed that ŽICG introduce internal monitoring of results for an additional two indicators. Those are:

- average revenue per kilometer of route charged and
- average costs per kilometer of the route charged.

Revenues and costs are the basic measures of business results, and the kilometer of the route charged is the basic output unit for using the infrastructure capacity. By reducing revenues and costs to a basic output unit, a better insight is gained into how much and how ŽICG earns and spends funds on the realization of one basic output unit and what trends are present. These are indicators that will enable a better understanding and adoption of the company's goals and take effective measures for good governance [5]. After the first observations, a decision can be made to include these indicators in the contract itself.
E. KPIs target values determining

It is proposed to use the following criteria to determine the target values of the KPIs:
- the sum of the available state compensation volume and the expected revenue of ŽICG from track access charges for the use of railway infrastructure for the observed year;
- the relationship between the realized values of the KPIs during the previous year and the volume of financing available to ŽICG during the given year;
- projects pipeline and activities list within the management of railway infrastructure, in accordance with the valid strategic documents of Montenegro;
- market prices of key raw materials, labor and energy in Montenegro at the time of negotiations, as well as projections of their movement in the year to which the Annex refers;
- ratio of the value of reconstruction works of the existing and construction of new railway infrastructure allocated to the ŽICG on the basis of the same Annex in the amount of State compensation for the given year, as well as possible impact that these works may have on productivity, regularity and safety of railway infrastructure in the given year;
- the dynamics of completion and commissioning of projects carried out outside the scope of this Contract, taking into account the expected impact of such projects on the productivity, maintenance and safety of railway infrastructure.

When the competent Ministry of Transport harmonize with ŽICG all performance indicators, including the method of their calculation, it is necessary to collect data for their budget for the previous relevant period as a basis for defining the target values of the KPIs for the next year. At the same time, it is necessary to consider the volume of planned funds in relation to the previous period. KPIs target values should be checked and adjusted in MAIC for each year and determined by the annex to the contract.

IV. CONCLUSION

The multi-annual contract on railway infrastructure, in its essence, represents a financial arrangement between the Government of Montenegro and the ŽICG. The purpose of this contract, seen by the Government, is to get value for the money invested, and on the part of ŽICG to provide safety and predictability of financing in the long run, i.e., the stability of financing. This contract requires ŽICG to manage the infrastructure in a commercial manner, meeting the expectations of users (train operators and end users) in terms of quality, reliability, and flexibility. Therefore, the adoption of commercial principles in business by ŽICG is now a condition for the provision of assistance by the Government of Montenegro, unlike the previous period (until the contractual relationship) when availability and capacity were the primary requirements. To meet the previous objectives, key performance indicators are introduced that the infrastructure manager needs to meet in the management of infrastructure and traffic and in maintaining the level of quality of infrastructure and traffic as well. The areas that need to be covered with indicators are defined by EU regulations, but the introduction of specific indicators depends on the current state of infrastructure and the amount of funds allocated by the governments for railway infrastructure. The definition of the KPIs for ŽICG has just started from the existing, i.e basic conditions in which the railway sector and infrastructure of Montenegro are located. Thus, 13 key performance indicators presented in this paper were set up.

Establishing the target values of the KPIs is currently the subject of negotiations between the Government of Montenegro and Ministry of Capital Investment and the authors plan to follow up with this topic in that direction.

ACKNOWLEDGEMENT

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REFERENCES

Assessment of External Transport Costs from Air Pollution in Republic of North Macedonia

Zoran Krakutovski¹, Darko Moslavac², Goran Mijoski³ and Aleksandar Glavinov⁴

Abstract – The objective of this paper is to present the assessment of external transport costs in Republic of North Macedonia from air pollution. Externality is a cost or benefit that is transferred and affects other parties that are not directly related to the project, but they are not financially compensated. The approach for evaluation of monetary values of transport air pollution is based of estimation of these costs in relevant EU studies.

Keywords – External costs of transport, air pollution

I. INTRODUCTION

Externality (or external effect) is a condition that occurs in production or consumption activities of a given entity that affect the welfare of another entity(s) without paying compensation for that effect. One externality has two important characteristics. On the one hand, externality creates a secondary effect that is seen as an external consequence of the main production or consumption activity, and on the other hand, the interaction between the creator and the recipient of that effect is not accompanied by any market exchange. Environmental pollution is a typical example of negative externalities. Transport activities greatly affect the quality of the environment and the quality of life of humans and animals. This is an interest for studying the externalities of transport and particularly to focus on how to reduce these negative externalities. This paper will consider the external costs of transport, their significance and their monetary value in Republic of North Macedonia. Reference documents of European Union are used in assessment methodology.

II. PREVIOUS ASSESSMENT OF EXTERNAL COSTS OF TRANSPORT IN EU

The first research and assessment of external costs of transport in European countries are made by International Union of Railways (UIC) and the document Green Transport Reducing External Costs is published in 2012 [1]. The approach to determine the value of external costs of transport in this paper uses a methodology to assess value of non-market goods. The HEATCO research project under the 6th EU Framework Program 2002-2006 for harmonization of European practices in the estimation of transport costs and project assessment, gives particular attention for estimation of the external cost of transport in the EU countries [2], [3]. Internationalization of External Transport Costs is presented in the study developed by CE Delft and published in the Handbook [4] supported by the European Commission in 2008. The update of this study is carried out in 2011 [5]. The cited Handbook was updated also in version from 2014 taking in account new input values [6]. The last edition of the Handbook of the external costs of transport is published in 2019 by European Commission [7].

III. METHODOLOGY FOR ASSESSMENT OF EXTERNAL COSTS OF TRANSPORT IN THE EU DOCUMENTS

External costs of transport vary considerably with the characteristics of vehicles, trains, boats, aircraft or area of transport activities. The relevant EU documents [7] cover all main externalities of transport:
- Accidents;
- Air pollution;
- Climate change;
- Noise;
- Congestion;
- Well-to-tank emissions;
- Habitat damage;
- Other external cost (soil and water pollution).

HEATCO's scientific research project [2], [3] uses an approach called “Impact Pathway Approach” based on damage cost. Using the concepts of welfare economics, monetary assessment follows the "willingness to pay" approach for valuation of the respective health effects and improving the quality of the environment. The best practice estimation of congestion costs is based on speed-flow relations, value of time and demand elasticity. The procedure for calculating external costs of transport from air pollution follows:
- Quantification of changes in the emission of pollutants (NOx, SO2, PM2.5/PM10) resulting from the project studied and expressed in tonnes, using national or European emission factors.
- Classification of emissions according to the amount of emission (near ground surface or high) and local environment (urban - out of urban areas).
- Impact calculation - years of life lost and costs per pollutant.
- Impact report and costs.

**IV. METHODOLOGY FOR ASSESSMENT OF EXTERNAL COSTS OF TRANSPORT IN REPUBLIC OF NORTH MACEDONIA**

Methodology for estimation of external costs of transport in Republic of North Macedonia is founded of EU researches and accepted methodology. This approach consists of the following successive stages:

1. Assessment of unit prices of external costs of transport by type of externality in a given year may be expressed as:

   \[ EC_{myi} = EC_{uy0} \times PPP_{my0} \times A_{gdp}^{yi} \]  

   \( EC_{myi} \) – unit value of external cost of transport for a given externality in Republic of North Macedonia in year \( y_i \)

   \( EC_{uy0} \) – unit value of external cost of transport for a given externality estimated as EU average in year \( y_0 \)

   \( PPP_{my0} \) - purchasing power parity indicator in Republic of North Macedonia in relation to the EU in year \( y_0 \) (that indicator is 100% for the EU)

   \( A_{gdp}^{yi} \) - average annual growth of gross domestic product in Republic of North Macedonia between year \( y_0 \) and \( y_i \)

   \[ A_{gdp}^{yi} = (1 + p)^i \]  

   \( p \) - average GDP growth rate between years \( y_i \) and \( y_0 \)

   \( i \) - number of years between \( y_i \) and \( y_0 \)

2. Emission quantities of externalities depend on the transport operation, type of vehicles, location of transport infrastructure, and other geographical and time factors. These quantities can be expressed by the following equation:

   \[ Q_{myi} = \sum Q_{myi,v,s} \]  

   \( Q_{myi} \) – total quantities for a given externality of transport in Republic of North Macedonia in year \( y_i \)

   \( Q_{myi,v,s} \) - quantities for a given externality of transport in Republic of North Macedonia in year \( y_i \) obtained from different transport activities, different vehicles and in specific spatial conditions.

3. Total external cost of transport for a given externality can be expressed by the following equation:

   \[ TC_{myi} = EC_{myi} \times Q_{myi} \]  

   \( TC_{myi} \) - total external cost of transport for a given externality in Republic of North Macedonia in year \( y_i \)

   \( EC_{myi} \) – unit value of external cost of transport for a given externality in Republic of North Macedonia in year \( y_i \)

   \( Q_{myi} \) - quantities for a given externality of transport in Republic of North Macedonia in year \( y_i \).

**V. ASSESSMENT OF EXTERNAL COST OF TRANSPORT FROM AIR POLLUTION**

The methodology presented above needs data for unit values of external costs of transport expressed as average values for EU countries. These data refer to year 2010 and they are extracted from the RICARDO-AEA study [6] on specific vehicle types, EU emission standards from Euro 0 to Euro 6 and on urban, suburban and rural environments.

The number of registered vehicles in 2015 in the country is 437,686 vehicles. The vehicle fleet is very old and the average age of cars is 18.7 years, for buses 18.1 years and for trucks 15.5 years. In 2015 half of the passenger cars and buses have EU standards with high emissions of harmful substances Euro 0, Euro 1 and Euro 2 (fig. 1, Table I).

![Fig. 1 Share of type of vehicles in Euro 0 to Euro 6 emission standards in 2015](image)

**Fig. 1 Share of type of vehicles in Euro 0 to Euro 6 emission standards in 2015**

**Table I**

<table>
<thead>
<tr>
<th>Registered motor vehicles</th>
<th>Year</th>
<th>2015</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td>437,686</td>
<td>485,612</td>
</tr>
<tr>
<td>Motorcycles</td>
<td></td>
<td>8,634</td>
<td>13,343</td>
</tr>
<tr>
<td>Cars</td>
<td></td>
<td>371,449</td>
<td>415,062</td>
</tr>
<tr>
<td>Buses</td>
<td></td>
<td>3,164</td>
<td>3,201</td>
</tr>
<tr>
<td>Goods vehicles</td>
<td></td>
<td>32,123</td>
<td>37,010</td>
</tr>
<tr>
<td>Road tractors</td>
<td></td>
<td>5,248</td>
<td>5,613</td>
</tr>
<tr>
<td>Tractors</td>
<td></td>
<td>3,164</td>
<td>3,201</td>
</tr>
<tr>
<td>Work vehicles</td>
<td></td>
<td>614</td>
<td>728</td>
</tr>
<tr>
<td>Trailers</td>
<td></td>
<td>8,424</td>
<td>8,246</td>
</tr>
</tbody>
</table>


The unit values of external transport costs are adjusted for Republic of North Macedonia using the purchasing power indicator published by Eurostat. According to this indicator (Purchasing Power Standards) Republic of North Macedonia in 2010 was 34% of the EU-28 average.
To estimate the unit values of external transport costs in a given year different of 2010 they should be weighted also by average growth rate of GDP from year 2010 to the 2015 year of analysis. The average GDP growth in the period 2010-2015 in Republic of North Macedonia is 2.54%, according to the official data published by State Statistical Office (SSO).

The estimation of emissions quantities can be made using SSO data for type of vehicle registered in the country and also data on average annual kilometres travelled by type of vehicle and the area of impact separated of urban, suburban or rural areas. Some of these data have been estimated from their own studies, and some have been obtained by processing data from SSO.

Official statistics of average annual kilometres travelled by cars on urban, suburban and rural roads and highways are not published. Since such data are not available, we made assumption that cars travel an average of 10000 km/year, of which 70% are on urban roads and 30% on suburban, rural roads and highways.

The SSO [8] Publication Transport and Other Services shows that in 2015 on average one bus travelled 79000 km. It is assumed that 70% of them are made in urban areas, 20% in suburban areas, and 10% in highways and rural areas.

The same SSO publication states that trucks in total in 2015 had 860 million kilometres. Assuming that in the same year there were 33237 registered trucks and on average in 2015 one truck travels 25875 km. It is assumed that 30% of trucks travel distances in urban areas, 20% in suburban areas, and 50% in rural areas and highways.

Concerning fuel consumption of motor vehicles, according to SSO data, the 53% of passenger cars use petrol and 47% of cars use diesel.

According to the above assumptions and described methodology, the estimations of the external transport costs of road transport from air pollution are follows:

<table>
<thead>
<tr>
<th>Euro St.</th>
<th>Cars</th>
<th>Buses</th>
<th>Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 0</td>
<td>8.1</td>
<td>3.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Euro 1</td>
<td>4.6</td>
<td>1.9</td>
<td>3.2</td>
</tr>
<tr>
<td>Euro 2</td>
<td>7.2</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Euro 3</td>
<td>3.1</td>
<td>3.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Euro 4</td>
<td>2.4</td>
<td>1.2</td>
<td>10.4</td>
</tr>
<tr>
<td>Euro 5</td>
<td>0.3</td>
<td>0.6</td>
<td>1.3</td>
</tr>
<tr>
<td>Euro 6</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>25.8</td>
<td>15.8</td>
<td>30.5</td>
</tr>
</tbody>
</table>

The estimated external costs of road transport only from air pollution in 2015 are 72.2 million euros.

VI. COMMENTS OF ESTIMATIONS

The most important external costs of road transport from air pollution are estimated in urban areas. The external costs of transport produced by diesel cars that are in EU classes Euro 0, Euro 1, Euro 2 or manufactured until 2004 are particularly high. The analysis of vehicle fleets shows that about 50% of passenger cars and buses have EU standards with high emissions of harmful substances. The assessment of noise pollution, using similar methodology, shows that about 64% of external transport costs of road transport from noise are appeared in urban area. Estimations of external costs of transport in EU countries plus Norway and Switzerland in 2008, account about 4% of these countries’ GDP. If we apply the same percentage to Republic of North Macedonia with a GDP of 9072 million EUR in 2015, then the total external costs after this calculation is about 363 million EUR.

VII. CONCLUSIONS

The official data for transport collected by SSO are not appropriated for estimation of external costs of transport. The new methodology of data collection should be involved in the future to produce solid data for estimation of external costs of transport. The external costs of road transport are predominant in urban areas comparing with rural regions and highways. The very old vehicle fleet in the country and large presence of vehicles in Euro 0, Euro 1 and Euro 2 standards contribute significantly to air pollution. The transport policies have to provide state aid to citizens and transport operators for renewal of vehicles and usage of more environmental friendly cars, buses and trucks. The external costs of rail transport are not assessed in this paper, but the UIC estimation for 2008 [1] in the 27 EU countries notes that these cost are only 2% of total external costs of transport. Development of inter modality and favour of rail transport can also contribute to decrease external costs of transport.

REFERENCES

[1] UIC “Greening Transport, Reduce External Costs”, 2012, p.28
Priorities in Transport Integration of the Republic of Croatia Into Trans-European Transport Network

Ljudevit Krpan¹, Drago Pupavac² and Robert Maršanić³

Abstract - This paper reviews the existing treatment of the Republic of Croatia within the EU transport system. Additionally, a series of activities has been proposed with the aim of providing adequate transport accessibility and thereby also the basics for the dynamical economic development of the whole Republic of Croatia with a particular emphasis on the County of Primorje and Gorski kotar and the port of Rijeka.

Keywords: Trans-European Transport Network, Transport Planning, Transport Policy, Port of Rijeka.

I. INTRODUCTION

Very specific and favourable geo-traffic position underlines Republic of Croatia as a connection among the countries of Western and Southern Europe with the countries of Southeast Europe and the Middle East as well as with the countries of the Central Danube Basin with the ports on the Adriatic. Therefore, the Republic of Croatia, the county of Primorje and Gorski kotar and particularly the port of Rijeka builds a part of their comparative advantages on the geostrategic position. The accession of the Republic of Croatia to the EU made possible the recognition, valuation and integration of the most important state transport routes into the Trans-European Transport Network (TEN-T).

The purpose of this paper is to prove the need for comprehensive observation and taking into consideration of the Adriatic-Ionian Region as an indivisible unique whole.

The aim of this paper is to point out the needs for high-grade transport integration of North Adriatic ports as a crucial factor for providing competitiveness in relation to North European ports.

This paper is structured in six chapters. After introduction, in the second part of the paper basic determinants of the EU transport system are presented. The third part analyzes the coverage of the Republic of Croatia by the TEN-T corridors whereas the fourth part presents activities of regional community in promoting and recognizing the need for adequate transport integration of the North Adriatic region. The fifth part is titled Basic prerequisites for high-grade transport integration of the Republic of Croatia. The sixth, last part i.e. Conclusion presents the results of the research carried out, reviews the hypothesis made in the research and points out specific transport requirements for its realization.

II. BASIC DETERMINANTS FOR STRATEGIC DEVELOPMENT OF THE EU TRANSPORT SYSTEM

Consideration of developing the key transport infrastructure of the European Union (the EU) is predefined by its strategic decisions and articulated by defining the Trans-European Transport Corridors i.e. by the Trans-European Transport Network - TEN-T. The Trans-European Transport Network was established to support build (up) of the EU transport infrastructure striving to attain goals of European competitiveness, cohesion and provision of jobs. It spreads throughout all 28 EU member countries and includes all transport branches, logistics and intelligent transport systems. It has been recognized and valued at two planning levels [7]: the core and comprehensive TEN-T network and additionally through emphasizing the most important priority projects.

The comprehensive TEN-T network is a multi-modal network of relatively high density. It is defined and dimensioned in such a way so it can enable quality integration to the core TEN-T network and thereby also economic, social and territorial development breakthroughs.

The core TEN-T network is a part of the comprehensive network that covers in strategic terms particularly important core European and global transport routes. [8]

While considering the EU development, the European Commission identified and separately emphasized 30 priority projects from the transport sector that are of interest for the EU. Selection of projects mirrors the strategic orientation development of an environmentally acceptable and sustainable transport system as a contribution to the fight against climate changes.

In taking into consideration the key EU transport network, the decision by the European Commission is very important i.e. the decision to consider the possibility to expand the TEN-T network to the area of the Western Balkans: this primarily in the part of continuing the motorway connection from Dubrovnik towards Albania and Greece. The motorway connection Belgrade-Niš-Bar is additionally planned and it will present the shortest transport connection towards the centre of Serbia so that its realization would additionally diminish the significance and role of North

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4 Out of these 18 railways, 3 railways and motorways combined, 2 inland waterway projects, and one refers to the Motorways of the Sea.
Adriatic ports when having in mind possibilities of Bar and Durres ports.

For considering development potentials it is important to take into consideration the fact that the TEN-T comprehensive network is perceived in the horizon until the year 2050, the core TEN-T network in the horizon until the year 2030 and the most significant 30 projects are expected to be carried out until the year 2020 with great EU financial and technical support.

III. COVERAGE OF THE REPUBLIC OF CROATIA BY TEN-T CORRIDORS

Consideration of development and new circumstances at the EU level stipulated adoption and afterwards amendments and revision of the network of core and comprehensive trans-European corridors on several occasions.

In the area of the Republic of Croatia only two core TEN-T corridors have been recognized, specifically the corridor that refers to transport connection of Rijeka with Hungary (former Vb Pan-European corridor) and the corridor that refers to transport exploitation of the potential of the Danube (former VII Pan-European corridor). Since until then the Republic of Croatia was not traced in the network of TEN-T corridors, as it wasn’t an EU member, it can be said that this inclusion is a step forward. Nevertheless, it must be pointed out that a possibility for full transport integration of the Republic of Croatia failed to come as well as a possibility for quality transport connection along the Croatian part of the Adriatic coast by land.

Accordingly, former Pan-European corridors that recognized the need for strengthening the transport axis Ljubljana/(Graz)Maribor-Zagreb-Belgrade-... (known as the Pan-European corridor X and Xa) were not taken into consideration in full, but only the section between Ljubljana and Zagreb was recognized as a link to the branch of the Mediterranean TEN-T corridor.

What completely failed to appear is recognizing the transport axis (corridor) along the Adriatic-Ionian region. This primarily implies the non-existence of strategic connecting of the North Adriatic ports of Venice, Trieste, Koper and Rijeka with adequate mainland infrastructure. In the process, only Rijeka was left isolated. The danger is threatening that North Adriatic ports join up in a way that the role of Ravenna is strengthened with the transport of the port of Rijeka being totally blocked. Moreover, consideration of a transport corridor from North-Adriatic ports (Rijeka, Koper, Trieste and Venice) up to Greek Igoumenitsa fails to appear, which is exceptionally unfavourable both for the Republic of Croatia and other countries of the Adriatic-Ionian region.

Here it’s important to recognize the fact that these corridors do not represent only a transport but also an energy axis and emphasize the Republic of Croatia as the hub of whole Southeast Europe. Omitting and neglecting i.e. non-including these in the priority core EU TEN-T network and even on the list of the most important strategic priority projects considerably weakens the geostrategic role of the Republic of Croatia and particularly the County of Primorje and Gorski kotar and the port of Rijeka.

IV. VALUATION OF THE GEOSTRATEGIC POSITION OF THE PORT OF RIJEKA

The development of transport infrastructure at national and supranational level is of particular interest also for regional development. With the aim of quality valuation of transport and economy significance of the County of Primorje and Gorski kotar within the framework of European regions, a range of dynamic and continuous activities has been carried out. One of the projects having a high rate of economic effect that has been actively promoted is certainly developing the port of Rijeka as the major port of the Republic of Croatia for transport of goods and its accompanying transport route, but also connecting the whole North Adriatic area to the EU transport network. This in the first place implies meeting all requirements for developing port and terminal capacities and the accompanying high-efficiency railway line towards Zagreb and Budapest, but also connection to Italian railway lines from Rijeka to Trieste. In order to provide adequate accessibility, quality roadway connection from Postojna to Rupa is essential, the construction of Rijeka bypass road Pernsani-Mali Svin and extension to the motorway Mali Svin-Križišće–Zuta Lokva.

The realization of the complete route would open up, apart from the potential of the port of Rijeka and strong upswing in the transport offer in the segment of transport of goods, significant tourism potentials that are brought by connecting to the network of transport infrastructure with a high level of service (high-speed railway line and motorway), particularly in the light of economic potential of Northern Italy. Efforts have been made to promote this and other most significant corridors through regional or, on the other hand, global initiatives and projects.

A larger number of counties at the transport corridor Rijeka – state border with Hungary accessed the CETC (Central Europe Transport Corridor) initiative (that has grown into the European Grouping of Territorial Cooperation EGTC-CETC), whose aim is the need for transport and energy connection of the Baltic Sea and the Adriatic Sea i.e. connecting the Szczecin port with Rijeka. This initiative has been supported by the Ministry of the Sea, Transport and Infrastructure. Alongside the aforementioned initiative, the Baltic – Adriatic initiative was active, whose aim was to connect ports of Gdansk/Gdynia and Trieste/Koper. On the grounds of the adopted current TEN-T network it is evident that exactly this initiative, supported by respective national governments, has prevailed and nominated the Baltic – Adriatic corridor for the network of the TEN-T corridor. Ports of Szczecin and Rijeka have been additionally nominated, in relation to the suggestion of the aforementioned initiative, however without quality integration with other ports in their respective maritime basins. By doing so, their geostrategic significance is being substantially decreased at their respective ends of the corridor (scheme 1).
Through activities of the Adriatic-Ionian Euroregion, the county of Primorje and Gorski kotar that presides over the Workgroup for Transport and Infrastructure, underlines and problematizes these significant strategic deficiencies. Taking part in a series of macro-regional, transnational and cross-border projects emphasized and proved the need for the complete integration of the North Adriatic ports system and securing adequate accessibility.

V. BASIC PREREQUISITES FOR HIGH-GRADE TRANSPORT INTEGRATION OF THE REPUBLIC OF CROATIA

The EU TEN-T network is subject to continuous expanding with the aim of improving life standard quality i.e. bringing intended economy policies into being. It is up to the Republic of Croatia to insist on nominating new priority TEN-T corridors and projects. This is particularly important due to the possibility of including strategic projects of the Republic of Croatia such as developing the port of Rijeka or building a high-efficiency railway line from Zagreb to Rijeka and Trieste with the aim of connecting to the EU railway network, but also inaugurating the Adriatic-Ionian corridor in the network of strategic European transport and energy corridors.

Current initiatives and suggestions to include the Republic of Croatia in the TEN-T Baltic-Adriatic corridors are for sure an important step towards providing adequate accessibility and thereby competitiveness in the Republic of Croatia. The development of a strong energy axis, in the form of connecting the existent LNG terminal in Świnoujście directly next to Szczecin and future LNG terminal in Omišalj on the island of Krk as well as the construction of main gas pipeline routes additionally increase energy stability of whole Eastern Europe.

Without formal inclusion of the Republic of Croatia in the Baltic-Adriatic corridor, the position of the Republic of Croatia in the international transport network would not improve significantly, whereas the financing possibilities and even the construction of transport infrastructure would remain at the same level. For this reason, along with accepting the declarative need for the inclusion in the Baltic-Adriatic corridor, it is necessary to clearly articulate to what this refers i.e. to request that it implies transport connection from the direction of Vienna and Budapest, Maribor, Ljubljana towards Zagreb and Rijeka i.e. from the direction of Koper (Divača/Postojna) towards the port of Rijeka.

Except for the aforementioned, new political, legal and international conditions emphasize development of a new Adriatic longitudinal transport route as necessary, which is defined by the Strategy and Program for Spatial Planning of the Republic of Croatia and the Strategy of Transport Development of the Republic of Croatia. The construction of appropriate road and railway infrastructure and affirmation of maritime transport in this corridor would create a possibility for diverse littoralisation of economic and other activities. The route would present a new connecting corridor of West and Central Europe to its South-East. Such a transport corridor would certainly attract international transit flows of passengers and goods and particularly tourist ones.

Transport valuation of the Adriatic-Ionian route solves a part of the problem of regional development of the Republic of Croatia whereby the impacts on demographic migrations of population would not be irrelevant.

For the Republic of Croatia and particularly for the County of Primorje and Gorski kotar, crucial projects that should be nominated and accepted at the EU level as priority TEN-T projects are:

- Connecting North Adriatic ports with adequate railway network of high-level of transport service,
- Finalisation of the missing part of motorways in the Republic of Slovenia from Pivka/Rasopasno to Rupa but also from Koper to Umag and to the conjunction to the Istrian epsilon,
- Construction of the motorway Mali Svib-Križišće-Žuta Lokva,
- Planning the construction of Rijeka bypass Veprinac-Permani-Mali Svib,
- Planning of port capacities extension to the island of Krk and adequate connecting transport infrastructure by land (including a new road/railway bridge),
- Upgrading the second railway track of the railway line through the city of Rijeka,
- Preparation and construction of a new high-efficiency railway line towards Zagreb and Hungarian border and other.

In the process, it is to bear in mind that, when nominating and negotiating on the implementation of single projects, the EU considers already established and nominated projects (like priority project 6 railway line (…)–Divača-Ljubljana-Budapest(…) and does not allow emphasizing and competing and even calling into question the already realized project by a new project. In our case this might refer to the construction of a high-efficiency railway line Rijeka-Zagreb-Budapest. In
other words, recent decisions at the level of the Republic of Croatia haven’t recognized the need for constructing a new double-track railway line (that wouldn’t have features of a mountain railway line), but the reconstruction of the existing route through Gorski kotar has been prioritized. Such considerations can be justifiable only under assumption that a political decision has been made that the extension to the port of Rijeka to the island of Krk is postponed and in this context that the imposed definition for the Republic of Croatia to rely on the Slovenian railway system should be accepted, which is not an acceptable scenario for the County of Primorje and Gorski kotar. Institutions in charge and various scientific and professional members of the public should continuously impose views on this issue and fact that are real and acceptable to the state and ipso facto that would protect our transport i.e. national interests.

VI. CONCLUSION

For the purpose of homogenous regional development at the European Union level it is necessary to take appropriate measures at all levels. First of all, it is essential to consider the real significance and role of the Republic of Croatia within the European Union and this part of Europe and the world. Afterwards, on the grounds of objective indicators, to adopt real economic development strategy, on which the Strategy of development of transport system shall be based by taking into consideration the known significance and role of the Republic of Croatia within the transport system of Southeast Europe. In the process, objects of transport infrastructure, whose existence synthesizes aspiration for harmonious operation of economic and transport system, hold central position.

Considerations of the development of key EU transport infrastructure are predefined by its strategic decisions and articulated by the TEN-T network. The TEN-T comprehensive network is perceived in the horizon until the year 2050 and the major corridors in the horizon until the year 2030. An additional list is defined of the most significant 30 projects that are expected to be carried out until the year 2020 with EU financial and technical support.

The need for quality valuation of Croatian transport system imposes a need for reconsidering the fundamental European documents. Thereby it is not enough to only declaratively nominate the participation of the Republic of Croatia in a single transport corridor but clear recognition of specific projects and their inclusion in the list of EU priority projects is the most important obligation. Only in this way it will be possible for the wanted goals of development of transport infrastructure to get realized but also the goals of general economic development of the State within an acceptable timeframe. It is not enough to say that the Republic of Croatia is to be included in the Baltic-Adriatic corridor but priority is to nominate the obligation of:

• Construction of a high-efficiency railway line:
  o Divača-Pivka-Rijeka-Zagreb-Budapest-Ukraine border/Baltic
  o Ljubljana-Zagreb-Belgrade-(...)
• motorway Postojna-Rupa-Pernani-Mali Sviб-
• motorway Maribor-Krapina-Zagreb
• extension to the port of Rijeka to the island of Krk (with upgrade of both road and railway infrastructure) and other.

Securing the inclusion of these projects in the priority projects EU list would provide their quality valuation as well as grants and financial instruments for their real implementation.

For this reason, in the future period it is essential to provide all political, economic and financial prerequisites for integral development of complete transport system that is above all bound to the TEN-T network. Bringing higher quality transport connection of European countries into being would set up a base for economic and social upswing of both EU countries and their neighbouring countries and ipso facto of the Republic of Croatia.

Active efforts to impose the Republic of Croatia within the Mediterranean corridor should not exclude from the focus the need for emphasizing the importance of realization of the Adriatic-Ionian corridor and also the previous Pan-European corridor X Zagreb-Belgrade.

With regard to often changes in national views and policies, the need for regional connection and emphasizing regional thinking and needs is evident. The County of Primorje and Gorski kotar implemented the aforementioned by working through several institutions and through active cooperation with all Croatian (and particularly Adriatic) counties and municipalities of the Republic of Slovenia (particularly with Ilirska Bistrica), but also with Italian regions (particularly Friuli Venezia Giulia and Veneto).

REFERENCES

Alternative transport systems in the function of micromobility

Jovan Mišić¹, Sinisa Sremac², Vladimir Popović¹, Dušan Radosavljević¹, and Stefan Mihajlović¹

Abstract – The paper will consider alternative transport systems as well as incentive measures to reduce the use of passenger cars in the visual distribution of travel, i.e., travel for business purposes, at the company level, as well as measures taken by companies to reduce passenger car travel.

Keywords – Mobility, Alternative Modes of Transport, Environmental Protection.

I. INTRODUCTION

The increasingly rapid development of science and technology brings great changes in human life in terms of more efficient and effective mastery of space. Mastering space is a very important parameter in the daily life of people in cities, as well as the daily migration of residents living outside cities. When mastering the space of the inhabitants, a very important factor is the travel time.

In order to minimize this travel time, residents, when choosing means of travel, often choose a passenger car in relation to the situation, in order to satisfy their own living needs, and of course, the need to move. This choice of travel often comes down to the fact that in that passenger car, in addition to the driver, there are no passengers, but we have only one transported resident per passenger car [1].

The capacities of roads, as well as the intersections of roads, have certain values, so that each appearance of a passenger car on the mentioned roads and intersections prolongs the travel time compared to the mentioned capacities.

In addition, the constant trend of increasing passenger cars, causes traffic jams, increased noise levels, deteriorating air quality, deteriorating safety, quality of life, as well as various other problems characteristic of urban traffic [3]. Based on this fact, it can be concluded that this trend of using a passenger car in the visual distribution of travel calls into question the "sustainability" of the transport system of any city.

The fact that huge financial resources must be allocated for the expansion of road capacities, brings a tendency to resort to alternative systems of transport of residents. In order to access these alternative systems of passenger transport, incentives are needed to influence the management of traffic demand, all at the expense of reducing the use of passenger cars in the visual distribution, and increasing the share of use by residents, public transport systems, promoting and increasing the participation of cyclists and pedestrians in traffic, as well as the integration of different modes of transport, as well as greater mobility of residents. The basic concept of these measures must be to raise awareness of environmental protection, in which users of passenger cars live.

Transport information and public campaigns can influence people’s awareness, attitudes and behavior in such a way as to encourage the use of bicycles, walking and the use of public transport. Campaigns can be conducted to raise awareness of the general public, for target groups or as individualized campaigns [4].

One of the goals of mobility management is to find ways to meet the need to move through more efficient and integrated use of existing alternative modes of transport and infrastructure, as well as to improve cooperation between different modes of transport, facilitate interconnection and functioning of existing transport networks.

There are several ways to encourage passengers to switch from, for example, car to bicycle transport. Providing good access to cycling facilities can lead to an increase in the use of all forms of public transport as well as a reduction in the number of journeys made by passenger car.

Measures for the use of a private car are being taken in order to use it more efficiently. The measures are concentrated primarily on improving the traffic flow and increasing the utilization rate of the vehicle itself through the shared use of cars by several people. Actions aimed at helping drivers solve the problem of traffic congestion, aim to develop telematics technology within a broader integrated road network. Measures to increase car utilization rates include prioritization schemes for vehicles with three or more passengers.

The system integration of public passenger transport aims to concentrate all public modes of transport in a common operational environment. The three most important elements of...
the integrated system are coordinated timetables, the purchase of tickets valid for all journeys at the beginning of the journey and multimodal terminals, ie the physical, tariff and logical integration of the public transport system.

Globally, the challenge of climate change and its impact on the environment, health and the economy is strongly linked to transport and the behavior that accompanies unsustainable mobility [2].

The paper will consider alternative transportation systems, as well as incentive measures to reduce the use of passenger cars in the visual distribution of travel, ie travel for business purposes, at the company level, as well as measures taken by companies to reduce passenger car travel.

II. ALTERNATIVE TRANSPORT SYSTEMS

In order to in a way reduce the number of trips made by passenger car, residents of any city must be offered an appropriate alternative of transportation that would have, if not approximately travel time, as well as travel time by passenger car, then certainly acceptable longer travel time for residents during the realization of their trip. Of course, the key factors when choosing an alternative to transportation, in addition to travel time, are the price of travel, as well as environmental protection, ie enabling a better and healthier life for residents in cities.

The main organizer of the city's transport system is the city itself. With its measures, as well as constant monitoring, research, and strategies, the city must define measures for coordinating the transport system, ie travel management. These measures should be primarily reflected in the price policy as well as price management, primarily the price of parking, and the price of transportation of public passenger transport systems [6]. The increase in the price of parking will certainly lead to the fact that the city has a larger number of trips realized by public mass transport systems, but this mass transport system must ensure the quality of transport service in terms of timetable accuracy, travel speed and travel comfort. These two concepts are very important for the choice of residents when deciding to make a trip, and giving a chance to alternative transportation systems.

In addition, the city must influence various measures, as well as subsidies to companies, which would reduce the passenger car travel of its employees.

In order for urban mobility to be sustainable, it is necessary, first of all, to develop models and guidelines for improving the conditions for the use of alternative modes of transport, in the field of [6]:

- taxi service,
- bicycle traffic,
- pedestrian traffic,
- inland water transport,
- other alternative systems that have potential.

III. MEASURES TO ENCOURAGE GREATER USE OF ALTERNATIVE TYPES OF TRANSPORT

Managing the demand for travel by applying land use policy instruments implies the creation of various forms of urban transport that encourage greater use of environmentally friendly modes of transport. Increasing the intensity of land use and combining different types of activities at the same location results in acceptable walking distances at which to travel. At the same time, preconditions are being created for quality servicing of city by the public transport system.

With the appropriate land use policy, the number of passenger car trips can be reduced by 10-30% [4]. Research on trends in the relationship between the distance traveled and the choice of mode of transport in German cities over the past thirty years has shown that the impact of built space has a strong impact on two elements of traffic demand: distance traveled and choice of mode [5]. According to the same author, the influence on the choice of mode of transport can be divided into direct and indirect.

1. Indirect impact. Increasing the density of content with the necessary combination of a number of different activities (mixed use) reduces the distance over which the trip is performed. Reducing the distance increases the possibility of traveling on foot or by bicycle.

2. Direct impact. Densely populated areas usually have a more developed public transport network, which with a limited number of parking spaces and large traffic jams results in a comparative advantage of public transport and its greater use compared to the car.

In addition to the positive effects of land use management, which are reflected in the reduction of dependence on car use, it is important to emphasize the reciprocal impact that the promotion of alternative modes of transport has on land use. The positive effects are reflected in the increase of accessibility to urban sub-units and as a consequence of accessibility, the increase in the attractiveness of various commercial and entertainment contents. Thus, for example, the relationship between retail trade turnover and pedestrian traffic intensity has been established, and even in some cases it has been proven that the value of land in the central business area is directly related to pedestrian traffic intensity [4].

The changes in travel that result from surface management strategies can help solve various traffic problems and achieve the goals of sustainable urban planning.

In addition, what needs to be emphasized is the elaboration of campaigns and strategies that influence the change of behavior of transport system users, ie passenger car
users, in the context of promoting greater use of alternative modes of transport at the expense of reducing passenger car use.

Based on world experience, measures to promote greater use of alternative modes of transport in cities, which have been implemented, show that the best results have been achieved by applying:

1. Campaigns and promotional measures for pedestrian and bicycle traffic and public transport, which resulted in a reduction in the participation of cars in the visual distribution of travel;
2. Individual travel counseling to help reduce car use;
3. Compensation for employees who use public transport instead of a passenger car;
4. School mobility plans that enable children to walk safely to school;
5. Measures of car sharing (joint driving) and carpooling (joint car rental).

**IV. LIVEMOBILITY**

When it came to travel management measures, travel management at the company level was mentioned. Every company is responsible for providing its employees with a comfortable and safe trip with the purpose of work, which is financially regulated. The social responsibility of companies, in addition to the compensation they give to their employees in order to regulate travel to and from work, is also reflected in the impact on the environment. That is why an increasing number of companies want to manage to travel of their employees[7]. This can be achieved by using modern information technologies that track, store travel data, provide real-time information about the mentioned trips, based on which a travel management algorithm can be created, and easily measure travel savings or costs, as well as the impact to the environment.

Livemobility is an application that deals with tracking, storage and thus the management of travel data at the company level. Based on the company’s research, when creating an algorithm for this application, it was found that about 20% of global warming comes from population mobility, and that 20% of CO2 emissions can be reduced by using this software [5].

**4.1. Livemobility Structure**

The structure of Livemobility is reflected in three entities that are of significant influence if the application is observed at the level of a certain company. The three entities are:

1. Users, i.e. employees;
2. Dispatch Center, which with the help of the mentioned application collects, stores and processes data on trips of users, i.e. employees. Also, in addition to this, they deal with monitoring the work of the application, as well as eliminating existing problems in the work of the application.
3. The Main Control Center, which on the basis of data obtained from the Dispatch Center, implements strategies, manages trips through subsidizing points to users and performs travel analysis.

It is very important to mention the coordination between these three entities, which must be at an enviable level, in order to benefit from the use of platform.

**4.2. Phases of Implementation Livemobility**

In order to implement the mentioned application, it is necessary to consider it in phases. This phased or phased review of the implementation can be done as follows:

**PHASE 1** This phase is reflected in the research of the current situation at the company level and includes:

1. Internal call to its employees by the company and introduction to the benefits of the mentioned application.
2. Filling out an online survey of employees, where the most important question is the length of the trip. The mentioned application was implemented in a hospital in the Netherlands, where it was determined that the average length of employees in that hospital is 7.5 km.
3. Registration of employees in the application, as well as training for the use of the mentioned application.

**PHASE 2** This phase is reflected in motivating employees to switch from a passenger car to alternative modes of transport. Employee motivation is implemented through two levels:
1. Internal motivation of employees, where the employee sets goals for how to travel to and from work, where he will get the least points if he travels, or will not be scored if he comes by car, and the most points if he travels on foot, or by bicycle to work and from work. This motivation of employees can be realized at the level of the work unit in the company, where team spirit is enhanced.

2. External motivation of employees, which is reflected in the awareness of reducing travel costs, and reducing the negative impact on the environment.

**PHASE 3** This phase is reflected in a concrete change in the behavior of employees in terms of the implementation of the said application, and the transition from a passenger car to alternative modes of transport. Of course, phase 3 is primarily reflected in the gemification of employees, where there can be competition and collection of points that can be used during various purchases and obtaining various subsidies and compensations for similar points. Of course, the employee can control panel on any account, on his smartphone or desktop computer.

**V. CONCLUSION**

Alternative transport systems have a major impact on the sustainability of cities, as well as on population mobility. All developed cities have agendas or strategies for developing alternative transportation systems. What is significant is that these strategies cannot just be rewritten as a model for our cities. It is necessary to first perform an analysis of the current situation, and only on that basis, as well as on the basis of knowledge of strategies for the development of alternative transport systems, to develop and design a strategy for the development of alternative modes of transport.

The plain terrain, especially in Vojvodina, is conducive to the use of bicycles as an alternative means of transportation. However, in addition to the appropriate infrastructure, integration with public mass transport, safer parking lots, larger investments, as well as bicycle rental campaigns, etc are needed.

Unconventional systems such as funiculars or cable cars can also be used as alternative transport systems, especially in cities that have a historically important facility such as a fortress. This would significantly improve the tourist offer, and thus the tourist attractiveness.

The basic concept of the development of mobile and sustainable cities is to give priority to walking, cycling, as well as public transport systems. Travels realized by a passenger car leave as much space as is left.

What is important to note is that the already mentioned strategy of transport system development should be harmonized with this concept. The reason for these measures and the adoption of a strategy for the development of transport with the participation of alternative transport systems is that the road infrastructure has already been set, ie cities with their content and road capacities have already been built, their expansion is very expensive and these measures would apply to some so-called "hard" measures.

In our conditions, it is more tangible to apply some "soft" measures, ie lighter measures, where through campaigns, strategy adoption, with the existing infrastructure, changes in the visual distribution of travel would be influenced.

By introducing knowledge through education, both about health and mobility, and raising awareness of the environment in which we live, we should strive for species distribution with the use of alternative modes of transport in as large a percentage as possible.

What is interesting is that in some countries, exercises can be organized that can be done while waiting for the funds of the public mass system at the standpoint. In order to affect the health of the population and to reduce the waiting time experienced by service users.

In addition to all of the above, the involvement of companies in the travel management of their employees and their subsidization by the city is crucial for reducing travel costs and reducing the negative impact on the environment. By using the Liveon mobility platform, the hospital in the Netherlands has reduced the total travel costs of its employees by 30% and 75% less CO2, without this being reflected in various employee delays, as well as any reduction in employee mobility.

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Influence of Train Stopping Distance and Overlap on the Railway Traffic Safety

Tihomir Subotić1 and Marko Vasiljević2

Abstract – Traffic safety should always be prioritized in all traffic systems. As the railway is a high-level complex technical and technological system, many factors affect its safety. Two factors that are the subject of research in this paper are train stopping distance and overlap.

Keywords – Railway Traffic Safety, Train Stopping Distance, Overlap.

I. INTRODUCTION

The main objective of this paper is to present train stopping distance, overlap, and their influence on railway traffic safety from the perspective of traffic and transport engineers.

Train stopping distance is an important factor not only in the aspect that covers the length that the train travels until the stop, but also is important for the railway system in general because it's used when designing certain parts of the system.

Another factor that imposes itself when traffic safety is a topic, is overlap. Similarly as stopping distance, besides the safety aspect, the overlap is used when designing signalling system.

This paper doesn't consider high-speed train systems.

II. TRAIN STOPPING DISTANCE

Train stopping distance is defined as the distance that the train travels from when the driver detects an obstacle (or signal) and applies the brake until a complete stop. Values of stopping distances on Republika Srpska Railways are shown in Table I [13].

\[ l_{sd} = l_{rd} + l_{bd} \ [m] \] (1)

where:
- \( l_{rd} \) is reaction distance and
- \( l_{bd} \) is braking distance.

As shown in Eq. 1., stopping distance consists of two parts: reaction distance and braking distance.

Reaction distance length depends on reaction time and movement speed, as shown in Eq. (2):

\[ l_{rd} = t_{rt} \cdot v \ [m] \] (2)

where:
- \( t_{rt} \) is reaction time and
- \( v \) is the train movement speed (converted to m/s).

Reaction time is time that passes from the moment when the driver detects an obstacle (or signal) to the moment of applying brakes. This time consists of two parts [4]: driver reaction time and brake delay time. The question that is often the topic of discussion, especially during the expertises of traffic accidents, is whether the train driver could react on time and avoid the collision. So, at what moment the train driver will react depends on when he'll notice the obstacle (or signal). That depends on several factors. Some of them are:
- train driver attention while driving,
- train movement speed,
- weather conditions,
- appearance characteristics of obstacles (dimensions, brightness, markings, colors, etc.),
- time of day (day time or night time),
- terrain configuration,
- rail line position and line gradient.

By some researches, driver reaction time is between 0.5 and 1 second [16]. Values of distances traveled during driver response time are given in Table II.

Mathematically, the above definition of the stopping distance can be expressed as Eq. (1):

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As already mentioned, when the train will stop depends not only on the driver and his response but also on the brakes and brake delay time. Brake delay time (for air brakes) for "P" type is usually between 3 and 6 seconds and for "G" type between 18 and 30 seconds [14]. Values of distances traveled by train during brake delay time for P and G types are shown in Table III (P) and Table IV (G).

| Table III | VALUES OF DISTANCES TRAVELLED BY TRAIN DURING BRAKE DELAY TIME FOR "P" TYPE |
|---|---|---|---|---|---|
| \( v \) | 3 | 4 | 5 | 6 |
| 10 | 9 | 12 | 14 | 17 |
| 20 | 17 | 23 | 28 | 34 |
| 30 | 25 | 34 | 42 | 50 |
| 40 | 34 | 45 | 56 | 67 |
| 50 | 42 | 56 | 70 | 84 |
| 60 | 50 | 67 | 84 | 100 |
| 70 | 59 | 78 | 98 | 117 |
| 80 | 67 | 89 | 112 | 134 |
| 90 | 75 | 100 | 125 | 150 |
| 100 | 84 | 112 | 139 | 167 |
| 120 | 100 | 134 | 167 | 200 |
| 160 | 134 | 178 | 233 | 267 |

| Table IV | VALUES OF DISTANCES TRAVELLED BY TRAIN DURING BRAKE DELAY TIME FOR "G" TYPE |
|---|---|---|---|---|---|---|
| \( v \) | 18 | 20 | 22 | 24 | 26 | 28 |
| 10 | 50 | 56 | 62 | 67 | 73 | 78 | 84 |
| 20 | 100 | 112 | 123 | 134 | 145 | 156 | 167 |
| 30 | 150 | 167 | 184 | 200 | 217 | 234 | 250 |
| 40 | 200 | 223 | 245 | 267 | 289 | 312 | 334 |
| 50 | 250 | 278 | 306 | 334 | 362 | 389 | 417 |
| 60 | 300 | 334 | 367 | 400 | 434 | 467 | 500 |
| 70 | 350 | 389 | 428 | 467 | 506 | 545 | 584 |
| 80 | 400 | 445 | 489 | 534 | 578 | 623 | 667 |
| 90 | 450 | 500 | 550 | 600 | 650 | 700 | 750 |
| 100 | 500 | 556 | 612 | 667 | 723 | 778 | 834 |
| 120 | 600 | 667 | 734 | 800 | 867 | 934 | 1000 |
| 160 | 800 | 889 | 978 | 1067 | 1156 | 1245 | 1334 |

Reaction distance can be simply calculated by summing values from Table II and Table III (or IV). It's important to mention that input data for reaction distance calculations (except movement speed) is empirical.

The difficult part in train stopping distance determination is the calculation of train braking distance. More precise results require more input factors that affect braking. In this paper, several equations for the determination of train braking distance are presented. The first model is given in Eq. (3) [3], [10]:

\[
l_{bd} = \frac{v^2}{2 \cdot (a + g \cdot \tan \alpha)} [m]
\]

where:
- \( a \) is deceleration provided by the braking system,
- \( g \) is gravitational acceleration,
- \( \alpha \) is the angle of the gradient.

Next model is Maison's formula, given in Eq. (4) [15]:

\[
l_{bd} = \frac{4.24 \cdot v^2}{10^3 \cdot \varphi \cdot p_k + 0.0006 \cdot v^2 + 3 - i} [m]
\]

where:
- \( \varphi \) is friction coefficient depending on gradient (for \( i < 15\%_0 \Rightarrow \varphi = 0.10; i > 15\%_0 \Rightarrow \varphi = 0.10 + 0.00133 \)),
- \( i \) is gradient,
- \( p_k \) is braking percentage.

Pedeluck's empirical model for passenger trains (\( v=70-140 \) km/h) is shown in Eq. (5) [15]:

\[
l_{bd} = \frac{\varphi \cdot v^2}{1.093 \cdot p_k + 0.127 - 0.235 \cdot i \cdot \varphi} [m]
\]

Minden models for passenger and freight trains are presented in Eq. (6) and Eq. (7) [15]:

for passenger trains:

\[
l_{bd} = \frac{3.85 \cdot v^2}{6.1 \cdot \psi \cdot \left(1 + \frac{p_k}{10}\right) + i} [m]
\]

for freight trains:

\[
l_{bd} = \frac{3.85 \cdot v^2}{5.1 \cdot \psi \cdot \sqrt{p_k - 5} + i} [m]
\]

where:
- \( \psi \) is the parameter which values are between 0.5 - 1.25 (concerning the brake type characteristics).

In eastern literature and researches, Method PTR is generally recommended. The total braking distance can be calculated as shown in Eq. (8) [19], [22]:

\[
l_{bd} = \sum_{q=1}^{n} \frac{4.17 \cdot (v^2_p - v^2_k)}{b_r + w_{ek} + i} [m]
\]

where:
- \( n \) is the number of \( q \) intervals,
- \( v_p, v_k \) are initial and final movement speed in \( q \) interval,
- \( b_T \) is specific braking force,
- \( w_{ok} \) is specific main movement resistance.

Variation of the previous model is shown in Eq. (9) [20]:

\[
l_{bd} = \sum_{q=1}^{n} \frac{500 \cdot (v_p^2 - v_k^2)}{(b_T + w_{ok} + \iota)} \cdot \theta [m]
\]

where:
- \( \theta \) deceleration provided by specific deceleration force (107 ÷ 120).

The last model presented in this paper is shown in Eq. (10) [4]:

\[
l_{bd} = \frac{4.13 \cdot v^2}{\mu \cdot \delta \cdot p_k + w_{ok} + \iota} [m]
\]

where:
- \( \mu \) is friction coefficient on the contact area between the train wheel and the brake pad,
- \( \delta \) is pressure coefficient (can be calculated as the ratio of the specific braking force per braking pad and braked mass per braked axle [4]).

### III. OVERLAP

Overlap is defined as the length of track in advance of a "stop" signal, that must be clear. The main purpose of the overlap is to provide additional safety in case the train overrun a "stop" signal by a short distance due to any reason related to braking [6] or track condition. There're are two types of overlaps (Fig. 1): block overlap (BOL) and signal overlap (SOL).

Fig. 1. Overlap

On lines with short block sections, an entire block section could be used as an overlap [6].

On Republika Srpska Railways, the overlap is needed when the train has movement authority (except when passing the station without stopping). In [9] is stated that block overlap on Republika Srpska Railways must be at least 50 meters long. Signal overlap, when used on the dead-end track, needs to be at least 100 meters long [8]. In normal conditions, overlap length should be between 100 and 200 meters, but no longer than 300 meters [8]. On special occasions, because of traffic circumstances, it can be shorter than 100 meters, but not less than 50 meters (there's an exception in block overlap where it can be shorter than 50 meters if line gradient after block signal is greater than 6‰, and speed isn't greater than 90 km/h) [8].

HŽ Infrastructure (Croatian infrastructure manager) recommends the length of the signal overlap to be 100 meters at the home signal when there isn't a shunt limit, and 50 meters if there're limits of shunt [2]. At the exit signal, signal overlap needs to be 100 meters long [2]. Block overlap is recommended to be at least 50 meters long (there is the same exception as on Republika Srpska Railways where it can be shorter than 50 meters if gradient and speed conditions are met) [2].

On German railways home and block signal overlap (called Durchrutschweg or D-Weg) is recommended to be between 100 and 200 meters depending on the point that needs to be protected and 50 meters for block signals that are only used for train separation with block length not shorter than 950 meters [5]. Behind exit signals, 200 meters is recommended for speed exceeding 60 km/h, 100 meters for speed not exceeding 60 km/h and 50 meters for speed not exceeding 40 km/h [5].

On Austrian railways, overlap (Schutzweg) behind main signals (entry/home, exit, block, etc.) is recommended to be 50 meters, or in special cases, due to physical space constraints, it can be 25 meters [1].

Overlap length on Russian railways (Защитный участок) needs to be at least long as the length of the braking distance provided by ALS (automatic locomotive signalling) emergency braking [21].

On NSW railways (in Australia), 300 meters is the minimum recommended for speed less than 60 km/h, 400 meters for speed between 60 and 80 km/h, and 500 meters for speed exceeding 80 km/h [12].

Generally, overlap length determination should be influenced by the following factors [7], [12]:
- historical precedents and experimental data,
- maximum line speed,
- permanent speed restrictions,
- train approach speed,
- emergency braking curves,
- gradient,
- train protection system,
- sight distance,
- weather conditions (where significant),
- physical space constraints (in stations).

### IV. INFLUENCE ON RAILWAY TRAFFIC SAFETY

Traffic safety should be the number one priority in all traffic systems. While managing traffic safety, the main rule that should be followed is that only improvement or maintenance of the current safety level is acceptable. Anything other than that shouldn't be allowed (reduction of traffic safety for cost
General conditions for drivers that should contribute to shorter distance are over 100 meters. To keep this time as low as possible if this time is 4 seconds (for same speed), driver reaction time 1 second, the train travels almost 30 meters.

Brake delay time is part of reaction distance that isn't correlated to the human factor. It depends on the train brake system, train composition, and train type (passenger or freight) [4]. This time is also measured empirically. It depends on the time required for pressure increasement up to 95 % in brake cylinders and the breakthrough speed of the command execution [4], [14].

It's important to mention that this paper considers only air brakes that are used on Republika Srpska Railways. Regular control and maintenance of brake systems should keep this time within its boundaries and with that, it'll undoubtedly provide shorter brake delay distances. The second part of the stopping distance, braking distance has the main influence on train stops. As already shown in the models presented, all formulas are empirical. It's impossible to calculate braking distance without uncertainties. Besides human and brake system factors, the braking distance is affected and by some external factors, like main movement resistance force, gradient, and friction. For braking distance determination, especially for higher speeds and advance systems, simplified models shouldn't be used for calculations [4]. When rail and road vehicles (or pedestrians, cyclists, etc.) collides on (or outside of) level crossings, stopping distance comes to the fore. Even if they are prescribed in advance, in the court of law, question, if the train could stop before the collision, is often. When it comes to level crossings, by BiH legislative, rail vehicles have right of way when encountering other vehicles (no matter from which side other vehicles are approaching the railroad), unless otherwise is specified by the sign [18]. This is confirmed by the Republika Srpska railway traffic safety act, where is stated that the train has right of way regarding other non-rail traffic units [17]. In [17] is also stated that pedestrians and cyclists are allowed to cross railroad only on level crossings. Knowing the previous article, if a collision occurs on an open rail line, outside of level crossing, there shouldn't be room for guilty of train drivers, regardless of the stopping distances, if they met all other railway traffic safety conditions (stated in [11], [13], [17]), especially if we take into account that on an open rail line, between stations, the train uses maximum speed allowed. On level crossings with the lowest level protection, "stop" signs are installed before the railroad, meant for road traffic users, who by themselves warn that stopping before the railroad is necessary. In most cases, when a collision occurs, the sight distance between rail and road units is too short for a train to stop. In addition to sight distances being too short, often physical obstacles, terrain configuration, rail line position, and adverse weather conditions further extend stopping distances. When designing block sections, each block length needs to be a minimum length as the longest stopping distance on that line.

Overlap is a component which length partially depends on stopping distance, but mainly on speed and gradient. Longer overlaps provide a higher level of safety but they take highly more infrastructure capacity. On block sections, they're used for authority granting to the next train (Fig. 2.).

Train stopping distance is the factor that greatly influences railway traffic safety. For trains to safely travel on railway, trains must be provided with sufficient distance in which to stop [3]. It's possible to classify two types of stopping distances. For railway systems, it's important to predetermine values of maximum stopping distances because they're used when designing certain parts of the system (for example block sections or overlaps). As already said, stopping distance length is affected by reaction and braking distances. If it comes to reaction distance, driver reaction distance is the factor that on first-hand doesn't seem to have a great influence on overall value, but if we take the worst possible outcome from Table II, for reaction time 1 second, the train travels almost 30 meters (for 100 km/h speed). If we take into account that this time is empirical and that in certain cases it can be longer, for example, if this time is 4 seconds (for same speed), driver reaction distance is over 100 meters. To keep this time as low as possible it's important for drivers to have full attention while driving.

General conditions for drivers that should contribute to shorter reaction distances are: [11] :
- physical and mental requirements,
- appropriate education,
- appropriate training under qualified supervision for driving,
- possession of a professional license,
- possession of a driving license,
- possession of additional specific certificates.

Quality and comprehensive periodical control of physical and mental health greatly help in traffic safety maintenance. The brake delay time is part of reaction distance that isn't correlated to the human factor. It depends on the train brake system, train composition, and train type (passenger or freight) [4]. This time is also measured empirically. It depends on the time required for pressure increasement up to 95 % in brake cylinders and the breakthrough speed of the command execution [4], [14].

It's important to mention that this paper considers only air brakes that are used on Republika Srpska Railways. Regular control and maintenance of brake systems should keep this time within its boundaries and with that, it'll undoubtedly provide shorter brake delay distances. The second part of the stopping distance, braking distance has the main influence on train stops. As already shown in the models presented, all formulas are empirical. It's impossible to calculate braking distance without uncertainties. Besides human and brake system factors, the braking distance is affected and by some external factors, like main movement resistance force, gradient, and friction. For braking distance determination, especially for higher speeds and advance systems, simplified models shouldn't be used for calculations [4]. When rail and road vehicles (or pedestrians, cyclists, etc.) collides on (or outside of) level crossings, stopping distance comes to the fore. Even if they are prescribed in advance, in the court of law, question, if the train could stop before the collision, is often. When it comes to level crossings, by BiH legislative, rail vehicles have right of way when encountering other vehicles (no matter from which side other vehicles are approaching the railroad), unless otherwise is specified by the sign [18]. This is confirmed by the Republika Srpska railway traffic safety act, where is stated that the train has right of way regarding other non-rail traffic units [17]. In [17] is also stated that pedestrians and cyclists are allowed to cross railroad only on level crossings. Knowing the previous article, if a collision occurs on an open rail line, outside of level crossing, there shouldn't be room for guilty of train drivers, regardless of the stopping distances, if they met all other railway traffic safety conditions (stated in [11], [13], [17]), especially if we take into account that on an open rail line, between stations, the train uses maximum speed allowed. On level crossings with the lowest level protection, "stop" signs are installed before the railroad, meant for road traffic users, who by themselves warn that stopping before the railroad is necessary. In most cases, when a collision occurs, the sight distance between rail and road units is too short for a train to stop. In addition to sight distances being too short, often physical obstacles, terrain configuration, rail line position, and adverse weather conditions further extend stopping distances. When designing block sections, each block length needs to be a minimum length as the longest stopping distance on that line.

Overlap is a component which length partially depends on stopping distance, but mainly on speed and gradient. Longer overlaps provide a higher level of safety but they take highly more infrastructure capacity. On block sections, they're used for authority granting to the next train (Fig. 2.).

Fig. 2. Authority granting by overlap.
Their length is important but it's not that significant for railway traffic safety as train stopping distance. It's important to provide a certain length behind the signal to contribute to greater traffic safety. The overlap length shouldn't be less than 50 meters, or longer than 500 meters, as all different railways proposed in their technical guides.

V. CONCLUSION

Railway traffic is a complex technical and technological system, which safety is influenced by many factors. Maintaining railway traffic safety on a high level produces high costs and greater capacity consumption. In the example of train stopping distances, shorter distances are more desirable, while in the case of overlaps, longer ones are preferable.

Train stopping distance has a great influence on railway traffic safety because it depends on three variables: human, internal (technical), and external (resistances). There're many ways and models for calculating this distance, but neither of them can provide 100 % accuracy. To access more precise results, it's required to use more advanced models which consider more factors.

In case of overlap, length can be also calculated using mathematical models, but it's preferable to use practices of other railways, and historical precedents, and experimental data. Besides the safety aspect, the overlap has a great influence on capacity.

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REFERENCES

A historical review of metro in Belgrade

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Abstract—Mass passenger transport systems bring new quality through an exceptional range of transportation services, and act to completely change process and practice in development planning and management. On the basis of the Belgrade GUP from 1950., the first metro study in 1968. was made, which showed the justification of a metro network with a total length of 33 km.

Keywords—Planning, Urban Development, Mass passenger transport systems, metro.

I. INTRODUCTION

The first tram on the streets of Belgrade started on October 14, 1892, and the tram with electric traction has operated since 1894. In 1912., trams carried about 7.5 million passengers a year. In addition to all the benefits that this system of transportation had in public transport, there were also problems due to insufficient width of roads, frequent conflicts with pedestrians, vehicles, high climbs in certain sections, etc. The main reasons why the metro was created remained current and valid to this day, namely that it was and remained a completely separate, closed, determined mass transportation system, with the most capacity for regularity, efficiency and reliability in operation.(2) The basic characteristics of mass passenger transport, from an environmental point of view, is that rail systems are a favorable means of transport. There are a number of large cities that see the need for such public transport, but their financial capabilities do not allow it, however, and despite this, the number of metro cities is constantly growing. (2)

In many cities, in addition to the metro system, the tram system is being improved as a light metro system. The metro was planned in Belgrade a hundred years ago, but to date, despite many analyzes, studies, plans and constructed tunnels, it has not been realized, and the aim of this paper is to present a review of the planning of the construction of the metro in Belgrade.

II. PLANNING THE CONSTRUCTION OF THE METRO IN BELGRADE IN THE XX CENTURY

The construction of the Belgrade subway, a high-capacity and fully independent rail system, as the basis of public transport in Belgrade, was planned in 1921 in the awarded competitive work of French architects. (1) The Master plan for the city of Belgrade (GUP) from 1923, drafted by Djordje Kovaljevski, envisaged a railway tunnel that would connect the central railway station at the Sava Amphitheater to the Danube railway station.

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A study commissioned by the State Railway Construction Department provided a tunnel of 2,718 meters long, with an interior designed for double track, and exclusively for rail traffic. The design of the tunnel was hampered by high altitude differences, unfavorable soil composition, and existing sewage installations. In 1932., 2,140 motor vehicles were registered in Belgrade, while a tram network of a total length of 45 km constituted the basis of the passenger transport system. In 1938. the introduction of subways on the city's three main traffic lines was considered: King Aleksandar - Terazije - Zemun, Kalemegdan - Slavija - Autokomanda and Topcider - Sava Railway Station - Terazije - Danube Railway Station, each with 10-13 million passengers per year (third line along the existing, roundabout route), given that Belgrade, with Zemun and the suburbs, then had about 310,000 inhabitants. Reforms in stages were proposed on all three lines, starting with the reorganization of existing tram lines, which was followed by the construction of tunnels and subways. The introduction of underground metro was first proposed on line 2, at the Kalemegdan - Terazije - Slavija - Autokomanda - Vozdovac line, with a total length of 5 km of tunnel route with 6 underground stations. This metro would be part of the city railway, which would also include an electric railway above ground in the extension of the metro at the Vozdovac - Banjica - Avala, 12.5 km long, and cable cars from the end of the railway station, at the foot of Avala to the Monument to the Unknown Hero in the length of 600m. Separation into the center and periphery encouraged the governors to further expand the public passenger transport network, so that before World War II, Belgrade had a population of 320,000 and tram lines to the borders of what was then a continuously built area. (3)

Immediately after the end of World War II, the action was directed in two directions: restoring the normal functioning of the city and drafting long-term planning documents for further development. At that time, architect Nikola Dobrovic was concerned with the spatial development of the city, whose numerous visionary moves would be understood and realized (Highway through Belgrade). Belgrade GUP adopted in 1950 he set out two tasks:
- Solve problems of complex city organization that will grow from 400,000 to 1,000,000 in 20 years.
- Design a new part of the city on the left bank of the Sava River and integrate it with urban Belgrade and Zemun.

The historic decision to move the city to the other bank of the Sava River has opened up new perspectives for Belgrade, from the end of the railway station, at the foot of Avala to the Monument to the Unknown Hero in the length of 600m. Separation into the center and periphery encouraged the governors to further expand the public passenger transport network, so that before World War II, Belgrade had a population of 320,000 and tram lines to the borders of what was then a continuously built area. (3)
conditions, would be left until it was finally replaced by new modes of transport.

On the basis of the GUP from 1950., the first metro study in 1968 was conducted, led by dr. eng. Savo Janjic and in which the first comprehensive metro concept was proposed, which envisaged three lines with a total length of approximately 33 km, which would connect 35 stations with three diametrical lines, which disconnect the city tissue from the center. The envisaged lines A and B followed the busiest traffic routes, and the C line was intended as a shorter transverse connection between the two lines with the construction of which would begin upon completion of the first two lines and then proceed to the densely populated residential areas of Banovo brdo and Karaburma. Line B is intended to be the location code for the new main passenger train station (later moved to Prokop at Autokomanda). The distances between the stations are projected at 600–800 m in the center and 1000–1300 m towards the periphery. (8)

When many of the GUP's forecasts of 1950 have already been overcome, there was a need to develop a new General Urban Plan for Belgrade in 1972. and about 2.000.000 inhabitants of the city, which imposes the need to build over 4.000.000 m2 of new living space on the free and slightly constructed terrain of Belgrade's development directions towards Batajnica, Vinca and Zeleznik. According to the GUP concept of 1972., the performance of commercial and public activities is realized through a system of general and specialized centers, with a special place for the main city center, the Kalemegdan-Slavia move with the most attractive public facilities and tertiary activities. The starting point for the 2.000.000 residents in Belgrade in public transport is a two-line metro. With the adoption of the GUP in 1972., a decision was made to develop a study on the development of public transport in Belgrade with the metro as the main means of fast and mass transportation of people in the city, with answers to be given regarding the choice of system, technology and economy, the final routes and locations of subway stations as well as other elements. On September 20, 1972., the President of the City Assembly, Branko Pesic, signed with the Institute for Construction and Reconstruction of the City of Belgrade an agreement on the establishment of the Metro and Underground Works Division at the Institute, headed by architect Bransilav Jovin. The GUP of 1972. envisaged the formation of a network of city centers in Belgrade: central zones (main center), secondary city centers, district centers and community centers. For the metro system, the backbones on the Batajnica - Vinca and Petlovbo brdo - Karaburma routes are planned, with a total length of 50 km. 500 km of the bus network were planned, as well as the reconstruction of the tram network in order to serve until 2000. In 1973., an agreement was made with the Urban Planning Authority to develop the necessary urban studies and an investment program for the railway junction in Prokop was adopted, and work began at the Urban Planning Institute on the Belgrade Stage Development Plan to 1985. (1)

The proposed network of capacity systems in the continuously built area of Belgrade (up to 10 km from the city center by City metro-GM) supports the distribution metro line with forked lines, which function together with interconnecting lines as a complete network system. Three points of intersection (two with regional subways) are formed in the very core of Belgrade, in order to enable fast and efficient transfer of passengers while creating the basis for the formation of a large pedestrian zone (Knez Mihailova Square, Republic Square, Terazije, Slavia). The Regional Metro Network (RM) serves development in the wider Belgrade area. It consists of two routes of general orientation East-West and North-South. With the existence of the Republic Square and the Faculty of Economics connected to the metro stations, a basic triangle is formed in the central core of Belgrade. The urban metro passenger network is provided at 7 more peripheral points. In this way, the more remote parts of the city are served quickly and efficiently, and at the same time, it creates a traffic base for the regional development of individual settlements in the wider area of Greater Belgrade (Pancevo, Indija, Barajevo, Obrenovac, Lazarevac, etc.). The capacity is estimated at 40,000 passengers per hour in one direction. The vehicles would depart in 2–4 minutes, with a station spacing of up to 800 meters and an exploited speed of between 30–40 km / h. (GM) Regional Metro (RM) would have a station spacing of up to 2 km and develop speeds of up to 80 km / h (Fig. 2,3).
Fig. 2 The first stages of the M1 subway from Mercator to the Vukov monument

The proposed solution would reduce the volume of surface traffic, air pollution and communal noise, increase the accessibility of attractive contents in the central zone, equalize the differences between individual dwellings, enable the revitalization and reconstruction, increase pedestrian spaces, and enable the dedication of surfaces to more attractive, economically more favorable and / or humane purposes. The study states that the proposed system is an essential prerequisite for the achievement of the objectives of the 1972 General Plan, noting that if radical measures are not taken in the public transport system, Belgrade's urban, functional and economic development will be endangered, while the spatial and environmental consequences of traffic dehumanize urban spaces and devalue the urban lifestyle. Urban and technical documentation at the level of conceptual designs as well as the financing structure for approaching the decision to build the First phase of the metro was done in 1981. The dynamic investment plan of the investment is made on the basis of the dynamics of construction and estimate of works, which requires the highest concentration of funds in the third and fourth year since then the most complex facilities are being worked, pre-invests in the technical base and procures more than half of the total required vehicles, and from fifth to fifth the seventh year, the volume of annual investments is somewhat increased with further decrease in the final stage of construction. (6)

The new GUP of Belgrade shortens the line of the first subway stage in 1985. and proposes a subway M1 stage from Mercator to Vukov monument 7.54 km long with 11 metro stations, out of which 5.94 km underground and 1.6 km above ground and road rail bridge across the Sava, a total length of 13.5 km with 18 metro stations.

In 1995., the Vukov Monument train station was put into operation, during which a tunnel connection was made for the future metro line below King Aleksandar Boulevard and the metro tunnels at the future Prokop railway and metro station.

In 1998, work continued on the metro project. In 1998, work continued on the subway project. Two variants of the general project of the metro bridge on the Sava River were made (to the existing old bridge in the extension of Zoran Djindjic Boulevard in New Belgrade now), and then along the route through the tunnel to Nemanjina Street. (as given by the competition work from 1921).

In 2000, the Metro Division at the Institute for Construction of the City of Belgrade was abolished and work on the metro project stopped.

III. METRO IN BELGRADE AT THE BEGINNING OF THE XXI CENTURY

The analysis of the presented planned construction of the metro in Belgrade until the beginning of the XXI century can state the following:
- In Belgrade, back in 1921, the competition decision "URBS MAGNA" confirmed that Belgrade needs a subway;
- In the Study "Conditions for running underground railways" a metro corridor is given;
- In the "Belgrade Metro Studio", a metro with three routes was given;
- In the GUP of Belgrade in 1972, two metro lines were given, with a total length of about 50 km;
- In the "Study of techno-economic suitability of fast public city transport in Belgrade" in 1981, a metro with 5 lines of the city metro GM and 4 lines of the regional metro RM was given;
- In the "Strategy of transport systems in the long-term development of Belgrade - the strategy of development of public transport" in 1996, it was given that it is necessary to build a subway and develop a program to finance the design and construction of the subway;
- In 1998, the Assembly of the City of Belgrade passed a Decision on the preparation of a regulatory plan for the construction of the Metro M1 line with 11 stations in the length of 7.54 km;
- The general project of the dual-purpose road-rail metro bridge over the Sava was done in 2000 and revised at the session of the Audit Commission of the Ministry of Construction and Urbanism in 2000;
- It is important to mention today that 35-40 years ago Belgrade was a "closed city" that could not be entered and when it could not be exited, and people traveled to and from work by existing transport (at distances up to 7 km), more than 50 min. It is also important to say that large investments are not only
financed from state and city funds, they are also financed, built and exploited by concession agreements with the state (project financing systems by methods, B.O.T and B.O.O.T.). The GUP of Belgrade from 2003. has removed the metro from public traffic in Belgrade, considering that its construction is uneconomical, so a surface tram is planned on the metro route. (whose part of the line was partially realized). In October 2005., the author of the team of the Metro Study on the Institute for the Construction of the City of Belgrade (Branislav Jovin, Jovan Katanic, Mihailo Maletin, Savo Djakonovic) in the "Study on the Metro in Belgrade" warns that the total funds for the construction of the first stage of the subway are objectively smaller than the Automobile Inner Main Semi-Ring UMP (with a bridge over Ada Ciganlija), and that the problem of traffic in the city of Belgrade will not be permanently solved, and the cost of constructing a UMP is, among other things, the complete destruction of valuable premises in Topcider. The authoring team warns: "as many times before ... there were" experts "with" life-saving solutions ". More recently, the false dilemma of the "light" or "heavy" metro has been planned, and the dilemma that does not exist is the question: will we begin the new millennium with a cosmetically refined tramway for the 21st century or finally begin to build a rail system called " metro". In March 2008, the Directorate for Construction Land and Construction of the Belgrade JP prepared the Traffic Master Plan of Belgrade "Smart Plan" (7).

The Academy of Architecture of Serbia in September of 2009. sends material on the Belgrade metro project to the Mayor of Belgrade and the Minister of Infrastructure of Serbia: Report on discussions with foreign traffic experts, "2009.-2016., Again-Belgrade with the metro system" and the conclusion, among other things, that is "....... a two-million city - European Belgrade a necessary-independent distribution metro system — not a street tram (LRT) of the Spanish company" Ineco "impersonated as“ Belgrade Metro ". The report was prepared by the architect Branislav Jovin for the Academy of Architecture. (1)

By adopting the modification of the Regional Spatial Plan of the AP Belgrade in 2011., the metro system was reintroduced in the GUP of Belgrade for public transport in Belgrade (8 years after the interruption of work on the metro), and work continues in the newly established institution of the City of Belgrade - Directorate for Building Land and Construction Belgrade JP.

The GUP of Belgrade, adopted in 2016 (Official Gazette of the City of Belgrade No. 11/2016, dated March 7), plans to build the Belgrade Metro on three lines: Line 1 Ustanička-Aleksandra Dupčeka (Tvornička) with a technical connection to the depot in New Belgrade in block 66, Line 2, Banovo brdo-center and Line 3, connection of the direction Banovo brdo over the new bridge on Ada with line 1. The GUP reads as follows: "The mentioned routes, which are defined by the amendment of the General Plan until 2021, from 2009, represent the basis of the future network of the Belgrade Metro. Priority in the realization, for the period until 2021, is given to Line 1, which, through the narrowest central old core of Belgrade and through the central area of New Belgrade, connects the east with the western area of the city. Having in mind the directions of development of Belgrade, as well as the previous perceptions of the possibility of further expansion of the metro network in the future, the following directions are proposed, which need to be technically and planned developed and defined in the coming period. The first phase of the construction of the Belgrade Metro, according to the current observations and on the basis of the documentation done so far, is Line 1, a stretch from Ustanička Street to Aleksandra Dupčeka Street (Tvornička Street). This plan provides a proposal for the development route of the metro network in Belgrade on the basis of previous observations and prepared technical documentation. In the following period, it is necessary to analyze the proposed routes through the preparation of study documentation, taking into account all spatial changes, needs and limiting factors, after which it is necessary to start making plans with elements of detailed planning, which will define all elements of regulation and leveling, as well as the positions of the stations on the route."

In 2016., the City of Belgrade adopted the Traffic Master Plan by 2033, developed by the English consulting firm WSP. In the Belgrade Traffic Master Plan until 2033., the first metro line will be 22 kilometers long, connecting Makisko Polje and Mirijevo and the second line connecting Zemun and Mirijevo, 20 kilometers long. (Fig 4)

Fig 4. Belgrade Metro Stages 2016. M1-red

According to the general project with the Preliminary Feasibility Study (2019), done by the French design house EGIS Rail, the route of the first metro line from Makiš to Mirijevo is 21.3 kilometers long with 23 metro stations with a distance of about 900 m. The study on environmental protection for the corridor of the two planned metro lines (under the jurisdiction of JKP Belgrade Metro and Train), was done in 2020. A Geological Study is being prepared, which will provide precise indicators that will indicate how which part of the metro route will be built. When the first metro line was determined and when the Traffic Master Plan of Belgrade and the General Project with the Feasibility Study (which are the basis for the development of the urban plan) were made, not only traffic but also urban and economic aspects were taken into account.
IV. CONCLUSION

The awarded competition work of a team of French planners for the General Urban Plan of Belgrade in 1921, even then provided for public transport in Belgrade a trolleybus, bus and metro with three lines, with the recommendation that the tram transport be abolished over time, noting that Belgrade lies on 7 hills and that public transportation should go through the hills, not on the hills. Unfortunately, even 100 years later, the Belgrade metro was not built except for the metro tunnel in King Aleksandar Boulevard near the Vukov monument. It has been proven that for large-scale ventures it is never too late and, until they are built, they are never deleted from the plans of the development strategy - neither the planned route nor the names, an example is the Lamanche tunnel (beginning of realization in 1882. and ending in 1995.). Due to the problems of experts' views for decades, I hope that our experts will not be asked any time soon, and that the problem of construction for the metro will be solved by those who are guided by the maxim time is money, and an independent high-capacity rail system - the metro will be built in Belgrade.

"The least we can do today is not to make short-term decisions that would prevent development projects from being implemented tomorrow." (Gojko Beara)

REFERENCES

Сообраќајно проектирање
Traffic Design
Micromobility – Infrastructure, Legislative and Safety Challenges

Draženko Glavić¹, Ana Trpković², Sreten Jevremović³, Marina Milenković⁴

Abstract – Modern cities and their transportation systems are challenged by new mobility options – micromobility, which includes light vehicles such as electric: scooters, skateboards, bicycles etc. Regardless of whether they are private or public service offer, the micromobility opened many questions concerning legislation, infrastructure limitation and traffic safety, which will be briefly discussed in this paper.

Keywords – Electric micromobility, Street redesign, Legislation, Safety, MaaS

I. INTRODUCTION

Rapid technological advancement and innovations lead to continuous social changes, which consequently has an impact on the development of the complete traffic system. Standard vehicles powered by fossil fuels are being replaced by electric and hybrid vehicles – more environmentally friendly and cleaner ones. Drivers do not have to operate vehicles since this is done by a computer. Due to the development of artificial intelligence, computers have made the implementation of autonomous vehicles possible. Artificial intelligence has enabled the development and testing of the V2X system for informing, warning and communication, which encompasses V2V, V2I, V2P, V2N technologies. The collection and usage of data in real time, development of new transportation modes, such as drones, electric bicycles and electric scooters, represent further technological advancement, developed with the aim of sustaining urban mobility and creating intelligent and ecologically clean cities.

Bicycles, skateboards, electric bicycles and the most recent transportation mode which is the subject of this paper – electric scooters – are representatives of a relatively new concept – micromobility. The term micromobility has become a catch-all term for previously named modes of transportation, and can be considered as a trip in short distances. This trip is usually between walking and driving distances or trip related with tramway tracks, are not safe for e-scooter riding. The 80 cm circumference and radius, limit their use on the above-mentioned streets. Although a large number of countries have started introducing amendments to the law in order to properly handle this transportation mode, insufficient attention is still paid to infrastructure development and modification.

Popularity of this transportation mode rose rapidly, primarily due to favorable features of e-scooters: easy to use, faster than the traditional public transport and more compact than bicycles, available to a wide range of users, healthy and environment friendly.

By the end of 2018, electric scooters mostly replaced bicycles and electric bicycles so there were 85 000 e-scooters in 100 cities in the USA. In the same period in the USA, 38.5 million of trips were realized by e-scooters, out of which 40% of the trips were in Los Angeles, San Diego and Austin [1]. Similarly, in all larger European cities, the offer of public renting of e-scooters has been enabled. Thus, it is estimated that Paris has approximately 20 000 e-scooters, Copenhagen about 7000, while in Cologne this number is estimated to reach 40 000 by the end of the year [2]. In Belgrade, approximately 35 000 e-scooters were sold during the period of several months in 2019 [3].

As urban population grows, car ownership is growing, along with the increase of urban mobility resulting congestion on street network. Micromobility could play a crucial role of additional mobility service in cities, thus helping tackle with increasing congestion. Due to its advantages, micromobility could easily replace cars for the significant number of short trips and especially short trips in cities, which can help in reducing and excluding cars from city centers.

II. INFRASTRUCTURE FOR E-SCOOTERS

Basic precondition for the efficient functioning of e-scooters is adequate infrastructure. Currently, this is one of the most important issues micromobility is facing. Physical limitations of the street network and road profile, different structures and characteristics of the base course and the existing separation represent the obstacle for the safe usage of e-scooters.

Traffic experts worldwide agree that streets with the surface course made of cobblestone or sheets, as well as the streets with tramway tracks, are not safe for e-scooter riding. The characteristics of these vehicles, primarily their small wheel circumference and radius, limit their use on the above-mentioned streets. Although a large number of countries have started introducing amendments to the law in order to properly handle this transportation mode, insufficient attention is still paid to infrastructure development and modification.

In the countries and cities where the arrangement and adaptation of the space has already begun, e-scooter users are mostly redirected to the cycling infrastructure. Such examples can be found in Tel Aviv, Paris and most American cities. In London the government intends to legalize the use of e-scooters primarily in business zones, parks and campuses. Company Voi in Sweden plan to introduce “Zones 20” where e-scooters would be allowed to move. The city of Copenhagen intends to introduce and test 200 electric scooters in the historical city center, as well as of 3000 e-scooters in satellite zones [4].

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For instance, in Texas it is allowed to ride e-scooters on sidewalks, while in Colorado sidewalks are the only places where they can be used. In California, it is strictly forbidden to ride e-scooters on sidewalks, but riding is allowed on the carriageway along the right brink of the sidewalk. In reality, the situation is considerably different, and e-scooters are frequently ridden on sidewalks in spite of the prohibition and warnings that this compromises traffic safety. A similar situation can be found in Serbia, where the use and movement of e-scooters is not regulated, so users frequently ride them on carriageways, sidewalks and bicycle paths, as can be seen in Fig. 1.

At the moment there is the issue of parking management as well as the implementation of the equipment necessary for e-scooter charging. Although most companies choose the system of parking on sidewalks, and the possibility of leaving e-scooters at any location in the city, after using them, has had an effect completely opposite to the desired one.

Generally speaking, there are two concepts regarding the redefinition of the space for electric scooters. The first one, based on the example of Germany and several American cities, relies on the complete separation of all user categories, as it is shown on Fig. 2.

![Figure 1. An example of using an e-scooter](image1)

This concept assures higher level of traffic safety for users of e-scooters, given that there is no interference with different categories of users: pedestrians, car drivers, cyclists etc. The main disadvantage of this principle is that it requires a lot of space for infrastructure implementation.

The second concept is based on the idea of “naked streets” where all traffic users operate in the shared space without separation [5]. The example is shown in Fig. 3.

![Figure 3. An example of a concept „shared space“](image2)

In essence, this concept creates a greater sense of uncertainty who has the right of way on a street, which consequently raises awareness of the presence of other road users.

Generally speaking, two mentioned concepts have their advantages, but present two completely opposite approaches. With the current situation in cities, which face both the exponential growth of the e-scooter number in the street network and the lack of space, the solution could lie somewhere between these two concepts, and could be a result of their combination and coordination.

### III. Legislation

The existing laws could not follow the increasing popularization and development of this transportation mode, even in the countries where e-scooter services can be used, a large number of traffic accidents and inadequate behavior have appeared.

For example, in Britain it is illegal to ride electric scooters on public roads, sidewalks and bicycle lanes and paths. In addition, an e-scooter rider has to be at least 14 years old [6]. E-scooter riders are fined with £300 and 6 penalty points on their driving licence. Consequently, the exponential growth of e-scooters and changes that came with them, induced active measures on the improvement of legislation in Great Britain. As a result, the strategy: “Future of Mobility: Urban Strategy” was adopted, at the beginning of 2019, in which micromobility holds an important place [7].

Some countries such as France and Germany have already defined or are currently classifying a new vehicle group (PLEVs – “personal light electric vehicles” [8]. Electric scooters are treated as PMD (“personal mobility devices”) in Singapore, while in Poland there is an initiative for amendments to the law in order to introduce a new vehicle category (PTD – “personal transport device”) [9].
California if one of the first states that regulated the use of e-scooters. For example, the driver has to possess a driving licence and the use of cycling infrastructure (paths of class II and IV) is allowed at the maximum speed of 25 km/h. It is allowed to ride an e-scooter on the street with the 40km/h speed limit, but only if the e-scooter moves at the speed of up to 25 km/h. Also, it is allowed to use the roads with the speed limit of up to 56km/h, with the previous permission of the authorities. In this case, the speed of the e-scooter must not exceed the 25 km/h speed limit [10].

In Serbia, there are no regulations regarding the use of e-scooters. However, certain amendments to the existing Law on Road Traffic Safety have been announced. The Road Traffic Safety Agency has proclaimed the amendments to the law to start in 2020. Until then, the users are only offered experts’ recommendations, which are mainly related to the use of protective helmets and careful operation of e-scooters.

IV. MICROMOBILITY SAFETY

In spite of many advantages, electric scooters have aroused strong public opposition. The main opponents of this transportation mode are cyclists and pedestrians. Namely, they are placed under a lot of pressure due to the need for sharing the infrastructure and the fact that their safety is jeopardized. Pedestrians are generally the most vulnerable category since in most countries riding e-scooters on sidewalks has not been regulated by law yet. As a consequence, traffic accidents including pedestrians are very frequent.

In the 2018, approximately 1500 recorded injuries were caused by the use of e-scooters, and eight people were killed in 47 American cities, [11].

A study conducted in Austin, Texas, for the period of three months (from September to November) found out that 271 people had been injured as a consequence of using e-scooters. A more thorough analysis showed that during the observed three-month period at each 100 000 trips by e-scooters 20 people were injured. In the total sample, 58% of the injured were the users younger than 30. Head injuries (48% of the respondents) and fractures (35%) were the most frequent. It is important to mention that in the total number of the injured, 62% were novice users, while only 4% of the users wore a helmet while riding [12]. Similar injury distribution is present in California, for one-year research period. Results are shown in Fig. 4.

V. SWOT ANALYSIS

The biggest contribution of micromobility is in its role as a part of MaaS, which could be the perfect solution for filling the empty spot between walking and public transport, as it is shown in Fig. 5. Moreover, micromobility has a potential of serving the user transport needs, for a distances up to 8 km [14]. Given its benefits, an increasing number of researchers and decision makers are recognizing and promoting micromobility as a promising mode of transportation.

Having previously said in mind, a SWOT analysis was conducted in order to highlight the main properties and characteristics of micromobility. SWOT analysis is a structured planning method that helps to evaluate the strengths, weaknesses, opportunities and threats.

According to SWOT analysis one can see that micromobility have many advantages and opportunities. While weaknesses and threats are caused mainly due to a rapid and booming usage of micromobility that did not
followed with rapid changes in space allocation and regulation.

Important strengths, previously explained in this paper, are directed to reduction of car traffic and reduction of parking congestion. In the era of green and urban mobility biggest strengths of micromobility are: air quality improvement, noise reduction, reduction of climate change and better land use. All of mentioned strengths have, as the main product, urban space improvement.

Significant opportunities are related to social equity, eco mobility and shared mobility. With targeted strategic actions, there is strong opportunity for reduction in number of parking lots and number of traffic lanes for cars, which could consequently unburden the main city areas.

Weaknesses and threats are mostly focused on the aspects that are previously explained in this paper: traffic safety, lack of regulation and legislative framework, enforcement measures, weather conditions and terrain conditions.

Table I. SWOT analysis of micromobility – e-scooters

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<th>Strengths</th>
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<td>• Reduction of car traffic</td>
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<td>• Reduction of parking congestion</td>
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<td>• Generation of revenues</td>
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<td>• Air quality improvement</td>
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<td>• Reduction of noise</td>
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<td>• Reduction of climate change</td>
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<td>• Urban space improvement</td>
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<td>• Better land-use</td>
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<tr>
<th>Weaknesses</th>
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<td>• Traffic safety</td>
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<td>• Lack of regulation</td>
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<th>Opportunities</th>
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<tr>
<td>• Social equity</td>
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<td>• Eco mobility</td>
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<td>• Shared mobility</td>
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<td>• Can reduce number of parking lots</td>
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<td>• Can reduce number of traffic lanes for cars</td>
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<th>Threats</th>
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<td>• Legislative framework</td>
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<td>• Weather conditions</td>
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VI. CONCLUSION

The established trends and expansion of new transportation modes within the concept of micromobility ask for the change of the previous attitudes and perceptions of the traffic system as a component of the city. The most recent representative of this concept – e-scooter – has shown that certain countries and cities are not prepared for the abrupt changes that this transportation mode brings.

Although certain countries have started to change and improve their traffic and legal systems, this process is long-lasting and requires considerable effort in order for the first significant results to be noticed. So far, Serbia has not taken any measures in dealing with these new changes. Therefore, it will have to actively and seriously address this issue. The first and most important step in dealing with this issue is the improvement of legislation in order to form a basis for taking further actions. A good example is set by Germany, France, Singapore, Poland, etc. In their legislation, these countries have defined or classified a new vehicle category. This can be a good starting point for defining domestic laws and by-laws.

The amendments to the law enable the incorporation of this new transportation mode into the existing traffic system; they offer the possibilities of arranging and constructing the required infrastructure, and sanctioning of improper behavior of traffic users. The examples seen around the world offer the solution of using shared spaces or part of the infrastructure, which requires all users to make certain concessions. Therefore, the improvement of the legislation and traffic system makes the solid basis which will provide equal conditions to all participants in traffic.

Lastly, micromobility, with its notable strengths and opportunities, could play an important role as a part of MaaS. This integration can significantly reduce our environmental footprint, save money, increase efficiency, increase population health and improve land use. With mentioned advantages and adequate implementation measures micromobility will progressively shape the future of traffic system.

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Graph Database Modeling of Urban Area Road Networks

Ilija Hristoski\(^1\) and Marija Malenkovska Todorova\(^2\)

Abstract – Specific features delivered by the class of Graph Databases allow for modeling road networks of different scales. In this paper, we propose and implement a Graph Database model of a typical road network inherent to urban areas. Such a database can be used along with diverse information systems, to provide information of various natures.

Keywords – Road networks, Urban areas, Traffic, Graph databases, Neo4j.

I. INTRODUCTION

Back in 1736, Leonhard Euler, the great Swiss mathematician, successfully resolved what later appears to become a notable historical problem in mathematics, the famous “The Seven Bridges of Königsberg” problem, and so laid the foundations of topology and graph theory \(^1\). Almost three centuries later, graphs have been rediscovered with the emergence of graph databases, which make a rapidly growing segment of modern non-relational databases.

The rapid progress of urbanization has induced, besides all known benefits, a lot of complex, yet highly important issues to be concerned about, such as traffic congestion and pollution. Inner human migrations that happen on a daily basis have pointed out the necessity of efficient and reliable transportation, as well as enlarged and enriched urban road network infrastructure. Effective traffic management that would lead to improving traffic flows and reducing both the congestion and pollution in urban areas needs a large amount of diverse data to be acquired and stored properly and processed quickly.

Inspired by Euler’s approach to representing geographical topology with graphs, and having minded the need of effective traffic management, the paper focuses on exploring the possibilities of representing urban area road networks with state-of-the-art graph databases. More precisely, the aim is to illustrate the procedure of manual building of such a database from scratch, as well as to point out the vast potentials and benefits of their application in a modern traffic science.

The rest of the paper is organized as follows. The most recent research related to the substance elaborated hereby is given in Section II. Section III provides a brief overview of graph databases, their basic building blocks, and their most notable characteristics. The analysis of data requirements is given in Section IV. Section V focuses on the implementation specifics using Neo4j and CQL. The last section concludes.

II. RELATED RESEARCH

The application of graph databases in technical sciences, especially in the sphere of transportation and traffic sciences, has become mainstream during recent years. Some of the most notable research endeavors are being attributed to Czerepicki, who sheds light on the perspectives of using NoSQL databases in intelligent transportation systems \(^2\), and also presents an innovative concept of applying graph databases in transport information systems, by implementing the solution of finding the optimal route between two stops in a public transport environment \(^3\). In addition, Zheng et al. proposed a spatio-temporal data model based on a graph database, which integrates the three temporal GIS’s key elements: space, time and attributes \(^4\). The urban data integration (UDI) framework, which is capable of integrating heterogeneous urban data stored in a graph database, has been introduced in \(^5\). The concepts, methodologies, and applications of urban computing, including many transportation issues, have been elaborated in \(^6\). The usage of the Neo4j graph database in modeling urban traffic has been explained in \(^7\).

III. GRAPH DATABASES

Graph databases belong to the family of NoSQL databases. Thanks to the fact that “in graph databases, relationships are considered to be ‘first-class citizens’”, they address one of the great macroscopic business trends of today: “leveraging complex and dynamic relationships in highly connected data to generate insight and competitive advantage” \(^8\). They organize and store data in the form of a graph, based on the mathematical principles of the graph theory. Fundamentally, a graph can be considered as a collection of nodes (vertices), graphically depicted by circles/bubbles, and edges (arcs), portrayed by directed arcs connecting two nodes. Nodes typically represent entities (i.e. particular instances of entity types), whilst edges are used to represent various relationships between those entities. Both nodes and edges can hold detailed data (i.e. attributes) in a ‘property/value’ manner, to describe the entities represented by nodes and to depict the nature of relationships among them, respectively.

Neo4j is the pre-eminent and pre-dominant graph database engine, offering ACID transactions, native graph data storage (it is fully optimized and designed for storing and managing graphs), and graph data processing, i.e. an index-free adjacency (connected nodes physically ‘point’ to each other in the database). It supports the Cypher query language (CQL), which aims to use an ‘ASCII-art’-like syntax to make storing and querying of graph data as easy as possible.

Graph databases are inherently schema-less and are characterized by high efficiency, scalability, and ability to handle a large number of concurrent users.
IV. ANALYSIS OF DATA REQUIREMENTS

Instead of transforming the relational database schema or the E-R diagram of a real (existing) or generic (non-existing) transport information system into a graph database model through the process of logical mapping, the process of physical mapping of urban area road network directly into a corresponding graph database model is being exploited and elaborated in this paper instead. It can be carried out in two, mutually exclusive, and inverse, ways, a primal way and a dual one, which are both based on the usage of urban area road maps. From a graph database perspective, the basic features of these two approaches are the following ones:

- The primal way: Road intersections are modeled as nodes (graph vertices), and particular road sections are modeled as relationships (graph arcs, graph edges) between two consecutive nodes;
- The dual way: Particular road sections are modeled as nodes, and road intersections are modeled as relationships connecting two consecutive nodes.

In this paper, the focus is put on the primal way, taking into account the following assumptions:

- An urban road network consists of roads and road intersections;
- A road consists of one or more road sections;
- A road section is a segment (i.e. fragment) of a road connecting two consecutive (i.e. adjacent) road nodes on a road map; The traffic on a road section can occur in one or two directions; Each direction can include one or more traffic lanes; In a graph database, a road section corresponds to a relationship connecting two consecutive nodes;
- A road node is a point on a road map, which can be either a terminal node (i.e. a road breaking point at the border of a road network map, and a beginning/ending point of a road, or a junction node - intersection point among two or more roads), type of an intersection (e.g. T-shaped, Cross-shaped, Star-shaped, Roundabout), geolocation (i.e. longitude, latitude as strings in DMS format, altitude, and geolocation data as decimal degrees);
- A road intersection is a road node that connects two or more road sections.

The equivalent general graph database model, depicting a two-way road section connecting two road nodes, is depicted in Fig. 1. This is a schematic view of the basic building blocks involved in the construction of a graph database: road nodes and road sections comprised of one or two traffic directions.

It should be also notified that, in this paper, the manual procedure of physical mapping of an urban area road network into a corresponding graph database is described. In fact, Cypher can be used to load urban road network data into Neo4j from a file, such as a CSV and JSON file, to facilitate and speed up the process of building the graph database. Alternatively, the Neo4j built-in ETL (Extract-Transform-Load) feature can be used to load such data from a JDBC-connected RDBMS. In this particular case, there was no urban road network data available in any electronic format and/or relational database for the urban area of interest, so the graph database had to be built manually from scratch.

Before implementation, one should consider what data (i.e. attributes) are going to be kept within the graph database’s nodes and relationships.

A. Data Stored within Nodes

Graph database nodes should keep the following basic information: unique identifier of the node, node name, urban area zone name, city name, type of the node (e.g. terminal node - road breaking point, terminal node - beginning/ending point of a road, or a junction node - intersection point among two or more roads), type of an intersection (e.g. T-shaped, Cross-shaped, Star-shaped, Roundabout), geolocation (i.e. longitude, latitude as strings in DMS format, altitude, and geolocation data as decimal degrees).

Besides these mandatory data, graph database nodes can also include other attributes relevant to the system the graph database is intended to be used with. For instance, in the case of a pollution monitoring system based on the utilization of a distributed system of measurement stations (sensors), graph database nodes can also include attributes corresponding to data about air quality (PM$_{10}$, PM$_{2.5}$, NO$_x$, CO, CO$_2$, SO$_2$, etc.), air pressure, air humidity, air temperature, UV radiation, sonic pollution (noise), gamma radiation, etc., which can be all acquired and updated in real-time. Alternatively, all of these measurement parameters can be included in the graph database as newly added graph nodes, connected to the existing ones.

B. Data Stored within Relationships

The most relevant information that should be kept in relationships (i.e. traffic directions of road sections) is unique identifier of the traffic direction, unique identifier of the road section, unique identifier of the road (street), name of the road (street), designation of the road (street), road category, road significance, road section length, number of traffic lanes, traffic lane width, maximum speed allowed. Relationships should also include traffic flow variables, such as average flow rate, average headway, time mean speed, space mean speed, traffic density, and distribution of vehicles’ relative frequencies [%] according to their category (bicycles, motorbikes, passenger cars, buses, and trucks).
V. IMPLEMENTATION

The starting point in the process of implementation is to obtain a road map of the urban area of interest, which can be generated based on a satellite image or simply manually sketched. In this particular case, Google Maps has been utilized for this task, however, other sources, like Google Earth, can be used, as well.

Further on, all road breaks at the borders of the map are being marked up with a symbol of a transparent circle, and hereby denoted clockwise with strings as ‘x1’, ‘x2’, ..., ‘xN’, \( N = 13 \) (Fig. 2). Additionally, all road beginnings/endorings, as well as road intersections within the map are denoted with integers (e.g. 1, 2, 3, ..., \( M; M = 20 \)), hereby starting from left to right, and from top to bottom. Specifically, the road beginnings/endorings (e.g. 2, 10, and 12) are being marked up with a symbol of a yellow-colored, double-lined circle, whilst all road intersections are being marked up with red-colored circles. Different ways of notation and markings are used in order to distinguish between the three types of circles. In Fig. 2, if circles are treated as nodes, and roads between some nodes as edges, then the resulting structure represents an undirected finite graph, \( G \).

In order to achieve maximum accuracy and reliability, the act of building a graph database manually out of such an undirected graph should be carried out in a consistent and systematic way, especially in the case of complex graphs, e.g. disconnected graphs and/or graphs that include a vast number of nodes (road intersections) and edges (roads). In this particular case, we have used a slightly modified version of the Depth First Search (DFS) graph traversal algorithm that assures consistency in building up the graph database’s nodes and relationships simultaneously with visiting all the edges in an undirected graph (a road map). The pseudo-code of the recursive version of the modified DFS algorithm is as follows:

```plaintext
// G: an undirected graph, // an input set of edges and nodes (a road map) // u, v, w: nodes in G // R: a directed graph, // an output set of edges and nodes // (a graph database)
procedure init_DFS(G) {
    for each u in G
        u.visited = FALSE; // on a road map
}
procedure DFS(G, v) {
    create node v in R; // in a graph database
    v.visited = TRUE; // on a road map
    for all neighbouring nodes w of node v in G
        if w.visited = FALSE then
            DFS(G, w);
        else
            if edge(v, w) exists in G then
                create relationship (v, w) in R;
            if edge(w, v) exists in G then
                create relationship (w, v) in R;
    }
}
procedure main(G) {
    init_DFS(G);
    for each u in G
        DFS (G, u);
}
```

The execution of the modified DFS algorithm assures visiting all nodes in graph \( G \), depicted by Fig. 2. The manual generation of the corresponding graph database should be performed in parallel with the execution of the algorithm. Each labeling of a node as ‘visited’ on the road map means creation of a node in the graph database \( R \), which can be either a terminal node resembling a road breaking point (at map borders), a terminal node resembling a beginning/end of a road (within the map), or a communication node resembling an intersection among two or more roads (within the map). On the other hand, each adding of an edge \((v, w)\) to the resulting set of output edges and nodes, \( R \), means the creation of a relationship between the nodes \( v \) and \( w \), i.e. a traffic direction between two nodes \( v \) and \( w \) comprising a particular road segment. This way, the undirected graph in Fig. 2 becomes a directed graph, and also a visualization of the equivalent graph database layout (Fig. 3).

The corresponding graph database (Fig. 4) is comprised of 33 nodes and 74 relationships.

![Fig. 2. Road map of the urban area of interest, presented as an undirected graph encompassing border nodes (breaking points), inner nodes (intersections and terminal nodes), and edges (roads)](image2.png)

![Fig. 3. Road map of the urban area, presented as a directed graph](image3.png)
It has been fully implemented in Neo4j using CQL (Cypher Query language).

In Fig. 4, the structure of the graph database is logically equivalent to the directed graph of the urban area of interest, represented in Fig. 3. Moreover, the intrinsic data stored within the graph database’s nodes and relationships match the facts about the existing urban road network infrastructure.

The appliance of various graph algorithms can be used to compute numerous metrics for graphs, nodes, or relationships [9-10]. For instance, given that each traffic direction within the underlying graph stores data for the attribute RoadSectionLength (in meters), and given that all nodes belong to the class road_point, the following CQL code, which embodies the allShortestPaths graph algorithm, computes the top 2 shortest paths between any two nodes (source, target) in a graph, in a descending order (Table I):

```cql
CALL algo.allShortestPaths.stream("RoadSectionLength", {nodeQuery:"road_point", defaultValue:1.0})
YIELD sourceNodeId, targetNodeId, distance
WHERE algo.isFinite(distance) = true
MATCH (source:road_point)
WHERE id(source) = sourceNodeId
MATCH (target:road_point)
WHERE id(target) = targetNodeId
WITH source, target, distance
WHERE source <> target
WITH sourceNodeId, targetNodeId, distance
YIELD sourceNodeId, targetNodeId, distance
RETURN source.NodeName AS source, target.NodeName AS target, distance
ORDER BY distance DESC
LIMIT 2
```

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<th>Top 2 Shortest Paths</th>
</tr>
</thead>
<tbody>
<tr>
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<td>target</td>
</tr>
<tr>
<td>&quot;20&quot;</td>
<td>&quot;12&quot;</td>
</tr>
<tr>
<td>&quot;12&quot;</td>
<td>&quot;20&quot;</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

In this paper, an urban area road network has been modeled and implemented using a graph database, Neo4j, and Cypher Query Language. The powerful and expressive semantics graph databases exhibit in representing relationships among entities makes them one of the best ways to store and manage both present and future data related to traffic and transportation in urban areas.

Based on the graph database data, running CQL code can provide answers to various users’ queries, such as:
- Selection of nodes and traffic directions belonging to a particular traffic path between any two arbitrary points, based on a given criterion;
- Finding out the total length of a given traffic path between any two arbitrary points;
- Finding out all the shortest paths (in number of steps or length) between any two arbitrary points in the graph;
- Implementation of various graph-based algorithms related to spatial navigation; etc.

As a bottom line, it can be concluded that, due to the unprecedented method of storing data and processing, graph databases offer a highly appropriate way to represent information for specific use in traffic and transport sciences.

REFERENCES

I. INTRODUCTION

Road infrastructure plays the multifaceted role in meeting the transportation needs in many countries around the world. It is considered as an important component in the processes of economic, environmental and social development, as three basic pillars of sustainability. In accordance with the relevant literature and professional expertise, the impact of increased vehicle automation and connectivity, especially when it comes to road infrastructure, will result in huge changes of road transport as a whole, and in that manner, on mobility, road safety, traffic management, energy saving, road environment, economy. [1]

This paper is focused on the challenges facing the road authorities and operators which are directed towards different aspects of road infrastructure adaptations to the mentioned technological progress. As a result of studying the various scientific research papers, reports and documents related to the connected and autonomous vehicles, as well as the major road infrastructure benefits and challenges, the article aims to point out the need of providing a framework for taking measures in overcoming the gaps between the current and future way of using the roads.

II. AUTOMATED AND AUTONOMOUS DRIVING

The essence of the automated driving definition is focused on the way of driving, i.e., in transfer of the responsibility for various driving activities from the human driver to the automated driving system.[2] The difference between the automated and autonomous driving is based on the degree of involvement the human interaction in the mentioned process. It further leads to the explanation of terms used to describe a type of vehicle such as: automated car (AC), (‘... it would follow orders about destination and route, and may only adopt some lane-keeping or car-following guidance’), [3], autonomous vehicle, (AV) - or self-driving vehicles (which is capable of fulfilling the operational functions of a traditional vehicle without a human operator), [4], as well as connected vehicles, (CV) and connected and autonomous vehicle, (CAV). In accordance with the fourth mentioned reference, the advanced feature of CV is reflected in its ability to make the connection between the vehicle and its external environs, while CAV is the combination between AV and CV.

How these vehicles work? The way of functioning is the same when the vehicle is driven by the human driver: collecting the information, deciding on the mode of response, and, as a final step, implementation of the decision. This is made possible by advanced technologies related to the vehicle equipment, road infrastructure and the whole driving environment. [5]

The participation of human and cars in different levels of automation is clearly presented in Fig.1,[5]. In addition, the explanation is given below.[6],[7].

0 level: NO AUTOMATION – Zero autonomy. The driver performs all driving tasks,

I level: DRIVER ASSISTANCE – Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design,

II level: PARTIAL AUTOMATION – Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times,

III level: CONDITIONAL AUTOMATION – Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

IV level: HIGH AUTOMATION – The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.

V level: FULL AUTOMATION – The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.
A. Potentials of automation for improving of road transport

Integration of automation on different mentioned levels is expected to have positive impacts on socio-economic development, (bearing in mind the user impacts, and effects on wider environment as well), through road safety improvement, higher level of personal mobility, changes and increasing in travel demands, better realization of vehicle operations, public health, energy and network efficiency, travel behavior, land use.

Therefore, going through the relevant references, [7],[8], it is expected that new safety technologies, will prevent up to 34% of accidents.

The positive impact is also reflected on shaping and increasing of transport mobility, (more independent mobility, as well as shared mobility, new solutions, better accessibility, social inclusion).

The increase in travel demand, (depending on the type of travel), will range from 2% to 47%. [8]

Automation has great potential for improvements in vehicle operations, starting from assisted driving with partially automated vehicles, up to full automation with the ability to free the human driver of his tasks during driving.

Air pollution resulting from transport is an important public health problem. Current estimations predict decreasing of greenhouse gasses as a result of new car technologies, from 40% to 60% in total. [9].

Energy efficient opportunities in the frame of automated driving is worth mentioning. For example, considerable benefits in fuel consumption are expected using of 90% of autonomous vehicles on suburban roads in USA.[9] On the other side, authors in [10], point to the fact that an increase in energy consumption is also possible, due to the reduced travel cost, higher highway speeds, longer commute distances and inclusion of elderly, disabled and young people as road users.

The road network operation, (through the improvement of traffic efficiency), is also considered as positive effect of automation in road transport, which is reflected on vehicle density and flow rates.

Going through the relevant references can be concluded that automation also have an impact on travel behavior, (number of journeys and vehicle kilometers travelled, transport mode choice, auto ownership), and patterns of land use which impact people’s activities.

B. Challenges in vehicle automation

Apart from the mentioned benefits, it is notable that the vehicle technological development is facing with many challenges in cars and outside the cars, [11] such as:

Implications on road policy;
Road infrastructure demands;
Truck drivers job loss, because the new technology can significantly reduce the need for truck driver employment;
Big security concern, bearing in mind the possibility for cyberattacks and in that way affecting and controlling the vehicle’s operation;
The necessity for changes in current laws or introduction of new ones;

Cost consideration, i.e., high price of these vehicles;

Improving the technology in order to achieve a higher level of vehicle adaptation to different circumstances, such as: type of the road, its surface, weather conditions;

Errors of computer devices which can be a reason for accidents;

Privacy, as an important aspect in using this type of vehicle;

Reducing of driving experience and competencies which could result in difficulties during human driving.

Analysis of the benefits and challenges, leads to the fact, that the automation development in road transport is characterized with considerable uncertainty. Due to the possible conflicts between above mentioned impacts, there is a need for development the strategies and guidelines directed towards optimization in the process of new technologies implementation.

III. ROAD INFRASTRUCTURE RESPONSE

Since the road infrastructure development, is a very complex one, containing several phases and connecting numerous “players”, it’s obvious there is a need for changes in planning, design, construction and operation, as well as in the roles of critical figures involved in the process.

Connected and automated driving will have impacts on planning related activities. Therefore, there is a need for policy making framework as a base for planning the introduction of new vehicles. The success of this approach depends on the analysis of current and future impacts on road infrastructure sustainability, level of balance between different transport modes and demands of transport users and the necessity for continuous monitoring and evaluation of the obtained results.[12].

Analysis the results of relevant sources leads to the conclusion that the impact of advanced technologies on highway geometric design elements is different.[13]. For example, for human-driven vehicles, the required lengths of different types of sight distance on level sections, upgrades and downgrades, the lateral clearance and curve length, (important for designing the horizontal and vertical curves), as well as the width of lane are substantially greater. However, no impact of vehicle type on curve radius and transition curve length has been identified. Also, there is no need for limitation of the straight sections in horizontal alignment. Due to these reasons, the current procedures for geometric design should be analyzed and, if it is necessary, changed in order to obtain the elements suitable for new vehicles moving.

Besides the mentioned, research indicates that vehicles of the future will have a greater influence on the pavement performance.

When it comes to operation of advanced vehicles, there is a need for facilitation of traffic management through new technologies which will be able to provide real-time information and highly visible traffic signs and road markings. Traffic on cross-roads should be managed by signals and additionally, it is expected that new cars will reduce the demand for parking places.

Road authorities, professionals and planners have a central role in the process of providing the framework for adoption and implementation the policy measures, changing and adaptation of design procedures, maintenance practices and traffic management rules. The main driving force of these stakeholders should be facilitating of this transition period from existing towards fully automated vehicles.

IV. CONCLUSION

The process of road vehicle automation is a part of big progress in technology and everyday living. Therefore, the future of connected and autonomous vehicles is full of promise. On the other side, there is no doubt that the new vehicle technologies produce numerous challenges in transport system development.

Road infrastructure adaptation is one of the crucial prerequisites for implementation of advanced vehicles. The reason for this statement is based on the fact that automation in road transport produces a gap between the way of using the current and future roads. Namely, the mentioned signalizes that the existing infrastructure is not able to meet the needs of increased vehicle automation and connectivity.

Going through the numerous published papers, reports, documents, it is obvious that the changes in different phases of road infrastructure development, (planning, design, construction, maintenance and operation), should be perceived as a bridging tool between the features of existing and future road transport system as a whole.

REFERENCES

Installing vehicle restraint systems on the State roads in RN Macedonia according to EN1317 standard

Olivera Petrovska¹ Jovan Hristoski ² Andon Petrovski ³ Darko Spasenovski⁴ and Ivica Stoilovski⁵

Abstract – This paper analyzes the legal regulations, analyzes the existing situation with the guardrail on the roads in relation to the degree of danger of traffic participants, and with measures for the improvement of the traffic safety were proposed. The use of this European norm and its practical application in the fastest time are essential for the state, to raise the level of traffic safety.

Keywords – Traffic safety, Guardrail, Legal regulations and Standards.

INTRODUCTION

Restraint systems - guardrails for vehicles are an extremely important means of passive traffic safety. Due to this fact, a strategy for fully harmonizing the criteria and technical conditions for the installation of protective guardrail is clearly defined in European countries, according to European standards EN 1317. The conditions and circumstances in which guardrails are installed change similarly to the overall social environment in which traffic processes are taking place. Continuous adaptation of normative practice, but also taking concrete measures, is imperative in reducing the consequences of traffic accidents.

In our practice, many different solutions and ways of installation of fence appear on the roads. The choice of type of the fence is defined in the project documentation, but in some sections there are frequent changes, according to the decisions of the supervisory authorities, contractors and investor, which depends on the limits imposed by the built structures at roads. A particular problem is the fact that, despite efforts to innovate technical norms, fences are not set up on roads in accordance with existing standards and needs for the protection of road users.

The situation with the guardrails on the roads in the Republic of North Macedonia is more than critical. The development of science, technology and material production in this area is advanced to the extent that the overall procedure for the use of guardrails (from materials, production, quality, appearance, testing to installation) is standardized, especially at the European level according to the EN1317 standard. By adopting this standard in the form of a national standard in the Republic of Macedonia, the possibility for its application is open. Technical instructions which has been adopted by PESR of Macedonia in 2018 should be implemented in projects. That application in areas of design, performance and surveillance, is necessary to harmonize and standardize, taking into account their specificities and conditions.

In this paper are included designed solutions for installation of vehicle restraint systems (guardrail), in accordance with the Technical instruction for the application of vehicle restraint systems on the state roads of the Republic of Macedonia and MKS EN1317 standard. These design solutions provide a more efficient level of vehicle retention, thereby enhancing the safety of all road users along State roads.

SCOPE OF AREA

The area taken for consideration in this paper are alignment of the State Road A4 section Shtip - Radovish from km5 + 066.00 to km7 + 413.09, State Road A3 sub-section Shtip - Krupiste from km0+000 to km14+300, State road A2, section Skopje – Gostivar, and State Road A1 (European Corridor X/E75) of the Republic of North Macedonia.

A. State Road A4 section Shtip - Radovish

State road A4, according to the legislation, is categorized as Expressway.

Part of the scope is also the surroundings of State Road A4 with all interchanges, underpasses and overpasses, access roads and road crossings. The scope of this section is designing of vehicle restraint systems (guardrail), in accordance to standard MKS EN1317, and in accordance with the technical regulations for the transportation infrastructure design and bylaw regulations for traffic design.

B. State Road A3 sub-section Shtip - Krupiste

State road A3, according to the legislation, is categorized as Expressway. The scope is the alignment of the State Road A3, section Shtip – Kocani, sub-section Stip - Krupiste km 0+000 – 14+300.

Part of the scope is also the surroundings of State Road A3 with all interchanges, underpasses and overpasses, access roads, road crossings and road belt. The scope of this sub-section is designing of vehicle restraint systems (protective steel fence - guardrail), in accordance to standard MKS EN1317, and in accordance with the technical regulations for

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the transportation infrastructure design and bylaw regulations for traffic design.

The maximum speed on Express way is limited to \( V=110 \text{km/h} \) in the zone of exit ramps on Express way as well as at the surface intersections the speed is limited to \( V = 30-50 \text{km/h} \) depends on geometric element’s.

C. State Road A2, section Skopje – Gostivar

The road alignment is part of the Pan-European Corridor VIII, labelled E65, which in the north starts from Malmo in Sweden and in the south ends in Chania in Greece. In the Republic of Macedonia it coincides with the national label A2. State road A2, according to the legislation, on the section from km0 + 000.00 to km53 + 600.00 is categorised as highway, and on the section from km53 + 600.00 to km57 + 500.00 is categorised as national road. The scope is the alignment of State Road A2 from the Saraj interchange to the Zdunje intersection in Gostivar, of km0+000.00 (29+730.00) to km57+500.00 (87+230.00).

The highway route has 11 road interchanges, Saraj, Matka, Grucipcin, Zelino, Tetovo East, Brvenica, Tetovo South, Kamenjane, Zerovjane, Negotino, Vrapciste, and Gostivar on the trunk road. On the highway there are 4 pay toll stations at Glumovo, Zelino, Tetovo and Gostivar, and 8 supporting service area buildings and one supporting service area building is on the trunk road.

The part of zone is the area of highway with all surface connections in the form of acceleration/deceleration lanes and interchanges, supporting service area buildings, underpass and overpass roads, as a services objects and road area.

D. State Road A1 (European Corridor X/E75)

The length of the subject section of Corridor X that passes through the Republic of North Macedonia is about 170 km between the border crossings Tabanovce and Gevgelija, while the part from Demir Kapija to Skopje (about 28 km) is not taken into consideration, because it was built recently and the vehicle restraint systems were built in accordance with the EN standard.

TRAFFIC SOLUTION

Based on research for the Implementation of Vehicle Restraint System, in accordance with MKS EN 1317 standard along the considered sections passing through Macedonia, it is found that the existing guardrail is in a rather poor condition, without proper containment level and it is not properly installed, with damages, often not enough length. Also, all dangerous locations are not protected, such as truss posts of road signs, portal posts of traffic signage, lighting poles, large and open drains/gullies, unsafe ending of "New Jersey", front part of retaining walls above the carriageway, high and steep embankments, passes on toll stations, etc.

The main purpose for the State road A4, section Stip – Radovis, is modifying and supplementing only the part of design of vehicle restraint systems (guardrail) due to the need to design it according to MKS EN1317 standard.

The guardrail for vehicles is designed according to the criteria given in the MKS EN 1317 standard, and its position is determined according to the geodetic base as well as according to the cross sections for this road.

The steel protective fence must contain three important characteristics:
- Degree of retention.
- Class of the operating range (working width W).
- Degree of device strength.

The steel protective fence is foreseen at places where there is a risk of slide off vehicles according to the criteria prescribed by the MKS standards, on embankments higher than 3 meters. In the design of the guardrail, the standard MKS EN 1317 (1,2,3,5) is applied, according to which the required level of protection is determined.

According to the standard MKS EN 1317 (1,2,3,5), the following types of fences are designed:

- N2W3, A (Eco safe 2.0) placed on the shoulder;
- H1W3, A (Eco safe 1.33) placed on the shoulder;
- H1W5, A (EDSP 2.0) placed on the shoulder;
- H2W4, A (Super rail 1.33) placed on the shoulder;
- N2W1, A (Eco safe BW 1.33) placed on the structure;
- H1W5, A (EDSP BW 1.33) placed on the structure;
- H2W4, A (Super rail eco BW 1.33) placed on the structure;
- Starting and ending construction L=12m;
- Transition element from H1 to H2;
- Transition element from H2 to N2 and from H1 to N2;
- Constructive elements for connecting the fence with concrete elements;
- Crush cushions for \( V=80 \text{km/h} \);
- Tubular lattice parapet (pedestrian fence);
- Protective net road overpass (attached on the pedestrian fence).

On the section Stip – Krupiste from km0+000 – km14+300 was modifying and supplementing only the part of design of vehicle restraint systems (guardrail) due to the need to design it according to MKS EN1317 standard.

The guardrail for vehicles is designed according to the criteria given in the MKS EN 1317 standard, and its position is determined according to the geodetic base as well as according to the cross sections for this road. The steel protective fence is foreseen at places where there is a risk of slide off vehicles according to the criteria prescribed by the MKS standards, on embankments higher than 3 meters. In the design of the steel fence, the standard MKS EN 1317 (1,2,3,5, and 5) is applied, according to which the required level of protection is determined with following types of fences:

- N2W3, A (Eco safe 2.0) placed on the shoulder;
- H1W3, A (Eco safe 1.33) placed on the shoulder;
- H1W5, A (EDSP 2.0) placed on the shoulder;
- H2W4, A (Super rail 1.33) placed on the shoulder;
- N2W1, A (Eco safe BW 1.33) placed on the structure;
- H1W5, A (EDSP BW 1.33) placed on the structure;
- H2W4, A (Super rail eco BW 1.33) placed on the structure;
- Starting and ending construction L=12m;
- Transition element from H1 to H2;
- Transition element from H2 to N2 and from H1 to N2;
- Constructive elements for connecting the fence with concrete elements;
concrete elements;
- Crush cushions for $V=120\text{km/h}$

On the state road A2 from km0 + 000.00 to km53 + 600.00 which is categorized as motorway the traffic guidance is in one direction, and on the section of km53 + 600.00 to km57 + 500.00 which is categorized as trunk road the traffic guidance is in two directions.

The maximum speed of the A2/E65 highway, section Saraj - pay toll station at Tetovo is limited to 120 km/h, and the maximum speed on the section Tetovo - Gostivar between adjacent intersections with installed pay toll stations is limited to 90 km/h. On the trunk road A2/E65 section pay toll station Gostivar - Zdunje, for safety reasons, is limited to 60 km/h.

According to the standard MKS EN 1317 (1, 2, 3, 5), the following types of fences are designed:
- H1W3 (А) (1.33) placed on the shoulder in the zone of the side boards;
- H1W5 (А) (2.0) placed in the separation zone and on the shoulder;
- H1W5 (А) (2.0) anchored, placed on retaining walls;
- H1W5(А) (2.0) mounting - demounting, mounted on official crossings;
- H1W6 (А) (4.0) placed on the Tetovo East interchange between the exit ramp to Gostivar and the highway;
- H2W2 (B) (0.5) placed in the separation zone;
- H2W4 (А) (2.0) placed according to the standard;
- H2W4(B) (1.33) anchored, placed on retaining walls;
- Initial and final construction with a length of 12 meters;
- Transition construction of H1 to H2;
- Constructive elements for connecting the fence with concrete elements;

Crush cushions for 110km/h were applied to the exit section of the interchange Tetovo East in the direction of Skopje - Tetovo and the outer section of the interchange Saraj in the direction of Tetovo - Skopje.

State Road A1 (European Corridor X/E75) has problems regarding the installation of restraint system on the observed road section of the highway. There are certain problems due to which it is not possible to install guardrail because of an inadequate base (e.g. bridges, overpasses, culverts, large drains, etc.), as well as problems related to guardrail because it cannot be installed in accordance with standard EN 1317. In addition, there are road sections where it does not seem rational to install the guardrail, so it is necessary to do some preliminary works (e.g. remove trees which is most often self-cultivated wild plant, replacement of inadequate curbs, rehabilitation of retaining walls, reconstruction of large concrete drains etc.) to eliminate the need for the installation of guardrail. Certain preliminary works (e.g. relocation or replacement of truss constructions, etc.) and construction works (e.g. reconstruction of inspection path on structures, reconstruction of large concrete drains, rehabilitation of retaining walls, rocky slopes, etc.) are necessary in order to install safety barrier.

Some of defined problems and their solutions are given on following figures:

![Fig. 1. Sub-guide on the section Kumanovo - Miladinovci, km 20 + 112](image1)

Fig. 1 shows that there are not necessary conditions for the installation of a safety barrier on most bridges and overpasses (structures). Inspection paths are not wide enough for the installation of safety barrier of required degree of retention and dynamic deflection, while concrete of certain inspection path on some structures is in poor condition. One of solutions is reconstruct inspection paths on structures so as to ensure conditions for the installation of H2-W4 guardrail (smaller structures where third parties are endangered) or H1-W2 (smaller structures where third parties are not endangered), and second is in case of small box culverts, it is necessary to cast concrete beam along the culvert to provide conditions for the installation of H2-W4 guardrail (structures where third parties are endangered) or H1-W2 (smaller structures where third parties are not endangered).

![Fig. 2. Entrance head from pipeline omission, km 15 + 830 (west lane)](image2)

The tops of large and open drains made from solid concrete are higher than the carriageway and positioned to the very edge of the carriageway, which represents a massive, non-deformable obstacle (Fig.2). One solution is such non-deformable barriers can be protected by H1 guardrail. Second is reconstruction of drains/gullies by reducing it to the level of surrounding terrain and covering it from the top with a concrete slab, as it has already been done on the observed road section, without installation of guardrail. The third is to set a metal grid drain cover that is not raised too much, without the need for guardrail installation.

On Fig. 3 are sporadic trees on both sides of the carriageway and in central reserve on the whole road section.
One of possible solutions is trees should be protected by H1 guardrail on both sides of the carriageway. Barrier H1 can be installed in central reserve if both lanes are at the same height, which in a joint operation is a system with a retention level as barrier H2. If there is any obstacle in the central reserve and joint operation of H1 barrier can not be achieved, H2 barrier must be installed on both sides of central reserve. Second solution is removing trees on both sides of the carriageway and in central reserve.

Locations of two presented tunnels (Fig. 4) are at km 47+150,00 and at km 65+200,00 (western carriageway lane). Problem is the entrance to a tunnel is not protected, so a vehicle may directly hit the tunnel portal construction. Proposed solution is installation of H2 guardrail in front of the tunnel on both sides of the carriageway and fitting to the tunnel wall using transition element.

Given that in the Republic of North Macedonia the installation of the guardrail according to the standard EN1317 is a relatively new procedure, it is necessary for the phase changing of the existing type of guardrail with a new type of guardrail.

ADDITIONAL REMARKS

Special thanks to the company 24 ING Bitola for the selfless cooperation and availability of data from the Basic Traffic designs that were required to prepare this paper.

CONCLUSION

The guardrail as part of the vehicle restraint system is the most commonly used element of road equipment that directly and extremely significantly influences the realization of passive road safety.

With implementation on the design project solution for installation of vehicle restraint systems (protective steel fence - guardrail), in accordance with the Technical Guidelines for the application of vehicle restraint systems on the state roads of the Republic of Macedonia and MKS EN1317 Vehicle Retention System Design Standards, provide a more efficient level of vehicle retention, thereby enhancing the safety of all road users along the subject sections.

The applied solutions have revealed the major shortcomings in the traffic safety of the sections in question, which emphasizes the need for its immediate repair. Only current issues have been resolved.

All Vehicle Restraint Systems (VRS) must meet the requirements of the European Standard EN 1317. The systems must undergo crash tests and the associated parameters and acceptance criteria that are defined by the norm. Depending on the test results, the systems are divided into performance classes. Each type of VRS is evaluated as an individual part of the EN 1317.

REFERENCES

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[3] EN 1317-2, Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets, 2010
[7] Basic traffic design for traffic signalization and equipment on State road A2, section Skopje – Gostivar, 24 ING dooel Bitola, January 2018
[8] Basic traffic project for traffic signalization and equipment of the state road A3, section Stip – Kocani, subsection Stip – Krupiste, 24 ING dooel Bitola, January 2020
Application of the MKS EN 1317 on the roads of the Republic of North Macedonia

Riste Ristov¹, Slobodan Ognjenovic², Ivana Nedevska³ and Zlatko Zafirovski⁴

Abstract – The paper contains a comparison of the previous standard for use of elastic guardrail with the newly applied. The comparison will identify the advantages and disadvantages of both standards regarding the type of the materials, installation, designer approach and maintenance. In addition, comparison will be conducted regarding the safety aspect via constructed test sections.

Keywords – Disadvantages, Materials, Guardrail, Advantages, Comparison.

I. INTRODUCTION

The guardrail, as part of the vehicle restrain system, is the most frequently applied element of the traffic equipment on the roads, which directly and considerably influences the achievement of passive safety of traffic.

The initial application of the new guardrail standard in Macedonia started as a recommendation in the road safety audits (Road Safety Audit – RSA) where the auditors gave initial directions to the designers on how to increase road safety by applying EN 1317. Of course, the experts did not initially considered these directions as serious because an applicable road safety standard had already existed in Macedonia and was considered than more than reliable.

The background for the introduction of the recommended standard opened only recently, with the increased number of road accidents where the inspection identified shortcomings in the guardrail. The application started with the elaboration of the Technical instruction on the application of the vehicle restrain on the roads in Macedonia, enabling for overall application of the МКS ЕN1317 standard, adopted as far behind as in 2011. A short comparative analysis of the two standards will be presented in this paper.

II. CHARACTERISTICS OF MKS U.S4

The MKS U.S4 standard in Macedonia was inherited by the previous JUS U.S4 one which was initially taken from the German standard of DIN.

• U.S4.100 – The technical conditions for the fabrication and delivery of steel guardrails (A and B profile). These conditions refer to the material of which the guardrail is fabricated and its general structural characteristics, as well as of their making and form, joints, surface protection, packing and delivery. This standard is based on the German document of RAL-RG 620: 1972, however allowing for certain modifications in view of adjustment to the than Yugoslav market. Those modifications refer to the IPE 100 pillar and the sigma (RAL), with the possibility to replace it by a U120 profile and a profile C spacer, with the features nearest to the profiles available on the domestic market. All tin-made parts are fabricated of C0361 steel, whereas the hardness of the bolts is of 8.8. The surface protection refers to class 2 steel constructions (other open air constructions) finally precised by the steel standard. The final parts, pillars and spacers are marked with the sign of the manufacturer, as per U.S4.108 the year and the month of fabrication [1].

• U.S4.104 – Guardrail and concrete bumpers - terms, definition and classification. This standard includes the basic terms regarding railings, general classification of railings, classification and marking of guardrails.

Figure 1. Classifications of steel guardrails
Source: MKS U.S4

This standard gives an detailed explanation of the steel guardrail type and of the concrete bumpers and presents the abbreviated terms that would be used upon design and effectuation. [2].

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Figure 2. Classification of protective concrete bunkers (New Jersey)
Source: MKS U.S4
- U.S4.108 – Form and dimensions of the steel guardrail (profile A and B). This includes the exact dimensions of each separate elements, the connection and the assembly, and a presentation of the dimensions of the constructed guardrail [3]

Figure 3. Form and dimensions of guardrail parts. Source MKS U.S4.
- U.S.4.110 – Technical conditions and method of placement. This standard refers to the conditions and method of placement on locations that have to be protected in situation and in cross-section [4].

Table 1. Guardrail lengths before/after the point of danger

<table>
<thead>
<tr>
<th>Road type</th>
<th>Before the danger point (m)</th>
<th>After the danger point (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorways and first category roads</td>
<td>min. 48 (60)</td>
<td>min. 12 (18)</td>
</tr>
<tr>
<td>Second category roads</td>
<td>min. 36 (48)</td>
<td>min. 24</td>
</tr>
<tr>
<td>Third category roads</td>
<td>min. 24 (32)</td>
<td>min. 18</td>
</tr>
<tr>
<td>Fourth and fifth category roads</td>
<td>min. 16</td>
<td>min. 12</td>
</tr>
</tbody>
</table>

Note: The values in brackets are the priority lengths:

Figure 4. PGDS diagram/dividing lane and Inclination/Embankment height. Source: MKS U.S4

III. MKS EN 1317

In relation to MKS U.S4, and led by the latest standard of 110 treating the placement of the guardrail, a comparison has been made with the newly applied standard of EN1317 in which the guardrail is generally placed according to the same principles in cross-section and in a layout plan. Therefore, the description
of EN1317 shall not refer to placement part, but only analyze the structural, safety and administrative preconditions.

Besides its basic function of protection of vehicle passengers against hard consequences of deviation from the lane because of the possibility of a crush into a dangerous obstacle or dashing off the road, this standard also refers to the necessary special protection of third persons or areas along the road as well as on the motorways for protection against traffic from the opposite direction.

The main criteria for evaluation of the efficiency class of the protective systems pursuant to the MKS EN 1317-2 are the following:

- Restain level,
- Action area,
- Crush intensity level.

The restrain level refers to the durability of a system of protection of vehicles against crush depending on the vehicle mass, the crush angle and velocity.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Crush velocity</th>
<th>Crush angle</th>
<th>Total vehicle mass</th>
<th>Vehicle type</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB 11</td>
<td>100 km/h</td>
<td>20º</td>
<td>900 kg</td>
<td>Pass. vehicle</td>
</tr>
<tr>
<td>TB 21</td>
<td>80 km/h</td>
<td>8º</td>
<td>1300 kg</td>
<td>Pass. vehicle</td>
</tr>
<tr>
<td>TB 22</td>
<td>80 km/h</td>
<td>15º</td>
<td>1300 kg</td>
<td>Pass. vehicle</td>
</tr>
<tr>
<td>TB 31</td>
<td>80 km/h</td>
<td>20º</td>
<td>1500 kg</td>
<td>Pass. vehicle</td>
</tr>
<tr>
<td>TB 32</td>
<td>110 km/h</td>
<td>20º</td>
<td>1500 kg</td>
<td>Pass. vehicle</td>
</tr>
<tr>
<td>TB 41</td>
<td>70 km/h</td>
<td>8º</td>
<td>10000 kg</td>
<td>Heavy vehicle</td>
</tr>
<tr>
<td>TB 42</td>
<td>70 km/h</td>
<td>15º</td>
<td>10000 kg</td>
<td>Heavy vehicle</td>
</tr>
<tr>
<td>TB 51</td>
<td>70 km/h</td>
<td>20º</td>
<td>13000 kg</td>
<td>Bus</td>
</tr>
<tr>
<td>TB 61</td>
<td>80 km/h</td>
<td>20º</td>
<td>16000 kg</td>
<td>Heavy vehicle</td>
</tr>
<tr>
<td>TB 71</td>
<td>65 km/h</td>
<td>20º</td>
<td>30000 kg</td>
<td>Heavy vehicle</td>
</tr>
<tr>
<td>TB 81</td>
<td>65 km/h</td>
<td>20º</td>
<td>38000 kg</td>
<td>Tow truck</td>
</tr>
</tbody>
</table>

Table 3: Protective devices – restrain levels (MKS EN 1317 – 2)

<table>
<thead>
<tr>
<th>Restain levels</th>
<th>Adequate testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal restrain capacity</td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>FV 31</td>
</tr>
<tr>
<td>N2</td>
<td>FV 32 and FV 11</td>
</tr>
<tr>
<td>Higher restrain capacity</td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>FV 42 and FV 11</td>
</tr>
<tr>
<td>N2</td>
<td>FV 51 and FV 11</td>
</tr>
<tr>
<td>N3</td>
<td>FV 61 and FV 11</td>
</tr>
<tr>
<td>Very high restrain capacity</td>
<td></td>
</tr>
<tr>
<td>H4a</td>
<td>FV 71 and FV 11</td>
</tr>
<tr>
<td>H4b</td>
<td>FV 81 and FV 11</td>
</tr>
</tbody>
</table>

The standard defines three basic levels of restrain resulting from the appropriate crush test of the adequate vehicle.

In order to provide for the basic level of protection and define the safety areas behind the guardrail upon the choice of a protective system it is also necessary to determine the action area, W, which is the distance between the front of the protective system and the maximal lateral position of each physical obstacle.

Figure 5. Action area. Source: MKS EN1317

<table>
<thead>
<tr>
<th>Classes of action area</th>
<th>Level of action area</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>W ≤ 0,6 m</td>
</tr>
<tr>
<td>W2</td>
<td>W ≤ 0,8 m</td>
</tr>
<tr>
<td>W3</td>
<td>W ≤ 1,0 m</td>
</tr>
<tr>
<td>W4</td>
<td>W ≤ 1,3 m</td>
</tr>
<tr>
<td>W5</td>
<td>W ≤ 1,7 m</td>
</tr>
<tr>
<td>W6</td>
<td>W ≤ 2,1 m</td>
</tr>
<tr>
<td>W7</td>
<td>W ≤ 2,5 m</td>
</tr>
<tr>
<td>W8</td>
<td>W ≤ 3,5 m</td>
</tr>
</tbody>
</table>

Crush intensity level is a theoretical feature to evaluate the body strain, the injury level or the mortal danger of the car passengers upon crush into a vehicle restrain system. The value of the ASI index is a given crush of a certain weight in a percentage of the driver’s weight suffered through a metal rail. It is calculated by the following formula:
The new EN1317 standard dictates complete elimination of all the above mentioned shortcomings, regardless of whether they are positions that do not exist in the previous standard of design.

### Table 5: Protective devices – crush intensity level (MKS EN 1317–2)

<table>
<thead>
<tr>
<th>Crush intensity level</th>
<th>ASI: Acceleration Severity Index THIV: Theoretical Head Crush Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ASI ≤ 1,0 and THIV ≤ 33 km/h</td>
</tr>
<tr>
<td>B</td>
<td>1,0 &lt; ASI ≤ 1,4</td>
</tr>
<tr>
<td>C</td>
<td>1,4 &lt; ASI ≤ 1,9</td>
</tr>
</tbody>
</table>

Depending on the danger level, speed of vehicles, AADT and the third persons risk level on a certain section, the first procedure to be effected is to determine the basic restrain level and the action area before specifying the crush intensity level. This is a general approach, most frequently referring only to the protective appliances [5].

As for the remaining part of the MKS EN 1317 standard, referring to the initial and final constructions, transitional constructions and crush buffers, other factors are also taken into consideration (as the action effect, permanent lateral deviation, dynamic deflection etc.) helping to accurately specify the dimensioned device.

Besides the basic principles of definition of the protective system, MKS EN1317 is also specific in the method of manufacturing, performance and control of each type. The standard itself defines accurate factory production control (FPC) consisting of:

- Control of input material and the provided components,
- Gives instruction on the treatment of an inadequate product,
- Corrective measures,
- Storage and packaging,
- Possibility of retroactive monitoring and marking.

After the initial control, the certification body gives its final evaluation and assessment of the results, after which the manufacturer receives the SE certificate and the product can be used with the declaration on conformity with the MKC EH 1317 standard.

The CE certificate shall be obtained for each system separately in the name of the manufacturer with the appropriate number. The manufacturer issues a declaration on the stability of features – that it releases its product as pursuant to the EN 1317 requirements. That declaration guarantees that the products have been manufactured in compliance with the provided documentation. Also, the manufacturer must accompany each batch of any certified system with assembly instructions, which are the same as those provided to the authorized laboratory before the performance of the crush test.

### IV. DISCUSSION

The features described above reveal the advantages and the disadvantages of the two standards which are (were) applied in Macedonia. The presented U.S4 bases leads to the observation that this is a solid standard, completely involving the protective lengths but without confirmation of any certain safety. It is based on previous crush tests with light vehicles and lower movement velocities. If this standard is not appropriately used, the guardrail will retain lighter freight vehicles at an exceptionally sharp angle and low movement velocity.

Nevertheless, the inconsistent use of this standard in our country resulted in considerable decrease in traffic safety. The following situations were identified on our roads in the period of application:

- Short protective lengths (shorter than the analyzed one),
- Unprotected obstacles (non-standard boards, portals, chandeliers, concrete pillars, tunnel portals, trees etc.),
- Protection of third persons is not taken into account,
- Inadequate use of the U.S4.100 and 108 standard (application of aluminum instead of steel profiles, buffers of metal sheets thinner than prescribed by the standard, inadequate pillars, bolts of quality inferior to the prescribed one, greater distance between pillars, thinner anti-corrosion zinc layer etc.).
or building omissions. Besides, this standard requires increased control both in the production of the protective system and in its installation, thus contributing to higher security of all project participants, which was not the case before. The application of this standard shall contribute to equality of all bidders in Macedonia, thus providing for standard quality of all applicable protective systems.

V. CONCLUSIONS

The above mentioned leads to the following conclusions:

- The previous MKS U.S4 standard applies two basic guardrail types, used on the roads, depending mostly on velocity, types but, due to weak guardrail characteristics, the appropriate protection level is not provided for on many sections, whereas the guardrail is over-dimensioned on points where the traffic load and the vehicle movement velocity are low,
- With MKS EN1317 all the protection systems applied are fully optimized and appropriate protection is provided at each dangerous point as per the actual need,
- A guardrail of MKS EN1317 is considerably more expensive, mostly due to the additional costs to provide an SE certificate, requiring increased production control and crush tests,
- MKS EN 1317 takes into consideration the protection of third persons, which is not the case with U.S4.

The practice so far demonstrates that in the countries where it is applied, the guardrail installed according to the EN1317 standard, achieves far better results than the one installed as per the MKS U.S4 standard, in every aspect of use. It must be mentioned that the vehicle restrain systems, designed and constructed as per the MKS EN1317 standard, do not provide for absolute protection of the traffic participants. The standard is designed as pursuant to the analysis of a large number of traffic accidents, but considering that they are an incidental phenomenon, there is also the possibility that the guardrail is not able to retain a vehicle. This standard reduces that possibility to a minimum.

For appropriate and consistent application of the MKS EN1317 it is necessary to provide for education and upgrading of all the participants in the project.

REFERENCES

(MKS U.S4.100 (1997) Technical Conditions for Delivery of a Steel-made Guardrail (A and B profile) (pp. 1-4)
MKS U.C4.104 (1995) Guardrail and concrete buffers – terms, definition and classification (pp. 1-5)
Analysis of the influence of the number of access points on the reduction of free–flow speed in Bosnia and Herzegovina

Marko Subotić¹, Željko Stević¹ and Vladan Tubić²

Abstract – In this paper, an extensive analysis of the number of access points on a rural road network in the territory of Bosnia and Herzegovina has been performed. The HCM methodology defines that each access point adversely affects the speed of free traffic flow. The negative impact is quantitatively shown through 19 sections of rural roads, as well as a trend of reducing traffic flow speed on each of the analyzed sections. By analyzing and synthesizing the data, the values obtained indicate that access points affect reducing free traffic flow speed in the Federation of Bosnia and Herzegovina twice more than in the Republic of Srpska. The analysis also shows the spatial distribution of accesses on the main roads section, which has been measured on 200 m subsections.

Keywords – access points, traffic flow, speed.

I. INTRODUCTION

Each road section on a state road of the first or second order or highway has a dual role. The section must provide efficient traffic connections and enable accessibility to desired locations in the immediate vicinity of the road. Managing access points on road sections is a comprehensive process for regulating access points on state roads, i.e. a process for facilitating access to the site with developing usage while maintaining safety and efficiency on nearby roads.

A road network, as one of the elements of transport infrastructure, is a direct indicator of development level and as such it must have defined rules under which the owner (road manager) can put it into use, but also rules intended for users. Simply, no development of any economic activity is possible without a well-developed road infrastructure. [1]

The influence of access point control is different in terms of traffic conditions on rural and urban networks due to significantly different characteristics of traffic flow (including structure, complexity, time imbalances and traffic flow conditions), as well as the attractiveness of the site which should (not) be adequately accessed. Chaotic urbanization in the immediate vicinity of roads in Bosnia and Herzegovina is especially evident on two-lane roads and their passage through populated areas.

According to HCM (Highway Capacity Manual) (HCM-2010, HCM-2016) [2,3], the access point control is not given a primary role in defining the Level of Service, while domestic recommendations give a priority role to access control in defining indicators based on traffic safety. Therefore, a hypothetical assumption that the number of access points on two-lane roads is in complex functional dependence on the percentage of time lapse, safe visibility, driving and dynamic characteristics of vehicles and road characteristics (as well as the type of terrain) has been particularly emphasized.

II. RESEARCH METHODOLOGY

According to their transport functions, public roads are divided into long distance, connecting, collection and access roads. [5,6] On the basis of the applicable Law on Fundamentals of Traffic Safety in Bosnia and Herzegovina [7], as well as the Law on Public Roads [8], two-lane roads, depending on their economic and social importance, are divided into:

- Main roads
- Regional roads
- Local roads and
- Streets in residential areas.

In this analysis, an empirical measurement was carried out on main roads of the first order by the method of observing in a moving vehicle. Using the method, it was measured the number of access points on the main road sections for every 200 meters of the measuring vehicle. In further work, the synthesis and processing of the obtained results is based on the corresponding HCM-2016 methodology for two-lane roads. Two-lane roads according to this methodology are divided into three classes. The application of the methodology is justified for roads of first and second class, but not for the third class (urban areas). By the method for calculating the free-flow speed based on the HCM methodology [2,3], the factor \( f_a \), which is an indicator of the density of the number of access points on sections of two-lane roads, is of particular importance. Free speed, according to HCM-2010 and HCM-2016, is calculated by the following equation:

\[
V_{sl} = V_{sto} - f_{bs} - f_A.
\]

where:
- \( V_{sl} \) – free speed;
- \( V_{sto} \) – base free speed;
- \( f_{bs} \) – speed reduction due to the effect of lane width and distance of lateral obstructions;
- \( f_A \) – speed reduction due to the effect of the number of access points (Table 1).

References:

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UDC:656.22.021.022.1(497.6)

The previous table, profiled by HCM-2016, provides an elemental indication that each access point reduces free speed by 0.25 mi/h (0.4023 km/h). These results are obtained by analogy, where every 10 access points per mile reduce free-flow speed by 2.5 mi/h (4.023 km/h). In HCM-2010, the effect of the number of access points is included in the analysis of capacity and service level of two-lane roads over the same factor $f_A$, which defines that each access point reduces free speed by 0.417 km/h. [2,4] By applying the weighted access density using the HCM-2010 methodology, it yields better agreement between the values of the operating speed obtained by calculation and the real values recorded in the survey on the selected section of the two-lane road. The research has showed that the difference between the operating speed obtained by HCM and the real speed is 13.19 km/h, whereas if the weighted access density is introduced, the difference between the weighted operating speed and the actual operating speed is 1.72 km/h. [4]

It is also possible to make a realistic hypothetical assumption that the increased number of access points per kilometer of a road adversely affects continuous traffic flow, reduces free speed and increases conflicts between vehicles. This paper has adopted the methodology for determining the number of access points on two sections of road given in HCM-2016 [3], analyzing the reduction of free speed for given sections, according to the results obtained by empirical research on 19 road sections of a rural road network.

### III. RESULTS OF THE RESEARCH

This paper analyzes the number of access points on 19 sections of main roads of first order, 10 sections in the Republic of Srpska and 9 sections in the Federation of Bosnia and Herzegovina. In this research, an access point means any type of access to a main road, where it is possible to approach the road by motor vehicles. In addition, fuel supply terminals were counted as two approaches, and bus stops were considered as one access point. Each intersection of the roads of the same category was viewed as a single access point, which is a disadvantage of this research since the private road and the road of higher category were classified as the same access point.

The results obtained show the number of access points per kilometer of the two-lane road and the number of access points along the left and right side of the two-lane road. Since the measuring vehicle measured every 200 m of the measuring section, the values of the number of access points on the left and right side were obtained by the data synthesis. Figure 1 shows the spatial distribution of the number of access points on the mountainous and, in Figure 2, the plain section, where a significant difference between the types of terrain is observed. It is also noticeable that there are significantly fewer access points in mountainous than plain observed area.

**TABLE I**

<table>
<thead>
<tr>
<th>Density of access points (number of access points/mi)</th>
<th>Free speed reduction according to HCM-2016 per mile/h</th>
<th>Density of access points (number of access points/km)</th>
<th>Free speed reduction according to HCM-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0 (km/h)</td>
</tr>
<tr>
<td>10</td>
<td>2.50</td>
<td>16.09</td>
<td>4.0 (km/h)</td>
</tr>
<tr>
<td>20</td>
<td>5.00</td>
<td>32.18</td>
<td>8.0 (km/h)</td>
</tr>
<tr>
<td>30</td>
<td>7.50</td>
<td>48.27</td>
<td>12.0 (km/h)</td>
</tr>
<tr>
<td>40</td>
<td>10.00</td>
<td>64.37</td>
<td>16.0 (km/h)</td>
</tr>
</tbody>
</table>

**FIG 1. NUMBER OF ACCESS POINTS ON TWO-LINE ROAD SECTIONS IN MOUNTAINOUS TERRAIN**
Based on the distribution of access points given in Figure 1, the existing extremes reflect zones of residential areas with a frequent number of access points. Table 2 shows the number of access points by measuring subsections of 200 m, as well as the arithmetic mean of access points of the given sections. This number of access points per kilometer ranges from the extremely low number of 2.47 (Klašnice-Prnjavor) to the extremely high number of 51.63 (Jelah-Karuše).

**Table II.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Section</th>
<th>Section mark</th>
<th>Section length (km)</th>
<th>AMAP/200m-right side</th>
<th>AMAP/200m-left side</th>
<th>AMAP/km</th>
<th>Road classes according to HCM 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doboj Novi-Doboj (Poljice)</td>
<td>110</td>
<td>1.469</td>
<td>0.25</td>
<td>0.88</td>
<td>5.63</td>
<td>III class</td>
</tr>
<tr>
<td>2</td>
<td>Doboj (Poljice)-Border RS-FBiH</td>
<td>110</td>
<td>2.945</td>
<td>1.00</td>
<td>1.21</td>
<td>11.07</td>
<td>III class</td>
</tr>
<tr>
<td>3</td>
<td>Doboj-Border RS-FBiH (Karuše)</td>
<td>105</td>
<td>3.517</td>
<td>0.67</td>
<td>1.83</td>
<td>12.50</td>
<td>III class</td>
</tr>
<tr>
<td>4</td>
<td>Rudanka-Doboj</td>
<td>105</td>
<td>7.405</td>
<td>2.66</td>
<td>4.42</td>
<td>35.39</td>
<td>III class</td>
</tr>
<tr>
<td>5</td>
<td>Johovac-Rudanka</td>
<td>105</td>
<td>6.854</td>
<td>1.44</td>
<td>2.38</td>
<td>19.12</td>
<td>III class</td>
</tr>
<tr>
<td>6</td>
<td>Klupe-Teslić (Barići)</td>
<td>110</td>
<td>16.734</td>
<td>2.36</td>
<td>1.90</td>
<td>21.31</td>
<td>III class</td>
</tr>
<tr>
<td>7</td>
<td>Obodnik-Klupe</td>
<td>110</td>
<td>20.134</td>
<td>0.84</td>
<td>1.05</td>
<td>9.46</td>
<td>II class</td>
</tr>
<tr>
<td>8</td>
<td>Šešlije-Johovac</td>
<td>105</td>
<td>4.701</td>
<td>0.79</td>
<td>1.21</td>
<td>10.00</td>
<td>II class</td>
</tr>
<tr>
<td>9</td>
<td>Teslić (Barići)-Border RS-FBiH</td>
<td>110</td>
<td>6.646</td>
<td>2.15</td>
<td>1.97</td>
<td>20.29</td>
<td>III class</td>
</tr>
<tr>
<td>10</td>
<td>Klašnice-Prnjavor</td>
<td>106</td>
<td>35.855</td>
<td>1.03</td>
<td>1.44</td>
<td>2.47</td>
<td>III class</td>
</tr>
</tbody>
</table>

The mean value of the access points on given sections in the Republic of Srpska **14.72**

<table>
<thead>
<tr>
<th>No.</th>
<th>Section</th>
<th>Section mark</th>
<th>Section length (km)</th>
<th>AMAP/200m-left</th>
<th>AMAP/200m-right</th>
<th>AMAP/km</th>
<th>Road classes according to HCM 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Donja Oršovica-Lukavac</td>
<td>110</td>
<td>20.155</td>
<td>1.66</td>
<td>2.33</td>
<td>19.95</td>
<td>III class</td>
</tr>
<tr>
<td>2</td>
<td>Gračanica-Donja Oršovica</td>
<td>110</td>
<td>6.89</td>
<td>3.29</td>
<td>5.14</td>
<td>42.14</td>
<td>III class</td>
</tr>
<tr>
<td>3</td>
<td>Border RS-FBiH-Gračanica</td>
<td>110</td>
<td>15.095</td>
<td>3.16</td>
<td>3.51</td>
<td>33.36</td>
<td>III class</td>
</tr>
</tbody>
</table>
addition, on the basis of HCM methodology, it is shown that the number of access points has increased in the zones of populated areas. In the collected data, it can be concluded that the number of access points in Bosnia and Herzegovina is 20.82 AP/km, which shows that their number is extremely high and that it significantly affects the reduction of free traffic flow speed on RS roads by 3.78 km/h (Obodnik-Klupe – Komparativa analiza regulative radova Građevinskog fakulteta, Beograd). However, the number of access points also has the effect of reducing the speed of free traffic flow. Free-flow speed in a function dependence on the number of access points decreases free speed on RS roads by 3.78 km/h (Obodnik-Klupe) and in the Federation of BiH by 3.93 km/h (Lukavac-Šićki Brod 2) according to HCM-2016, since these are class II rural roads. According to the research on 19 sections, the average number of access points in Bosnia and Herzegovina is 20.82 AP/km, which shows that their number is extremely high and that it significantly affects the reduction of free traffic flow speed on average.

In addition, the two-lane road sections of the Republic of Srpska have a significantly lower number of access points than in the Federation of BiH. The obtained results show that the number of access points (26.96 AP/km) in the Federation of BiH is almost twice higher than in the territory of the Republic of Srpska (14.72 AP/km). The number of access points also has an adverse effect on the continuous traffic flow, reducing free speed on two-lane roads. The unfavorable trend of increasing the number of access points due to the negative trend on the observed roads. The unfavorable trend of increasing the number of access points requires detailed realistic field recording on all sections of two-lane roads. It is especially important to create a single database of their number, which would be input parameters for planning, design and operational analyses.

IV. DISCUSSION OF RESEARCH RESULTS

The obtained research results show that there are significantly fewer access points in mountainous than in plain terrain. This decrease in access points in mountainous terrain can be explained by the fact that there are fewer settlements in mountainous terrain since those are mountainous rural areas, not tourist resorts.

In addition, the two-lane road sections of the Republic of Srpska have a significantly lower number of access points than in the Federation of BiH. The obtained results show that the number of access points (26.96 AP/km) in the Federation of BiH is almost twice higher than in the territory of the Republic of Srpska (14.72 AP/km). The number of access points also has an effect of reducing the speed of free traffic flow. Free-flow speed in a function dependence on the number of access points decreases free speed on RS roads by 3.78 km/h (Obodnik-Klupe) and in the Federation of BiH by 3.93 km/h (Lukavac-Šićki Brod 2) according to HCM-2016, since these are class II rural roads. According to the research on 19 sections, the average number of access points in Bosnia and Herzegovina is 20.82 AP/km, which shows that their number is extremely high and that it significantly affects the reduction of free traffic flow speed on average.

V. CONCLUSION

Based on the conducted research, analysis and synthesis of the collected data, it can be concluded that the number of access points has increased in the zones of populated areas. In addition, on the basis of HCM methodology, it is shown that each access point has the effect of reducing the free-flow speed, deteriorating traffic safety due to the increased number of conflicts, impeding the continuity of traffic flow, etc. On the basis of the above, the hypothetical assumption that the increased number of access points per kilometer of road adversely affects the continuous traffic flow, reduces free speed and increases conflicts between vehicles has been proved.

The research has also proved that a significantly higher number of access points on two-lane roads are in the Federation of BiH than in the Republic of Srpska. This trend needs to be addressed by regulatory plans and the prohibition of unfounded construction of accesses on a main road network. In the next period, special attention should be paid to monitoring an increase in the number of access points due to the negative trend on the observed roads. The unfavorable trend of increasing the number of access points requires detailed realistic field recording on all sections of two-lane roads. It is especially important to create a single database of their number, which would be input parameters for planning, design and operational analyses.

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A new concept of the operating speed and speed limit credibility analysis

Vladan Tubić¹, Nemanja Stepanović², Miloš Petković³

Abstract – This paper presents a new concept of the operating speed and speed limit analysis, using analytical models and empirical research. Also, the analysis of operating speeds as a function of different hourly volume classes was conducted. This method represents the basis for improvement of the operating speed models and a tool for analytical determination of the speed limit credibility.

Keywords – Speed limit credibility, Operating speed, Speed management, Hourly volume.

I. INTRODUCTION

Traffic conditions and road geometric characteristics have a considerable impact on the actual vehicle speeds in the traffic flow. In the literature, the actual speed of vehicles is named the operating speed of the traffic flow. This speed is of great significance. The operating speed is one of the basic parameters for describing traffic flow conditions, i.e. it is one of the main criteria for estimating the efficiency (level of service) of a road section. Actual speeds on two-lane roads depend on a large number of factors which are related to drivers, vehicles, road environment, radius of the horizontal curve, curvature rate, longitudinal grade, length of horizontal curves, deflection angles, sight distance, side friction angles and pavement state [1]. The operating speed value is significantly affected by the speed limit value. Speed limits, as one of the key elements of the road management policy, aim to harmonize the speeds in the traffic flow using technical and operational characteristics of the road section and environment, thus minimizing potential risks. However, speed limits are frequently set without appropriate consideration of the basic road and traffic characteristics. This results in exceeding the speed limit and considerable speed dispersion in the traffic flow.

Numerous studies have shown that the increase of speed results in the occurrence of traffic accidents and their consequences [2, 3]. However, the expressed values of speed limit exceedance have a completely opposite effect – they increase the risk of traffic accident occurrence. The reason for this is the (non)credibility of the posted speed limits, i.e. the fact that the speed limits are not in accordance with the characteristics of the road, traffic flow and environment [4, 5]. Drivers would probably comply with the speed limit if they considered it to be realistic and suitable for the road, i.e. reasonable (logical) or “credible” [6, 7]. Otherwise, the driver’s perception of the appropriate speed on a specific road section might not be in accordance with the set speed limit. According to Gardner & Rockwell, drivers tend to rely more on their own estimation regarding the appropriate speed than on the posted speed limit [8].

In addition, the non-compliance with speed limits results in the great dispersion of vehicle speeds in the traffic flow, which has a considerably negative impact on traffic safety. The larger the difference in vehicle speeds in the traffic flow, the greater the number of traffic accidents [1, 9] and severity of traffic accident consequences [10, 11]. In their paper, Garber and Gadiraju attempted to quantify the relationship between the speed dispersion and traffic accident rate [12]. They confirmed that the speed dispersion in the traffic flow was greatly influenced by the difference between the speed limit and design speed. It was determined that the speed dispersion would be the lowest if the posted speed limit was lower than the design speed by 8 to 17 km/h. Outside this range, the increasing difference between the mentioned speeds leads to an increase in the speed dispersion in the traffic flow. It was also determined that drivers tended to increase their driving speed in case of favourable geometric characteristics of the road (regardless of the posted speed limit) and that the rate of traffic accident occurrence did not necessarily rise with the increase in speed, but that it did rise with the increase in the speed dispersion in the traffic flow.

The review of the relevant literature which underlined all problems related to non-credible speed limits showed that a study dealing with this problem should be conducted in order to provide specific conclusions, measures and recommendations.

Therefore, this paper presents a new concept for the operating speed and speed limit analysis by means of analytical models and empirical research applying new technologies. The research was conducted on the representative road sections of the class I state roads in the Republic of Serbia.

The main objective of this paper is to examine the existing and innovative models for calculating the operating speed and carry out a comparative analysis of the obtained results and the actually realized speed values. In this manner, the most favourable model can be defined and it could be applied on all sections of two-lane roads when analyzing the posted speed limit credibility.

II. METHODOLOGY

Following the review of the relevant literature which highlighted all the problems of non-credible speed limits, it was determined that there was a need for conducting adequate research in the Republic of Serbia. Previous intensive research
on the speed limit credibility in the Republic of Serbia had included all sections of the class I state roads equipped with automatic traffic counters, i.e. as many as 227 sections with approximately 492 million vehicles per year. On the basis of foreign and local experiences in the previous examination of this problem, a methodology was created to analyze the speed limit credibility. The methodology contains several steps:

1. defining the representative sections equipped with automatic traffic counters (ATCs),
2. determining the geometric characteristics of the selected sections,
3. calculating the free-flow speeds of vehicles,
4. analysis of the operating speeds (the actual values and the values obtained in the models),
5. analysis of the speed limit exceedance,
6. systematic analysis.

As seen in the stated steps, the methodology requires the selection of the sections equipped with modern automatic traffic counters (ATC). Namely, the automatic traffic counters operating on the basis of induction loops register not only the traffic volume and flow structure but also the passing speed of each vehicle. Therefore, they provide a considerable sample of the actual operating vehicle speeds on the cross-section of the road sections. On the basis of the geometric characteristics of the selected sections in the ATC zone, the free-flow speed and operating speed obtained in the model should be calculated and compared with the posted speed limits. The conducted analysis can provide the conclusions regarding the credibility of the posted speed limits and the engineering measures which can be applied in order to harmonize the traffic flow speeds and decrease overspeeding.

However, the problems regarding the analysis of the speed limit credibility occur on the sections without automatic traffic counters, i.e. the sections where the actual operating speed cannot be obtained. Examining the speed limit credibility on these sections can be conducted only on the basis of the operating speeds obtained by applying the appropriate models. The literature contains a large number of different approaches for determining this speed. The question is how to define the average operating speed which would be the best representative of the traffic flow conditions. This is the reason why this study examined several most frequently used models on the specific sections with automatic traffic counters in order to find out which one is the most suitable for conducting the analysis of the speed limit credibility in the local conditions.

One of the most used models for calculating this speed is the HCM (Highway Capacity Manual) model, which is also implemented in the software package HCS - Eq. (1) [13]. According to HCM, the operating speed is defined as the average traffic flow speed in the predominant road and traffic conditions.

\[ ATS_d = FFS - 0.00776 \times (v_{d,\,ATS} + v_o,\,ATS) - f_{np,ATS} \]  

Where:

- \( ATS_d \) – average travel speed in the analysis direction (mi/h) – Operating speed;
- \( FFS \) – free-flow speed (mi/h);
- \( v_{d,\,ATS} \) – demand flow rate in the analysis direction (pc/h);
- \( v_o,\,ATS \) – demand flow rate in the opposing direction (pc/h);
- \( f_{np,ATS} \) – the adjustment factor for the percentage of no-passing zones in the analysis direction.

Local studies define the operating speed as the average speed of the traffic flow in normal conditions, i.e. the conditions in which traffic participants distract each other [14]. This definition makes this speed representative for the use in the analysis of the posted speed limit credibility. The linear model for calculating the operating speed \( V_o \) - Eq. (2), which is the most frequently used method in the local practice, considers only one value of the design hourly volume (for example, the values corresponding to the 30th or 200th hour), while disregarding other hours in a year which are characterized by significantly lower levels of traffic volume.

\[ V_{ot} = \left[ V_{sl} - \left( \frac{q_m}{C} \right) \cdot (V_{sl} - V_C) \right] \cdot (1 - R) + \frac{R \cdot P}{100} \]  

Where:

- \( i \) – vehicle category;
- \( V_{sl} \) – free-flow speed (km/h);
- \( q_m \) – design hourly volume (veh/h);
- \( C \) – capacity (veh/h);
- \( V_C \) – speed at capacity (km/h);
- \( R \) – the adjustment factor for passing visibility
- \( P \) – percent of the allowed passing zone

This can result in a series of wrong strategic decisions in the process of evaluating and creating road project designs, as well as estimating the credibility of the posted speed limits. The only way to present the traffic flow conditions more realistically is to include the weighted values of the hourly volume classes as a function of the number of hours into the process of calculating operating speeds.

Using the current level of knowledge regarding the traffic flow theory and engineering economics, new methods have been developed for determining the actual values of the design volume and operating speeds, based on the analysis of volume per classes. Previous analyses, based on the recommended number of hours per class provided by the HDM4 model (C5-87.6; C4-350.4; C3-613.2; C2-2978.4; C1-4754.4), resulted in low sensitivity, i.e. a small change of average volume values, particularly for the two last classes (C4 and C5). Consequently, the classes were redefined (C5-50; C4-200; C3-1000; C2-4000; C1-3534) [15]. Therefore, this study also calculated the operating speed values as a function of design hourly volumes on the observed sections by calibrating the local model according to the mentioned volume classes.

### III. RESULTS AND DISCUSSION

In order to test the stated models for calculating the operating speeds, the speed credibility analysis was conducted on the sections equipped with automatic traffic counters. The comparative analysis includes the comparison of the data on the actual speed values and calculated operating speed values, and their comparison with the speed limits. In this manner it is possible to make initial conclusions regarding the credibility of the posted speed limits on the class IB roads, i.e. on the
sections observed in the study, and determine which model is the most applicable in the local conditions.

On the basis of the mentioned previous research on the speed limit credibility conducted on 227 sections, characteristic representative sections were selected. For the comparative analysis of all the stated results, the sections of class IB with different geometric characteristics were selected. Namely, the following sections were selected as the subject of the study: five sections without critical road elements (WCRE), three sections with the critical radius of the horizontal curve (Rmin), two sections with the critical longitudinal grade (Grade) and two sections with the combined impact of critical radius and longitudinal grades (Rmin+Grade). The sections without critical road elements were the sections of the so-called Ibarska Magistrala, i.e. the sections of one of the most significant routes in the Republic of Serbia. The selected sections have different average annual daily traffic (AADT) and flow structure. They were selected in order to examine the impact of these traffic flow characteristics on various models of operating speeds. When it comes to the sections with the critical minimal radius of the horizontal curve or longitudinal grade, the examples with the most critical geometric characteristics were selected. It should be mentioned that there is a small number of such sections in the class I network since the traffic counting methodology does not involve posting automatic traffic counters on critical segments. The results of the conducted analysis are presented in Figure 1 and Table I.

Comparing the actual operating speed from the ATCs and the posted speed limits, it was determined that the highest overspeeding was recorded on the sections with low speed limits (50 km/h). These are the rural sections where ATCs are posted at the very beginning of the residential zones where technical and operational road characteristics enable driving at a high speed. Consequently, the greatest speed limit exceedance was recorded on the section Meljak-Stepojevac (ATC 1043) amounting to as much as 97%, as well as on the Ćelije section Ćelije (ATC 1244) amounting to as much as 96%. On the other hand, the sections with poorer geometric characteristics (Rmin, critical longitudinal grade or the combined impact of these two characteristics) included the sections where the realized actual operating speeds were lower than the speed limits. This is the case on the section Bečej-Nov Bečej (ATC 2036) which has the minimum radius of the horizontal curve of 129m in the ATC zone, which is why only 4% of drivers exceed the speed limit, while the actual operating speed is lower than the speed limit by 31%. Also, the section which has a potential for the possible reduction of the speed limit due to poor geometric characteristics (the minimum radius of 57m and longitudinal grade of 5.9% in the length of 911m) is the section Dub-Dubci (ATC 1043). On this section, 99.7% of drivers were registered to comply with the 80 km/h speed limit, while the actual operating speed was by 39% lower than the speed limit.

![Fig. 1. The comparative analysis of speeds](image)

The matching of the operating speeds obtained in the models with the actual operating speed from ATCs is presented in Table I.

<table>
<thead>
<tr>
<th>Percentage of divergence (%)</th>
<th>$\frac{V_{0,ATC}}{V_{0,ATC}}$</th>
<th>$\frac{V_{0,ATC}}{V_{0,ATC}}$</th>
<th>$\frac{V_{0,ATC}}{V_{0,ATC}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATC 1244</td>
<td>0.18</td>
<td>-0.13</td>
<td>-0.19</td>
</tr>
<tr>
<td>ATC 1151</td>
<td>0.04</td>
<td>-0.10</td>
<td>-0.17</td>
</tr>
<tr>
<td>ATC 1122</td>
<td>0.08</td>
<td>-0.10</td>
<td>-0.16</td>
</tr>
<tr>
<td>ATC 1034</td>
<td>0.03</td>
<td>-0.13</td>
<td>-0.17</td>
</tr>
<tr>
<td>ATC 1157</td>
<td>-0.06</td>
<td>-0.17</td>
<td>-0.19</td>
</tr>
<tr>
<td>ATC 2036</td>
<td>-0.11</td>
<td>-0.24</td>
<td>-0.27</td>
</tr>
<tr>
<td>ATC 1157</td>
<td>0.17</td>
<td>0.00</td>
<td>-0.03</td>
</tr>
<tr>
<td>ATC 1088</td>
<td>-0.12</td>
<td>-0.16</td>
<td>-0.18</td>
</tr>
<tr>
<td>ATC 2051</td>
<td>0.12</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>ATC 1209</td>
<td>-0.04</td>
<td>0.09</td>
<td>-0.10</td>
</tr>
<tr>
<td>ATC 1196</td>
<td>0.14</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>ATC 1043</td>
<td>-0.06</td>
<td>-0.06</td>
<td>-0.08</td>
</tr>
<tr>
<td>Average</td>
<td>0.10</td>
<td>0.12</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Generally, the obtained results show that the HCM model offers the operating speed values which are the most similar to the actually realized speeds. The absolute percentage of divergence of the speeds calculated by means of the HCM model and the actual speeds amounts to only 10%. On the other hand, the absolute percentage of divergence of the operating speeds obtained in the local and calibrated local models from the actual speeds amounts to 12% and 14%, respectively. When the observed sections are separately studied in terms of the existence of critical road elements, the results are as follows. On the roads without critical road elements where the operating speed is based on the road cross section, the speeds obtained in the HCM model showed a significantly greater matching with the actual speeds (8% of divergence) than the speeds obtained by the application of the two other models (divergence of 13% and 18% in the local and calibrated local model, respectively). Different AADT values (from 14465 veh/day to 5742 veh/day) did not have a significant impact on the obtained values. Their impact is only observed in the fact that the difference between the classic and calibrated local model slightly decreases with the reduction of
the values. The traffic flow structure also insignificantly affects the obtained results in the model. On the contrary, on the sections with the critical minimum radius of horizontal curves and critical longitudinal grades, the HCM model and the calibrated local model have the operating speed values which are the most similar to the actual speeds (divergence of 11%), while somewhat poorer matching was recorded for the speeds obtained in the local model (divergence of 12%).

IV. CONCLUSION

Speed limits represent a significant element of the speed management policy. The analysis of the speed limit credibility on the basis of the existing foreign and local experiences was limited to the sections equipped with ATCs. The main contribution of this paper is the improvement of the model for the operating speed analysis, comparative testing of these speeds and definition of the most suitable model for the analytical determination of the speed limit credibility on all two-lane sections of state roads.

The analysis was conducted on 12 representative sections of the class IB state roads in the Republic of Serbia, which contain different road geometric and traffic flow characteristics. The study tested the two most frequently used models for calculating operating speeds – the HCM model and local model, as well as the calibrated local model as a function of hourly volume classes.

On the basis of the obtained results it can be concluded that the HCM model for calculating operating speeds has the best matching with the actual operating speeds obtained from the ATCs. This was expected having in mind this model’s complexity (the largest number of influential factors) and constant improvements. When it comes to the local and calibrated local model as a function of the hourly volume classes, it can be concluded that the traditional local model is more adequate for the application on the sections without critical technical and operational characteristics, while the calibrated model offers slightly better results on the sections with critical radius of horizontal curves and longitudinal grades. Generally speaking, the HCM model is universal and applicable on the largest number of sections, while the calibrated local model as a function of the hourly design classes can be applied on the sections with exceptionally poor geometric characteristics.

The limitation of the paper is the relatively small number of studied sections (the total of 12), which should be increased in the future research. This primarily refers to the sections with critical technical and operational characteristics (Rmin, longitudinal grade, carriageway width, etc.) which are equipped with ATCs and which are not highly present in the class I state road network. In addition, future research should conduct the analysis of using hourly volumes per class in the HCM model, i.e. examine the matching of thus obtained operating speed values with the actual speed values from ATCs. This is the only manner to reach the final argumentative conclusion regarding the most suitable model for the calculation of operating speeds while analyzing the speed limit credibility.

REFERENCES

Управување и контрола на сообраќајот
Traffic Management, Operations and Control
Ways to Improve the Quality of Asphalt Roads
Anatoly Dotsenko¹ and Konstantin Mandrovskiy²

Abstract – The system of complex monitoring of the main parameters of road-construction machines and asphaltic concrete mixture during its transportation and laying on the road surface is considered. The implementation of this trend is carried out with the help of the GLONASS satellite system, which provides not only an improvement in terms of the quality of the work performance but also contributes for increasing of productivity and also reduces the human factor on the quality of the finished road surface.

Keywords – Monitoring, GLONASS, Road-construction machines, Asphaltic concrete, Quality.

I. INTRODUCTION

Highways are a complex engineering and technical constructions, one of the most critical elements of which is the road surface. It is the condition of the road surface that determines the quality and service life of the road, and also ensures safe movement of vehicles.

One of the promising areas for improving the quality of roads is the comprehensive monitoring of the parameters of road-construction machines as well as stacked material in the process of performing construction operations.

The concept of monitoring in relation to control systems of road-construction machines includes a remote contactless method of parameter control. In monitoring systems, satellite systems are assigned the function of transmitting information in the forward and reverse direction from operating machines to remote control centers. The monitoring systems allow is accumulation of large volumes of information, which makes it possible to use tools to improve efficiency.

When considering issues related to improving the quality of asphaltic concrete pavements, it should be taken into account that asphaltic concrete is a multicomponent structure, the final operational properties of which are affected by both factors related to the production of asphaltic concrete mixture at an asphaltic concrete plant (ABZ), as well as external ones, in relation to production factors [1,2], namely:

Internal (production) factors
- Properties of the asphalt mixture components and their types;
- Recipe and structure of the mixture;
- Technology of the production of asphalt mixture;

External factors
- The quality of the road cover project;
- Quality of the road base;
- Technology of transportation, laying and compaction of the mixture.

Fig. 1 shows a generalized process for the formation of the quality of asphaltic concrete pavement.

Fig. 1. The generalized process of quality formation of an asphaltic concrete pavement

Now consider the individual components of the presented technological chain, significantly affecting the quality of the finished coating.

II. MATERIALS

This part provides the information on the properties of all components of the asphalt mixture. It consists of the information contained in the passports for the components of materials, and the results obtained by the factory laboratory in the course of experimental studies on the actual properties of materials [3].

We will consider, for example, the manufacture of an asphalt-concrete mixture, the components of which are gravel (G), sand (S), mineral powder (MH), bitumen (B) and additives (D). Then:

\( G_{ij} \) is the \( j \)th feature of the \( i \)th type of gravel; \( S_{ij} \) is the \( j \)th feature of the \( i \)th type of sand; \( MH_{ij} \) is the \( j \)th feature of the \( i \)th type of mineral powder; \( B_{ij} \) is the \( j \)th feature of the \( i \)th type of bitumen; \( D_{ij} \) is the \( j \)th feature of the \( i \)th type of additive.

In this case, to evaluate the 1st type of gravel, one can use the following estimate:

\[
G_1 = \{g_1,1; g_1,2; \ldots; g_1,k_g\}
\]

where \( k_g \) is the number of indicators for gravel.

Then, all the gravel (\( m \) types in total) available in the company can be described by the following matrix:

\[
G = \begin{bmatrix}
G_1 & G_2 & \cdots & G_m \\
\end{bmatrix}
\]

Similarly for other materials.
Here, $k_m$, $k_s$, $k_{mn}$, $k_b$, $k_d$ is the number of regulated parameters for gravel sand, mineral powder, bitumen and additives, respectively; $m, d, c, e, f$ is the number of different types of these materials in the company's warehouse. On the basis of this representation we can introduce a generalized record of the aggregate of properties of the asphalt-concrete mixture components and parameters of the technological process:

To display the properties of the asphalt-concrete mixture, we will use the following set:

$$ACV = \{ acv_1, acv_2, ..., acv_k \}$$

where $acv_i$ is the $i$th indicator of the asphalt-concrete mixture quality; $K_{ASV}$ is the maximum number of indicators of the asphalt-concrete mixture.

Moreover, the properties of the asphalt-concrete mixture at the outlet of the ACP can be represented as a mathematical model [4]:

$$ACV = \varphi (M, TP, F_{TP})$$

where $F_{TP}$ is the perturbation affecting the technological process.

During transportation of the asphalt-concrete mixture from the ACP to the object ($TR_i = \{ TR_{i1}, TR_{i2}, ..., TR_{ik} \}$ operation), its properties are modified

$$ACV_{TR_i} = \psi (ACV, TR_i, F_{TR_i})$$

Similarly, the properties of the finished asphalt-concrete pavement can be written as:

$$ACV_{i,j}^B = q (ACV_{TR_i}, PL_i, F_{PL})$$

where $ACV_{i,j}^B$ is a set of properties of asphalt concrete for the $i$th facility and $j$th supply of materials; $PL_i$ – a set of indicators of the quality of laying and compaction of the mixture for the $i$th object; $F_{PL}$ is the perturbation.

### III. TECHNOLOGICAL PROCESS

This part provides information on the actual values of the process parameters [5], among which the most important are:

- Granulometric composition of each components of the asphalt mixture.
- Dosing error.
- Actual mixture composition for each batch.
- Temperature of bitumen, mineral materials, finished mixture at the outlet.
- Accuracy of control.
- Frequency of control.
- Systematic error of the control system.
- Methods and algorithms for processing of measurement results.

Transportation of asphaltic concrete mixture to the place of laying ($\omega$Transport)

- Monitoring of the vehicle parameters - dump truck (cargo mass, speed and direction of movement);
- Monitoring of the parameters of asphalt mixture (temperature in the upper and lower parts of the dump truck’s body, in its side parts);
- The time of loading, delivery and unloading of the mixture;
- The rhythm of supplies;
- Fuel consumption level;
- Environmental conditions.

«Laying and compaction» of asphaltic concrete mixture:

- Monitoring of paver’s parameters (paving speed, fuel consumption level);
- Monitoring of the parameters of the asphalt mixture during installation (temperature and thickness of the layer to be laid);
- Monitoring of the parameters of the compaction machines (speed of the rollers, amplitude-frequency characteristics, the number of passes on one track, the level of fuel consumption);
- Monitoring of the parameters of the asphalt mixture during compaction (temperature, density);
- Environmental conditions.

To implement the presented structure of the integrated monitoring of the parameters of the asphalt mixture and road-construction machines, they are equipped with the GLONASS-tracker satellite system, which ensures the real-time recording of the above parameters and the data transferring to the Central computer server (Center of an integrated control system).

This server, taking into account the current situation along the route of vehicle, as well as during the laying and compaction of the mixture, adjusts the operation mode of the factory equipment and ensures that the required quality of asphalt mixture is obtained at the outlet of asphaltic concrete plant.

The GLONASS-tracker system determines the coordinates of the location of vehicles by using the satellite signals. Sensors that determine the temperature of the mixture, fuel consumption, cargo mass and others are also connected to the tracker.

![Fig. 2. Interaction of an integrated management system with the subsystem «Transport»](image)
Fig. 3. Interaction of an integrated management system

Fig. 2 and 3 show the interaction in the process of monitoring of an integrated control system with the subsystems "Transport" and "Laying and compaction".

To implement the above program, the dump truck must have the following additional equipment:
- computer control unit,
- Falcom F 35-XXL and antenna system Glonass / GPS,
- dump truck position control subsystem,
- dump truck identification subsystem,
- communication subsystem,
- mixture temperature control subsystem,
- ambient temperature control subsystem,
- wind speed sensor,
- automatic system for covering the mixture with a tarpaulin in the body of a dump truck,
- memory bloc.

Figure 4 shows a KamAS 55118 dump truck with a system for monitoring parameters of asphalt concrete mixture during its transportation.

It should be noted that as a result of monitoring, a significant array of data is generated, and its processing requires lengthy computing resources. So, for each truck after receiving its actual coordinates, it is necessary to determine the position on the ground, the average speed in the last segment, the average speed from the start of movement, as well as the presumable total delivery time and temperature fields in the truck body.

The software allows the user to receive the satellite monitoring data from the «Asphaltic concrete plant (ABZ) – Road-construction machines - Asphaltic concrete» system in the form of visual reports, graphs and tables.

IV. CONCLUSION

Integrated monitoring of the parameters of road-construction machines and asphalt mixtures with using of the GLONASS system provides an increased productivity of the work performance, reduces the influence of the human factor on the quality of the finished road surface, and it becomes possible to carry out the remote control of the main parameters of not only the vehicles, but also the laid material, as well as operational response to the adjustment of the «Asphaltic concrete plant (ABZ) – Road-construction machines - Asphaltic concrete» system parameters in case of emergency.

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On the acquisition, correct analysis and dissemination of knowledge about safety problems as an important managerial tool to improve the functional reliability of transport systems

Nikolay Georgiev

Abstract – No doubt that safety is the most important and difficult to achieve characteristic of whatever transport system. In this field of the technical exploitation, significant measures are being made not only by the relevant government structures but also individual transport undertakings (infrastructure manager and transport operators). On a different note, it should be admitted that without creation, processing, correct analysis and dissemination of knowledge regarding operating safety problems even the best intentions for safety improvement would probably be in vain. The present paper discusses the necessity to design and also the specifics to govern a technological system (within the technical exploitation of a transport undertaking) for the usage of information concerning factors influencing operating safety and on this base for improvement of reliability of undertaking performance.

Keywords – Transport, Operating reliability (safety), Knowledge management

I. INTRODUCTION

The successful management of transport technological systems (transport companies) requires reliable information, proper assessment and correct analysis of events and phenomena that occur during the course of technical operation. In particular, when making decision on operational reliability (safety) issues, the essential requirement is the availability of information (knowledge) on the risks to the transport process. The more complete this knowledge is, the more relevant the decisions and actions made are.

Historically, transport managers have always relied on "sufficient professional experience and knowledge" for this type of industry when assessing the risks associated with the functioning of technical facilities and most notably how they are used by operating personnel. In other words, thanks to its long history and its specific features, the transport industry has been unquestionably successful in maintaining meaningful "basic knowledge" about safety in volume and content.

Over recent decades, however, there has been a significant increase of the usage of new technical and technological solutions used for specific purposes in the transport industry.

These technical and technological solutions (systems) are very complex. This complexity is continuously increasing, pushing managers to better understand of how the respective system behaves and what its influence over transport service quality is. It should be admitted that the lack of sufficient and specific knowledge of systems’ safe behaviors necessitates the development of new forecasting techniques, most of which are based on the risk concept and management principles.

Of course, there is a wide variety of scenarios under which transport accidents (incidents) could occur. However, their common characteristic is the element of surprise when they arise. This element of surprise clearly shows that in a very large percentage of accidents there is a "lack of preparedness" of the respective transport company with respect to the potential risks to the operational process.

Therefore, a proper understanding of the nature of risks, their elements, management principles and specificities of decision-making process in this field is essential for achieving an acceptable level of the operating reliability (safety) within the transport undertakings.

The present paper discusses the necessity to establish, the essence and basic elements of safety knowledge (and its management) in the field of transport process management.

II. FACTORS FOR SUSTAINABLE FUNCTIONING AND DEVELOPMENT OF THE TRANSPORT SYSTEMS

Transport service quality

Even a not so thorough review of literature shows that there are a great number of definitions for quality used in many industrial fields (e.g. [5], [9], [11], [12], [13]) but few in the area of the transport services, no matter that this term is often used in papers, research reports, operating rules and regulations. Considering the specific of transport service and with adaptation of the definition of quality stated in [1], the quality of transport service could be defined as: a complex feature of a given transport technological system (e.g. some kind of transport company) to perform its functions connected with the transportation of passengers and goods properly and with the observation of certain pre-determined operating standards, designed in compliance with specific criteria and operational indicators (characteristics of the system).

The definition given above suggests the following basic properties of service quality regarding a transport enterprise: Duration of transportation (speed of conveyance of goods or passengers), Convenience (existence of ergonomic travel
conditions for passengers in the transport means, facilities for loading and unloading cargoes, etc.), Culture (ethical and polite relation to customers of a transport undertaking), Cargo protection (prevention from damage to the cargo during the transport process), Reliability (ability of the transport technological system (transport undertaking) to perform its required functions under stated conditions within a specified period of time.

For its part, Reliability has three main features: Punctuality (timely arrival/departure of transport means at/from transport rout points), Regularity (reliable implementation of each single transport route), Safety (ability of the transport technological system to prevent accidents (incidents) from occurring during the transport process)

The transport company - a cybernetic type of business system functioning within system safety environment

Continuous improvement of a given activity (including the transportation process and ensuring its reliability and safety) is an organizational belief (culture) that the effectiveness of the technological processes performed in the organization can and should always be in the focus of company management in order to respond to customers' demands. Continuous improvement is usually interpreted as a repetitive four-step management strategy, known as the PDCA cycle (Plan-Do-Check-Act - [2], [9]) and "relies" on active and positive involvement (attitude, desire and action) of the operating staff to identify problems related to the functioning of a company. Such a participation is possible and only happens when the employees have sufficient knowledge on the specificity of the company, potential problems and possible ways to remedy them. Having this knowledge and developing their creativity, they will be able to improve their activity, and hence the business process of enterprise. There are many different types of failure causes of the operation of transport technological systems (enterprises), but what unites them is their principle predictability (and preventability). Avoiding failures is possible only when there is sufficient knowledge regarding the influencing factors, the potential hazards and concomitant risks (referred to as safety knowledge). All this means that knowledge is a very important tool for a reasonable balance between the business goals (the implementation of the transport service) and the compliance with safety requirements.

To understand the role of safety knowledge within the improvement cycle of a transport undertaking it is necessary to define the basic features of its performance, and no doubt that reliability and safety (as its property) are the most important of them. Therefore, it is of great use to consider the transport company as: business system that is designed and organized to generate useful and intended outputs (conveyance of goods and people) which are realized within a specific and changeable operating environment characterized by substantial potential for occurring of adverse (risky) outputs (accidents and incidents). The definitions above mean that the transport company could be reckoned as a cybernetic type of system requiring the appliance of some management approaches and tools (e.g. organizational acquisition of knowledge) to control the quality of transport service (in other words, measures to control the influence of incidents as adverse outputs of the business process over the quality). The relationship between the two basic functional elements of a transport undertaking considered as a cybernetic system, namely: Operating process management system (OPMS) and Safety management system (SMS), including the role of knowledge as a unifier of business and safety objectives, is depicted in Figure 1.

Role and contribution of the human-operator in achieving reliable transport process

Every human activity is connected with a set of "potential hazards" with respect to its normal realization. Even the minor hazard poses risk to people and could seriously disrupt the performance quality of the system concerned, which would have serious financial and social consequences. In full, this also applies to transport (all modes of transport), from the proper functioning of which the normal daily life of society as a whole depends. Achieving that requires a continuous process of "decision making to prevent adverse events (incidents, accidents) from occurring", which means risk (safety) management in order to provide a qualitative transport service. In a broader sense, risk management can be defined as a process of identifying, evaluating, and implementing measures to prevent or reduce the impact of potentially possible hazards to the technical exploitation. Of course, the absolute elimination of the risk of accidents is not possible, but it must be reduced to an acceptable level on the basis of practically possible measures. The definition and proper implementation of the latter requires the availability of general information and specific knowledge possessed by the operating personnel (operating managers) about the type and purpose (functions) of the system, its structure (subsystems and individual elements), its life cycle (specifics of its functioning), approaches and tools for analyzing its behavior, factors influencing its reliable (safe) performance, the development process, etc.
III. ESSENCE OF SAFETY KNOWLEDGE

Attributes of safety knowledge

There is a specific type of contradiction (sometimes very obvious) within our modern, information-based and high technological world. On the one hand, the citizens of modern society live and work using lots of contemporary information devices, scientific approaches to decide problems, invent new technologies and construct more and more complex man-machine systems. The practical realization of this requires the presence of a certain type of knowledge and skills, depending on the respective activity being performed. All this applies to all spheres of society, including transport. Ordinary people and professionals get and expand their knowledge through specific education, planned or accidental observation, gathering and processing of information, logical consideration, etc. Not to say that, the access to information is becoming easier than never before thanks to computers and Internet network.

On the other hand, and based on the experience gained from everyday life or technical exploitation of a given technological system, it could be said that the considerable advantage of the new technologies is often not enough for the society as a whole or for the single individual. If we look at the specific features of transport (but not only there) we will see that, regardless of the availability and use of modern technical systems and technologies, there are lots of cases of wrong decision making. Usually it happens due to the lack of uncertainty assessment regarding the respective information. As a result, many serious transport accidents happened because the transport companies ignored the possibility to gain very valuable knowledge from non-desirable operating situations occurred in the course of technological process (technical failures, human errors, organizational deficiency, etc.).

As for safety knowledge, the existing operational experience connected with the transport safety management allows the next definition to be given: it is familiarity and understanding of specific activities and concomitant risks associated with the transport process, including operating data, facts, information, descriptions, or human skills, which is acquired by experience or education. Safety knowledge primarily encompasses understanding of written operating rules, hazard information, process technology information, and requirements for safe usage of equipment.

As can be seen from this definition, safety knowledge is inextricably linked to two other categories (knowledge elements) - data and information, which in many cases are used equivalently to knowledge but according their role within safety management process they have different essence and meaning. Data consists of facts which usually represent raw numbers and as a whole give just a general vision with respect to the safety level of investigated process. The number of accidents occurred within a given operating period is an example of data. Information involves processing of data for obtaining a more appropriate understanding of the trends of change regarding a specific process under investigation. The probability of occurrence of an investigated cause for transport accident (of a concrete type) is a good example for information.

Data, information and overall knowledge regarding the safety of the transport process (or its individual elements) can be acquired through:
- Special tests of specific transport technical systems during their design, development, or initial exploitation;
- Specific events (incidents, accidents, near-miss events, etc.) within the real operating process;
- Analytical models simulating actual operation.

Figure 2 shows the relationship between safety knowledge (its attributes) and process of decision making.

Knowledge collection

There is no doubt that of the three ways of obtaining data, information and appropriate safety knowledge (described above) the second is the most plausible one - known as Incident Learning approach.

Incident learning concept is a result of the combination of two competing and complementary theories, namely: Normal accidents theory and High reliability theory.

Normal accidents theory is a consequence of the understanding that any system is designed, operated, and maintained by people who are essentially not perfect in their actions. Therefore, the system itself is not perfect and when there are changes in the system itself or in its surrounding work environment, it is perfectly normal for the system to adapt to these changes incorrectly (for one or another reason). As a consequence - mishaps occur - [6], [7], [10].

High-reliability theory says that while mishaps as a whole may be reckoned as normal to occur, serious ones could be prevented by defining and implementing certain practices. One of them is the organizational approach to design, develop and manage a normative system (internal for the respective transport company) for acquisition of knowledge on the basis of investigation of past incidents (acquisition of safety knowledge) - [4], [8], [14], [15], [16], [17].

But at the same time, there is a large number of examples showing that many serious accidents happened due to the fact that at least one of the organizations involved in the mishap has disregarded the warning of prior similar unwanted events and failed to adequately acquire or accurately analyze the knowledge regarding the causal factors and consequences of the event. When it comes to safety analysis and management,
it should be emphasized that in most transport accidents, one specific and common feature is observed - the inability of the organization (that caused the respective disaster) to effectively acquire, synthesize, disseminate (towards the interested people within its structure) and to most adequately use the information relating to past incidents. In this way, the opportunity to take appropriate measures to control hazards and reduce concomitant risks is missed. The fact that, by their nature, transport accidents are stochastic events and their accurate prediction is impossible, does not in any way mean that they should not be investigated very accurately aiming at taking certain measures to prevent them from occurring in the future.

The next conceptual framework allows the achievement of a successful accident investigation process:
- Each individual transport accident (incident) is unique in nature and should not be hastened to associate with similar one that has occurred in the past.
- The investigation is conducted in order to discover facts, not guilt and responsibility, because the latter are a source of "defensive reactions" and "bias".
- The investigation of accidents should always be reckoned as a very serious activity and as an important part of the overall safety management system, aimed at:
  - identifying and describing in an appropriate manner the actual course of events in the accident scenario;
  - identification of the causes of the accident (root, direct and contributing ones);
  - provision of sufficient information on the basis of which accident prevention measures can be proposed and implemented;
  - providing evidence for subsequent search for guilt and responsibility.
- The investigation should be carried out by a team of experts with a diverse range of theoretical knowledge and practical experience.
- Due to the fact that in most cases accidents are related to the implementation of several heterogeneous events (occurring in different systems, subsystems and their elements), the investigation must compulsorily use a system approach, with a certain desire for detailed analysis.
- The investigation should be carried out in stages and each stage should have clearly defined objectives and scope (limits) for the problem under consideration.
- The investigation must be carried out by the usage of appropriate scientific approaches and methods in order to achieve:
  - identification of the potential information gaps (lack of facts that need to be further identified) about the events in the accident scenario;
  - identification and description of the sequence of occurrence of the individual events and phenomena (causes of the accident).

IV. CONCLUSION

The main purpose of this article is to discuss and analyze the role and influence of safety knowledge on the reliable operation of the transport enterprises. It cannot be argued that this important problem is sometimes underestimated in the field of technical operation of transport. The statistics shows that more than 80 percent of transport accidents occurred due to human ignorance to act appropriately during the implementation of a specific activity within the operating process. There are two reasons for that. Either the respective human-operator does not have enough knowledge and skills on how to act or he/she has knowledge but apply it in a wrong manner. In both cases, the consequences can be extremely fatal. Therefore, within the framework of safety management systems, each transport undertaking must provide a mechanism for obtaining, analyzing and disseminating information on current safety issues. It must ensure that managers and employees have sufficient knowledge at all times about the safety situation in the enterprise and all related activities, e.g. the results acquired after an incident investigation should be made known to all interested parties.

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Abstract – Traffic congestion and resulting pollution affect the quality of life in cities, notably in countries with dominant old diesel engines. One solution is Adaptive Traffic Signal Control using vehicle type and emission measurements. Therefore, a fuzzy controller using a magnetic sensor for classifying vehicles and a sensor for measuring emissions is proposed.


I. INTRODUCTION

The problem of traffic congestion and the resulting environmental pollution is not new and affects the quality of life in urban areas. Such problems are undoubtedly more significant in developing countries where traditional transportation modes with many old diesel engines are still dominant. One way to tackle this problem is to apply Adaptive Traffic Signal Control (ATSC) that uses additional real-time measurement information as input for changing the signal program on intersections [1]. Such information can be related to vehicle type and current vehicle emissions levels and is applied in this work also. The envisaged approach is feasible, especially when modern optimization methods [2] are used in a connected vehicle environment [3]. An important fact is that an appropriate adaptation of the signal program can reduce vehicle stops and shorten queueing lines improving intersection throughput and reducing vehicle emissions [1, 8].

In this paper, a proposal for a fuzzy logic-based ATSC using a newly developed magnetic sensor capable of classifying vehicles and sensor/integrated air quality monitoring station for measuring vehicle emissions is described. The proposal is based on the authors’ previous work given in [4, 5, 8] that is augmented with the extension of the inputs of the fuzzy logic traffic signal controller with information about truck and bus presence coming from a magnetic sensor. The concept of the ATSC’s structure and simulation-based evaluation is described, and plans for real-world testing on a highly polluted isolated signalized intersection are outlined in continuation.

This paper is organized as follows. After the introduction, the ATSC based reduction of vehicle emissions is described in Section II. Section III elaborates on the newly developed sensor, and Section IV the proposed fuzzy logic-based ATSC. Simulation-based testing methodology is given in Section V and Section VI ends the paper with a conclusion and description of future work.

II. REDUCTION OF VEHICLE EMISSION AND ATSC

Traffic signal control systems with fixed signal programs are still being used today on many of the signalized intersections in urban environments. That leads to decreased comfort of traveling, traffic safety, and a general increase in queue lengths and waiting times. Since traffic flows change significantly during the day, there is a need for ATSC. Today there are a lot of contributions and methods that are used for ATSC. Many of them range from classic solutions to holistic approaches using services from the domain of Intelligent Transportation Systems (ITS) combining several popular tools for optimization [2, 9] or methods from the area of artificial intelligence such as fuzzy logic, genetic algorithm, neural networks, and computer vision for finding the optimal signal programs [2, 4, 7, 9]. ITS based approaches can adapt the signal program by changing a particular phase duration and their sequence. To alleviate the signal program's adaption and ensure all safety requirements, the NEMA (The National Electrical Manufacturers Association) ring structure of signal programs is used [8, 9]. Decision points for phase sequence adaptation can be implemented to respect safety requirements regarding the amber and red time needed for the proper transition between phases.

With increased concern about the environmental state in recent years, vehicle caused emissions have become a significant indicator of driving behavior in road traffic. Among other measured parameters like travel times and queue length, vehicle emissions have shown to be very important when traffic control criteria are being defined [11]. Both in terms of determining the rate by which they need to be reduced and for discovering other traffic-related problems like their correlation with stop times on signalized intersections. Especially when different vehicle types have different dynamics and pollution rates [1, 10], and when in such cases, preemptive traffic signal control can be applied. Usually, preemptive traffic signal control is applied to change the signal program to reduce the travel time of emergency or public transport vehicles [10]. The same principle can be applied for high polluting vehicles like vans, trucks, and buses [1]. Modern sensors can detect such vehicles proofing the feasibility of such an approach [1, 5]. Especially in an environment of connected vehicles that are more and more present in today’s traffic flows [3]. The availability of new

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measurements triggered the research about the correlation between vehicle emissions and traffic control strategies [11]. Reducing the number of stops and acceleration and deceleration cycles of high polluting vehicles reduces their fuel consumption and emission. At the same time, there is a positive effect on all other vehicles (mainly cars) also. This positive effect results from the fact that high polluting vehicles like vans, trucks, and buses have slower dynamics then cars acting as a traveling bottleneck/congestion point on the road. This is most evident for the high-loaded trucks. Since still today most vans, trucks, and buses use diesel engines, they contribute significantly to traffic-related pollution. Defining better traffic control strategies for protected areas of a city (usually city center) can, thus, reduce the pollution resulting from road traffic [11].

III. MEASUREMENT OF VEHICLE EMISSIONS AND VEHICLE CLASSIFICATION

Road transport is a significant contributor to emissions of greenhouse gases and air pollution. According to the European Environment Agency (EEA), the road transport sector is responsible for almost one-fifth of Europe’s greenhouse gas emissions [12]. Measuring exhaust emission from vehicles is a complex issue; there is a significant difference between official emission measurements and vehicle performance on the road. For example, nitrogen oxides (NO\textsubscript{x}), a major air pollutant that harms health and the environment, can be more than seven times higher under real-world driving conditions for new vehicles than in official tests. New vehicles can emit up to 40% more carbon dioxide (CO\textsubscript{2}) than official measurements would indicate [13]. Thus, the on-road vehicles sensing/counting are not sufficient to determine the actual level of emissions based on laboratory emission data.

A significant advantage in this proposal is the four-leg isolated signalized intersection measurement of emission and air pollution with one integrated air quality monitoring station based on SAM3x (ARM Cortex M3, 32-bit MCU) with Inova PM10/2.5 sensor, Winsen CO, CO\textsubscript{2}, NO\textsubscript{x}, and SO\textsubscript{2} gas sensors, Sensirion temp/hum sensor, with Real-Time Clock and Data Logging on SD card, followed with four sensor nodes (for each intersection approach lines one) for vehicle sensing/counting based on the triple-axis HMC class magnetometer from Honeywell and ESP32 Espressif ultra-low-power MCU (Fig. 1). Air quality monitoring station and magnetometer sensor nodes use an ESP32-NOW low power 2,4GHz Wi-Fi communication protocol to communicate with a master access point. All measured data will be stored on a server and available to the ATSC.

After successful on-road vehicle sensing/counting, the vehicle classification process is very important. The later addresses the process and methodology to classify a vehicle signature in a specific format into a pre-defined vehicle class (e.g., passenger vehicle, bus, or truck [5]). For the purpose of our proposal, the vehicle magnetic signature from each magnetic sensor node needs to be transformed into average-bar and hill-pattern recognition schemes [14]. Such recognition schemes depend on vehicle types enabling a high accuracy classification of vehicles. Vehicle sensing/counting and vehicle classification data followed with real-time data from an air quality monitoring station implemented on a four-leg signalized intersection are real input data for the proposed fuzzy-based ATSC.

IV. PROPOSED FUZZY LOGIC CONTROL METHOD

Apart from day-to-day use in reoccurring and predictable traffic scenarios, adaptive fuzzy traffic control systems serve well in non-recurring traffic situations and can be used to decrease the overall number of stops and travel times significantly [4,8]. Subsequently, this effect also decreases overall fuel consumption and, therefore, also vehicle emissions. Further use of fuzzy-based systems for ATSC, which rules were additionally optimized with the genetic algorithm, shows that Carbon Monoxide (CO), Hydrocarbons (HC), Nitrogen Oxides (NO\textsubscript{x}), and Carbon Dioxide (CO\textsubscript{2}) were all strongly correlated with fuel consumption except for NO\textsubscript{x} [7]. The research paper [8] shows vehicle emission values simulated on an isolated intersection model along with the measured fuel consumption. All the scenarios in [8] show improvement in terms of decreasing the emission rate compared to the fixed traffic control scenario, especially the one with the highest traffic demand.

The proposed adaptive system is an augmentation of the fuzzy traffic controller described in earlier work [4]. It consists of two fuzzy controllers, one for controlling the adaptive phase duration, and the other one for controlling the adaptive phase sequence. Each one is using different sets of interference rules and membership functions while working simultaneously during operation. In this paper, trapezoidal membership functions and Mamdani based inference are used. Both systems are used to calculate the output “Urgency” of the current phase. It describes which phase is the most urgent one, and therefore, it should be the next one executed in the current signal cycle decision point. The cumulative urgency of a particular phase is calculated using Eq. 1:

$$U_p = \frac{\sum_{i=1}^{n} U_i}{n},$$

where $U_p$ is the urgency of a particular phase; $n$ is the number of lanes in a certain phase; and $U_i$ is the urgency of a certain
lane obtained using the proposed fuzzy logic interference system. The urgency value is from the interval \([-1,1]\) and enables phase shortening and prolongation. To obtain the final duration of a particular phase, the following equations are applied:

\[
\Delta T = U_p \cdot \Delta T_{\text{max}}, \quad (2)
\]

\[
\Delta T_{\text{max}} = T_p \cdot CDC, \quad (3)
\]

where \(\Delta T\) is the final duration of a particular phase, \(\Delta T_{\text{max}}\) is the maximum amount of time a phase can be shortened/prolonged, and CDC is the maximum duration change coefficient. The later is usually set to a value between 0.20 and 0.30, denoting a maximal relative duration change between 20 and 30% of a particular phase. Obtained phase duration and sequence adaptation are applied in the scope of a control loop given in Fig. 2.

V. SIMULATION METHODOLOGY FOR TESTING

The urban intersections are a vital element of transport infrastructure and have a significant impact on traffic efficiency and environmental aspects. Before a real-world implementation of a solution in the form of ATSC, it is best practice to consider all the parameters and evaluate them using a microscopic traffic simulator with realistic traffic scenarios. Taking the purpose of the ATSC into account, it is crucial to test the newly constructed ATSC against the already existing fixed signal program across different traffic demand scenarios to accommodate for possible inconsistencies.

The testing and evaluation of the proposed adaptive system will be performed on a highly polluted, isolated urban intersection. The chosen intersection is located in the wider urban area of the city of Bitola, North Macedonia, as displayed in Fig. 4. To collect research data for the evaluation of the proposed ATSC, the following field data will be measured using the produced sensor from results described in [5]: a) geometric elements of the chosen intersection, and b) vehicle volume and data from the magnetic sensor capable of classifying vehicles and sensor/integrated air quality monitoring station for measuring vehicle emissions.
real traffic detectors and controllers. Additionally, VISSIM records all the required data for calculation of vehicle exhaust emissions into a detailed output data file after the simulation ends. These output data, after imported into the software EnViVer, will be used to calculate and obtain vehicle traffic emissions, observed during the simulation period. Using EnViVer, the results of traffic simulation software with emission models can be combined. This enables one to predict and to study the environmental impact of the proposed ATSC and to optimize its parameters accordingly [6].

The testing and evaluation of the newly proposed adaptive system in different traffic demand scenarios must be additionally obtained. For this, typical traffic demand scenarios related to morning and afternoon peak hours, transit periods between the peak hours, and free-flow traffic must be considered.

VI. CONCLUSION

ATSC systems can improve throughput on a signalized intersection and reduce the travel time of certain classes of vehicles when applied correctly. The later is called preemptive control and is usually applied for emergency and public transport vehicles. It can also be used for adding priority to high polluting vehicles like vans, trucks, and buses. By reducing the number of stops and acceleration and deceleration cycles of such vehicles, their emission levels can be reduced, and at the same time, traffic throughput increased. The resulting traffic controller can fulfill two criteria important today in urban traffic control: reduction of traffic congestion and reduction of vehicle emission. Such an approach is needed to achieve the EU goals of a smart, green, and integrated transport network.

This paper proposes a concept for a fuzzy logic-based ATSC that can utilize vehicle type measurements, and a framework for its simulation-based evaluation is described. The next step of this work will be the implementation of the proposed controller and its in-depth evaluation using calibrated realistic traffic scenarios in the chosen microscopic simulator. Optimization based on the genetic algorithm will also be considered to solve the complexity problem of creating fuzzy reasoning rules and needed membership functions.

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The impact of transport exchanges on the market of transport services in the process of realization of sustainable transport

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Abstract – The information age is characterized by the ability of individuals or businesses to freely exchange information and to have unhindered access to the market. Available online services allow fleet owners to offer available capacity and/or support goods for transport and the transport route that suits them. Also, such arranged services enable the owners of goods and/or providers of logistic services to submit a request for the transport of goods and/or to look for a transport vehicle and a transport route that suits them. This paper presents the forms and manner of functioning of services for the supply and the demand of transport services as well as their impact on the market of transport of goods in the Republic of Serbia.

Keywords – Transport exchanges, Transport market, Supply and Demand.

I. INTRODUCTION

The law of supply and demand is an economic model for the formation of the market, i.e., the prices of goods and services. The information age, available services and transparency over the Internet enable individuals, entrepreneurs or companies to gather the desired supply and demand information, i.e., to access the market. For the need of the functioning of the transport services market, at the beginning of the twenty-first century, transport platforms were created and developed. Transport platforms represent supply and demand services of transport capacity and transport demand in one place. Such services are often called "Transport exchanges". They arose as a need of fleet owners to transport goods to reduce the distance traveled by empty vehicles. Reducing the transport distance of an empty vehicle reduces costs and increases revenue. At the very beginning, "Transport exchanges" provided the opportunity to fill or replenish the available capacities on the transport route of an empty vehicle and participated in the total volume of collection of transport orders with a modest 5%. Today, a large number of users and providers of transport services rely on the supply and demand established on the "Transport exchanges".

According to the latest research in the Republic of Serbia, transport orders collected through "Transport exchanges" participate in over 50% of the total volume of realized transport orders [2].

The aim of this paper is to present the functioning of the transport services market and the impact of transport platforms on the transport of goods by road in the Republic of Serbia, problems in working with platforms, challenges, risks and prevention. The paper presents the influence of transport platforms on the formation of supply, demand and prices of transport services and gives concluding remarks.

II. TRANSPORT SERVICES MARKET

Achieving a sustainable transport process in the market of transport services is a goal that can be realized by the interaction of several factors, of which special stand out (Figure 1) [1]:

- state, i.e., social community,
- educational, professional and scientific community and
- owners of fleets for transport of goods.

The state as a socio-political community creates the most favorable solution for its citizens based on the current internal situation, and in interaction with the environment. The state develops the transport policy guidelines, time limits for its implementation, defines the restrictions, the degree of freedom, and the environment for the realization of sustainable transport. It creates an environment in which it will act as an educational,
professional and scientific community, as well as fleet owners. The institutions of the system, in accordance with the goals of transport policy, shape the instruments of action through strategies, programs and plans, defining them as various legal acts and financial means for their implementation. [3] Adequately established environment directs transport towards sustainable development.

The educational, professional and scientific community has the task of pointing out the consequences of development in the coming period, which allows the state to adjust transport policy and make quality decisions. The challenge for transport policy is to use the results of various scientific and professional research in practice, as well as the analysis of the adoption and implementation of transport policy.

Fleet owners provide road transport services to commercial activities that meet market demand. The state does not determine which services will be provided, or where, or at what time. These are commercial decisions made by fleet owners in cooperation with their customers. The main goal of fleet owners is to increase benefits, ie increase profits. They adapt their actions to the defined environment, and through rationalization, look for a way to greater profit.

Fleet owners are faced with the daily challenge of offering quality and affordable prices on the transport services market, ie finding a new transport order in order to use the available capacities and reimburse external costs arising from the realization of transport services, which transport service users do not pay. Owners of freight fleets realize their participation in the market of transport services through public procurement and public calls for tenders, auctions or direct agreements with the owner of goods, subcontractors or providers of logistic services. In this way, fleet owners cede their available capacities to users of transport services [3]. A contract or agreement is concluded with the users and they contain the conditions of transport, the obligations of the subcontractor, the price of the transport service, the conditions of payment, etc. The transport service is contracted for: one-way transport route, return transport route, for a larger number of journeys and the same and/or different transport route, for the transport route and a certain period of time, by hiring vehicles on the motorway, etc. By contracting a transport service, a transport task or order is delivered to the vehicle owner. The ordered can be for a single vehicle or several vehicles and contains details about the place of loading, terms, type of goods, method of packing and securing the cargo, date and place of unloading of goods, additional notes, etc. After the successful completion of the transport task or the realization of the order, the vehicle is assigned a new transport task or an order with new details. Vehicles between transport tasks or orders must cross a certain route empty, without cargo. The length of the empty vehicle traveled depends on the organization and fleet management policy. Previously, the price of the transport service that the users of the service were ready to accept gave the possibility of transporting the cargo in one direction and returning the empty vehicle. Economic crisis, competition, supply-demand ratio of transport requirements, etc. they affected the price of the transport service [6]. Fleet owners, in the desire for the greater profit on the one hand and the desire to reduce the costs of the transport task on the other hand, demand greater efficiency of their vehicles from the direct executors, which refers to the utilization of cargo space capacity and reduction of the distance traveled empty.

III. TRANSPORT EXCHANGES

In order to meet new challenges and increase the effectiveness of their vehicles, fleet owners, goods owners and/or logistic service providers in freight transport, more often than before, use the services provided by transport platforms on the Internet, the so-called "transport exchanges". Transport exchanges are supply and demand services of transport capacity and transport demand in one place. In the broadest sense, they can be divided into two groups, open and closed transport exchanges.

Those where access to users is free are open. The user of the transport exchange becomes a registrar, fulfilling the basic prescribed conditions and submitting the necessary documentation, after which the user is assigned an identification number. Access to open transport exchanges is charged. The user is given the opportunity to search the database by filling out a query, then to find a suitable offer and direct contact of the partner and finally in direct communication to reach an agreement or to withdraw from the offer.

Closed transport exchanges have limited access. The founders of such exchanges are large operators, logistics companies, transport companies, producers of goods, etc. Their subcontractors or users have access to such platforms. Their role is to reduce the work and pressure to which operators (commercialist and/or dispatchers) are exposed. By searching, the user finds the transport order that suits him, accepts the obligations by sending the necessary data and starts the realization of the order without direct contact with the operators. Access to closed transport exchanges is free of charge. The transport service is realized between the owner of the platform and the user, more precisely, there is no possibility of exchange of goods between the users or partners [4].

While on freight exchange, exchanges one can generally find available requests for freight transport, open transport exchanges offer a wider range of services. The largest number is the offer of cargo, but you can also find a public call for bids (tender), as well as offers of free vehicles, warehouses, transshipment spaces, parking spaces, vehicle maintenance services, consulting services, etc. The number of active transport exchanges varies, at the beginning of 2018, over 170
transport platforms were registered in Europe [2]. TIP Trailer Services, one of the largest European logistics companies, on its website at the end of February 2018, published the eleven most used transport exchanges in Europe [2].

On the territory of the Republic of Serbia, three transport exchanges are the most represented, two of which are from the list of the most used by Timo-com and Loads Today, and the third is Cargoagent. Timo-com belongs to the group of open platforms, and with paid access, Loads Today is closed with access for registered users and partners, while Cargoagent is an open transport exchange.

IV. BUSINESS OPPORTUNITY ANALYSIS, CHALLENGE, RISK AND PREVENTION

According to the assessment of companies for the transport of goods by road in the territory of the Republic of Serbia, in which the research was conducted, it was determined that transport exchanges represent a challenge that increases the efficiency of the fleet and the risk that can jeopardize business.

4.1. Challenge

Filling the available capacities with the help of transport platforms affects the effectiveness of fleets, and the indicators are increasing the utilization of vehicle availability by load capacity and volume, reducing the share of unladen journeys and increasing the number of loads with cargo.

The characteristic of transport exchanges is flexible access to the market, ie, if necessary, for the currently available capacities. Revenue from orders provided through transport platforms is higher than the costs of order realization and the costs of access to transport exchanges together [3].

4.2. Risk

Business opportunities on transport exchanges bring business risk. Increased transparency and competition influence fleet owners to see their survival in the market in reducing the prices of transport services, thus jeopardizing the business of transport service providers whose business is based on trust and sustainable business relationships with customers. The system of business through lending provides the possibility of forming a continuous chain and this leads to a reduction of responsibility [3].

The risk is also posed by clients who are not reliable, the characteristic is that they delay the payment of the fee for performing transport services outside the agreed deadlines or do not pay their obligations. Such users of transport exchanges use the opportunity to withdraw an already assigned order to their subcontractor before realization without explanation. Then the additional costs, if any, are borne by the fleet owners. Such clients are difficult to exclude from the system because they can always find a new user or subcontractor.

4.3. Preventive

Transport platforms are not stock exchanges and do not meet the requirements of stock exchange operations, ie stock exchange operations represent a defined set of rules of conduct for participants in the organized market, stock exchange operations take place under the control of stock exchange bodies and are supervised by the state and its bodies.

There are transport platforms that are safer, more secure and more reliable, ie platforms that have established business conditions, controlled access and procedure when accepting new users, they also have legal services, control of participants' business, processing and sanctioning users who do not respect the meeting rules of conduct in the transport market.

In order to contract for the realization of transport services, it is necessary to define and use precise transport tasks, orders and contracts. It is necessary to anticipate these documents: possible risks of uncertainty and loss, extraordinary costs, insurance of vehicles and goods, etc [3]. Also, telecommunications services should not be provided to partners without previously defined restrictions. If the conditions allow, it is necessary to control the access to information by the staff and drivers, ie to entrust the business with important clients to verified commercialists and driving staff [5]. Report irregularities in business or criminal activities to transport platform operators and competent authorities.

V. INFLUENCE OF TRANSPORT PLATFORMS ON THE MARKET OF TRANSPORT SERVICES IN THE REPUBLIC OF SERBIA

In accordance with the defined subject, goal and basic theoretical assumptions presented in the previous chapters, this part presents the research of the impact of transport platforms on the market of transport services in the Republic of Serbia. In the period of August and September this year, a dependent research was conducted - a survey on a sample of 22 companies engaged in the transport of goods by road. On that occasion, a conversation was held with the managers and owners of the vehicle fleets, and significant information was gained. Transport platforms are used by 20 companies. Two companies do not use them. Companies that use transport platforms use the same operators. Timocom, Cargoagent and Loads Today use nine of them, Timocom and Cargoagent use seven of them, and four companies use only Cargoagent and they are companies engaged in the transport of goods by road in the Republic of Serbia, Macedonia and Bosnia and Herzegovina [6].
The data collected indicate that the percentage of orders provided by users through transport platforms varies and varies between 7% and 52% [3]. The largest number of orders is provided for fleets that have a set of vehicles in their composition (tractor with a semi-trailer), and semi-trailers are with a tarpaulin (body shape: flexible sides - tarpaulin). The reason for this is the fact that for this shape of the body and the length of the cargo space of 13.6 meters, the offer of orders is the largest. While the smallest number of orders via transport platforms is provided for fleets that have semi-trailers with a special superstructure (body shape: refrigerator, silo, tank, etc.). The number of orders that dispatchers and salespeople provide using transport platforms depends on the transport route where the vehicles are engaged. Namely, in some countries global transport platforms are used, while in other countries they are not developed or only local ones are used, which are represented in certain countries or regions is a more extensive offer of requests for transport service on the mentioned platforms. Transport organizers try to use the vehicle available for work on the territory of the EU with transport orders as much as the administrative conditions allow (international agreements and/or CEMT conventions), ie as much as the available time allows until the appropriate return journey to the destination. Also, the organizers of the work of the vehicle use more transport platforms for return rides and to reduce the distance traveled by an empty vehicle in relation to the outgoing rides from the departure destination [6].

In a conversation with the owners of smaller fleets, who base their market share on transport platforms, it was found that they made contact and cooperation with most of their users through the platforms. According to records and available documentation, in these companies, the percentage of orders provided on the stock exchange is between 40% and 50%, but this number is higher than shown because they reached their customers through transport platforms, made direct contact with them and employ capacity beyond transport platforms [1]. Based on the presented results, it is concluded that the number of users of transport platforms is growing and that there is a positive trend of increasing the number of orders that are provided through transport platforms in the total number of realized transport orders.

The second part of the research was focused on the prices of transport services. Specifically, the research showed that the prices of transport services for the same distance traveled in the period from 2012 to 2018 decreased by 4% to 5% per year. Inspecting the documentation, it was determined that the price of the transport service for the mentioned period is lower by more than 20%. Such a drop in prices was contributed by greater transparency and competition, the economic crisis and recession, but also electronic business and transport platforms, whose influence on the market of transport services is becoming dominant [2].

VI. CONCLUSION

Advantages and temptations on the one hand and disadvantages and risks on the other hand represent the limitations that transport exchanges resist in the market of transport services. Companies for the transport of goods in road transport are increasingly using transport exchanges and benefit from them.

The degree of development of the transport market is reflected in the development of business through transport platforms, which is the case in the EU. Good functioning of the transport market is a condition for successful economic development in a country and an indicator of economic trends [7].

On the territory of the Republic of Serbia, closed transport platforms whose organizers and owners are providers of logistic services that operate within world brands in the field of logistic services are taking an increasing part. Along with large logistic operators, domestic logistic service providers are also developing, which see sustainability in the market in the formation of transport platforms.

Stock exchange operations are a basic indicator of the functioning of the capital market in a country. Are transport platforms an indicator of the functioning of the transport market? Are the transport platforms up to the task assigned to them? The answers to these questions will be provided by time and analyzes that will be the subject of further research. Transport platforms that provide services and work in controlled conditions are necessary for the transport process and are inevitable.

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Estimation of Velocities in an Urban Segment through CTM model

Rrecaj Arlinda¹, Alimehaj Vlera² and Lokaj Drita³

Abstract—Because of its close relationship to density and flow, velocity play a key role in prediction of traffic parameters with the purpose of use in real-time traffic control. In this paper is proposed a procedure of estimation of velocities through a macroscopic model that originates from LWR (Lighthill-Whitham-Richards) model called Cell Transmission Model. Beside the possibility to update the densities of cells through time step, the CTM model enables the estimation of evolution of the velocities thanks to some known models that describe these relationships. A case study in an urban segment is treated in order to estimate velocities. Validation of these velocity values is done by comparing the inter cell flows from CTM (Cell Transmission Models) model and flows as function of updates velocities.

Keywords – Cell, density, inter cell flow, outflow, velocity, model hypothesis

I. INTRODUCTION

A. Usage of CTM model for Estimation of Velocities

By exploiting the conservation law of flow, in CTM models can be used to update the densities of each cell in time dimension by using parameters of free flow speed and backward speed instead of number of vehicles. Implication of new demand function makes new CTM model [1] capable emphasize the difference of the outflow rate from the SBC (Stop Bar Cell) on different consequential portions of green interval. In [1] the analyzed parameters can be considered as microscopic since are evaluated for each individual entity/vehicle.

Beside the possibility to update the densities of cells through time step, the CTM model offers the estimation of evolution of the velocities which may be an important factor of challenging real time prediction and control strategies.

The earliest models that describe the relationships of velocity, flow and density were obtained from scattered plots of the filed data of freeway segments. In this paper is discussed the suitability of four models with our FDR (Fundamental diagram of relationship between traffic flow parameters) of the representative samples/cells of the subjected arterial. The most popular and earliest one that is formulated 84 years ago, from Greenshields has been derived while trying to bring a match between a linear model and drawn curves of velocity-density data [2]. As a model is applicable to all traffic conditions, but it is not characterized by its fit accuracy. The Greenshields model is

\[ v(\rho) = v_f \cdot \left[ 1 - \frac{\rho}{\rho_j} \right] \] (1.1)

Another model that describes a logarithmic relationship between velocity and density was proposed 60 years ago by Greenberg [2]. It is based on analogy with hydrodynamics theory.

\[ v(\rho) = a \cdot \log \left[ \frac{\rho}{\rho_j} \right] \] (1.2)

A more or less modified Greenshields model was modeled from Pipes-Munjal and Drew in 1967 and in 1968, respectively. In conventional Greenshields model the ratio of density to jam density was empowered by coefficient and so could be derived a variety of models for velocity-density relationship [2].

\[ v(\rho) = v_f \cdot \left[ 1 - \left( \frac{\rho}{\rho_j} \right)^a \right] \] (1.3)

B. Case Study-Data Collection for Fundamental Diagrams Building

It is the urban segment of bulevard “Bill Clinton” an extension of the Highway M9- “Peja League”, along with three signalized intersection, one on ramp and one facility for both entry and exit operations. The arterial is of legth 970 meters, with lane widths 3.2, meters on the first and second intersections and 3.0 meters on the third intersection. The length of road cells are chosen of 25 meters long [1]. For the first vehicle in the queue at the beginning of green, is assigned the time between the start of green and the time when this vehicle (its front bumper) passed the stop line. For the other queued vehicles behind the first one, discharge headways is calculated as the elapsed time between two successive (one after other) passing the stop line. Through Stop Watch application the times collected are obtained amount of flows, speeds and densities for every five second interval. Summarizing, for every single cell, are obtained 180 flow/densities data. (5 second intervals of 15 minute). Fundamental diagrams (FDR) for every representative cell-sample are depicted in below figures (fig.1-fig.11).

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Fig. 1. Flow-density diagram of Sample 1

Fig. 2. Flow-density diagram of Sample 2

Fig. 3. Flow-density diagram of Sample 3

Fig. 4. Flow-density diagram of Sample 4

Fig. 5. Flow-density diagram of Sample 5

Fig. 6. Flow-density diagram of Sample 6

Fig. 7. Flow-density diagram of Sample 7

Fig. 8. Flow-density diagram of Sample 8

Fig. 9. Flow-density diagram of Sample 9

Fig. 10. Flow-density diagram of Sample 10
The main characteristic traffic parameters for the most representative cells-samples are given in Table 1.

### Table 1. FDR parameters for each sample/cell

<table>
<thead>
<tr>
<th>Sample</th>
<th>Relevant CELL</th>
<th>Nr.of Lanes</th>
<th>Qc [veh/hr]</th>
<th>ρc [veh/km]</th>
<th>Vc [km/hr]</th>
<th>w [km/hr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] (1.10-1.3) Middle</td>
<td>3</td>
<td>2880,00</td>
<td>147,00</td>
<td>20,00</td>
<td>6,35</td>
<td></td>
</tr>
<tr>
<td>[2] (1.2&amp;1.1) Middle</td>
<td>2</td>
<td>4230,00</td>
<td>115,00</td>
<td>37,00</td>
<td>14,84</td>
<td></td>
</tr>
<tr>
<td>[3] (1.0) Merge</td>
<td>3</td>
<td>4320,00</td>
<td>117,00</td>
<td>37,00</td>
<td>8,94</td>
<td></td>
</tr>
<tr>
<td>[4] (2.4) Middle</td>
<td>3</td>
<td>4320 (3600)</td>
<td>149 (113)</td>
<td>29 (32)</td>
<td>9,57 (7,39)</td>
<td></td>
</tr>
<tr>
<td>[5] (2.3) Merge</td>
<td>3</td>
<td>3600,00</td>
<td>176,00</td>
<td>20,00</td>
<td>15,25</td>
<td></td>
</tr>
<tr>
<td>[6] (2.2)</td>
<td>3</td>
<td>3600,00</td>
<td>164,00</td>
<td>22,00</td>
<td>10,10</td>
<td></td>
</tr>
<tr>
<td>[7] (2.1)</td>
<td>2</td>
<td>2880,00</td>
<td>88,00</td>
<td>33,00</td>
<td>6,16</td>
<td></td>
</tr>
<tr>
<td>[8] (2.0) Merge</td>
<td>2</td>
<td>3600,00</td>
<td>183,00</td>
<td>20,00</td>
<td>16,58</td>
<td></td>
</tr>
<tr>
<td>[9] (3.2)</td>
<td>2</td>
<td>2880 (2160)</td>
<td>77 (102)</td>
<td>37 (21)</td>
<td>8,91 (7,24)</td>
<td></td>
</tr>
<tr>
<td>[10] (3.1)</td>
<td>2</td>
<td>2280,00</td>
<td>115,00</td>
<td>20,00</td>
<td>8,49</td>
<td></td>
</tr>
<tr>
<td>[11] (3.7-3.6) Middle</td>
<td>3</td>
<td>2880,00</td>
<td>133,00</td>
<td>22,00</td>
<td>8,91</td>
<td></td>
</tr>
</tbody>
</table>

### C. Estimation of Velocities with Pipe Munjal Model

Using the e Pipes-Munjal Generalized Model [2] which resembles the Greenshields function of the relationship of traffic parameters and the characteristic parameters of our model samples, can be calculated the velocity as function of density as in (1.4).

\[ v(\rho)(t)_i = v_{fl} \cdot \left[ 1 - \left( \frac{\rho(t)_i}{\rho_{Ji}} \right)^a \right] \quad (1.4) \]

Where are:
- \( v_{fl} \) - Free flow speed of the cell \( i \) in time \( t \),
- \( \rho_{Ji} \) - Jam (maximal) density of cell \( i \),
- \( a \) is the coefficient of the model for each FDR

Determination of function with its coefficient is given on the below table 2.

### Table 2. Velocity function from density of the CTM model

<table>
<thead>
<tr>
<th>Sample of FDR</th>
<th>Relevant CELL</th>
<th>( v(\rho) = v_{fl} \cdot \left[ 1 - \left( \frac{\rho}{\rho_{Ji}} \right)^a \right] )</th>
<th>Coefficient (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] (1.10-1.3)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.264} \right] )</td>
<td>0.264</td>
<td></td>
</tr>
<tr>
<td>[2] (1.2, 1.1)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.716} \right] )</td>
<td>0.716</td>
<td></td>
</tr>
<tr>
<td>[3] (1.0)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.803} \right] )</td>
<td>0.803</td>
<td></td>
</tr>
<tr>
<td>[4] (2.4)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.510} \right] )</td>
<td>0.510</td>
<td></td>
</tr>
<tr>
<td>[5] (2.3)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.401} \right] )</td>
<td>0.401</td>
<td></td>
</tr>
<tr>
<td>[6] (2.2)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.571} \right] )</td>
<td>0.571</td>
<td></td>
</tr>
<tr>
<td>[7] (2.1)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.459} \right] )</td>
<td>0.459</td>
<td></td>
</tr>
<tr>
<td>[8] (2.0)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.433} \right] )</td>
<td>0.433</td>
<td></td>
</tr>
<tr>
<td>[9] (3.2)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.535} \right] )</td>
<td>0.535</td>
<td></td>
</tr>
<tr>
<td>[10] (3.1)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.560} \right] )</td>
<td>0.560</td>
<td></td>
</tr>
<tr>
<td>[11] (3.7-3.6)</td>
<td>( v(\rho) = 40 \cdot \left[ 1 - \left( \frac{\rho}{600} \right)^{0.264} \right] )</td>
<td>0.264</td>
<td></td>
</tr>
</tbody>
</table>

Velocity evolutions through the representative cells seems to change with respect to changes in density values, regarding to the function in (1.4). Due to the more distinct changes in velocity parameter, the elaboration of these results for medium to congested conditions has been intentionally made.
is characterized by a continuation of the vehicle motion. This continuation motion is provided by the low effect of the signal status. A slightly drop of the velocity is observed at the first cycle and after it the fluctuations are present till the end of the running time. On cells upstream to stop bar of the three intersections such as: 1.3, 1.2, 1.1, 2.1, 3.1, velocity values frequently decrease to the zero as vehicles are restricted to stop at red light. These values tend to reach the maximal values after the start of the green interval of each cycle at the beginning of the running time, but they can reach the average values at the end of the running time since the queue length increases due to congested conditions. An observed running simulation of the CTM model in light conditions would show a constant trend of velocity decrease during the entire running time as the density also remains constant during the entire running time (fig.17,18 and 19). Results would be promising for any worst case of traffic conditions where the artery may be characterized by long queues from intersection to intersection providing extremely high densities and extremely low velocities.

II. CONCLUSION

The potential to obtain velocity values is discussed for different relationship models in this paper. Future research task is make model for enable for predicting traffic parameters at short time intervals (time steps) and short length distances (cells) as part of the segments between the signalized intersections [5]. The CTM model provides the availability of posing parameters in short term terms of time and distance and these advantages should be used for traffic management purposes.

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PSO contract management – achievements and challenges

Miloš Stanojević¹, Uroš Stanimirović², Dr Branislav Bošković³, Dr Mirjana Bugarinović⁴

Abstract – Introducing competition in the railway passenger market is still a complex problem, especially with certain, insufficiently addressed aspects of PSO contract management. Considering this have a significant influence on the performance of the rail traffic, this paper reviews the practice in relevant EU countries and the Republic of Serbia in terms of PSO contract management.

Keywords – PSO, contract management, passenger traffic.

I. INTRODUCTION TO PSO

Through a series of directives and their implementation in national legislation, the European Union (EU) is trying to integrate state railways into a single transport system of Europe in which all modes of transport will be compatible and complementary, and not competitive. To a certain extent, Serbia is trying to implement such a system as well by, among other things, implementing the contract on Public Service Obligation. The single transport system should operate on the principles of transparency, non-discrimination, liberalization, interoperability, uninterrupted mobility, standardization of service quality and creation of Trans-European networks. For the railway market and the laws that govern it to function in general, there needs to be competition between railway operators. It enables an increase in the quality of services, a reduction of costs and prices of services, more innovation, as well as a reduction in the negative impact on the environment. These effects of competition have a synergistic effect on achieving the goals of EU transport policy, i.e. meeting the needs of railway transport users.

In addition, the main goals of the European public transport policy are to provide safe, efficient and quality passenger transport services through regulated competition. Social, environmental and regional development factors need to be taken into account in order to guarantee their transparency, quality and satisfactory performance. Although rail transport is cost-effective only for large flows of passengers, i.e. when it comes to mass transport on medium distances, it is necessary to take into account these socio-economic factors as well as situations where the railway is the only efficient way of transporting passengers between regional and urban centres, regardless of cost-effectiveness. [1].

In this regard, the European Community has adopted Regulation 1370/2007/EC, which introduced a new concept - Public Service Obligation (PSO). In EU legislation, which is also implemented in Serbian legislation, PSO is a contract that the competent authority (republic, region or local authority) awards to a railway operator through a tender, thus providing it with a monopoly for performing a certain public transport service during certain period of time. Regarding this service, the competent authority grants compensation to the railway operator, which is generally in the amount of the difference between the revenue generated on a particular route and the cost of providing the service. [2].

However, by taking advantage of the possibility of an exception to the tendering rules, (and yet) in a large number of cases, EU countries opted for direct award of contracts, which limits the possibility of new operators entering the market. Finally, with regulation of the so-called fourth package, 2016/2338 from 2016, it is possible that passenger operators registered in any EU country can provide services on the territory of any other, but it also introduced the principle of mandatory award of PSO contracts exclusively through tenders - with a transitional period relating to all contracts concluded until December 2023.

II. PSO CONTRACT MANAGEMENT INDICATORS

The largest part of the total volume of railway passenger transport is covered by PSO [3]. Consequently, large amounts of taxpayers’ money are allocated from the budgets on an annual level, which, on the other hand, are not adequately managed, nor has it led to a significant increase in the quality of transport services or the share of railways in total passenger traffic. Given the possibility and tendency of states, by using the transitional period from Regulation 2016/2338, to conclude long-term contracts just before the expiration of this deadline, it is concluded that in the current circumstances, better planning of contractual services and more efficient monitoring and execution is crucial, but also improvement of supervision and control, quality standards, introduction of mechanisms of sanctions for non-fulfillment of obligations, etc. - in a word, improvement of the contract management process.

To analyze the way in which the PSO contracts are managed, based on a review of the available literature and the current EU regulatory framework, it is concluded that it is necessary to analyze 9 main factors. These are: contract award procedure (and method of negotiations), duration of contract, level of profit margin, percentage of service coverage by contract, service quality standards, existence of tariff obligation, provisions on sanctions, structure of costs included in PSO and mechanisms of supervision and control (Fig. 1).
without competition for the market. The tendency of the competent authority to introduce (and potentially indicate the desire of the competent authority to pre-assign part of the services, in terms of whether the initiative (service proposal) comes from the railway operator or is determined by the competent authority (as it should according to regulation), their compliance with the principles of "public interest", groundedness on market analysis, etc.

**Duration of the contract**

As with the previous factor, the longer duration of contract potentially indicates the desire of the competent authority to "protect" the national railway undertaking from competition, which in turn may be to the detriment of service quality and efficiency. On the other hand, they provide financial certainty to the carrier. Short-term contracts, however, pose a kind of "threat", as they put the operator in a situation of uncertain operation and revenue planning.

**Level of profit margin**

By definition, the profit margin is a "reward" for the railway operator, i.e. the amount of funds that exceeds the net coverage of service costs. It becomes of special importance in the conditions of competition, considering that it is a "bait" for companies to have any interest in entering the market at first place.

**Percentage of service coverage by contract**

This factor is especially important in conditions when there is only one (national) railway undertaking in a certain country. When this percentage is lower than 100 it indicates that either there is a part of the services that are profitable or simply a part of the non-profitable ones did not fall under the contract. The reason for the latter may be in cases where there are limited budget funds available, and on the other hand, no willingness to implement the reduction of unprofitable lines or optimize the railway operator operations.

**Service quality standards**

Extremely significant factor. The way in which service quality standards are defined shows the focus and aspiration of the competent authority (but also the operator) to raise the quality of services that are the subject of the contract. It is important to note that the current regulation do not prescribe these standards in detail, but the decision is left to the competent authorities. They get full meaning only when a financial (or different) sanction is provided for deviation from the required quality levels.

**Existence of tariff obligation**

It can legitimately be said to be an instrument of social policy of the competent authority. In fact, it is an obligation of the railway operator to perform transport of all or certain categories of passengers (students, pensioners, etc.) at prices lower than the market ones. In these cases, when the railway operator is not able to change the prices of its services on its own, it is of special importance to be transparent and adequately compensate these losses.

**Provisions on sanctions**

Sanctions, whether financial or otherwise (for example, the possibility for the competent authority to pre-assign part of the services to another operator), are the basic "weapon" in the hands of the competent authority when it comes to contract management. The absence of sanctions, in the opinion of the authors, represents a practical meaninglessness of quality standards, and thus, in a way, the very essence of the contract.

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1 When awarding a PSO contract, it is not about competition on the market, but about competition for the market.
Structure of costs included in the PSO

In accordance with the current regulation, only the costs incurred in connection with PSO service (they are clearly defined by Regulation 1370/2007) may be subject to the compensation of PSO services. The reason for this is to ensure a “financial balance”, i.e. to prevent overcompensation that would distort the market. However, some countries have defined these costs somewhat differently, which provides a good insight into how the contract is managed and knowledge of both the market and the way the operator operates.

Supervision and control over implementation

Another factor of great importance. Mechanisms for monitoring and control of implementation of the contract need to be well developed and efficient in order to achieve the purpose of the contract itself.

III. COMPARATIVE ANALYSIS OF SELECTED COUNTRIES

In connection with all the above factors, the question arises where Serbia is in relation to the surrounding countries and the EU. In order to provide an answer to this question, this paper will perform a comparative analysis with selected countries that have relatively similar characteristics as Serbia (demographic, economic, traffic, etc.). Based on that, the efficiency of management of the PSO contract between the Government of the Republic of Serbia and the railway operator JSC "Srbija Voz" can be relatively reliably assessed.

In the following sections, an overview of the key characteristics of PSO contract management in Bulgaria, Romania, Slovakia, Czech Republic and Serbia is given, based on data for 2016 [4]. Comprehensive data for more recent years was not available, but authors believe that the data for 2016 is relevant enough taking into account the multi-annual nature of contracts and the sluggishness of the changes on the railway passenger services market.

Bulgaria

The PSO contract in Bulgaria was concluded on the basis of a tender procedure between the Ministry of Transport (Council of Ministers) and "BDŽ passenger services", with an important note that this company was the only registered passenger operator in Bulgaria. The contract was concluded for a period of 15 years, with a profit margin of 3%, and refers to 95% of the total volume of passenger traffic. When determining the amount of compensation, the operator is obliged to periodically submit to the competent authority a three-year cost projection. The contract provides framework for the quality that operator must meet in the context of regularity, punctuality, cleanliness of trains, supervision, capacity, qualifications of employees and the system of handling passenger complaints. The existence of sanctions for non-fulfillment of contractual obligations is envisaged as follows: deviation of up to 5% from basic indicators is tolerated (train-km, number of seats, driving hours), and for each deviation of 0.1% over these 5%, compensation is decreased by 0.05%. The compensation can be reduced by 2% in case the hygiene requirements are not met, while for train delays of more than 60 min compensation is not paid. The cost structure includes costs of staff, energy, infrastructure access, vehicle maintenance and repair, rolling stock, payment of historical debts and other fixed costs. Supervision and control are, among other, performed by regular quality checks and processing of passenger complaints and giving recommendations for elimination of identified deficiencies. The contract also defines the tariff obligation for the operator, which is paid on a monthly basis, in accordance with the services actually provided.

Romania

In Romania, a four-year PSO contract, covering 100% of services, was awarded directly, with prior negotiations between the contracting authority and the operator. The main qualitative criteria set out in the contract are commercial speed, services in trains and comfort. More detailed standards are set by normative documents that are the subject of negotiations between the competent authority and the operator. The compensation is calculated on the basis of determined train-km and pass-km for each type of the service. The operator determines the scope of services for each year and, together with the cost estimates, submits it to the competent authority, with whom it negotiates the amount of compensation. Costs include costs of staff, energy, infrastructure access, maintenance and repairs, rolling stock, installations necessary to provide services, payment of historical debts, depreciation and other fixed costs. Profit margin is 3%. The tariff obligation related to the price and discounts for certain categories of passengers is an integral part of the contract. Audits are conducted annually in order to control the accuracy and justification of the level of incurred costs and revenues, and the national railway supervisory body, among other, monitors the railway services market.

Slovakia

There were concluded contracts with two different operators in Slovakia, covering 94% of services. However, they were not awarded in the tender procedure, given that, at the time, two mentioned operators were not interested for same contract (however, direct award is necessarily preceded by negotiations - in practice limited by budgetary constraints). The contract with the national railway operator was concluded for a period of 10 years. Quality standards include reliability and punctuality of trains, safety, cleanliness, functionality of certain technical functions (heating, windows, etc.), train composition and other requirements (internet, space for bicycles, etc.). As far as the penalty provisions are concerned, the competent authority has the right to take away part of the services from the operator and assign it to another or put them on tender. Each quality standard defined by the contract has a defined minimum that must be met, otherwise a sanction is prescribed. One of these requirements is the percentage of the realization of the timetable, i.e. the number of departures, in connection with which the ministry annually reduces the compensation in case of cancellations caused by the fault of the operator. Costs include the costs of energy, material, direct earnings, direct
depreciation, direct maintenance and repairs, levies, tickets, infrastructure access, other direct costs, overheads, and financial compensation costs. Profit margin is not provided for in the contract, while the operator also bears certain tariff obligations. Control and supervision are carried out so that the accuracy and justification of the amount of costs and revenues are subject to independent audit. The ministry also conducts regular inspections of train services.

**Czech Republic**

There were in total 8 passenger operators in the Czech Republic in 2016, of which 5 operated under a PSO contract, while 3 received compensation only for certain tariff obligations. Some of these contracts were awarded directly, through negotiations, and some within the tender procedure. They cover a total of 92% of the total volume of services. Only about one third of the services are covered by a national contract, and as many as two thirds by the regional ones. Quality standards refer to the fulfillment of the timetable (the norm is 95%), connected services (also 95%), reliability, equipment and convenience of the rolling stock, washing and cleanliness. The penalty provisions of individual contracts provide for the possibility of the contracting authority that a certain part of the services (limited to a maximum of 75%) may be gradually awarded to another operator before the contract expires. Also, the operator is obliged to pay the competent authority a certain amount in case of non-compliance with defined quality levels. The validity period of the contracts is different, but goes up to a maximum 10 years. In practice, the obligation is determined by the operator submitting its business plan with the scope of planned services, assessment of costs, revenues and profit margin, to the competent authority. Costs covered by the contract include energy costs, direct material costs of towing vehicles, staff costs (train drivers and other), fleet costs (depreciation and interest), shunting services, assistance to passengers with reduced mobility, service controls, infrastructure access, fixed costs, variable costs and other costs related to passengers. The contracts also contain tariff obligations for certain categories of passengers, such as pupils and students. Control and supervision are carried out by unannounced financial checks, standard quality checks in trains and regular submission of reports related to punctuality, train composition, access charges, etc.

**Republic of Serbia**

In Serbia, the first PSO contract with JSC "Srbija Voz" was concluded in 2016 with a validity period of one year. The following year a new contract was concluded, on a period of 5 years and, it will be the subject of the analysis in this paper. This contract was awarded directly considering that JSC "Srbija Voz" was (and still is) the only registered passenger operator. Once a year, an annex to this contract is concluded, which defines the scope of the services and the amount of costs and compensation. Costs include transportation costs (towing and shunting costs, on board and other personnel costs, vehicle maintenance, infrastructure access) and indirect transportation costs (financial costs, other costs and depreciation) [5]. Regarding the coverage of services by the contract, considering that the Report on the determined obligations of public transport of passengers in railway traffic for 2018 [7] states that the carrier is obliged to realize 6.79 mil. train-km, while the Report on the implementation of the business program states that in 2018, in internal traffic (without special transports), 7.92 mil. train-km was realized [6]. It follows that the percentage of service coverage was 85.7% in 2018. In the same way, it can be concluded that in 2019 the coverage was 95%, which indicates the gradual increase, but at the same time the reduction of total traffic is noticeable. The amount of the profit margin is not publicly available. Quality standards include ensuring the same level of quality of service to all passengers, adequacy and equipment of rolling stock, cleanliness, maintenance and punctuality (service is considered performed if the train arrives at the final station with less than 25 minutes delay) [7]. However, the contract does not foresee penalties [7]. Supervision and control are performed by the ministry in charge for traffic affairs, and reporting is performed by defined monthly, quarterly, semi-annual and annual reports that JSC "Srbija Voz" regularly submits to the Ministry [7]. Data on special tariff obligations are not publicly available, but in accordance with the Law on Public Enterprises and the Statute of a joint stock company, any change in tariffs requires the consent of the Government. Also, based on the business programs from previous years, it can be concluded that the amount of compensation paid to the operator is not at an adequate level, ie that it is not sufficient to cover the costs of providing services.

**IV. STATE OF PLAY – REPUBLIC OF SERBIA**

In order to analyze the PSO contract management in Serbia, but also to provide a basis for making recommendations for improving this process (which may also be the subject of a future paper), a comparative analysis of key factors for selected countries has been done. For a better insight into the results, a summary is given in the table in Annex I.

The key conclusion was that the process of PSO contract management in Serbia is at an initial level, ie below the level of selected EU countries. The reasons for this are numerous, but now only the few key ones will be mentioned: (1) quality standards take into account already existing traffic/safety parameters, which as such cannot stimulate the operator to raise the level of service quality; (2) the contract does not provide for sanctions for non-fulfillment of contractual obligations and quality standards. The absence of that kind of pressure on the operator also does not work in the direction of improving services; (3) the supervision and control mechanisms available to the competent authority are very modest, which further contributes to the above; (4) a significant problem is also a fact, which is not strange even in a number of EU countries, and that is that the PSO compensation is conditioned by budgetary constraints and it is not sufficient for efficient operation; (5) there is a part of the services whose profitability is questionable, which are not covered by the contract, and which can potentially have a negative impact on the operator's operations; and (6) the analysis of the cost structure points out to the conclusion that they are not managed according to the services (trains) but rather cumulatively, which makes it...
difficult to plan traffic in PSO regime, and also to monitor and adjust the services during the validity of the contract.

Due to insufficient publicly available information, it was not possible to analyze in more detail the manner of determining the services that are the subject to the contract, the manner of negotiations and the position of operator within them, as well as the justifiability of the amount of costs and compensation.

REFERENCES

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Транспорт на патници
Transport of Passengers
Analysis of Tourist Travel Behaviour for the Train/Bus Transport Service Establishment - The Case of Kopaonik

Zorica Milanović¹ and Nataša Pejić²

Abstract – This paper reports the survey results of tourists’ travel behaviour. The case study covers the sample of 1000 adult respondents visiting Kopaonik National Park (Serbia) in the winter season of 2020. The survey results indicate that some integrated train/bus transport services have to be initiated in the future.

Keywords – Travel Behaviour, Passenger, Railway, Transport Service, Tourism.

I. INTRODUCTION

Transport is the key element in tourism industry. Tourism, as an economic activity, relies on transportation to bring tourists to destinations. Transportation itself can be a part of the touristic experience.

Leisure travel demands are a challenge for transport planners. Leisure travel is more concentrated around annual holidays and can be fairly well predicted. A real challenge for most transport planners is accessibility to and within tourist attractions and destinations because accessibility is the ultimate goal of the majority of transport activities.

The sector of travel & tourism is one of the world’s largest sectors, driving socio-economic development and job creation. This sector accounted for 10.3% of global GDP (8.9 trillion $) and 10.4% of total employment (around 330 million jobs) in 2019. The average annual growth rate for the past ten years is 3.5%. This rate is 40% higher than that of the global economy (2.5% overall economy growth) [1]. Europe is the world’s largest market, accounting for more than 50% of all tourist arrivals worldwide. One-third of foreign tourists arrive in Europe are in Southern/Mediterranean Europe (17 countries). The share of the Republic of Serbia in total foreign tourist arrivals in this area is almost statistically irrelevant (around 0.5%). Only three countries have fewer foreign tourist arrivals than the Republic of Serbia (Republic of Bosnia and Herzegovina, Republic of North Macedonia, and Republic of San Marino)[2]. Nevertheless, in the last ten years, travel & tourism has become the sector with the highest growth rate in Serbia (5.0% in 2019), accounted for 5.9% of total GDP. Around 3.7 million tourist arrivals (49.9% domestic and 51% foreign tourists) are registered in 2019. In 2019, compared to 2010, there were 84.4% more tourist arrivals. The number of foreign tourist arrivals rose 2.7 times. Average overnight stays are 4.2 days [3].

Sustainability is the core of growth in all sectors. Travel &

tourism is an especially vulnerable sector. This sector is highly dependent on many factors and their changes over time, especially on behaviour changes. Therefore, constant monitoring of tourists’ travel behaviour is crucial.

It is well-known that accessibility refers to people's ability to reach desired services and activities. Many factors affect accessibility, including mobility, the quality and affordability of transport options, transport system connectivity, mobility substitutes, and land-use patterns. Conventional planning tends to overlook and undervalue some of these factors and perspectives [4].

It is noticed that a significant limitation in the methodology of creating the Tourism Development Strategy of the Republic of Serbia 2016 - 2025 is the lack of current and credible local research of the travel & tourism market, attitudes and opinions of tourists, and relevant entities in the tourism sector [5].

This case study is a small contribution to the efforts in travel & tourism market research. The target group is adult visitors of the Kopaonik tourist resort in the winter period. A special emphasis is put on the origin of tourist and transport mode choice. The main goal of the survey is to obtain valid data for the establishment of a new concept of accessibility to the resort in the form of an integrated train/bus transport service.

II. STUDY LOCATION

Kopaonik Mountain (in further text Kopaonik Mt.) is situated in the southern part of central Serbia, in the Raška and Brus municipalities. The total area of Kopaonik Mt. covers 2758 km². The highest point is the peak Pančićev Vrh (2017 m). Kopaonik Mt. is one of the most important centres of biodiversity of endemic flora in Serbia with a variety of animal species as well. It was recognized and established as an area of exceptional natural value (National Park) in 1981 with three stages of protection. The oldest and largest ski resort in Serbia is located in Kopaonik National Park. It was founded in the 1930s and has been developing rapidly since the 1970s. Today the ski resort has more than 62 km of ski paths and trails (ski lift system 55 km in length with the capacity of 32,000 passengers/hour). Leisure activities on Kopaonik Mt. are walking excursions, sports (biking, basketball, tennis, riding, paragliding, etc.), slimming, fitness, and other programs. Tourist attractions are spas and mineral springs. The most popular destinations are the remains of fortified towns of the medieval Serbian state, as well as churches, monasteries, and other cultural heritage sites.

Kopaonik Mt. is one of the most popular tourist mountain destinations in Serbia. In 2019, around 135,613 visitors (79.2% domestic and 20.8% foreign tourists) and 565,980 overnights are registered [3]. Around 66.8% of overnights are...
registered in the period from late November to the end of March. In the same year, local tourist organization (TO) Raška registered more than 150,000 visitors who stayed for just a day without spending the night in collective or private accommodation (so-called "same-day visitors"). The local TO authorities estimated that there were numbers of not registered visitors. The coefficient of monthly unevenness of tourist visits was extremely large (2.69) in 2019.

Seasonality in the number of tourists on Kopaonik Mt. changed in 2020. The most crowded days in 2020 were: in the winter season the 2nd of January (with 6,500 skiers) and in the summer season the 22nd of August (with 4,400 tourists, mostly domestic) [6]. The rise of domestic tourism in 2020 is the consequence of epidemiological measures due to the coronavirus pandemic.

Seasonality is extremely important in passenger transport planning, especially to and from tourist destinations. It is well known that the data of registered tourists and overnight stay do not provide a complete insight into travel behaviour and distribution. Therefore, at the destination level, for the analysis of seasonality in the distribution of tourists a new approach is needed.

III. ANALYSIS OF THE PRESENT PASSENGER TRANSPORT SERVICE TO KOPAONIK MT.

For traveling to Kopaonik Mt. and ski resort tourists can choose between road and railway means of transportation. Helicopter transportation is also available in certain situations. Available means of road transportation are:

• scheduled public transport bus service;
• rent-a-car;
• door-to-door private or shared transfers by vehicles with professional drivers: VIP limousines up to 8 passengers, minibus up to 15-20 passengers, minivans up to 8 passengers, or taxi transfer. The service can be organised as a one-way transfer or sightseeing round-trip transfer.

Since the direct railway transportation service to the Kopaonik Mt. ski resort does not exist, an intermodal passenger transport is needed. The nearest railway station is 16.4 km far away (Rudnica railway station). In 2020, only 2 pairs of passenger trains operated daily on the Kraljevo - Kosovska Mitrovica railway line, with planned stops in Rudnica station. The connection with the bus service for transfer to Kopaonik Mt. ski resort was not planned.

A. A historical overview of the rail transport service

If we look into the past six decades, the railway services from Belgrade municipality to the Kopaonik area were poor. In the period from 1950 to 1990, there was one pair of trains operating daily on railway line Belgrade-Skopje via Kraljevo. The departure time from Belgrade station was 21:55 and the arrival time in Rudnica station was 03:59. Total travel time was 6 hours and 4 minutes.

In the beginning, in 1950, the transfer from the station to the Kopaonik Mt. ski resort was organised by the local population. Tourists have been transferred by horse or ox wagons with a maximum travel speed of 5 km/h, and a total travel time of over 3 hours in one direction. Later on, a transfer by public bus service was obtained, but the arrival of trains and departure of buses was not adjusted. Tourists waited too long at the bus station.

The first real attempt for the establishment of railway service according to travel demands of skiers was held in the mid of the last decade of the 20th century. The daily rail service named "ski train" operated only for a year, and then was withdrawn.

The malformation of this service was a lack of train/bus transfer time adjustability. The railway company did not make an agreement with local bus operators about the integrated train/bus services. Nevertheless, from that period until today the interest of tourists for traveling by train to Kopaonik Mt. still remains.

IV. SURVEY RESEARCH METHOD AND METHODOLOGY

For this research, a survey methodology and e-questionnaire have been developed. It is based on theoretical approaches to travel behavior and demand analysis such as activity-based approaches, approaches using subjective variables (attitude), approaches using population segmentation, and approaches directly involving choice models.

The e-questionnaire consists of 12 questions in total (multiple-choice and open questions) divided into two sections. The first section consists of 4 questions (general observation of the interviewer such as sex and approximate age of a tourist, place, and time). The second section consists of 8 questions that have to be answered by a tourist. These questions are referring to the following:

• Origin of a tourist (where the tourist comes from);
• Frequency of visits to Kopaonik Mt.;
• Duration of stay;
• Transportation mode in arrival and return to the tourist's origin;
• Factors influencing the mode choice;
• Attitudes of the tourist towards a train/bus integrated transport service;
• Travel quality demands of the tourist.

The primary data were gathered using a face-to-face survey among adult visitors to Kopaonik Mt. The survey respondents were selected using random sampling, and the on-site survey was carried out on a voluntary basis. The survey was conducted over a time period of 4 weeks (from mid-January to mid-February 2020), each day from 10:00 to 16:00, on the most visited sites (in and outdoor leisure & recreational areas).

The data collected by the e-questionnaire (electronic Blaise questionnaire) were transformed and compiled, then converted into SPSS format (SPSS - A software package for statistical analysis). Data collected this way are easy to handle (sort, analyse and present in tables and graphs).
V. THE MAIN RESULTS OF THE INTERVIEW

The pilot survey was performed on the 26th and 27th of March 2016 with a sample of 100 tourists. The results were presented in the Bachelor's degree final project of the student in charge [7].

In the survey, carried out in 2020, a total of 1,000 visitors were interviewed (51% male and 49% female).

Among interviewed 92% were domestic and 8% were foreign tourists.

The age of respondents is given in Table 1.

<table>
<thead>
<tr>
<th>Age of tourists</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 20</td>
<td>10</td>
</tr>
<tr>
<td>20 - 30</td>
<td>29</td>
</tr>
<tr>
<td>30 - 40</td>
<td>27</td>
</tr>
<tr>
<td>40 - 50</td>
<td>26</td>
</tr>
<tr>
<td>over 50</td>
<td>8</td>
</tr>
</tbody>
</table>

The age of the majority of the surveyed tourists is clustering from 20 to 50 years (82%).

The origins of tourists (where tourists come from) are given in Table 2.

<table>
<thead>
<tr>
<th>Region</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgrade</td>
<td>50</td>
</tr>
<tr>
<td>Vojvodina</td>
<td>14</td>
</tr>
<tr>
<td>Sumadija</td>
<td>8</td>
</tr>
<tr>
<td>Western Serbia</td>
<td>12</td>
</tr>
<tr>
<td>Eastern Serbia</td>
<td>1</td>
</tr>
<tr>
<td>South Serbia</td>
<td>7</td>
</tr>
<tr>
<td>Neighbouring countries</td>
<td>5</td>
</tr>
<tr>
<td>Other European countries</td>
<td>2.8</td>
</tr>
<tr>
<td>Other countries</td>
<td>0.2</td>
</tr>
</tbody>
</table>

The largest number of tourists (50%) come from the Belgrade region (47% from Belgrade municipality), then 14% from the Vojvodina region (5% from Novi Sad) and 12% from Western Serbia (7% from Kraljevo). The majority of foreign tourists come from the Republic of North Macedonia.

Around 87% of respondents visit Kopaonik Mt. in the winter season, 10% in the winter and summer season, and 3% in the winter and some other season.

The duration of staying for the majority of tourists (43%) is 7 to 10 days. Most of the visits are organized by travel & tourism agencies. The greatest number of tourists prefer one-day visits (3%) or weekend and short holidays visits with 2 or 3 overnights (39%). Around 15% of visitors stay longer than 10 days.

The majority of respondents (88%) for their overnight staying chose hotels or apartments, 9% chose private houses and lodges. On the list, 3% of visitors did not stay overnight.

Of the total number of respondents, 73% came by car, while 27% used public bus transportation.

Attitudes of tourists towards a train/bus integrated transport service show that 38% of respondents are highly interested, 41% are not interested and 21% are indefinite and will show their preferences after the travel service establishment.

Those who are not interested in new integrated transport service specified their reasons as follows:
- car dependency;
- personal travel comfort;
- travel with children and a great amount of luggage;
- other reasons.

Those who are interested or indefinite specified their priority in travel quality demands as follows:
A) Demands toward transport service
- timetable (38%),
- total travel time (26%),
- comfort and internet (22%),
- integrated ticketing and tariffs (6%),
- free door to door luggage service (5%),
- high cleaning standards for vehicles (4%).

B) Demands toward Kopaonik Mt. railway stations (Rudnica and other stations)
- station functionality - the collective function that a station offers to passengers as part of a journey;
- station building services - waiting area, left luggage lockers & offices, dressing and changing rooms with bathrooms, etc.;
- station as a transport hub - extended range of services in addition to services for the journey - restaurants, cafeteria, shops;
- station as a transfer point - more transfer opportunities (variety bus types by capacities, rent a car, rent a motorbike and a bike, rent a vehicle with driver, etc.).

The majority of visitors under the age of 30, who stay one day, have more demands toward timetable and railway station services.

The main demand toward timetable is that arrival and departure time should have seasonal characteristics. In the winter season, arrival and departure times have to be in correlation with lifts & ski trails operation schedule (arrival at the spot at least 1 hour before opening, and departure at least 1 hour after closure). In the summer season, arrival and departure time has to be in correlation with the daylight period (arrival at the spot at least at 10 o’clock and departure time at the most 1 hour before sunset).

The demand toward train running dynamics is that in both seasons long-distance railway passenger service (over 150 km) should be organized 3 times a week (Friday, Saturday, and Sunday), and short distance service (up to 150 km) on a daily basis.

The majority of visitors interested in integrated rail/bus passenger transport services come from Belgrade, Kragujevac, and Kraljevo.

The results of the comparative analysis of distance from the place of origin to Kopaonik Mt. are given in Table 3. Presented data imply that distance as a travelling parameter is highly competitive.
The results of the comparative analysis of travel time from origins to Kopaonik Mt. are given in Table 4.

### Table IV
**Travel Time from Origin to Kopaonik Mt. Ski Resort in 2021**

<table>
<thead>
<tr>
<th>Departure city</th>
<th>Time (h,min)</th>
<th>Car</th>
<th>Bus</th>
<th>Train*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgrade</td>
<td>3h 15min</td>
<td>5h 15min</td>
<td>6h 10min</td>
<td></td>
</tr>
<tr>
<td>Kragujevac</td>
<td>2h 34min</td>
<td>3h 10min</td>
<td>3h 48min</td>
<td></td>
</tr>
<tr>
<td>Kraljevo</td>
<td>1h 53min</td>
<td>2h 00min</td>
<td>1h 50min</td>
<td></td>
</tr>
</tbody>
</table>

*travel time has to be extended with the period of time for transfer and travel by bus, from Rudnica station to the resort

The travel time by bus, from Rudnica railway station to Kopaonik Mt. ski resort, is 21 min in the summer season and up to 40 min in the winter season. The transfer time is around 10 min.

Presented data imply that on distances up to 100 km the travel time is competitive. Cars and buses are used on local roads with speed limits, so the average speed is around 53 km/h.

On distances over 100 km, travel time by car is far less than travel time by bus or train.

From Belgrade to the destination, section of the main road can be used, so the average speed is around 83 km/h.

The average speed of buses on all distances is nearly the same. The average speed of trains is highly dependent on conditions of the infrastructure elements, and varies from one section of tracks to another (goes from 40 km/h to 53 km/h).

### VI. OPPORTUNITIES & CHALLENGES OF RAILWAY PASSENGER TRANSPORT SERVICE

The rise in demand for railway passenger services is closely related to investments in railway infrastructure driven by the government and to service standards of railway undertakings (RU) and infrastructure managers. Travel demands can put large pressure on the authority in charge.

Leisure tourism spending worldwide has increased steadily since 2015. In 2020, inbound tourism (visits and spending) has declined, and domestic tourism has risen. The presence of rail passenger service on the travel & tourism market is necessary. Consequently, constant transport market research is crucial for the improvement of rail travel service planning. Rail passenger services, which are close to travel demand, may shift the share of the railways in passenger transport modal split.

The results of this research indicate that there are demands toward integrated rail/bus service. The travelling parameters of such a service could be competitive on the transport market.

The proof for that claim is lying in the plans of the Government of the Republic of Serbia for further investments in the railway infrastructure and vehicles. Therefore, continuous rising of the speed of trains and reduction of travel time can be expected.

### VII. CONCLUSION

Accessibility is the main function behind the basics of tourism & transport. The improved transport infrastructure facilities and services have incited tourism, and the expansion of tourism has incited the development of transport infrastructure [8].

In the last ten years, the Government of the Republic of Serbia has made significant progress in the field of transport infrastructure. The investments have covered reconstruction, improvement, and building new capacities in all modes of transport, especially road and railway.

One of the main pillars for the travel & tourism uprising, appointed in the development vision for travel & tourism in the Republic of Serbia, is the continual improvement of the quality of all types of transportation services. A special emphasis is put on enhancing public transport services.

The further actions need to be taken toward continuous monitoring of travel behaviour and demands, and establishment of a high level of cooperation between operators of rail and road public passenger transport.

Local tourism organizations have to be active partners in planning and realizing transport services to, from, and within attractive tourist destinations.

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Influence of public passenger transport reliability on users behavior

Pavle Pitka¹, Milan Simeunović², Tatjana Savković³, Milja Simeunović⁴, Ivana Milenković⁵

Abstract – Unreliable functioning of public passenger transport (PPT) system has direct influence on different aspects of passenger's journey. Often disturbances in vehicle headway influence users in such manner that they plan their journeys accordingly (leave earlier, choose different line, transfer to another line, changes in mode of travel). This paper will analyse the influence of PPT system's reliability on decisions and behaviour of PPT system's users.

Keywords – Public passenger transport, reliability, user's behaviour, vehicle headway

I. INTRODUCTION

Urban mobility in urban areas is highly dependent on the functioning of public passenger transport (PPT). The personal mobility of residents, i.e. their freedom of movement, should be a primary product of the PPT system. For a PPT to be beneficial to many residents whose transportation requirements are not mutually synchronized, the transportation service must be predictable.

The reliability of the PPT system's functioning has a direct impact on the elements of passenger travel. Any unplanned change during the operation of the PPT system forces the passenger to change and adjust the planned trip to new circumstances.

Reliability is a key aspect of public transportation services, and surveys have shown a consistently high importance attributed to various reliability aspects by travelers [1, 2]. The most significant negative experiences that drove a reduction in public transport use were delays perceived to be the fault of the transport agency, long waits at transfer points, and being prevented from boarding because of crowding [3].

This paper presents the results of a survey of passenger behavior in the PPT system in Novi Sad in the event of a system malfunction.

II. INFLUENCE OF THE HEADWAY DISTURBANCE ON THE PASSENGER

Headway disturbance adversely affects the operational functioning of the PPT system (prolonged turnaround time, vehicle delay for subsequent departure, full load vehicles, vehicle grouping, etc.). On the other hand, headway disturbance also adversely affects the following aspects of passenger travel: average passenger travel time; uncertainty of travel time for passengers; comfort of passengers in the vehicle.

The prolonged average travel time, uncertainty of passenger travel time and reduced comfort level in the vehicle lead to the following changes in passenger behavior:

a) Within the PPT system: change of departure time; changing the departure point of the trip; change of the arriving position; route change (second line, additional transfer, etc.)

b) Outside the PPT system: change in the mode of transport; changing or canceling a trip.

A. Passenger travel time

Travel time for passengers in the PPT system consists of the following time components: system access time; waiting time; on-line travel time; transfer time; walking time from the exit stop to the final destination.

System access time of the user to and the travel time of the user from the exit stop to the destination depend on the static elements of the lines, while the headway disturbance does not affect these temporal components of the passenger journey. In the structure of travel time, headway disturbance affects the waiting time of the passenger at the stop, the travel time of the passenger and and transfer time.

The waiting time for passengers at a stop is a direct function of the realized vehicle headway which is less than 10 minutes, and is a consequence of the nature of the accumulation of passengers at the stops [4].

The minimum expected waiting time for passengers at a stop in the event of constant headways is defined as a time period equal to half the headway. The waiting time defined in this way has absolute accuracy in conditions of steady accumulation of passengers at the stops. As the definition of a mathematical expectation of a waiting time implies a uniform interval, any prolongation of the headway results in prolonged waiting time relative to the minimum expected.

According to the results of a survey on a network of lines in Novi Sad, the accumulation of passengers on city lines where headways are less than 15 minutes is done randomly. The waiting time for passengers depends directly on the standard deviation of the headway disturbance, which means that the extended waiting time of the passenger is in a direct correlation to the headway disturbance. Extending the waiting time for passengers represents a waste of time and significantly affects the deterioration of the transport service quality [5].

The prolonged on-line travel time of passengers in conditions of disturbed headway is a consequence of longer vehicle delays than planned [6]. Prolonged on-line travel time
of passengers exists in conditions disturbed headway, but is not expressed as extended waiting time for passengers at a stop and is much more difficult to quantify.

B. Uncertainty of travel time for passengers

Based on the previous analysis of the travel time of passengers in the PPT system, it can be concluded that, in the conditions of disturbed headway, the travel time of the passengers is extended. Variations in travel time depend on many factors and are not predictable for the passenger so, in the PPT travel planning process, the passenger must consider possible time losses as a buffer time in order to successfully (without delays) reach the destination.

Buffer time in the travel planning process exists in other modes of transport as well. The subjective valuation of the buffer time that the passenger must take into account in the PPT system and its comparison with other modes of transport greatly influences the choice and preference of the PPT as a mode of transport in the realization of the trip.

C. Comfort of passengers in the vehicle

The vehicle load factor expresses the capacity utilization on the most loaded section of the line, that is, on the characteristic section of the line [7].

The vehicle load factor, as defined in the literature, gives the average hourly utilization of the number of seats offered on the most heavily loaded section of the line. It is realistic to expect that the utilization of seats on the most heavily loaded line will be different for each individual vehicle and in each half-cycle.

Differences in peak flow values within peak hours observed by vehicles on the same line are conditioned by many factors such as headway disturbances, uneven accumulation of passengers, conditions of other surface traffic, etc. Factors that condition the realization of different values of maximum passenger flow rates on vehicles of the same line lead to the realization of different values of the vehicle load factor per vehicle and even change the characteristic inter-station distance for individual vehicles of the same line at peak time [5]. The diversity of comfort parameters is mainly conditioned by headway irregularity and passenger flow characteristics [8].

In conditions of headway disturbance passenger comfort is reduced, while in extreme situations the passenger demands for transport are often not realized (full load vehicle – passengers cannot enter the vehicle).

III. RESEARCH METHODOLOGY

Novi Sad is the second largest city in Serbia, with population of 277,522 inhabitants. The population of the administrative area of the city totals 341,625 people [9].

In Novi Sad public passenger transport system is realized by using the bus transportation subsystem, which is organized by lines. Network consists of 17 city lines. Total length of city lines is around 260 kilometers. If lines connect certain parts of the city with industrial zones, the average headway on city lines is around 13 minutes.

Survey of passengers in the PPT system in Novi Sad was conducted in order to identify changes in passenger behavior caused by transport reliability. The survey was performed on 17-th December 2017. Research has been done inside the vehicle, manually, by the interviewers. Preliminary phase of the research included preparation of materials for survey and training of interviewers.

The survey has been performed by directly interviewing the users of PPT, according to the predefined questions within the framework of questioner. Survey of users has had three groups of questions for users. The first group contains data on user. The second group contains data on characteristics of the trips. The third group of questions contains data on changes in passenger behavior caused by transport reliability.

The survey was conducted on 663 passengers. Interviewees have been randomly chosen.

IV. RESULTS ANALYSIS

Disruptions in the functioning of the PPT system create problems for users while traveling. The results of the survey, i.e. passenger characteristics, journey characteristics and passenger behavior during disturbances in the PPT system are given in the next section.

The main characteristics of passengers are given in Table I. The largest number of users surveyed is between 19 and 30 years old (52.64%), while the smallest number of passengers surveyed is older than 65 years (7.39%). Students and pupils have the largest share in the occupational status structure, 51.73%, while the unemployed have the lowest share, 2.87%. The largest number of passengers surveyed uses PPT daily (74.51%).

### Table I

<table>
<thead>
<tr>
<th>Characteristics of PPT users</th>
<th>Number</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>320</td>
<td>48.27</td>
</tr>
<tr>
<td>Female</td>
<td>343</td>
<td>51.73</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 18</td>
<td>64</td>
<td>9.65</td>
</tr>
<tr>
<td>19-30</td>
<td>349</td>
<td>52.64</td>
</tr>
<tr>
<td>31-40</td>
<td>86</td>
<td>12.97</td>
</tr>
<tr>
<td>41-50</td>
<td>52</td>
<td>7.84</td>
</tr>
<tr>
<td>51-65</td>
<td>63</td>
<td>9.50</td>
</tr>
<tr>
<td>≥ 65</td>
<td>49</td>
<td>7.39</td>
</tr>
<tr>
<td>Occupational status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employed</td>
<td>221</td>
<td>33.33</td>
</tr>
<tr>
<td>Unemployed</td>
<td>19</td>
<td>2.87</td>
</tr>
<tr>
<td>Pupil, Student</td>
<td>343</td>
<td>51.73</td>
</tr>
<tr>
<td>Retired</td>
<td>78</td>
<td>11.76</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>0.30</td>
</tr>
<tr>
<td>Scope of Journey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>494</td>
<td>74.51</td>
</tr>
<tr>
<td>Several times a week</td>
<td>122</td>
<td>18.40</td>
</tr>
<tr>
<td>Several times a month</td>
<td>40</td>
<td>6.03</td>
</tr>
<tr>
<td>Several times a year</td>
<td>7</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Passenger subjective senses of on-line travel time, as well as waiting time at the stop are given in Fig. 1. The largest number of users at the stop waits for transportation up to 5 minutes (45.10%), while 36.05% of the respondents are waiting on
transportation 5 to 10 minutes. The travel time of the largest number of passengers is realized in the interval from 15 to 20 minutes (27.00%). The average passenger ride time is 18.9 minutes.

Table II provides information on user responses to what they do most when the vehicle waited is late. The results of a survey of passenger behavior in the PPT system in Novi Sad showed that when a vehicle is late most passengers (69.08%) seek a solution within the PPT system, that is, 42.99% of passengers wait for the next vehicle, while 26.09% the passenger changes the line/using the second route they reach the destination.

<table>
<thead>
<tr>
<th>What do you most commonly do when the vehicle is late?</th>
<th>Number of interviewees</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wait for the next vehicle</td>
<td>285</td>
<td>42.99</td>
</tr>
<tr>
<td>2. Choose another line/change your route</td>
<td>173</td>
<td>26.09</td>
</tr>
<tr>
<td>3. Change mode of transport</td>
<td>175</td>
<td>26.40</td>
</tr>
<tr>
<td>4. Give up your journey</td>
<td>18</td>
<td>2.71</td>
</tr>
<tr>
<td>5. Other</td>
<td>12</td>
<td>1.81</td>
</tr>
<tr>
<td>Total</td>
<td>663</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The users’ response to how long they are willing to wait for the longest delayed vehicle is shown in Fig. 2. The largest number of users is ready to wait for the vehicle from 10 to 15 minutes (34.7%), as many as 17.9% of users would wait for the vehicle up to 25 to 30 minutes. The maximum time a passenger agrees to wait at a stop, presented as the average for all passengers surveyed, is 18.8 minutes.

When the vehicle is delayed, 26.40% of users change the mode of transport (Table II), with the largest number of users (57.7%) changing the PPT for taxi transportation, while 31.4% decide to go on foot (Fig. 3).

Table III provides information on the users’ responses to what they do most when a full load vehicle arrives to the stop. Most of the passengers surveyed (31.37%) are waiting for the next PPT vehicle; 23.68% of travelers chose the answer “5. Other”; 22.32% of passengers changes the line or reaches the destination by another route; mode of transport changes 18.40% of passengers. Passengers surveyed (157 passengers) who chose “5. Other” profiled their response in more detail, with 59.87% (out of 157 passengers) stating that they still managed to get into the vehicle by pushing.

Data on the response of users to how long they are willing to wait for the next vehicle when a full vehicle comes to a stop is shown in the following Fig. 4. The largest number of users, 30.3%, is ready to wait for a vehicle from 10 to 15 minutes, while 15.9% wait for the vehicle 25 to 30 minutes. The maximum time a passenger agrees to wait at a stop, presented as the average value for all passengers surveyed, is 19.0 minutes.

When a full load vehicle comes to the stop, 18.40% of users change the mode of transport (Table III), with the majority of users (45.1%) changing the PPT for taxi transportation, while 37.7% decide to take go on foot (Fig 5.)
Disturbances in the PPT system adversely affect the passenger. In the event of a PPT disruption, the passenger is forced to change and adjust the planned trip to new circumstances. Changes made by the passenger within the journey plan can be classified as changes to journey within the PPT system and outside the PPT system.

As part of this paper, an analysis of the behavior of passengers was made based on a survey conducted on PPT users in Novi Sad for the cases when a vehicle arrives late or a full load vehicle arrives at a stop.

The results of the analysis showed that regardless of whether the vehicle is late or full at the stop, the behavior of people is similar, with the majority of users striving to stay in the PPT system, while every fourth or fifth user changes the mode of transportation. Most passengers use PPT daily (74.51%). They are aware of the reliability of the system and are prepared in for any delays. The buffer time taken by passengers when traveling with the PPT system (when they need to arrive on time) is approximately the waiting time for the next vehicle to which the passengers have agreed. This time is also close to the longest headway PPT system in Novi Sad which is about 20 minutes.

Based on the analysis, it can be concluded that the value of buffer time used by passengers in a system is a subjective assessment of the reliability of the PPT system by passengers. Buffer time in the journey planning process exists for each mode of transport. Future research will focus on a comparative analysis of the buffer times of different transport modes in Novi Sad.

Acknowledgment

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Analysis of the railway system in the region of Serbian Banat

Gordan Stojić¹, Ilija Tanackov¹, Sanjin Milinković² and Siniša Sremac¹

Abstract – Technical and exploitation condition of most railways in Serbian Banat is unsatisfactory. Railway stations in Serbian Banat region transport extremely small number of passengers. The volume of railway freight transport, even in the conditions of liberalization of the railway market, is still small.

Keywords – Administrative divisions, railway infrastructure, railway transport, condition, realization.

I. INTRODUCTION

Banat is a geographical and historical region straddling between Central and Eastern Europe that is currently divided among three countries: the eastern part lies in western Romania; the western part in northeastern Serbia (mostly included in Vojvodina, except a small part included in the Belgrade Region); and a small northern part lies within southeastern Hungary (Figure 1).

Fig. 1. Map of the region of Banat [1]

On the territory of Vojvodina, Banat is administratively divided into three districts: North Banat, Central Banat and South Banat, North Bačka, West Bačka, South Bačka and Srem (Figure 2).

That Serbian Banat region comprises the following administrative districts: North Banat, Central Banat and South Banat.

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Synergy between the level of economic and social development and the level of transportation system development is a generally known fact. The development of economic potentials of some region significantly depends on the development of transportation system and its interconnectivity with neighbouring regions. Quality railway service is a very important factor in a successful transport system.

On the territory of the contemporary Romanian and Serbian Banat, the oldest railway was built and put into operation on 20th August 1854 on the relation Oravica (Romania) – Jasenovo (Serbia) – Crvena Crkva – Bela Crkva – Vračev Gaj – Sokolovac (Serbia) – monastery Bazijaš (Romania), on the left riverside of the Danube. The purpose of the railway Oravica - Bazijaš was the transport of coal for steamships supplying. The concession for the railway construction was given to Viennese Mining Directorium. Early historical development of the railway in the above mentioned regions certainly played an important part in structuring a specific business culture of their population. Due to this, these regions even today result in representative positions in their countries.

On the account of the conducted analysis it can be concluded that railway network between Serbia and Romania is inherited from the period of Austria-Hungarian monarchy, that is, administrative-state continuity of counties Torontal (Kikinda, Zrenjanin and Pančevo), Timis (Timisoara, Vršac, Bela Crkva) and Krašo-Zorenji (Lugoj, Karansebes and Resita). Bordering parts of the Kingdom of Serbia and Kingdom of Romania did not develop the strategy of mutual railway interconnectivity. In contemporary circumstances, Romanian interests in this part of their territory are directed to the development of Paneuropean Corridor 4, and Serbia is analogously directed to the development of the Paneuropean Corridor 10. Common strategies of railway interconnectivity of these corridors via the Danube still have not occurred.
Technical and exploitation condition of most railways in the region is unsatisfactory. The average age of railway tracks, particularly in Banat, is over 100 years, and on most tracks the same surface is still being used, although its envisaged maintenance cycle has expired (overhaul).

Railway stations in Serbian Banat region transport extremely small number of passengers. In the observed region in 2019 more than 175,800 passengers were dispatched via railway traffic, and around 170,400 passengers arrived. Generally, this represents 10% lower volume of travel in relation to the year of 2015.

In the period 2015-2018 there is a rise in the volume of transported goods, primarily due to the rise in transport in international traffic. In 2019 there is a fall of 13% in the total international traffic and also in the domestic traffic. However, the volume of railway freight transport, even in the conditions of liberalization of the railway market, is still small. North Banat district achieves around 0.5, Central Banat 0.35 and South Banat 0.83 million tons of goods trade.

Banat region has great potentials for a dynamic economic progress in the following period. The development of railway in Banat region should be focused on using the railway as a primary traffic mode for transport.

II. THE CURRENT RAILWAY INFRASTRUCTURE IN SERBIAN BANAT REGION

The analysis of the part of region in Banat implies that north-eastern part of North Banat District (north of Kikinda along the border with Romania) is sparsely populated with low natality rates and mechanical outflow of population. Similar situation can be found in the east of Central Banat District by the border with Romania. In South Banat District, the situation is slightly better, primarily due to the position of the town Vršac and the proximity of the capital of Serbia - Belgrade, which generates significant passenger and goods flows to Serbian-Romanian border. At the same time, out of two railway border crossings between Serbia and Romania (Kikinda-Jimbolija and Vršac-Stara Moravica), the railway towards Vršac is incomparably more active. Also, it can be stated that the infrastructure of the inherited railway system is incomparably better preserved in the Romanian part of Banat.

From the outermost South Banat District the development of the so-called “Banat Gorge” begins, that is, today known as “Derdap Gorge” of the river Danube, which crosses the state border Serbia-Romania.

These railways are marked in the following way in acts of law of the Republic of Serbia (Figure 3): – Main railroad:
- Line 107: Belgrade Centre – Pančevo Glavna – Vršac – state border – (Stamora Moravica)
- Regional railroad:
- Line 201: Subotica – Horgoš – state border – (Röszke);
- Line 202: Pančevo Glavna – Zrenjanin – Kikinda – state border – (Jimbolija);
- Line 205: Banatsko Miloševo – Senta – Subotica;
- Local railroad:

- Line: 309 Pančevo Varoš – Pančevo Vojlovica;
- Line: 313 Vršac – Bela Crkva;
- Manipulative railroad
- Line: 401 Vršac – Vršac Vašarište;

Fig. 3. Railway network in the observed region

On the account of the conducted analysis it can be concluded that railway network between Serbia and Romania is inherited from the period of Austria-Hungarian monarchy, that is, administrative-state continuity of counties Torontal (Kikinda, Zrenjanin and Pančevo), Timis (Timisoara, Vršac, Bela Crkva) and Krašo-Zorenji (Lugoj, Karansebe and Resita). Bordering parts of the Kingdom of Serbia and Kingdom of Romania did not develop the strategy of mutual railway interconnectivity. In contemporary circumstances, Romanian interests in this part of their territory are directed to the development of Paneuropean Corridor 10. Common strategies of railway interconnectivity of these corridors via the Danube still have not occurred. Romania as a EU member directs its interests primarily to other EU members, first of all, to Hungary and Bulgaria. Serbia, which still is not a EU member, does not have a clear internal strategy for the development of direct railway interconnectivity over the river Danube, between Banat and other region (Podunavlje, Braničevo District), which would significantly relieve railway junction Belgrade. [3]

The categorization of railways is very different from category A railways (16.0 t, 5.4 t / m) to category D2 (22.5 t, 6.4 t / m). All lines are single-track without modern signaling systems.

In the region of Serbian Banat, there are a large number of industrial tracks that are used very little. Industrial tracks are in poor conditions, with the tendency of their closing. A lot of industrial tracks are not maintained at all, and those which are maintained, there is a minimum of investment. Due to this, their allowed capacity is unsatisfactory and it is mostly 16-18 tons/axle. It is assumed that the main reason for their being unused is poor quality and lower reliability of railway services.
Developed logistics centres with intermodal terminals in Serbian Banat dont exist, except port “Dunav” Pančev on the river Danube: ship-land transport (road, railway) extremely rarely due to rare arrivals of the ships with containers at this port.

III. RAILWAY PASSENGER TRANSPORT IN SERBIAN BANAT

Joint stock company for railway passenger transport “Srbija Voz” ad is the only operator in passenger transport on the railway market. Observing the passenger transport in railway traffic on the republic level, it can be said that the number of passengers in domestic and international traffic is in decrease. In internal (domestic) traffic, the number of passengers had been decreasing since 2011. There was a noticeable increase by around 25% in the number of transported passengers in 2013 in relation to the previous year, and in relation to 2011, by around 22%. After 2013, the number of passengers decreased from one year to another. In relation to 2011, the traffic volume in 2019 fell by 26% in domestic and 78% in international traffic. We can come to similar conclusions by analyzing the realized operations in passenger kilometers.

The fall in passenger transport volume in railway traffic is directly related to the trend of decrease of the number of passenger trains which operate on the railway network in Serbia, mostly due to limited financial resources of the competent institutions for the services of public transport (Passenger Service Obligation - PSO). ¹

From the aspect of railway traffic in North Banat administrative district a more significant passenger transport volume was realized by railway stations Kikinda, Senta and Čoka. At other stations the passenger transport was negligible. In North Banat District, at the above mentioned stations, during 2019 the realized passenger transport accounted for 24,569 (Figure 4).

In the Central Banat administrative district a more significant volume of passenger transportation was realized by railway stations Zrenjanin, Zrenjanin factory, Novi Bečej and Banatsko Milošev. At other stations the passenger transportation was significantly lower. In this district at the above mentioned stations during the year of 2019, the transportation of 179,942 passengers was realized (Figure 5).

1 Srbija Voz is a company which operates in keeping with legal regulations of EU No. 1370/2007.
Table 1. Number of trains on railway lines in North Banat and timetables

<table>
<thead>
<tr>
<th>Railway line</th>
<th>Number of trains according to the timetable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016/17</td>
</tr>
<tr>
<td>Beograd – Pančevo Gl. – Vršac</td>
<td>5 pairs</td>
</tr>
<tr>
<td>Vršac – Alibunar</td>
<td>2 pairs</td>
</tr>
<tr>
<td>(Beograd) – Pančevo Gl. – Zrenjanin</td>
<td>4 pairs</td>
</tr>
<tr>
<td>Kikinda – Zrenjanin – Pančevo Gl. (Ovča)</td>
<td>/</td>
</tr>
<tr>
<td>Zrenjanin – Debeljača – (Pančevo Gl.)</td>
<td>1 pair</td>
</tr>
<tr>
<td>Zrenjanin – Kikinda</td>
<td>3 pairs</td>
</tr>
<tr>
<td>Kikinda – Senta – (Subotica)</td>
<td>1 pair</td>
</tr>
</tbody>
</table>

IV. RAILWAY FREIGHT TRANSPORT IN SERBIAN BANAT

A. The volume of freight transport

The following figure shows the ratio of the total volume of goods transport by rail in the Banat region and the whole of Serbia (except for transit). The Serbian economy can use rail transport services in domestic traffic, import and export. The transit was initiated by the needs of an economy that does not originate from Serbia. With the exception of 2019, it can be concluded that railway freight traffic (except for transit) on the territory of Serbia is stagnant and is around 9 million tons. Railway freight traffic on the territory of Banat in Serbia since 2016 has a declining trend and ranged from 0.6 to 1.3 million tons, which is a share in the total rail transport of 7.5 - 15% (Figure 6).

![Figure 6](image)

Fig. 6. Comparative overview of the volume of railway transport in Serbian Banat and Serbia (source [5], prepared by the authors)

Generally, in North Banat administrative district, there is export oriented trade. The economy of the Central recorded growth in import. The economy of South Banat administrative district is characterized by exceptional dominance of export. The following figure shows the volume of transport in the districts of Banat in Serbia. As can be seen from the picture, the largest volume of rail transport (internal, import and export) is realized in the South Banat District. However, in all districts of Banat there is a declining trend in the volume of rail transport.

![Figure 7](image)

Fig. 7. Volume of railway freight transport in Serbian Banat (source [5], prepared by the authors)

Regarding economic centres in Serbian Banat region the railway station Pančevo Varoš in domestic freight traffic achieves a portion of the volume of loading and unloading in relation to the whole network in the interval of 16-25%. The station realizes a significant export flow to Romania.

The main transit goods flows for and from Romania, transposed by means of railway traffic, are directed to the railway station situated by the border, Vršac Border. Bordering railway station Kikinda Border is not used for transit goods flows transported by means of railway traffic. This station is only used for goods flows which are imported or exported to Romania (mostly for/from Kikinda, and sometimes Senta, too).

B. Using transport modes in trade

From the aspect of using transport modes by the quantity of trade in the period 2012-2019, road transport participates with 74%, and railway with 25%, while waterborne transport modes (river) and other participate with less than 1%. The participation of intermodal transport is negligible (Figure 8).

![Figure 8](image)

Fig. 8. Modal split of traffic in trade of the economy of North Banat administrative district (source [6], prepared by the authors)

The highest participation is achieved by road transport with the countries of the former Yugoslavia, and with the countries of Central and Southeast Europe. Railway traffic was mostly used for the transport of goods to / from the countries of Central, Southeast and Southwest Europe. Figure 9 shows the foreign trade of North Banat administrative district by transport modes.

From the aspect of using a transport mode by the quantity of trade in visibles, in the period 2012-2019, road traffic participates with 87%, waterborne transport (river) with 8% and railway with 5%. Air transport participates with less than 1% (Figure 10).
Road transport has the largest participation in foreign trade in visibles of Central Banat administrative district by mode of transport with the former Yugoslavian countries and the countries of Southeast Europe. It is also significantly represented in the goods transport with the countries of Central, North and Southwest Europe. Railway traffic was mostly used for goods transport to/from former Yugoslavian countries and Southwest Europe, while waterborne transport was used for Southeast Europe (Figure 11).

From the aspect of using transport modes by the quantity of trade in the economy of South Banat administrative district in the period 2012-2019 road traffic participates with 53%, waterborne (river) with 36%, railway 10% and pipeline traffic with 1%. Air traffic participates with less than 1%. The participation of intermodal transport is negligible (Figure 12).

Figure 13 shows foreign trade of South Banat administrative district by mode of transport.
transport of goods to/from the former countries of Yugoslavia, Southeast and Southwest Europe. The use of intermodal transport from/to Northern Europe, Far East, Russia, Africa, America and Southwest Europe is noticeable.

V. RECOMMENDATIONS AND VISIONS IN THE FIELD OF RAILWAY TRAFFIC IN THE SERBIAN BANAT REGION

In the existing plans for the modernization of railway network there is only preparation of spare railways for the support of corridor X while it is being modernized. In accordance with the plan, the conducted/planned activities are on the railways number 202 and 205. Future plans should reconsider the possibility and need for the modernization of other railways in region, as well.

In the previous period the Republic of Serbia procured new transport means (21 EMU of the label Stadler Flirt 413/417 and 27 DMU series 411 of the manufacturer Metrowaggonmáš). The development of the railway should be accompanied by a continuous renewal and modernization of transport means.

On the level of TEN-T network, the railways which belong to Serbian Banat region are not planned as an integral part of this group. In the following period it is necessary to examine the possibility and elaborate the plans for joining the railways of the region to the network TEN-T.

Analysis of the transported goods show that the railway traffic is only used in bigger industrial centres. The development of railway in region should be focused on using the railway as a primary traffic mode for transport. In that sense, in the planned period it is necessary to analyse the possibility of using railway transport for goods transport in industrial centres of Serbian Banat region.

Since there is only one transporter in passenger traffic, there is no possibility of formation of transport prices by market principles. In the future, alongside the development of railway passenger traffic, gradual introduction of other transporters into the system should be considered.

Due to the absence of complete implementation of the regulative 1370/2007/EC, in practice, there is a tendency of suspension of passenger trains, which negatively affects the quality of transport, consequently the decrease of railway traffic use. In the following period it is necessary to elaborate plans and initiate activities which have the aim of eliminating this negative trend.

The analysis also determined that in none of the municipalities of administrative districts of Banat region, except in the municipality of Vršac, there is not clearly defined “public service obligation” (PSO). As one of the measures for the advancement of railway traffic, it is necessary to consider the possibility for defining this model of financing by unprofitable transport services in all other municipalities of the observed region. In this way in time railway companies could significantly improve their business operations.

As a special part of transport system there is intermodal transport which is poorly developed in observed region. The analysis established that on state level there are not any plans for the development and stimulation of intermodal transport development. One of the aims of traffic system development in the observed region definitely should be this mode of transport.

VI. CONCLUSION

Technical and exploitation condition of most railways in Serbian Banat region is unsatisfactory.

The assessments of the authors are that the in the following 5-10 years, like in the previous 5-year period, the state will not have enough money nor time to deal with regional and local railways in Serbian Banat region. Most of the investment into railway infrastructure is and will be directed towards the modernization of railways on Corridor X (Budimpešta – Belgrade and Belgrade – Niš for velocities up to 200 km/h, and Šid – Stara Pazova, Niš – Preševo and Niš – Dimitrovgrad for velocities up to 200 km/h), and on the directions Belgrade – Bar and Belgrade – Pančevo – Vršac, and very rarely on other railways. It will definitely not provide the necessary quality of railway infrastructure.

Certain types of goods, due to the quantity, characteristics, transport price and similar, will be transported by railway traffic. The expected development of this region economy will definitely affect the increase of railway freight traffic use.

The existence of private freight operators in the observed region is a positive prerequisite for the offer of cheaper transport services and of better quality.

Further absence of PSO in railway traffic by local self-governments in the region will cause further collapse of passenger traffic quality.

ACKNOWLEDGEMENT

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One Approach to Forecasting Methodology in Rail Passenger Traffic

Slavko Vesković, Sanjin Milinković, Gordan Stojić, Norbert Pavlović, Ivan Belošević

Abstract – The paper presents a methodology for predicting the number of passengers on a line that is being modernized by increasing the existing speed to 160 km/h. The forecast was made for two scenarios: without project and with project. The process is complex and involves the application of correlation methods, growth rates, surveys, and heuristic forecasting models.

Keywords – forecast, railway, heuristics, surveys.

I. INTRODUCTION

Forecasts or predictions are estimates of the occurrence, process, or condition that are highly likely to be expected in a given period in the future. They are based on quantitative and qualitative parameters in the past period and according to the estimation of the development of important parameters that are expected in the future. The process of making a forecast is called forecasting. The main issue with a forecast is a number of factors that affect it. Many of these are factors that are sometimes difficult to assume, and even more, to estimate.

In this paper, we present a methodological approach to forecasting the number of passengers on a selected section of line that will be modernized (upgrading the speed to 160 km/h) for two scenarios: Scenario 1 (S1) without project and (S2) with project. The process itself is complex and involves the application of correlation methods [1], growth rates [1] and heuristic forecasting models [1,2].

II. FORECASTING METHODOLOGY

A. Forecasting approach

In many cases, forecasts are made for two or more scenarios, and their number depends on the number of variant solutions in the project. For this paper, the forecast of passenger traffic volume was prepared for two scenarios:

- Reference (baseline) scenario, representing the “without project” scenario, i.e. the existing condition of the railway infrastructure is maintained. Passenger traffic forecasts in this scenario are based on the projected operating characteristics of the line.
- Scenario for modernization of the line, with newly designed technical and operational characteristics, “with project” scenario. In this scenario, new equipment and track parameters are foreseen for speeds of 160 km/h.

B. Reference period

The selected approach in the study covers three basic periods:

- the period preceding the planned project, where the data is gathered for the data base and further analysis,
- the period during which the project is implemented,
- the period during which a project is monitored, with the aim of assessing the cost-effectiveness of the project.

The period preceding the planned project usually covers a period of 10 years with special emphasis on the last years of the observed period, depending on the availability of certain data. It is desirable, if possible, for a longer period, as well as to particularly emphasize and analyze the characteristic years in which significant trends of traffic volume movement occurred, either in the negative or in the positive direction.

The next step is to determine the project implementation period, as well as the key years of the intersection of the estimated size (number of passengers). Most often, these are five-year intervals, rarely ten-year intervals. Also, it is necessary to take into account the years in which the completion of infrastructure and other projects significant for the exploitation of the observed line (and connecting lines, significant stations, etc.) occurs. The project lifetime of railway projects usually covers a period of 30 years.

C. Development program for the railway line/network

The program of construction and modernization of the railway network is implemented in accordance with the Strategy and the Master Plan of Transport (development projects and priorities for investment in transport sector). Railway development projects are incorporated into the State Spatial Plan.

D. Basic methodology for forecasting

Given that traffic forecasts for such projects should cover a period of 30 years, and given the instability of all significant parameters.
the estimation of traffic demand in the future is based on the Gross Domestic Product (GDP) growth projection, the results of the surveys conducted, as well as a number of other socio-economic parameters and indicators.

It is expected that the modernization of the railway section will help to keep the existing traffic, but also to attract part of the road transport (modal shift). Modal shift is based on an estimate of the cost of traveling by road and the cost of rail travel, from the perspective of the user. The cost of travel includes the difference in the price of transport and the travel time (results from modernization of the railway). In order to properly estimate the number of modal shift passengers, it is necessary to take into account the responses of the previously surveyed passengers and companies. The applied model for the forecast of demand in passenger traffic is based on:

- expected increase in GDP in the coming period will affect the growth of employment and population standards, which will also lead to an increase in population mobility and overall demand for transport services,
- shorter rail travel times and higher quality rail offer (organization of trains in tact mode and more trains) will lead to a passenger transport modal shift from road to rail.

It is expected that the modernization of the railway will increase the market share of rail traffic by attracting a portion from road traffic (diverted traffic).

Shifting or change in mode of transport percentage is based on an estimate of the cost of travel by road and rail, from a user perspective, where the cost of travel and travel time (after modernization) is included in the cost of travel.

The diversion of passengers from road to rail is always present when a new high-level service is created on the rail. For some types of surveys, certain questions should be statistically significant estimates of passenger satisfaction covered is large enough (over 3500 passengers) to identify unsatisfactory), passenger safety (priority in planning railway companies and in railway improvement activities), and by identifying substandard areas to invest in them in the future (to prioritize passenger needs).

Forecasts of passenger traffic in the scenario "without Project" is based on the projected exploitation characteristics of existing lines.

In view of the estimated demand, it is expected that in the scenario “with project” shorter travel time compared to road transport and organization of passenger transport as a periodic type timetable mode, with frequent departures of trains, lead to a redistribution of a part of passengers from road to rail. The assumed redistribution was determined on the basis of experience and research in the available projects and studies, and a survey of passengers at bus and train stations was conducted.

In the development of the forecasting model, a combined approach was used: quantitative (using mathematical and statistical modeling) and qualitative (using heuristic modeling: intuition, personal experience, and value system based on survey responses). The factors considered in the development of the forecast model are:

1. data on the volume of road and rail passenger traffic,
2. data on the flows of railway passengers on the specific stations (domestic, international, arrived and dispatched),
3. plan for the line modernization and construction schedule,
4. a survey of rail passengers,
5. a survey of expert opinion (by Delphi method),
6. assessment of the passengers modal shift (alternative, ambivalent and antagonistic passengers),
7. Estimation of the socio-economic parameters for the relevant period (GDP, population, demographic data,…),
8. Average year daily traffic on the Corridor and estimated rate of modal shift of car users to rail transport.

The results of the forecast (outputs) are: OD matrices; Volume of passengers per station; Passenger traffic density.

III. HEURISTIC MODEL - SURVEYS

A. Passenger surveys

In the process of traffic planning, in addition to information on space, economy, population and transport infrastructure, an information base is created through transport research. The quality of the designed traffic solution will depend on the quality of the data collected from the real-life systems.

Passenger satisfaction surveys are conducted regularly and according to established rules. In the UK, the National Rail Passenger Survey (NRPS) has been in existence since 1999 and measures the satisfaction of passengers with different railway companies in England, Scotland and Wales [4]. The analysis of the work of all the railway companies is done, through their comparison and the satisfaction of the passengers on different routes and stations. National Rail Passenger Survey (NRPS) is used to: raise the standards of the rail industry through outreach, create an environment conducive to continuous progression (most rail companies create work plans to improve segments where results are unsatisfactory), passenger safety (priority in planning railway companies and in railway improvement activities), and by identifying substandard areas to invest in them in the future (to prioritize passenger needs).

The Rail Passenger Survey is mainly used to measure passenger satisfaction with rail services [3,4]. In this research, the survey was also used to estimate the number of passengers, and to determine the shift of passengers from road to rail. Passengers were surveyed at 10 rail and 10 bus stations on Corridor X in November and December 2019. The sample covered is large enough (over 3500 passengers) to identify statistically significant estimates of passenger satisfaction with potential shift of passengers from road to rail. The survey questions are presented in Table I.

For some types of surveys, certain questions should be allowed to have multiple answers, such as:

- Do you use any other form of transportation to reach the station?
- What do you think would be the priority for further investment in rail transport?
- What additional station services should be introduced?

For the question “What do you think would be the priority for further investment in rail transport?” more answers can be offered (e.g. increase of speeds on lines, reconstruction / revitalization of existing lines, connecting rail with other modes of traffic), and that multiple responses can be selected.
TABLE I
QUESTIONS ON THE SATISFACTION OF RAILWAY USERS

1. Sex:
   - Female/Male

2. Age:
   - to 18 years / 18 to 30 / 30 to 40 / 40 to 50 / 50 to 65 / over 65

3. Profession:
   - full time / part time / seasonally employed / unemployed / dependent / other.

4. Purpose of the journey:
   - Business / School-College / Shopping / Tourism / Administration / Homecoming / Other

5. How often do you use the train as a means of transportation?
   - Daily / several times a week / several times a month / several times during the season / rarely / almost never

6. What is the train route that you use most of the time?
   - From:________ / To: ________

7. Compared to other modes of transport (bus, car, van, ...), how would you compare the cost of a train ride on the route you travel?
   - More expensive by train / Same price / Cheaper by train / I do not know.

8. What is the total earnings in your household?
   - up to 30 000 dinars / from 30 000 to 60 000 dinars / from 60,000 to 90,000 dinars / over 90,000 dinars

9. Do you use any other form of transportation to get to the train station?
   - Car / bus / motorcycle / bike / on foot / other transportation (comment)

10. Do you think that the quality of the rail service on your line has increased since ....?
    - Yes, it has increased significantly. / Yes, it has increased. / It remained the same. / No, it's worse. / I do not know.

11. Is the train timetable suitable for passengers?
    - Yes, it's much better. / Yes, he's better. / It's the same. / No, it's worse. / I do not know.

12. What rating would you give for the regularity of train traffic?
    - Traffic without delay / Works with very little delays / Traffic with small delays / Traffic with long delays / I do not know

13. In your opinion, what would be the priority for further investment in passenger rail transport in your region?
    - New trains / Increase train speed / Electrification / Increase safety / Level crossings / Railway stations / Other

14. What additional services / objects in stations should be introduced?
    - New ticketing services / New info systems / Park & Ride Facilities and services / Something else

15. If you are not a rail user, please provide a reason.
    - Unrealiable / Unfavorable timetable / High cost / Long travel time / departure and arrival delays

Some other questions may be added to indicate the criteria for choosing the mode of transport:

- If there are more alternatives / modes of transport on the route you are traveling on, by what criteria would you choose the mode of transport? This should be defined by type of travel (suburban/regional, long-distance and international).

- What quality of service is important for regional transport? (e.g. ticket price; time of travel; time of departure; comfort; reliability).

- What is important for long distance / international transportation? (e.g. ticket price; time of travel; time of departure; comfort; reliability).

It is very important that the survey has minimal number of questions, and to carefully approve and choose the questions. As defined in the survey, passengers were divided into three groups of passengers:

1. Alternative passengers: predominantly use the road transport system and sometimes existing rail system, but they will shift to rail in future (20% of these passengers in our survey).

2. Ambivalent passengers: always use the bus system and never use the existing rail system. They are potential rail passengers (in our survey approximately 63%).

3. Antagonistic passengers: use bus system, and never usetrain. They are not willing to shift to rail regardless of the service quality (17% of total number of passengers).

F. Survey of expert opinion

The basis for the without project case forecast was made as a quantitative forecast as it is based on the data obtained on passenger and transport. Forecast for the case with project used a qualitative approach and heuristic methods forecasts. Heuristic methods allow to direct experts’ intuitive opinions, to obtain quantitative characteristics and to increase the quality of prognosis. Experts opinions are given for alternatives or specialists are ranked for individual factors and results are...
processed using mathematical statistics. In order to obtain the most objective evaluation of experts in forecasting heuristic methods, it is necessary to follow the following principles:

- form an expert group objectively;
- ensure independent expert judgment;
- stage the research in several rounds.

The essence of heuristic methods is to form a group of specialists capable of assessing the prospective development of passenger transport. It usually consists of selected specialists who are well acquainted with the work of the system.

In this case, we choose the Delphi technique [5] to collect expert data. Delphi Technique seeks to eliminate the negative impact of authority and preserve the positive effect of diversity in expert opinion. It consists of several steps, the first being the preparation for the survey. Then a group of questions is asked again and the answers are analyzed. The next iteration uses the results of the previous survey to ask questions in a specific way. Due to the sensitivity and accuracy of the forecast, it is necessary to formulate questions clearly and precisely. The survey was conducted on selected experts through an online form. Each expert provided basic personal information and answers to questions related to the rail passenger forecast. The number of experts should not be small in order to avoid the excessive influence of the individual opinions of the experts on the collective evaluation. However, it should not be too big to avoid losing the opinion of some experts, which is significantly different from the opinion of the majority. The sample size can be determined by using mathematical statistics over the coefficient of variation of the majority. The sample size can be determined by using experts, which is significantly different from the opinion of

\[ N = \frac{t^2 V^2}{\varepsilon^2} \]  

where:
- \( t \) – argument taken from the normal distribution table for a given probability,
- \( V \) – coefficient of variation;
- \( \varepsilon \) – estimation error.

After processing the data and the results obtained by the Delphi method, verification and consistency of the experts' opinion on the forecast is made.

Next, the values of the forecast are compared with socio-economic characteristics as well as with the conclusions of similar projects from the previous period, as well as with other factors that have a direct impact (socio-economic development, socio-demographic development, goals and measures of transport policy and plans and measures for railway development).

Experts are required to estimate the number of passengers through a percentage reduction or increase in existing values for two time intervals. The first time horizon is the moment when the conditions are obtained for the entire line to be constructed and reconstructed. The experts were contacted directly with a request to participate in the survey, and were selected on the basis of their position, place of work and knowledge/education. The survey offered two groups of questions: the first group identifies the expert and his expertise, while the second group requires answers and experts to make a prediction of a certain parameter (Table II).

<table>
<thead>
<tr>
<th>QUESTIONS IN THE EXPERT SURVEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What job/ function were you involved in: (Railway worker, manager, planner, researcher, policy maker, etc.)</td>
</tr>
<tr>
<td>2. Rate your competency, knowledge and experience? (1 min - 10 max)</td>
</tr>
<tr>
<td>3. For scenario without project estimate the percentage of change in the number of passengers in the next 5 years: decrease / increase / remain by %</td>
</tr>
<tr>
<td>4. For scenario without project estimate the percentage of change in the number of passengers in the next 20 years: decrease / increase / remain by %</td>
</tr>
<tr>
<td>5. For scenario with project estimate the percentage of change in the number of passengers in the next 5 years: decrease / increase / remain by %</td>
</tr>
<tr>
<td>6. For scenario without project estimate the percentage of change in the number of passengers in the next 20 years: decrease / increase / remain by %</td>
</tr>
<tr>
<td>7. How would modernization and speed increase on the line (scenario with project) affect the number of international passenger trains in Serbia? decrease / increase / remain by %</td>
</tr>
</tbody>
</table>

F. Conclusion

The process of forecasting passenger demand is always dependent on the data available. When there is a transport model of a line or an area the forecasting model will be based on the data obtained from the model. However, if there is no available data, or the data is not of acceptable quality, the forecasting must be more complex and include both historical data and surveys, qualitative and quantitative approach. As we have presented in the paper, combination of several statistical methods should be validated and complemented with the quality survey data. Complex approach and combined analytical tools can produce the quality forecasting results even when the historical data on system behavior are not available or not complete.

REFERENCES

Application of the QFD method for improving railway transport services

Andrijana Vučković¹, Luka Janković², Aleksandar Blagojević³ and Nermin Čabrić⁴

Abstract – Quality is the key to increasing passenger transport by rail and also to the business success of the railway undertaking itself, because the market, whether domestic or international, is conquered with a sufficiently high quality of service and not just a low cost of service. This paper defines the problem of improving the rail passenger service in accordance with customer requirements, and for this purpose, the QFD method was used as a tool for improving the service.

Keywords – QFD, quality, passenger transport, railway undertaking.

I. INTRODUCTION

The importance of the presence of railway transport companies for the carriage of passengers in a competitive race in a liberalized rail market imposes the need to constantly increase the quality of transport services. Every business, including rail companies, depends on their customers. Companies need to understand the current and future needs of their customers, meet their requirements and strive to exceed their expectations. Thus, there is no increase in the share of rail services in the liberalized rail market without an increase in the quality parameters.

Quality is the key to increasing passenger transport by rail and also to the business success of the railway company itself, as the market, whether domestic or international, is conquered with a sufficiently high quality and not just a low cost of service. To obtain such a level of service in passenger transport by rail that will meet high standards in the liberalized railway market, it is necessary to achieve a high degree of innovation with the inevitable reduction of operating costs. On the other hand, customers dissatisfied with the quality of railway services rapidly share their disappointment with other users and simply pass it on to them.

The basic measures of quality of transport service can be defined through the following requirements such as safety, reliability, regularity, speed of service, convenience of the timetable, comfort in the station and on the train, compatibility with other related transports, staff kindness, hygiene, level of information, personal and property security, catering services, complaints and more.

This paper defines the problem of improving rail passenger service under customer requirements and introduces the QFD method as a tool to improve the service. Proper implementation of the QFD method helps the railway company to listen to the voice of the user. Therefore, the railway company can design new services more efficiently as well as improve existing ones.

II. QUALITY OF SERVICE IN TRANSPORT OF PASSENGERS BY RAIL

Transport of passengers by rail in itself is a service provided by a railway company to its users and can be described as a service having the following characteristics:

Intangibility - Passengers only have a ticket and promises that they and their luggage will arrive safely and on time to a certain place.

Inseparability - Passengers using transport cannot be separated from the means of transport by rail without using services.

Variability - Quality depends directly on the level of sophistication of the railway company, not only its technical equipment (new trains, additional services) but also the determination, knowledge and complete commitment to ensuring the quality of service that meets all passenger requirements and needs.

Brevity - means that transport on certain routes can be used at a specific time and place and it cannot be kept for later.

Railway transport services can not contain certain characteristics of tangible and intangible elements.

The inability to accommodate all activities and events in a particular urban area, as well as going to these activities in parallel with the growth of cities, creates an increased need for travel between places of residence, work, schooling, supply, recreation, treatment and other activities.

The problem arises when there is a mismatch between transportation costs and transportation options. In order to solve this problem, it is necessary to know the parameters that cause the need for travel. These parameters are called independent variables such as [7]: number of family members, family structure, social habits, origin, number of employees, income and ownership of a motor vehicle. It should be noted that the number of trips varies during the day, by months and seasons. Studies show that the main reasons for traveling are returning home and taking up about half of all trips, respectively [7]:

going to work from 12% - 18%, going to school from 10% - 11%, going shopping and supplying 10% -12%, and going to recreation and entertainment from 7% - 9%.

Obviously, daily commitments such as work and school take up about 30% of all daily trips, which is a stable number of travelers, but these trips are concentrated at certain times during
the day, which impedes the organization of traffic. The most important travel parameters are [7]:

Reason for travel – it has been found that there is a relationship between travel mode and reason. Travel related to work is mostly public, while private travel is about individual transport.

The length of the trip is correlated with the choice of means of transport, such as: Short trips - non-motorized and sometimes a car; Medium-distance travel - public transport; Long distance travel - depends on the length, comfort and cost of alternative modes. Passenger parameters are related to the socio-economic characteristics of families: number of members, age, income, ownership of the vehicle, etc.

The parameters of the transport system are: time and cost of travel, and accessibility index.

According to the motive, travel can be: official, for the purpose of education, supply and sale, for health reasons, weekends and tourist trips, excursions and holidays. Based on the purpose of the journey, it is necessary to assess the needs of the passengers and the ability of the railway to fulfill the requirements and wishes, that is, to provide trains for use by the passengers through the organization of passenger traffic.

Which means of transport will passengers choose in today's market economy depends on the action of several competition factors. The factors that influence the choice of means of transport and thus the greater competitiveness are: transportation costs, speed of transport, comfort of travel and accuracy of traffic.

Transport costs in terms of competition in transport play a key role in deciding when the other terms offered are approximately equal.

Transport speed is a very important parameter of service quality. Railways invest a lot in their capacities (technical, technological and human) in order to increase the speed of transport. Facts show that on certain routes in Europe, trains run at speeds greater than 300 km/h. This led to the renaissance of the railway. Studies show that rail is faster than air at speeds of 200 km/h on distances up to 500 km, and for speeds of 300 km/h on distances up to 1000 km.

Travel comfort is very important for travelers of a higher standard, especially for official and business trips. When choosing means of transport, the passenger chooses one that offers more comfort at about the same price. Passenger comfort is ensured by the proper composition of the train, the equipment and tidiness of the railway car, the staff of the train and the large range of services.

Travel safety is a basic determinant of users in the process of choosing transport means. In terms of the number of passengers transported and the number of injured and killed passengers, rail can be considered as the safest carrier.

Regularity of traffic is one of the reasons for the reorientation of passengers to other modes of transport, and above all to the railway and this factor often plays a crucial role in the choice of means of transport.

The concept of quality is very complex and is basically a measure of meeting the needs of individuals and society as a whole. According to many authors, the qualitative indicators of railway traffic can be used to analyze the level of quality of services in rail transport and are calculated through:

• capacity - capacity can be viewed from two aspects: vehicle capacity and infrastructure,
• speed - this feature of traffic is a direct indicator of the quality of services. According to many studies, speed is always in the first three indicators of the quality of transport services for the user,
• reliability - system reliability makes the complex rail system one of the most reliable modes of transport (with air traffic),
• comfort - many travelers equate comfort with quality, which is not enough to determine quality,
• safety - the quality of services depends on safety and the need for safety meets the current needs after food, water, air (the second level in the Maslow needs hierarchy),
• efficiency - system efficiency is related to many factors such as: modern technical means, good organizational structure, good control, good infrastructure and adequately educated human resources to improve the rail passenger transport system. When all these factors come together, system efficiency is inevitable, and thus cost-effective.

In the context of this division, according to Cicak and Veskovic, the quality of services in rail passenger traffic can be seen from the following indicators:

• Transportation time (total travel time) or travel speed,
• Reliability in maintaining the timetable (regularity and accuracy),
• Frequency of departures (number of trains per route),
• Transport safety and security (level of security systems introduced, number of emergencies in relation to transported passengers ...),
• Comfort in trains and stations (places in trains, waiting rooms ...),
• Availability of stations and stops (public transport to the station, connectivity to roads, accessibility to the center of populated place ...),
• Coordination with other types of traffic (connection with other types of traffic, but also with the same type of traffic on different routes),
• Staff attitude to passengers (diligence, cheerfulness, confidence ...),
• Assortment of additional services in stations and trains (food and drink, internet ...) and
• Information about what travelers might be interested in (information before the trip, while traveling ...).

The above indicators were used for the survey of the customer's voice and the development of the QFD model.

All service companies should offer consistent, high quality service in relation to the competition. In line with manufacturing companies, a number of service companies have joined the revolutionary application of TQM (Total Quality Management), and this is especially related to the passenger transport companies. Many service companies have come to the conclusion that excellent quality gives differentiated superior value that leads to competitive advantage and profit. It is true that providing quality service results in high costs, but the investment is usually worthwhile because higher customer satisfaction leads to customer retention and increased passenger transportation.
III. QFD METHOD

The QFD (Quality Function Deployment) method is based on the concept of "Measure for process improvement", aiming to introduce a continuous organizational improvement. The QFD method is based on the requirements of transport service users and, as such, is used to improve the processes that provide the transport service. This systematic approach represents a necessary communication tool for understanding and meeting the needs and expectations of users, by correlating the voice of the customer with the capabilities of the service.

The purpose of this method is to identify correlations, i.e. critical processes and activities, and to introduce corrective measures to improve them. By using this method, the railway company evaluates its work and, based on the findings, improves its operations. Also, this method allows the company to compare its operation over the time as well as with other companies.

QFD method is mainly described through four stages, which are implemented within four so-called ‘houses of quality’ (Figure 1). ‘Houses of quality’ represent matrices formed in a way that they have the same basic look in every stage (Masing 1988). ‘House of quality’ consists of six major steps (Chan, Wu 1998; Wuet al. 2005; Wu 2006; Shieh, Wu 2009): customer requirements (WHATs), planning matrix, technical measures (HOWs), relationship matrix between WHATs and HOWs, technical correlation matrix and technical matrix. At the entrance to the ‘house of quality’, in the left column, there is always a question: ‘What is required?’ and at the exit, there is always the answer: ‘How to comply with requests?’ QFD presents system service planning process, which starts with the Stage I where users’ wishes, needs and expectations are defined based on the research results.

Afterwards, within Stage II, critical service components, which require more detailed research are defined. Stage III comprises defining of production process critical parameters i.e. service providing, and finally, in Stage IV, service quality control processes, i.e. instructions and measures to be taken for implementation of the process itself with certainty, are defined. Users’ attitudes are the basis for defining the most important service features, which have the biggest effect on the level of quality of service offered to users. Therefore, for further research analysis, the most critical part of the process is Stage I. Results of this stage represent key users’ requests and their importance as well as key service features essential for required quality production. This lead to users’ satisfaction and market advantages achievement.

The procedure of Stage I within defining research methodology was implemented through the completion of the first ‘house of quality’ (Figure 1).

IV. APPLICATION OF THE QFD METHOD IN TRANSPORT OF PASSENGERS BY RAIL

Railway companies that use market analysis generally apply several research methods which often do not require the involvement of experienced or trained researchers but are conducted by full-time employees through pre-structured questionnaires, books of complaints and compliments, etc. They also conduct measurements of fixed-term passenger flow for analyzes according to different operational needs. Very often, surveys are conducted during the planning of a timetable that considers the desired departure and arrival times for passenger trains.

To investigate the quality of service in the transportation of passengers by rail for the purposes of this work, a survey of users of the railway service Serbia Train was conducted. Data were collected through a questionnaire. The aim of the questionnaire was to collect user views, i.e. their expectations that the rail service should meet. The group of 185 subjects were interviewed (46% students, 6% pupils, 27% employed, 13% unemployed and 8% others). The group consisted of 68% male and 32% female subjects.

There are several software for QFD method. Quality Function Deployment Versao 1.1 – Free, was used in this work. Figure 2 shows the layout of the software used [9].

The user requirements were quantified respectively from 1 to 10, where they were assigned absolute and relative ratings, i.e. significance. Significance was obtained by grading from 1 to 5, where 1 means less and 5 means greater significance. Through this process, a number of significant factors were formed. The assessment of the interdependence of all combinations of user requirements is indicated by: (Δ) → small dependency → (1), (O) → medium dependency → (3) and (Θ) → large dependency → (9). The coefficient of significance of the qualities from the point of view of satisfaction of the user demands, i.e. the correlation is shown by the labels: (+++) → very positive correlation, (+) → positive correlation, (-) → negative correlation, (--) → very negative correlation, and, if there is no correlation, an empty field was left. Only technical characteristics can have measurable goals. Unmeasurable quality elements were discarded.

In the last step, data were entered for some of the direct competitors to rail passenger transport, after which the significance of service quality was assessed in relation to customer demands, on a scale from 1 to 5, with demand rated 1 having less and 5 higher significance. Using the QFD 1.1 program, entering the "WHAT" requirement begins the

Figure 1. Stages of QFD method (method implementation on service)

Figure 2. Layout of the QFD software package used in this work
construction of the first "quality house" whose final layout is presented in Figure 3.

Analyzing the results of the first "quality house", it can be seen that there is not a single "WHAT" requirement that does not have the answer "HOW", which is a prerequisite for the construction of "quality house". Likewise, the roof of the "quality house" and the "HOW-HOW" correlation indicates that there are no "HOW" answers that contradict each other, or the execution of one would impede the execution of the other. On the basis of the relative weights obtained from the Pareto diagram of the request "WHAT", the order of the characteristics crucial for ensuring adequate quality of service was defined. In the first three places are the following features: comfort (21%), reliability (21) and safety (15%). The Pareto Diagram of the answer "HOW" gave priorities that need to be improved in order to increase the quality of service in passenger transport of Serbia trains. In the first three places are the following features: train delay (38%), car age (30%) and car capacity (21%).

V. CONCLUSION

The level of rail passenger transport services in Serbia is quite modest in its content. The main reason for this is the fact that very little is invested and that insufficient attention is paid to the development of the railway network and trains. Many trains are at the very limit of their depreciation life. Rail transport has a future and this is confirmed by the current strategies of the EU and its relevant institutions. Rail transport has a much more environmentally friendly mode of transport because it can use renewable energy and can be a fully automated system. However, the path to taking a leading role in passenger transport is quite long, and a higher level of service quality than competing modes of transport must be ensured. The main features required for a good image of the service quality are the convenience of rail transport, security, additional services, etc. The QFD method applied to analyze the quality of rail passenger services has shown that the quality of services is influenced by many factors. The survey compared the perceptions and expectations of the service received by the customers. Comparison of user requirements and service quality yielded relative weights of features. Based on the obtained relative weights, the features crucial for ensuring adequate quality of service were ordered by their importance.

The sequence of identified features indicates that these features are critical to ensuring the satisfactory quality of rail passenger service. By using a comparative analysis of our performance and those of competitors, it can be concluded that the quality of rail passenger transport service is not adjusted to the needs and expectations of users. Based on these results, it can also be concluded that the QFD method is a useful method for developing and improving the quality of rail passenger services. The QFD method can help railway companies to improve the quality of their services by linking them with customer requirements, ensuring their competitive advantage in the market.

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A warehouse location optimization model for emergency humanitarian logistics for Republic of North Macedonia

Emel Hamza Sherif and Ile Cvetanovski

Abstract – The increased need for effective disaster response, rises the need of creating a model for optimization the location of a warehouse for humanitarian logistics. The model presented in this paper can be used for selecting the location of a warehouse for humanitarian logistics in the Republic of North Macedonia.

Keywords – Facility location, humanitarian logistics, warehouse.

I. INTRODUCTION

Due to the importance of the correct model regarding the improvement of problems with the facility location during emergency humanitarian logistics, this paper aims to conduct research on location problems of facilities related to emergency humanitarian logistics based on the types of data modeling and the types of problems and to examine the conditions before and after the disaster in relation to the location of the facility, while retaining the locations of storage facilities such as the location of distribution centers and warehouses. In this paper is presented a model that includes the identified important factors and a tool that can be used even in a variable environment for selecting the location of an object – a distribution centre/warehouse for humanitarian logistics in the Republic of North Macedonia.

II. REQUIRED SOLUTIONS WITHIN THE TRANSPORTATION CHAIN

A. Required solutions within the transportation chain

Warehouses as part of logistics chains need to be explored and analyzed in terms of their rationalization, faster flow of goods, increased efficiency of logistics systems, harmonization of logistics processes and co-operation of logistics chains. The classification by structure, size, function, purpose, specialization of certain goods and certain freight units points to the wide range and importance of these points for the rational realization of transport chains.

Choosing the right location for the facility is one important step for an efficient supply chain and can reduce costs as well as the response time of each operation. The growing need for effective disaster response in terms of targeting the right resources to the right people and efficient disaster response in terms of optimal resource utilization rises the need to create a model for optimization the location of a storage center that will meet the needs of the warehouse humanitarian logistics. Disaster relief organizations tend to use ad hoc methods, such as experience and intuition, when they are making location decisions. Ad hoc methods are used because quantitative methods that take into account the characteristics of the landscape environment have not yet been developed or practiced. The use of Ad-hoc methods can lead to cost inefficiencies and slow response.

The prior literature review served to create an initial basis for understanding humanitarian logistics and to provide a theoretical framework.

B. Data collection steps

The data collection process is divided into five different steps as it is shown at Fig.1 bellow. The first step is data from field studies. These field studies give an empirical depth in which the goods were tracked through the UNHCR hand-to-hand distribution system. Although this paper does not focus on the flow of supply at that level, the information is valuable as it sets the context in which humanitarian organizations operate. In addition to the data obtained from the UNHCR, semi-structured interviews and group discussions were also held that provided a broad empirical basis for analysis.

Fig.1. Data collection steps

Group discussions organized by the Crisis Management Center (CMC) and the Center for Development of the Pelagonija region made a contribution, which increased the knowledge about the organization and their challenges. The technical and operational presentations of the project activities...
of the J-CROSS (program for Joint cross-border cooperation for protection of the population from natural disasters and catastrophes caused by man-made) contributed to the formation of the strategy for humanitarian logistics.

A number of potentially important factors influencing the model were identified on the basis of the literary study. These factors were summarized in the questionnaire that was sent to a large number of people at the CMC. The goal was to identify the factors relevant to the organization. Respondents were selected from different positions within the CMC and from different backgrounds to get the widest possible information.

The last step was a request for statistics, where quantitative data from Crisis Management Center of North Macedonia were requested and obtained electronically.

III. MODEL CONSTRUCTION

The model is based on theoretical framework analysis and empirical studies. The outcome of the analysis determines which model should be constructed and how it should be modified in order to adapt it to the need of the Crisis Management Center. This process includes four main phases. The first one is the definition of the problem, then the main phase occurs during the data collection process. Collection and processing of data has the main impact in the model. The model is based on theoretical framework analysis and empirical studies.

The model is built in Microsoft Excel, using the Solver tool. The program could be done on another platform, but it has several advantages with Excel. For starters, this is a program that is widely used and usually installed by everyone computers. Furthermore, it is a well-known program with which the user feels comfortable. Finally, Excel has a programming language installed, VBA, which provides a number of functions.

Excel and VBA can also be designed to allow the user to control the model through buttons, shapes or dialog boxes, or to make a report from the simulation, where the optimal flow and price or time. This feature is important to answer the second research question. Model building in Excel also has some drawbacks: Excel cannot create reports as databases; may require a large portion of hard disk space; small changes can change the whole model; Error searching can be time consuming.

However, the advantages mentioned above are considered far more important than the disadvantages. The model includes three levels based on the level identified in supply chain mapping: supplier, warehouse and point of demand. The goods move from the manufacturer to the warehouse then to the point of demand or from the global warehouse to the warehouse in the specific country.

The model works as a Excel worksheet with Solver solution. Excel Worksheet from FLP (Facility Location Problem - Spreadsheet Solver) model consists of five parts. The first part deals with locations (Locations), where the number of desirable locations for the construction of a warehouse can be entered and it allows input from 5 to 300 different locations as shown at Fig.2. The model can be extended to a larger number of possible locations but then the processing time of data with Excel would be larger and errors could occur.

As a result it would be optimal to take a number of locations which will be between 5 and 300. What refers to the number of sites less than 5, then the optimization procedure of location of an object can also be done by manual calculations or by someone simpler computer command. The model will help to choose the optimal location for serving other near locations by optimizing the set function (minimum distance/maximum coverage).

Fig.2. FLP Solver console sheet view

The second part deals with Costs and Coverage. This section includes:

- Distance computation method (Bing Maps/Google Maps), driving distances in kilometers;
- The type of route (Fastest / Passenger vehicle, Fastest / Passenger vehicle in real traffic, Fastest / freight vehicle, fastest / freight vehicle in real traffic);
- Costs per unit distance (this value is taken as positive although it refers to costs and in our case is taken as 1 Euro per km);
- Costs scaled by demand (Yes/No);
- Service distance limit - is a limit in kilometers that is set as the maximum upper limit to which a particular storage center would serve (in this model is set an upper limit of 300 km);
- Coverage distance limit - is a limit that is set at each of the locations where they could cover the demand (in our case it is limited to 200 km, all locations that are farther than 200 km will not be served by selected
storage center and will not be taken into account in further calculations);

- Coverage type (Step function - each location on demand will be served step by step).

- The third part refers to the solution. Three parameters are entered in this section:
  - Number of facilities (Number of facilities [1,150] - the solution can be integer number greater than 1 and with a maximum value of 150 of the possible 300 locations);
  - Main goal (Primary objective - Minimize total costs, Maximize Demand Covered, Minimize Maximum Service Distance) Minimize total costs, Maximizing the satisfied demand, Minimizing the maximum service distance.
  - Do all objects need to be located ? (We choose Yes or No, whether we want all objects to be located in a specific location or no (All facilities must be located) Yes / No).

The fourth part of the worksheet refers to Visualization.

This is an optional tool that is used to visually display the result on a map. Bing Maps / Google Maps or some other image that we think should be placed in the background of the results (are sets via the Insert menu from Excel). The same visual display shows the locations that are selected as well as the locations that are served (via arrows – shown below in the results section).

Finally, the fifth part refers to the Solver tool, where the time for realization of the calculations is set, which should not be less than 60 seconds (recommendation).

During the validation and implementation of the model in our conditions, ie. in the Republic of Northern Macedonia we have selected ten cities that would cover the entire territory of the Republic and the volume of data should not be large so that the system can work without errors.

At the top of the worksheet there are standard tools that appear on every document created in Excel by the Office suite, namely: document name, minimize, maximize, close and FILE menus, HOME, INSERT, PAGE LAYOUT, FORMULAS, DATA, REVIEW and VIEW.

IV. EVALUATION OF THE MODEL

To evaluate the model with data from North Macedonia, we started with 10 locations and set function minimum distance with 3 main locations serving all other. When the number of locations is less than 5, the procedure for optimization of object location can be done with manual calculations or with a more simple computer command.

At Fig.3 is shown the location worksheet which consists of a table with 9 columns and 10 rows – one for each location.

Columns A and B give the ordinal numbers for each location, column C gives the addresses of the locations, in our case they are the names of the cities themselves. If location coordinates are automatically determined by using Bing Maps then addresses should be entered with post code and city. But if the coordinates are entered manually via data from Google Maps than the location names can be as we like as. Columns D and E are latitude and longitude data that we have found automatically through Bing Maps or manually filled via Google Maps. Columns F, G, H and I refer to „Demand”, „May be a facility”, „Capacity” and „Setup costs” respectively.

The fields in the table are filled in according to the actual situation, and then these data are used to calculate the most optimal location for the construction of a storage center that will serve in a crisis situation or a natural disaster.

When the set function is to minimize the total cost of supplying 10 locations with 3 storage locations, we obtain the results shown in the figure 4. That is, the facility at Location 1 will serve Locations 1 and 2, the facility at Location 3 will meet the needs of Location 3, Location 4 and Location 7, and the last facility at Location 6 meets the needs of Location 6, Location 5, Location 8, Location 9 and Location 10. The results show that all Locations are satisfied with the choice of Locations 1, 3 and 6, with total costs being minimal.
There are several practical aspects to consider during the implementation of the model. First, the lifespan of facilities can have a major impact on decisions. This is an important point for humanitarian actors who own their own warehouses. Although the demand is constantly changing, the facilities have a certain lifespan and cannot be easily transferred without cost. For actors who do not own the warehouses, this is not a problem.

Second, cultural implications should not be truncated. This is an important point for humanitarian actors because they are often close to each other. Managers need to communicate with surrounding facilities to identify potential ones synergistic effects or adverse effects that may occur.

Third, the quality of life issues affects the workforce and performance. For humanitarian actors, who often work in remote areas and in difficult conditions, this is an important aspect to keep in mind. Workers' mentality is changing and people's attitudes towards sacrifice can change.

Finally, tax breaks and tariffs should not be forgotten. If the organization is exempt from tax, the issue is an exemption that can be costly and time consuming. If the organization is not exempt, the problem arises just like in a commercial company.

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Simulation Model of Belgrade Suburban Passenger Trains Service Using OpenTrack

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Abstract – In this paper, simulation models, created in the OpenTrack simulation tool, were used to compare the proposed timetable with a variant in which all trains from and Lazarevac would be extended to Belgrade Center. This paper aims to analyze the effects of the increasing number of trains on part of Belgrade railway junction from Resnik to Belgrade Center. The results have shown that the section from Dedinije junction to Resnik has more than enough capacity for the increased number of trains. Also, the simulation results show us that when the number of trains increases by 40%, BG trains can operate without or with acceptable delays.

Keywords – railway, simulation, BG voz, OpenTrack.

I. INTRODUCTION

The constant increase of the population in big cities, the separation of the place of living from the workplace, and road traffic congestion led to the need to better organize and improve the public transport system as much as possible.

Planning and organization of public transport is a very important task that contributes to the better connection, integration, and functioning of different parts of the city.

Rail transport, as one of the key modes of public transport, plays a vital role in the development and modernization of the transport system not only on long distances but also in suburban and urban areas. One of the main advantages the suburban rail transport is its possibility of transporting a large number of passengers, independent of weather and time of day from suburban areas to the city center. Among other advantages of suburban rail transport, it is also important to mention that rail transport has a minimum effect on traffic jams, noise, and environmental pollution and destruction.

In many cities, rail transport is the main mode of passenger transport, which offers the best service. Public rail transport can be divided into metro, light railway, suburban lines, or tram systems. However, most of these systems are very expensive, and building them requires huge investments. Because of that we must analyze the rail traffic and create a simulation model which is very important as an input to a process of planning in railways.

Railway simulation is used to generate data on the number of lines, lines capacity, number of traveled passengers, train delays, travel times, and other output parameters. In the last two decades, many authors have used various simulation techniques, methods, programming languages, or specialized software to model railway traffic, like Petri Nets [1], Matlab [2], or software Open Track [3], [4].

II. OPENTRACK SIMULATION SOFTWARE

The observed problem is solved by simulation. Simulation models are developed using the software package OpenTrack. OpenTrack was developed at the Swiss Federal Institute of Technology’s Institute for Transportation Planning and Systems (ETH IVT). OpenTrack is a dynamic rail simulation software for continuous simulations. As such it simulates the behavior of all railway elements (infrastructure network, rolling stock, and timetable), as well as all the processes between them [5].

A. Input data

The Open track manages input data in three modules: rolling stock (trains), infrastructure, and timetable. The software offers users the possibility to create their own databases. Once data has been entered into the software, it can be used in many different simulation projects.

In this paper, the main infrastructure database consists of the length of the block sections, number, and length of the station tracks and intersections, and location of the signals.

B. Simulation process

During the simulation, OpenTrack calculates train movements under the constraints of the signaling system and timetable. All trains try to obey the given timetable. Occupied tracks and restrictive signal aspects may impede a train’s progress.

OpenTrack uses a mixed continuous/discrete simulation process that allows a time-driven running of all the continuous and discrete processes (of both the vehicles and the safety systems) under the conditions of the integrated dispatching rules. Therefore, parameters including occupied track sections, signal switching times, and restrictive signal states all influence the train performance [3].

OpenTrack is a dynamic rail simulation program, which enables users to run the software in a step-by-step process and monitor results in real-time. This allows users to monitor the simulation in an animation mode so they can easily analyze possible conflicts, occupied tracks, reserved tracks, or signal aspects.

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C. Output data

One of the major benefits of using an object-oriented language is the great variety of data types, presentation formats, and specifications that are available to the user. After a simulation run, OpenTrack offers some evaluations, and software can analyze and display the resulting data in the form of diagrams, train graphs, occupation diagrams, and statistics [6]. Similarly, users can choose to model the entire network or selected parts, depending on their needs.

III. MODEL FORMULATION

To provide better services to public transport in Belgrade, following the example of other European cities, the city of Belgrade, in cooperation with the „Zeleznice Srbije“, in 2010, implemented project „City railway - BG voz, new public transport“ [7]. Over the past six years, this railway suburban system has been constantly upgraded with the introduction of new and the extension of existing lines.

Nowadays, in Belgrade suburban rail service operates four lines which operate from: Batajnica to Ovča (line 1), Resnik to Ovča (line 2), Belgrade Center to Mladenovac, and a new line from Belgrade Center to Lazarevac. On this line, some of the trains are planned to overlap existing service between Belgrade Center and Resnik while others terminate in Resnik with possible connections to Ovča – Resnik trains. The total number of trains that operate on this line is 12.

In this paper we create two different models: the first model considers the current state and provided number of trains and rail traffic organizations. The second model considers the abolition of all trains from Resnik to Lazarevac and running new 34 trains from Lazarevac to Dedije junction. This state gives an opportunity in the traffic planning process, whether trains will run to Ovča or Belgrade Center. In the newly built timetable, trains on line 4 run every hour without conflicts with other trains on the observed section from Resnik to the Dedije junction (Belgrade Center).

Both models were created using current data with some approximations and 2019/2020 timetable. The total number of trains in the first model is 187 and 209 trains in the second model. The total number of trains in both models (variant 1 and variant 2 represent models) are given in Table 1 [8].

<table>
<thead>
<tr>
<th>Train Category</th>
<th>Line detail</th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight train</td>
<td>Domestic &amp; international trains</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Passenger</td>
<td>Domestic &amp; international trains</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>BG voz</td>
<td>line 1: Ovča - Batajnica</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>line 2: Resnik - Ovča</td>
<td>29</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>line 3: BG Centar - Mladenovac</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>line 4: BG Centar - Lazarevac</td>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

Some dead-end tracks were not included in the model, and train speeds were used from the current timetable. The graphic representation of both models is the same and is shown in figure 1.

IV. SIMULATION RESULTS AND DISCUSSION

The motivation for this paper is the need to analyze the effects of the new timetable and the increasing number of trains on part of the Belgrade railway junction from Resnik to Belgrade Center. This provides an answer to the question of whether there are delays and unscheduled stops of trains, and what is the length of delays. This paper aims to analyze occupations of tracks in stations Rakovica and Resnik in both variants.

There are many output files that OpenTrack generates during simulation. Some files contain global information about the whole simulation while others contain information about a particular train, station, or track section [5].

In that case, the purpose of these models was to give us an answer to the question can BG trains operate without delays when the number of trains was increased by 40%? For this comparison four criteria were used: average delays per train, number of trains with late arrivals and departures at stations, stop the train at the main signal, and station track occupation. All information was obtained from files OT_Messages.txt, OT_Delay.delavg, and OT_OccStatistics.txt.

OT_Messages.txt is an output file that includes all warnings and normal messages which appear during simulation. Warnings include late arrivals, departures and stops at stations and signals for each train, and the duration of these conflicts. Also from this file, we can which course changed priority. Average train delays for all trains in a model can be seen from OT_Delay.delavg. Station occupations by tracks in stations can be seen from OT_OccStatistics.txt.

A. Number of stopped trains at signals

In regular operating conditions when all trains are running on time, stoppings in front of the entrance or exit are not planned. If these events occur, they unnecessarily prolong traveling times and decrease traffic flow. The first simulation
results show the total number of stopped trains in front of the signal in station Rakovica and Resnik (Table 2).

**Table II**

<table>
<thead>
<tr>
<th>Station</th>
<th>Train type</th>
<th>V1 Exit</th>
<th>Entrance</th>
<th>V1 Exit</th>
<th>Entrance</th>
<th>V2 Exit</th>
<th>Entrance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resnik</td>
<td>BG train</td>
<td>12</td>
<td>15</td>
<td>19</td>
<td>3</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>21</td>
<td>29</td>
<td>23</td>
<td>15</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Rakovica</td>
<td>BG train</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>35</td>
<td>50</td>
<td>45</td>
<td>25</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

As we can see from Table 2 the total number of stopped trains is increased from 50 in the first and 70 in the second model. On the other hand, there is a small increase in stopping the BG trains at the signal. All trains mostly stopped at some of the exit signals in station Resnik.

**B. Late arrivals and departures at stations**

The number of BG trains with late arrivals at stations Rakovica and Resnik in both models is shown in Table 3. Also, this table consists of arrivals of all trains in models and their delays.

**Table III**

<table>
<thead>
<tr>
<th>Station</th>
<th>All trains</th>
<th>Total delays (min)</th>
<th>Average delays per train (min)</th>
<th>BG trains</th>
<th>Total delays of BG trains (min)</th>
<th>Average delays per BG train (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resnik</td>
<td>24</td>
<td>63.37</td>
<td>2.64</td>
<td>10</td>
<td>33.43</td>
<td>3.34</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>81.35</td>
<td>3.25</td>
<td>10</td>
<td>50.75</td>
<td>5.08</td>
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</tbody>
</table>

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</table>

Results show that the number of trains with late departures at stations is larger for variant 2 than for variant 1. Compared to the total number of trains BG trains have a lot less average delays in both models and these delays are similar in both stations.

**C. Average delays per train**

By analyzing the obtained results for both models it can be seen that a lot of trains traffic on time or ahead the time in model two, compared to model one. It is noticeable that for increasing the total number of trains, from 53 to 71 BG trains, the average delay decreased. This is especially pronounced for line 4 from Belgrade Center to Lazarevac. The total average delay per train in both models is less than two minutes and train 7116 had a maximum delay of 10 minutes. If the number of freight and local passenger trains operates according to the current timetable the second model with an increased number of BG trains can be considered as a possible solution. Figure 2 shows the average delays per train in both models.

**D. Track occupations in Resnik and Rakovica**

The last output from the OpenTrack simulation shows a total number of occupations and trains per hour on every station track in Resnik and Rakovica. The station track in Rakovica starts from the second to seventh track in the current infrastructure project. The results are shown in Table 5.
Table V shows that the most occupied track are T2, T3, and T5 in station Resnik and T4 and T5 in station Rakovica. Also, there is no significant occupation increase for most station tracks, and for some tracks we have more max trains and bigger average trains per hour which is a good output parameter. Resnik track occupation in peak period in model 2 is given in figure 3.

Table 5 shows that the most occupied track are T2, T3, and T5 in station Resnik and T4 and T5 in station Rakovica. Also, there is no significant occupation increase for most station tracks, and for some tracks we have more max trains and bigger average trains per hour which is a good output parameter. Resnik track occupation in peak period in model 2 is given in figure 3.

As the results show there is no significant increase in the number and duration of delays when suburban trains from Lazarevac are extended to Belgrade Centar and their number increased. Most of the delays occurred in Resnik which is understandable since Resnik has a limited capacity for parallel movements but also due to the ending of double track. Nevertheless, results show that the section from Dedinje junction to Resnik has more than enough capacity for an increased number of trains. Further increase in a number of trains to Lazarevac would require more detailed analysis and simulation of complete single-track line to Lazarevac.

REFERENCEs

The impact of trailer active safety system on improving the safety of transport of dangerous goods

Momčilo Matijašević 1, Siniša Sremac 2, Jugoslav Ilić 3

Abstract – The intense technological growth results in the increase of demands for mobility of dangerous goods, mostly carried on the roads. The regulations that define the Transport of Dangerous Goods, give special emphasis to the mandatory equipment that must be installed (electronic suspension and braking systems) as well as its mandatory control of technical correctness. The efficiency of the braking system as well as the vehicle suspension system significantly affects the length of the stopping distance when moving through populated areas, moving at night or in heavy traffic and is of great importance in relation to the overall traffic safety. Proper technical control of vehicles with built-in electronic systems, includes well-trained workers, quality diagnostic equipment and the necessary awareness of transport participants about the importance of technical correctness of vehicles. All these factors and the impact of correctness of the braking and suspension systems on the vehicle safety are analysed in this paper.

Keywords – Technical requirements for vehicles, transport of dangerous goods, ADR.

I. INTRODUCTION

Requirements for increased safety for dangerous goods transport are regulated by European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR), which regulates set of unique conditions for dangerous goods transport in 50 countries.

In this paper, means for inspection of technical correctness of suspension and braking system are shown and impact of tire pressure is explained. Also in this paper, explanation is given about tire load according to international and national laws, with goal of increasing transport safety and efficiency.

Having reliable and robust breaking system is of highest priority especially in modern times. Efficiency of breaking system i.e. stopping distance when moving through populated areas, at night or in heavy traffic is of great importance in relation to overall traffic safety.

Braking characteristics are based on two important assumptions (2):
- Instant increase of the slowdown to the maximum or required value;
- The distribution of braking forces across the axles, allowing full use of available traction.

The first assumption is almost impossible to achieve because there is always the reaction time (reaction of the driver), while the second assumption, on vehicles with electronically controlled systems, can be achieved.

Braking diagram, shows the dependence of deceleration and braking force (force on the master brake cylinder) in the time cycle, Fig. 1 (real brake diagram and simplified diagram).

These diagrams clearly show the increase in deceleration depending on the change in force on the vehicle's master brake cylinder over time.

The process of braking with complete vehicle based on such diagrams can be divided into time intervals in which the changes in the braking forces are linear. The durations of these time intervals are denoted by $t_1$, $t_2$, $t_3$, $t_4$, $t_5$ and $t_6$.

Time interval $t_{ak}$ is the time of active braking ($t_{ak} = t_4 + t_5$), while $t_6$ is the total time that passed until the vehicle stops ($t_6 = t_1 + t_2 + t_4 + t_5$).

![Fig. 1 Real brake diagram acquired from measurement and simplified breaking diagram (theoretical).](image)

If the active braking time is added to the response time of the braking system $t_2$, the actual braking time $t_k = t_{ak} + t_2$ is obtained.

In the case of a vehicle where we have a trailer, and if the adjustment time of the trailer and towing vehicle is $\Delta t_1 = 0.6s$ and when the trailer braking precedes the braking of the towing vehicle, the stopping distance is longer by 11 - 14% than the stopping distance corresponding to if the towing vehicle's braking would precede that of the trailer.

The smallest stopping distance when stopping a complete vehicle is achieved only when the adjustment period of the braking system of both the towing and trailer vehicle equals 0.
(t₁ = t₂ = 0), and when there is the maximum utilization of the grip in the contact surface - tire, which is the case with the complete vehicle equipped with electronically controlled braking systems.

The adjustment of the towing vehicle and the trailer (1) is also defined in Regulation ECE R13, Directive 71/320, Section 8.5.2.1.28.5. The length of the stopping distance, as well as the stability of the complete vehicle when braking, depends on the degree of adjustment of the towing vehicle and the trailer. With the well-adjusted towing vehicle and trailer, the dependence of braking force from load or the deceleration angle of the towing vehicle and trailer is constant. For towing vehicles the force on the trailer coupler is equal to 0, and for the connection of the semi-trailer to the towing vehicle, the ratio of horizontal and vertical forces in the connection itself corresponds to the deceleration angle.

From the total rolling resistance and observing our concept shown on Fig. 2 on which we will base all our further tests it is experimentally shown (tests conducted by Goodyear Company) that 17% of the total rolling resistance goes to the front wheels of the towing vehicle, 33% to the driving wheels towing vehicle and 50% of the total resistance is the tire resistance on the semi-trailer, at speed of 80 km / h.

Fig. 2 Rolling resistance percentage on one set of vehicles.

Rolling resistance is also significantly influenced by wheel orientation as one of the most important safety parameters on a vehicle that needs to be checked periodically.

Abovementioned 50% of the total rolling resistance related to the rolling resistance of the trailer tires draws attention to the importance of the tires on the braking process itself. One-third of the fuel consumption of commercial vehicles is due to rolling resistance. This means that of the total fuel consumption, approximately 12 l / 100 km is due to tires. Tire pressure is defined based on the axle load, all depending on the tire manufacturer's recommendation, type of mounting (drive axle, control axle or semi-trailer axle) and tire size.

Vehicle stability depends on the concept of the suspension system. The HALDEX test results indicate that the stability of the vehicle should be such that the lateral acceleration at which the vehicle reaches the tipping point is not less than 4m/s², in accordance with ECE Regulation R 111.

Research from the DAF vehicle manufacturer's company has shown that with improper suspension systems, traction can be reduced by up to 20%.

II. RESEARCH RESULTS

Testing on the brake rollers can only provide rough information of the actual braking performance of the vehicle, i.e. of the quality of the brake system (2). The technical solution of the brake test rollers does not allow for real grip conditions, low speeds of movement (the test is performed at a speed of rollers corresponding to a speed of 3 – 8 km / h, unrealistic alignment of the wheels on the substrate (they lie on circular surfaces, of relatively small diameter, which creates the effects of "jamming" the brake wheel between the rollers on which it rests.) However, for a very simple procedure, such tests are suitable for technical checks and for this level of required information.

In this part of paper efficiency of breaking system will be addressed. One of the conditions that complete vehicle has to fulfill is the correct axle load, i.e. proper load distribution across the axles of the complete vehicle (3) (5). Article 21 of the Regulations stipulates that the axle load of a vehicle must not exceed the values declared by the manufacturer and indicated on the vehicle identification plate.

Also, Article 41 of the Regulations defines the assessment of the braking performance of a vehicle through the braking coefficient:

- Braking coefficient indicates the percentage of vehicle deceleration and gravitational acceleration. For the purposes of this regulation, it is adopted that the acceleration of the earth's gravity is 9,81 m / s².
- The vehicle braking coefficient is calculated as the ratio of the sum of all the forces generated during the measurement on the measuring device and the total mass of the vehicle multiplied by 9,81 m / s² and is expressed in percentages.
- The prescribed minimum values of the brake coefficient listed in Table I must be achieved by the action of a force on the brake system which shall not exceed the prescribed actuating force given in the same table.

**Table I**

<table>
<thead>
<tr>
<th>CATEGORY AND TYPE OF BRAKING</th>
<th>REQUIRED MINIMUM VALUES OF BRAKE COEFFICIENT BY VEHICLE TYPE OF VEHICLE</th>
<th>FOOT BRAKING</th>
<th>Activation force</th>
<th>FOOT actuated</th>
<th>Hand actuated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FoK, Kso</td>
<td>Braking</td>
<td>Activation force</td>
<td>Foot</td>
<td>Hand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>coefficient</td>
<td></td>
<td>actuated</td>
<td>actuated</td>
</tr>
<tr>
<td>L</td>
<td>40</td>
<td>≥ [%]</td>
<td>F ≤ [daN]</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>M1</td>
<td>50</td>
<td></td>
<td></td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>M2, M3</td>
<td>50</td>
<td></td>
<td></td>
<td>70</td>
<td>-</td>
</tr>
<tr>
<td>N</td>
<td>45</td>
<td></td>
<td></td>
<td>70</td>
<td>-</td>
</tr>
<tr>
<td>O</td>
<td>40</td>
<td></td>
<td>PK = $6,5bar$*</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>T, C, Kso</td>
<td>25</td>
<td></td>
<td></td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>R, Kso</td>
<td>25</td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The maximum permissible difference between the braking forces braking on wheels on the same axle, at any given time from the time when the first braking force reaches one third of its maximum value, by the time the maximum braking forces are reached on both wheels is 30%. The basis for calculating the percentage of difference in braking force on wheels on the same axle, at all times, is the higher braking force at that
moment. Non-uniformity of brake force per revolution of the wheel must not exceed 20%.

Figure 3 shows the layout of the brake diagram for the semi-trailer and trailer. In the example of stopping one trailer, the feed pressure on the red coupling head increases, as does the brake pressure \( P_{zyl} \) from 0 to 0.4 bar. At 0.7 bar the activation pressure is applied to the brake in the wheel of the vehicle, so that the vehicle can generate brake force from now on. This point, therefore the pressure to activate the complete semi-trailer brake, can be adjusted within the braking calculation for that type of semi-trailer. For trailers, we have two ARSK controllers with different input pressures, so we have to record and measure them both, and the behavior of the loaded trailer is shown in Figure 3 (4).

The front axle has a slightly higher inlet pressure (6.5 bar) than the rear axle inlet pressure (5.7 bar). This arrangement of pressures on the front and rear axles is very important when operating on the hills.

If during the operation there is a change in the operating mode, inadequate pressure on the pressure gauges or improper loading, a diagnostic examination and analysis of the data should be carried out in order to take appropriate preventive or corrective measures if necessary.

In the next part of the paper, ways of controlling the proper work of the braking system are going to be addressed. According to Directive 71/320 EWG Annex II, Section 1.1.4.2. Paragraph 7 and ECE Regulation no. 13 Annex 10 Paragraph 7, the vehicle must have the data plate required for testing the ARSK controller, as shown on Fig. 4 (example for trailer and semi-trailer).

Press the master brake cylinder so that the pressure in the command line is increased to the pressure in the command line indicated on the table (usually 6.5 bar). If no plate is found, the master brake cylinder is fully actuated. On the control terminal "41" and "42" of the ARSK, a fine pressure regulator, Figure 6, is installed, which performs the simulation of the load in the cushion, i.e., fine-tuning the pressure from the unloaded position to the maximum pressure position indicated on the system board. The pressure measurement on the brake cylinder is done for the positions unloaded, semi-loaded and loaded.
The measured pressures on the unloaded vehicle shall not differ from the pressures shown in the table for the unloaded vehicle by more than +/- 0.3 bar. If the ARSK valve plate does not exist, the pressure behind the ARSK valve (pressure in the rear axle brake cylinder) must be less than the pressure in front of the ARSK valve (working pressure). Normal pressure values for brake cylinders of empty trailers are in the range of 1.5 bar to 2.5 bar.

If we look at the table showing the sizes recorded when checking the technical safety of the braking system on a commercial vehicle of category "O" (Table 2), it is easy to see that the columns in which the measured pressures in the pneumatic installation are to be entered are empty. This raises the question of the accuracy and quality of control during the technical inspection. If we do not have pressure, the question arises how to calculate the factor of correction of the braking force, when we know full well that its calculation requires both calculated pressure and pressure on the brake cylinder at maximum load. Table II.

<table>
<thead>
<tr>
<th></th>
<th>Contact pressure</th>
<th>Maximum PM</th>
<th>Maximum PZ</th>
<th>Maximum PD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bar</td>
<td>bar</td>
<td>bar</td>
<td>N</td>
</tr>
<tr>
<td>Calculated pressure</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

A brake coefficient is used to evaluate the effectiveness of the braking system. The mathematical formula (2) for calculating the maximum braking coefficient is:

\[ k_{\text{max}} = F_k \cdot i_n / G \]

where:
- \( F_k \) - total braking force for the entire vehicle;
- \( G \) - total weight of the vehicle;
- \( i_n \) - axle braking force correction factor.

The brake force correction factor of the axles is mathematically obtained as

\[ i_n = (P_e - 0.8) / (P_{zn} - 0.5) \]

where \( P_e \) is the designed pressure for the loaded vehicle and \( P_{zn} \) is the cylinder pressure when the vehicle is empty. Usually the design pressure is taken at 6 or 6.5 bar and the reaction pressure in the cylinder is about 0.5 bar. One should always check the pressures against the system chart or, if there is none, then take the measured values.

Following section of paper will describe how to control vehicle movement history using ODR Tracker application (4). Data are displayed and analysed using the ODR Tracker application. In the generated report, the data are classified into three groups: statistics, active logging of all events and travel data. The report covers the last 200 trips, and for the purposes of the analysis below, the data from the first group were processed - statistics.

The analysis is based on 4,454,172 kilometers traveled, 174,778 vehicle hours and 87,750 vehicle journeys. On the basis of the statistics obtained, in order to determine the exploitation conditions more closely, the values of the operating indicators were calculated.

The data shown in Fig. 7 show that during the exploitation of the vehicles, 35% of the total distance traveled is in the load of 80-90% of the maximum load, and that is the exploitation when the payload of the vehicle is used. In this case, the load on all axles is equal to the load on the middle axle. Under load in the interval 0-20% on all axles the vehicle exceeds 50% of the total road length. Such information indicates an increased number of unloading places, which implies a more complex structure of the driver's working hours (activities in handling dangerous cargo at the unloading points), which can result in driver fatigue. On the other hand, if we look at the load on the middle axle, as much as 55% of the total distance traveled, the load on the middle axle is in the range of 20-50%, which indicates an incorrectly distributed load.

In Figure 8 we can see that the middle axle of a trailer operating in urban driving conditions most of the way undergo a 20-50% load. Such data indicate that during the supply of urban areas, freight vehicles have a greater number of unloading points which are reached as equal participants in traffic with other participants.
If the frequency and intensity of vehicle braking under different operating conditions is the same, this information is an alarm to the employer, i.e. the need to pay attention to drivers driving style. The technical safety of the vehicle is also reflected by the amount of time the pneumatic installation system was in the operating pressure mode, Fig. 9. If all active pressures above 4.5 bar are taken into account, the analysed fleet can be said to have been operational so far.

Fig. 10 Distribution of the number of brake activations relative to the decline of the road.

The influence of the earth's gravitational force on the movement of the vehicle is inevitable and is directly dependent on the weight of the vehicle.

Fig. 11 Distribution of the number of brake activations relative to the deceleration achieved during braking.

If we analyze the data on the number of actuations of the master brake cylinder in relation to the configuration of the terrain, we find that 76% of the total braking was on flat terrain or ascent (Figure 10). Such information confirms that when driving a vehicle, the brakes were timely braked on the slopes, there was no need for sudden braking, and the risks of loss of stability and rollover were minimized.

Fig. 12, it can be seen that the number of activations of the ABS system over 10,000 kilometers has increased.
compared to the previous period of exploitation of the vehicle. This result may be due to seasonal changes in operating conditions, a change in the driver operating the vehicle, or changes in the mode of supply of the vehicle (changes in the load schedule of the vehicle). With each of these changes in vehicle operation, a diagnostic examination and analysis of the data should be carried out in order to identify, if necessary, an appropriate corrective measure or an already applied measure to recognize it as a preventive measure and to apply it to other vehicles in the fleet as an example of good practice.

Fig. 12 Frequency of response of electronic vehicle systems.

If we consider the RSS (Roll Stability Support) response of the system in relation to the conditions of exploitation (Fig. 13), the highest number of responses was in the combined driving conditions and in the out-of-town driving conditions in the hilly areas. Such results are the result of driving in different conditions and constant adaptation of the vehicle to the conditions of the road, and the configuration of the terrain.

Fig. 13 Frequency of response of electronic vehicle systems in relation to vehicle operating conditions.

Any diversion from the desired trajectory and loss of control over the movement of vehicles in this sense, represents a dangerous traffic situation for all road users.

III. CONCLUSION

The international rules and directives, as well as the national rules on the conditions that must be met by vehicles for safe traffic, are absolutely clear. However, the lack of quality national procedures, the lack of adequate equipment on the inspection lines, the lack of trained workers on the inspection lines, affect the quality of the technical inspection as well as the safety of all road users.

The largest part of the fleet is equipped with electronically controlled systems, as the designers recognized the need for safe transport. By using diagnostic equipment, you can control the exploitation of your fleet and decrease the need for corrective the maintenance and thus have a positive effect on reducing the running costs of the fleet.

Development of quality control rules for vehicles on technical inspection lines, continuous training of employees on technical inspection lines, provision of appropriate control equipment are prerequisites for quality control and, consequently, increased safety of all road users.

This paper presents a normal course of testing (applied by the surrounding countries) as well as the observed shortcomings in the control of commercial vehicles of category "O". The lack of possibility to measure the axle load (in most technical inspections) is compensated by requiring the vehicle owner to bring a record of the load as well as a confirmation of the date of calibration of the scale. The braking rate for the maximum permissible vehicle mass is not calculated, which is another major omission. The influence of the system that prevents the wheels from locking during sudden braking on the technical inspection lines is not recognized, which again represents a shortcoming in the control.

In all vehicles, non-compliance of the braking system on the vehicle can lead to serious damage to the safety of all road users, to the safety of property and persons, the environment. For this reason, the control of the technical safety of vehicles is a legal obligation, but in order to produce results, habits and access to the control method must be changed, the existing literature used for employee training adapted to legal requirements, regular checking of the level of knowledge of employees, equipping of inspection lines and in the end, in this segment of our life, the profession must prevail and not be burdened with politics (the current situation).

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Evaluation of Urban Consolidation Centers from the Customer’s Perspective

Reinhold Schodl¹ and Sandra Eitler²

Abstract – An Urban Consolidation Center (UCC) is a logistics solution aimed at reducing negative environmental and traffic effects of freight transportation in cities. This is mainly achieved by the consolidation of loads across customers. Despite having potential benefits, UCCs have not been widely implemented in practice. To realize the theoretical potential of UCCs in practice, a UCC has to attract customers. Crucial for the success of a UCC is a good fit between its services and the requirements of its market. Therefore, this paper addresses how UCCs can be evaluated from the perspective of its direct customers, i.e., freight forwarders and carriers. The Value Proposition Canvas, an established tool for business modeling, is adopted as a framework. The presented framework can be applied in a practical setting and provides the basis for an estimation of a UCC’s actual benefits.

Keywords – Urban Consolidation Center, Value Proposition Canvas, city logistics, urban freight transport

I. INTRODUCTION

It is estimated that nearly two-thirds of the world’s population will live in cities by 2050 [1]. Volumes of urban freight transport are expected to grow as a consequence. Despite the fact that urban freight transport is an essential element of a city’s economic development, it has a growing negative impact on the health and quality of life of city residents [2]. It generates various externalities such as traffic congestion, accidents, road damage, noise pollution, and greenhouse gas emissions [3]. As a result, cities around the world are looking for ways to manage urban freight and its negative impacts. The focus here often lies on restricting urban freight traffic, e.g. through travel time regulations, parking restrictions, road-pricing or vehicle weight and size rules. Ideally, policymakers will find ways of increasing the efficiency of freight transport in urban areas while also reducing its negative effects. Such measures include implementing traffic information systems and intelligent transportation applications, encouraging the use of environmentally friendly trucks, providing dedicated road space for truck loading and unloading, and promoting Urban Consolidation Centers (UCCs) [4][5]. As UCCs are frequently discussed as a measure for reducing negative impacts of urban freight transport, this paper addresses how UCCs can be evaluated with a particular focus on the perspective of the customers of UCCs.

In Section II we provide an overview of the current situation. We then propose a framework for the evaluation of UCCs in Section III, and discuss the framework’s application in Section IV. Finally, our conclusions are presented in Section V.

II. CURRENT SITUATION

UCCs are most commonly defined as operational concepts designed to reduce urban freight traffic by encouraging consolidation of cargo at a terminal located at the periphery of cities or urban areas [6]. One of their most important features is the infrastructural, operational and service-related optimization of the connection between the interurban and urban elements of the transport chain [7]. Carriers that would otherwise make individual trips to the consignee with relatively low load factors instead turn their loads over to a neutral carrier who consolidates the freight and handles the last mile of deliveries within the urban area [6]. The general idea behind UCCs is that freight transport is divided into two parts. From origin to the UCC large long-distance transportation vehicles can be used, and then from the UCC to the drop-off points in the city, smaller and potentially more environmentally friendly vehicles can take over [8][9].

The most frequent benefits include lower air and noise emissions, less traffic congestion, and fewer traffic accidents, all of which can be attributed to having fewer trucks in the urban area due to consolidation of loads across the UCC’s customers [10]. Nevertheless, there are also some disadvantages which should be mentioned. UCCs use a large amount of land and the traffic around the UCC will increase, which can lead to opposition from local residents [6]. It is also important to note that due to the necessary transshipment in the UCC total operating costs and delivery times may increase. Overall, however, a UCC can generally contribute to the enhancement of the urban economy, mobility, sustainability, and quality of life.

In essence, the following factors should be considered when establishing a UCC: (a) the selection of the most suitable location for the facility, (b) the identification of the characteristics of the facility to meet the needs of customers and stakeholders, and (c) the suitability of the concept within the wider context of other projects which are planned for the area in question [7]. UCCs have been discussed or implemented in various European cities, including Amsterdam, Utrecht, Berlin, Bremen, Cologne, Munich, La Rochelle, Basel, Stockholm, Genoa, Padua, Venice, Ancona, Naples, and Milan [11]. Because environmental benefits of a UCC are generally easier to achieve than economic benefits, UCCs have often been publicly funded. As soon as public payments are reduced or stopped completely, there is a risk that the initiative will be discontinued due to an inadequate financial basis [10][12].
A notable and rare exception here is Binnenstadservice in the Netherlands, which has been successfully operating UCCs for over 10 years. One of its success factors is its business model, which has evolved considerably. Whereas initially small city center retailers were targeted as customers in the beginning, the focus is now on logistics service providers [13]. The development of the business model was based on identifying customers who were actually willing to pay for the UCC services [14]. In summary, this means that the long-term survival of city logistics solutions requires sustainable business models [12]. In order to ensure profitable operation, it can be advisable to expand the scope of the service offering and provide additional services beyond consolidation and distribution that are useful from the customer’s point of view [15]. Other critical factors for a sustainable business model include the ability to scale up and down, the flexibility to respond to changes in the dynamic business environment, the entrepreneurial role of the UCC’s initiator, community recognition, innovativeness, logistics and supply chain management expertise, and the use of ICT solutions [16].

From the perspective of local authorities, logistics activities often appear to be disorganized and a UCC is seen as a solution for solving the issues that this creates. However, logistics companies may take a different view, as solving issues is actually their job [17]. This shows that a thorough understanding of the requirements of logistics companies, which are the customers of UCCs, is essential for a UCC’s long-term success. We will therefore now go on to present a framework for the evaluation of UCCs from the customer’s perspective.

III. FRAMEWORK

The framework set out below can be used to evaluate a UCC from the direct customers’ perspective, i.e. from the perspective of freight forwarders and carriers. The framework does not address shippers or consignees, which can be seen as indirect customers. The framework aims to fulfill three main requirements: (a) comprehensiveness, i.e. that all the important customer-oriented aspects of a UCC are covered, (b) flexibility, i.e. that the framework can be adapted to different situations, and (c) simplicity, i.e. that the framework can be easily understood and applied.

Crucial for the success of a UCC is a good fit between its services and the requirements of its market. In other words, a proper fit between the value proposition of the UCC’s services and the needs of its customers has to be guaranteed. The Value Proposition Canvas, an established tool for business modeling initially developed by Osterwalder et al. [18], has been applied as a theoretical framework to model this fit. The creators of the Value Proposition Canvas also devised the wider concept of the Business Model Canvas, which has been applied for evaluation of city logistics solutions. [12]

The Value Proposition Canvas systematically aligns the value proposition of products or services with the customer profile. According to the ideas of Osterwalder et al. [18], this can be explained as follows: The value proposition describes how the products or services offered to customers support them in completing their tasks. Beyond that, the value proposition includes so-called gain creators and pain relievers. A gain creator explains how added value is created for customers by the products or services. A pain reliever states how the products or services offered help to solve customer problems. The customer profile describes the customer jobs, i.e. the tasks that customers need to complete. For corporate customers, these are essentially specific business activities. The customer profile also comprises gains and pains. Gains are statements of added value desired by customers, and pains are the problems experienced by customers when completing their tasks. A product or service will be successful if there is a good fit between (a) the services offered and the customer jobs, (b) the gain creators offered and the desired gains, and (c) the pain relievers offered and the customer’s actual pains.

Below the Value Proposition Canvas is applied for customer-oriented evaluation of UCCs. Figure 1 illustrates the adopted framework. The value proposition is described for a UCC and the customer profile for its direct customers, i.e. freight forwarders and carriers.

![Fig. 1. Evaluation Framework](image)

The services of a UCC can be summarized as last-mile-delivery and first-mile-collection of goods in urban areas. The consolidation of loads across customers and providing a convenient transition point for customers, which allows loading and unloading outside an urban area, are key features of the services. The job of the customers is fundamentally arranging and/or carrying out transportation of unit loads with origin or destination in urban areas.

In the typical situation presented in the framework there is a fit between the services and the customer jobs. However, a fit is not guaranteed if goods require special treatment, such as temperature controlled transportation, or if consolidation across customers is not possible due to the shippers’ requirements or for legal reasons.

A fit between the services and the customer jobs is not necessarily sufficient for a UCC to achieve market success. A UCC should additionally aim to offer gain creators which are aligned with the gains desired by customers. The framework includes three gain creators which correspond with three desired gains. Firstly, a UCC typically creates positive environmental effects, which may improve a customer’s corporate image if its communications highlight these positive effects. Such positive effects can be achieved by the use of...
environmentally friendly vehicle drive technologies by the UCC. Such technologies are currently limited in terms of range and load capacity. Relatively short journeys between the UCC’s facilities and destinations in the urban area, and relatively small load sizes facilitate the use of environmentally friendly vehicles. Positive effects can also be achieved by a reduction in traffic, and consequently emissions, due to optimized routes. A UCC consolidates loads across customers, which helps to optimize routes in terms of utilization of the cargo space and distance traveled. Secondly, a UCC is generally open to all logistics companies, which can help UCC’s customers to improve their access to markets. This should be particularly relevant for small- and medium-sized logistics companies with limited capabilities and resources. Thirdly, a UCC can offer additional logistics services, such as kitting, packing, labeling, quality control, returns management, and waste disposal. A UCC can also provide logistics consulting services and training. The UCC’s customers can benefit from the availability of such value-added services, especially when integration with the UCC’s core services is achieved. Small- and medium-sized logistics companies with limited capabilities and resources may again particularly benefit here.

In the ideal typical situation presented in the framework, a good fit between the UCC’s gain creators and the gains desired by the customers is achieved. However, in practice such a fit depends on the specific circumstances and preferences of the UCC’s customers. If customers do not believe that a UCC is capable of delivering the defined gain creators and/or have no actual need for the defined gains, there is a danger that the fit will not be achieved.

In addition to a fit between the services and customer jobs, as well as gain creators and gains, the UCC’s market success may depend on the alignment of the UCC’s pain relievers with the pains customers are actually experiencing. The framework defines three pain relievers which correspond with three customer pains. Firstly, a UCC offers customers a facility for convenient loading and unloading. The location outside an urban area and the easy road access constitute a pain reliever for traffic-related problems. Several customer pains related to urban traffic are directly addressed by a UCC, e.g. traffic disruptions, problems with loading and unloading, as well as strict regulations relating to urban freight traffic. Secondly, customers deliver to or pick up loads from the UCC and the UCC takes care of the distribution in the urban area. This results in a single stop for customers, i.e. the UCC relieves customers of the pain of multi-stop routes. Such multi-stop routes add to logistics companies’ cost pressure, as route planning requires resources and loading and unloading are generally cost-intensive activities. Thirdly, logistics companies may have to meet demanding requirements of their customers, i.e. shippers. Such pains may include, but are not limited to, requests for high delivery reliability, specification of narrow delivery windows, and refusal of irregular deliveries with relatively small quantities. The UCC can offer a pain reliever by at least partly decoupling logistic companies’ operations from these demanding requirements, as the UCC takes over the distribution on the last mile.

The ideal typical situation of the framework presents a good fit between the UCC’s pain relievers and customers’ pains. As already mentioned above, the practical realization of the fit depends on the specific circumstances and preferences of the UCC’s customers, as well as on their assessment of the UCC’s capabilities.

IV. APPLICATION

The framework presented in the previous section helps to evaluate a UCC from a customer’s perspective. The framework represents ideal typical fits between the value proposition of the UCC and the requirements of its customers. These are not derived from empirical results, but primarily based on logical assumptions. These assumptions should be scrutinized by means of an empirical survey addressing potential or current customers of a UCC. The following questions should be answered: To what extent do customers believe that a UCC is capable of delivering the defined services, gain creators, and pain relievers? To what extent customers really have to complete the defined tasks, want the defined gains, and experience the defined pains? The deviations between the ideal typical situation and the actual situation as expressed by the customers provides the basis for an estimation of the UCC’s actual benefits. Indications for the proper configuration of the UCC can also be derived from such a comparison.

The framework presented here focuses on the benefits of a UCC. These benefits do not come for free, i.e. they come at a cost to the customer. Consequently, a comprehensive evaluation also has to investigate the related costs incurred by the customers of a UCC. These costs are not just the charges that the customers of a UCC have to pay for the service, but may also include losses in terms of quality and time. A quality loss may occur if the customer is no longer able to control the entire transport chain. A time loss can result from the transshipment step at the UCC, which adds some additional time.

V. CONCLUSIONS

A UCC aims to address two major challenges in city logistics: It helps to reduce environmental pollution and to ease traffic congestion caused by urban freight transport. UCCs are therefore a common topic in the literature and city planners are familiar with the UCC concept. Despite having the theoretical potential to improve city logistics UCCs have not been widely implemented in practice, and there are even examples of failed UCCs. This begs the question of how the full theoretical potential of UCCs can be realized in practice.

To be successful, it is obvious that a UCC has to attract customers, i.e. freight forwarders and carriers. There are at least three possible levers on demand for the services a UCC offers. Firstly, legal interventions, such as restrictions on entering a city or congestion charges, can make UCCs an attractive alternative. Secondly, public funding can give UCCs a competitive advantage. Thirdly, a customer-orientated service design, founded on actual customer needs which stimulates customer demand. If the customer-oriented approach is
followed, a thorough understanding of the customers’ requirements is essential. In this paper we have presented a framework for the evaluation of UCCs from the perspective of its customers.

In 2021 this framework was applied in a practical setting in Austria. The use case proved the framework’s applicability and practicability. However, the framework also has limitations. For the success of UCCs, the needs of indirect customers, i.e. shippers and consignees, can be crucial, but are not addressed by the framework. Other stakeholders of UCCs, like employees and local residents, may also determine whether operations are successful in the long-run. Consequently, we suggest a comprehensive evaluation that considers the requirements of all stakeholders. The framework presented in this paper could be integrated into such a comprehensive evaluation approach.

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Development Prospects of Logistic Outsourcing in Russia

Vladimir Sekerin¹ and Igor Soppa²

Abstract – Now contract logistics and logistic outsourcing are among the perspective directions of development of transport companies. In paper it will be developed the model of development of logistic outsourcing, it will be proved that main objectives of cooperation of trading and production companies with logistic intermediaries is obtaining competitive advantages.

Keywords – Logistic outsourcing, Transport logistics, Transport and logistic service, Complex logistics service.

I. INTRODUCTION

Now in Russia the concept of outsourcing was widely adopted. It is accepted to understand transfer by the company of separate business processes or concrete production functions on service of other company specializing in the respective area [6]. On the international classification the market of logistic outsourcing (transport and logistic services) as outsourcing includes the following main segments: Services of cargo transportation and forwarding (transport-forwarding services); Warehouse services (logistic services); Management logistics.

Russia is among the countries with the high level of logistic expenses. In many respects it is connected with inefficiency of the organization of internal logistics of the production and trading companies. Problems of internal logistics of the companies are aggravated with huge distances and poor quality of the Russian roads, irrational placement of productions and inefficiency of the organization of cargo delivery from the producer to the consumer [3]. One of possible ways of correction of a situation - logistic outsourcing.

The common problem of development of logistic outsourcing in Russia is connected with the general macroeconomic difficulties of scaling of this business which growth can be quite supported from demand, for example format retail. The high cost of credit resources, unevenness of geography of economic expansion and formation of chains of deliveries, market risks traditionally narrow the potential of growth of the transport and logistic industry.

II. MODEL OF DEVELOPMENT OF LOGISTIC OUTSOURCING

Among the major a tendency in the market of transport and logistic services it should be noted increase of demand for complex logistic decisions in the last decade from the companies and the enterprises that is directly connected with acceleration of process of transfer on outsourcing of warehouse and administrative services [2, 4]. Thus reduction of a share of transport-forwarding services in the total volume of the market of transport and logistic services (fig. 1) is noted [1].

![Fig. 1. Structure of the world market of transport and logistic services, 2008-2016, as a percentage](image)

Depending on the level of involvement of the independent companies (carriers, forwarding agents, logistic providers) for the solution of business challenges in interests and on behalf of the customer (the producer, the distributor etc.) are allocated 1PL, 2PL, 3PL, 4PL and 5PL-logistics.

1PL (First Party Logistics), as a rule, is understood as autonomous logistics when all necessary operations (transportation, warehousing etc.) are carried out by the cargo owner independently by means of own infrastructure and the personnel.

2PL (Second Party Logistics) – the simplest form of logistic outsourcing. The third-party specialized company within contractual obligations assumes performance of tasks of transportation of goods and to management of the elementary warehouse operations.

3PL (Third Party Logistics) – more developed outsourcing form: except standard tasks, the professional logistic company (3PL-provider) provides a wide service range with a considerable value added and possibility of involvement of subcontractors.

4PL (Fourth Party Logistics). The main function of system logistic integrators is planning and coordination of information flows of the client, optimization of a chain of deliveries, including integration of clients of the company, customers of clients and suppliers.

5PL-provider (Fifth Party Logistics). When the 4PL-provider begins to render also services of network business, it becomes 5PL-operator. Thus, it is the outsourcer of the logistic

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III. SCOPING OF THE MARKET OF TRANSPORT AND LOGISTIC SERVICES AND ITS STRUCTURE

Activity of the specialized transport organizations and businessmen (natural persons) who are employed belongs to a segment of the services in transportation of freights provided on a commercial basis.

For assessment of value of the market of transport services goods turnover indicators, price level on transportation/transfer of freights and income on 1 t-km of the transported freights have basic value.

Forwarding of freights – a complex of services in ensuring transportation of goods, including their documentary registration and maintenance. Development of most shipping companies is followed by expansion of the range of services of added value which include: drawing up optimum routes of cargo delivery, ensuring full load of vehicles, control of passing of freights at all stages of a logistic chain, customs and broker services, etc.

Value of the market of transport-forwarding services is defined as comprehensive income from transportation/transfer of freights on a commercial basis plus the cost of services of forwarding which is determined as "a forwarding margin" (added value) to transport services.

Warehouse services are services of rent of warehouse spaces in commercial use, services of safe custody and also warehouse services with high added value (packing, a stikerovka, a kopaking, etc.).

Value of the market of warehouse services includes: the cost of services of rent (triple-net), cost of services of safe custody and other warehouse services on commercial warehouse spaces (without operating costs).

Services in management of chains of deliveries and optimization of logistic business processes, consulting in the field of logistics; provides use digital and IT technologies, a cloud computing and integrated solutions for management of transport and warehouse logistics.

Value of a segment of 3PL-services is defined as the gross revenue of logistic providers which includes cargo transportation services by own or attracted transport, services of third parties (subcontractors) and actually service of added value (forwarding, warehouse logistics, management logistics).

Slow development of transport logistics in Russia is noted. The main problems of transport logistics which appeared on its way of development:
1. an inefficiency of use of routes of deliveries of production from suppliers to consumers;
2. backwardness of transport infrastructure, first of all, in the sphere of highways; insufficiency of cargo terminals, their low technological equipment;
3. lack of the modern vehicles meeting the international standards in all means of transport;
4. inefficiency of use of own and leased vehicles;
5. waiting for loading and unloading operations essential losses from idle time of vehicles take place;
6. various losses from inefficient functioning of vehicles take place.

In the Russian practice of such logistic operators it is a little. According to the marketing agency RBC [5] to 3PL-providers capable to render complex services, it is possible to carry about hundred twenty companies, eighty of which are Russian, and forty western. The gross revenue of the companies providing complex logistic services does not exceed 8% of a turnover of the Russian market of transport and logistic services. The similar indicator for the European Union countries is 19%.

The prospects of the Russian market of logistic outsourcing are rather optimistic. According to forecasts of Boston Consulting Group, in 2012-2030 the volume of the Russian market of logistic outsourcing will increase on average by 9% a year and by 2030 will be 11.4 trillion rubles. And the segment of management logistics (service of level 3PL/4PL) will grow at the largest rates – the average annual growth rate will reach 14% a year whereas the segment of services of transportation grows on average in 8% a year. It will lead to increase in a share of segment 3PL/4PL of services up to 6% of all market of logistic outsourcing.

IV. PREREQUISITES AND PURPOSE OF COOPERATION OF THE COMPANIES WITH LOGISTIC INTERMEDIARIES

In general in the market of contract logistics and complete industry solutions which basis in Russia are services of 3PL-providers there is a considerable volume of pent-up demand. Main objectives of cooperation of trading and production companies with logistic intermediaries of this class is obtaining competitive advantages for the account:
- reductions of operational logistic expenses, general increase in efficiency of functioning of a logistics system and, as a result, decrease in product cost,
- increases in flexibility of firm and ability to adapt to continuous changes of conditions of business,
- risk mitigation,
- reductions of duration of operational and logistic cycles.

The main demand for services of 3PL-providers is formed by the companies which are specializing in production and trade in goods with high added value, engaged in foreign economic activity or implementing the projects demanding special conditions and schemes of cargo delivery by several means of transport.

The Russian logistics passes to a new stage of its high-quality development where the address to her from operators of the
market becomes a strategic imperative of their survival in the market. Low level of concentration in the last will be corrected due to consolidation of 3PL of operators who will divide among themselves cargo base of the main largest retailers. It means transition to a trajectory of development of logistics in Europe and also depreciation of logistic services in Russia that is equitable to interests and strategic requirements of corporate business and specifically retail.

Development of complex logistics and consolidation of the logistic market will lead to redistribution of service functions to the companies accumulating key competences of logistics. The main resource of growth formats of logistic business 3 PL and 4 PL will receive, the having key competences and broad use of information technologies. We will see various development strategies (specialization on the express to delivery, development of difficult design logistics, M&A) aimed at increase in productivity [1].

V. CONCLUSION

In paper it is shown that the problem of development of logistic outsourcing in Russia is connected with the general macroeconomic difficulties of scaling of this business which growth can be quite supported from demand, for example format retail. The high cost of credit resources, unevenness of geography of economic expansion and formation of chains of deliveries, market risks traditionally narrow the potential of growth of the transport and logistic industry. In paper the model of development of logistic outsourcing is offered, offers on scoping of the market of transport and logistic services and its structure are proved, prerequisites and the purposes of cooperation of the companies with logistic intermediaries are revealed. It is proved that in Russia development of complex logistics and consolidation of the logistic market will lead to redistribution of service functions to the companies accumulating key competences of logistics. The main resource of growth formats of logistic business 3 PL and 4 PL will receive, the having key competences and broad use of information technologies.

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Evaluation of criteria for performing oversized transport using Fuzzy PIPRECI A method

Željko Stević, Melisa Bajgurić, Zdravko Nunić and Marko Vasiljević

Abstract — Oversized transport is an organizationally and infrastructurally demanding way of performing transport activities. It is a very important factor in an overall economic system. Since it is a mode of transport that has specific requirements in terms of organization and infrastructure, this paper evaluates the factors for its execution. The Fuzzy Pivot Pairwise RElative Criteria (Fuzzy PIPRECI A) method was used to determine the significance of ten criteria. The purpose of this paper is to analyze the necessary conditions for adequate and safe oversized transport.

Keywords — oversized transport, Fuzzy PIPRECI A

I. INTRODUCTION

Oversized or special transport is considered to be transport of all cargoes with dimensions or masses exceed certain prescribed limits. More specifically, it is a cargo that exceeds legally permissible dimensions. Considering the language of certain area and depending on the legal regulations of a country, there are several identified names for oversized transport. This mode of transport is carried out exclusively by means of transport of specific construction, which largely depends on the type of cargo. Oversized transport requires special approvals of a competent institution and mandatory security measures. The design and implementation of an oversized cargo chain is a multi-level logistical process that focuses on preparation of cargo, as well as traffic infrastructure, for the safe movement of cargo on a particular part of a route or the complete route along which transport is performed.

The organization of oversized transport, effectively following regulations and prescribed conditions by each segment of transport, is a very specific job that requires good organizational skills and an excellent knowledge of laws governing such services. Its specificity is based on the size of structural elements, equipment or machines that require a special and individual approach. The appropriate choice of means of transport in relation to the cargo carried is the most important element in the overall planning process. It is due to the fact that the persons responsible for transport planning tend to minimize the occurrence of risk for all road participants.

Road transport in B&H is currently the most frequently used transport sector due to its wide availability, speed, flexibility and affordable service costs. For the same reasons, it is also most frequently the problematic area of transport due to many legal regulations and inadequately prepared roads for the transport of heavy cargo. It is known that very often there are not many options when choosing the mode of transporting oversized cargo. Long, wide, high and heavy loads are transported to new facilities, wind farms, production halls, buildings and roads, and often the cargo itself by its structure determines the mode of transport. The transport of oversized cargo is more complicated due to the regulations and procedures it has to comply with, and is more expensive financially because of required permits and supporting documentation.

The purpose of this paper is to analyze the necessary conditions for adequate and safe oversized transport. The criteria for successful oversized transport were analyzed. Ten criteria, which are explained in detail in the following section, were considered and evaluated using the Fuzzy PIPRECI A method. The transport of cargo of greater length (pipes, trees ...) can be accomplished in a way that the load by its one end is set on a towing vehicle and by the other on a trailer. Thus, the load plays a role of a link between the towing vehicle and the trailer. A large number of vehicles for this purpose are equipped with cranes, which can be equipped with various gripping devices: hook, rake, etc. [1]. Oversized transport includes cargoes such as: [2] construction machinery, urban infrastructure elements, elements of the power, chemical, mining and metallurgical industries.

II. METHODS

The main advantage of the PIPRECI A method is that it allows criteria to be evaluated without sorting criteria by significance first, which is not the case with the SWARA method [3,4]. The Fuzzy PIPRECI A method was developed by Stević et al. [5]. It consists of 11 steps shown below.

Step 1. Forming the required benchmarking set of criteria and forming a team of decision-makers. Sorting the criteria according to marks from the first to the last, which means they need to be sorted for each decision-maker individually evaluates the pre-sorted criteria by starting from the second criterion, Eq. (1).

\[
S_j^r = \begin{cases} 
1 & \text{if } C_j > C_{j-1} \\
>1 & \text{if } C_j = C_{j-1} \\
1 & \text{if } C_j < C_{j-1} 
\end{cases}
\]

\(S_j^r\) denotes the evaluation of the criteria by a DM \(r\). In order to obtain a matrix \(S_j\), it is necessary to perform the averaging
of matrix $\overline{s}_j$ using a geometric mean. Decision-makers evaluate the criteria by applying the linguistic scales developed and defined in [5,6].

Step 3. Determining the coefficient $k_j$

$$k_j = \begin{cases} \frac{1}{2} - s_j & \text{if } j = 1 \\ 2 - s_j & \text{if } j > 1 \end{cases}$$

(2)

Step 4. Determining the fuzzy weight $q_j$

$$q_j = \begin{cases} \frac{1}{k_j} & \text{if } j = 1 \\ q_{j+1} - \frac{1}{k_j} & \text{if } j > 1 \end{cases}$$

(3)

Step 5. Determining the relative weight of the criterion $w_j$

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}$$

(4)

In the following steps, it is necessary to apply the inverse methodology of the fuzzy PIPRECIA method.

Step 6. Evaluation of the applying scale defined above, but this time starting from a penultimate criterion.

$$s_j' = \begin{cases} 1 & \text{if } C_j > C_{j+1} \\ 0 & \text{if } C_j = C_{j+1} \\ 0 & \text{if } C_j < C_{j+1} \end{cases}$$

(5)

$s_j'$ denotes the evaluation of the criteria by a decision-maker $r$. It is again necessary to average the matrix $\overline{s}_j$ by applying a geometric mean.

Step 7. Determining the coefficient $k_j'$

$$k_j' = \begin{cases} \frac{1}{2} - s_j' & \text{if } j = n \\ 2 - s_j' & \text{if } j > n \end{cases}$$

(6)

$n$ denotes a total number of criteria. Specifically, in this case, it means that the value of the last criterion is equal to fuzzy number one.

Step 8. Determining the fuzzy weight $q_j'$

$$q_j' = \begin{cases} q_{j+1}' - \frac{1}{k_j'} & \text{if } j = n \\ q_{j+1}' & \text{if } j > n \end{cases}$$

(7)

Step 9. Determining the relative weight of the criterion $w_j'$

$$w_j' = \frac{q_j'}{\sum_{j=1}^{n} q_j'}$$

(8)

Step 10. In order to determine the final weights of the criteria, it is first necessary to perform the defuzzification of the fuzzy values $w_j$ and $w_j'$,

$$w_j'' = \frac{1}{2}(w_j + w_j')$$

(9)

Step 11. Checking the results obtained by applying Spearman and Pearson correlation coefficients.

III. EVALUATION OF CRITERIA BY THE FUZZY PIPRECIA METHOD

The determination of criteria and their mutual evaluation have been performed by managers of Hes-Komerc company, which is a carrier in charge of oversized (special) cargoes. Table 1 lists all the criteria that affect the selection of an optimal transport route, as well as their description.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>CRITERIA AFFECTING THE SELECTION OF OPTIMAL TRANSPORT ROUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Cargo dimensions</td>
</tr>
<tr>
<td>C2</td>
<td>Number of countries in transit</td>
</tr>
<tr>
<td>C3</td>
<td>Cost of international permits</td>
</tr>
<tr>
<td>C4</td>
<td>Police escort</td>
</tr>
<tr>
<td>C5</td>
<td>Tolls</td>
</tr>
<tr>
<td>C6</td>
<td>Bridges, tunnels and viaducts along the route</td>
</tr>
<tr>
<td>C7</td>
<td>Roundabouts</td>
</tr>
<tr>
<td>C8</td>
<td>Crossing of roads and railway lines</td>
</tr>
<tr>
<td>C9</td>
<td>Cost of motor fuel</td>
</tr>
<tr>
<td>C10</td>
<td>Transport identification plates</td>
</tr>
</tbody>
</table>

On the basis of practice and experience, the most dominant criterion is considered to be the one that directly affects the choice of route since it dictates: the choice of customs crossing due to dimension constraints; choice of means of transport; (im)possibility of passing through tunnels or over bridges; determines whether police escort is required, and with all of this directly affecting transport costs. An important factor in obtaining oversized transport permits is that the more countries through which transport is carried out, the greater the number of required permits or approvals of competent authorities, and costs and the length of the route are also increased, which proportionally increases the time for performing the transport.

The cost of international permits depends on C2, i.e. the number of countries in transit. The necessity of police escort increases the duration of obtaining a transport permit and increases costs. All local police stations need to be contacted on the territory of B&H for consent to transit through a certain place, as well as obtaining permits for police escort from the Ministry of Interior of the countries in transit.

By optimizing a transport route, the cost of tolls reduces, which directly affects the overall costs and time of transport. The possibility of avoiding bridges, tunnels, viaducts, etc. on a transport route is important, as otherwise the statistical load
carrying capacity of bridges or other structures must be checked and a safety analysis regarding the height and width of the cargo being transported must be carried out. Transport of cargo of great width or length requires stopping traffic in a roundabout to remove traffic signs and warn other traffic participants in order to perform the transport without damaging or endangering any traffic participant as well as the carrier itself along with the cargo. The authority managing the railway must carry out controls on all dimensions of cargo and a road transport vehicle in order to decide on whether it is possible to approve the oversized transport over the crossing of road and railway lines.

It influences the overall transport costs, which further affects the optimization of the transport route. If there are many countries in transit where different transport identification plates are required by legal regulations, it is necessary to possess transport indication plates in accordance with requirements of each country in transit. The evaluation was performed using a linguistic scale that includes quantification into fuzzy triangle numbers. Table 2 shows the evaluation of the criteria for fuzzy PIPRECIA and Inverse fuzzy PIPRECIA by the decision-maker and the values are used for further calculation.

**Table II**

<table>
<thead>
<tr>
<th>PIPR.</th>
<th>C2</th>
<th>C3</th>
<th>C9</th>
<th>C10</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>0.400</td>
<td>0.500</td>
<td>0.667</td>
<td>...</td>
</tr>
<tr>
<td>PIPR-I</td>
<td>C10</td>
<td>C9</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>DM</td>
<td>1.000</td>
<td>1.150</td>
<td>1.200</td>
<td>...</td>
</tr>
</tbody>
</table>

Based on the evaluation of the criteria, Equation (1), a matrix \( sj \) is formed. By applying Equation (2), these values are subtracted from number two. Following the rules of operations with fuzzy numbers, the matrix \( kj \) is obtained as follows: According to Equation (2), the value \( k_1 = (1.000,1.000,1.000) \)

\[
\bar{k}_2 = (2 - 0.667, 2 - 0.500, 2 - 0.400) = (1.333,1.500,1.600)
\]

By applying Equation (3), the values of \( qj \) are obtained as follows: \( q_1 = (1.000,1.000,1.000) \)

\[
\bar{q}_2 = \left( \frac{1.000}{1.600}, \frac{1.000}{1.500}, \frac{1.000}{1.333} \right) = (0.625,0.667,0.750)
\]

By applying Equation (3), the relative weights are calculated:

\[
\bar{w}_1 = \left( \frac{1.000}{7.750}, \frac{1.000}{3.969}, \frac{1.000}{3.264} \right) = (0.129,0.252,0.306)
\]

\[
\bar{w}_2 = \left( \frac{0.625}{7.750}, \frac{0.667}{3.969}, \frac{0.750}{3.264} \right) = (0.081,0.168,0.230)
\]

In order to determine the final weights of the criteria, it is necessary to apply Equations (5)-(9), i.e. the methodology of the inverse fuzzy PIPRECIA method. Based on the evaluation performed by the decision-maker, a matrix \( sj' \) is obtained.

By applying Equation (6), the values of the matrix \( kj' \) are obtained:

\[
\bar{k}_{10}' = (1.000,1.000,1.000)
\]

\[
\bar{k}_9' = (2 - 1.200, 2 - 1.150, 2 - 1.100) = (0.800,0.850,0.900)
\]

By applying Equation (7), the following values are obtained:

\[
\bar{q}_{10}' = (1.000,1.000,1.000)
\]

\[
\bar{q}_9' = \left( \frac{1.000}{0.900}, \frac{1.000}{0.850}, \frac{1.000}{0.900} \right) = (1.111,1.176,1.250)
\]

After that, it is necessary to apply Equation (8) to obtain the relative weights for the fuzzy Inverse PIPRECIA method.

\[
\bar{w}_{10}' = \left( \frac{1.000}{25.244}, \frac{1.000}{19.228}, \frac{1.000}{14.973} \right) = (0.040,0.052,0.067)
\]

\[
\bar{w}_9' = \left( \frac{1.111}{25.244}, \frac{1.176}{19.228}, \frac{1.250}{14.973} \right) = (0.044,0.061,0.083)
\]

The results of the inverse fuzzy PIPRECIA method are presented in Table 4. By applying Equation (9), the final weights of the criteria are obtained. Before applying this equation, it is necessary to defuzzify the values of the criteria obtained by applying Equations (1)-(9). Table shows the complete previous calculation, and the last column presents the defuzzified values of the relative weights of the criteria.

**Table III**

<table>
<thead>
<tr>
<th>P.</th>
<th>sj</th>
<th>kj</th>
<th>qj</th>
<th>wj</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0.400</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.241</td>
</tr>
<tr>
<td>C2</td>
<td>0.400</td>
<td>0.500</td>
<td>0.667</td>
<td>1.333</td>
<td>0.306</td>
</tr>
<tr>
<td>C3</td>
<td>0.500</td>
<td>0.667</td>
<td>1.000</td>
<td>1.333</td>
<td>0.230</td>
</tr>
<tr>
<td>C4</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.333</td>
<td>0.306</td>
</tr>
<tr>
<td>C5</td>
<td>0.500</td>
<td>0.667</td>
<td>1.000</td>
<td>1.333</td>
<td>0.230</td>
</tr>
</tbody>
</table>

Table
The calculated statistical tests indicate a complete correlation of the Fuzzy PIPRE CIA and the Inverse Fuzzy PIPRE CIA method. Spearman’s correlation coefficient is 1.000 and Pearson’s correlation coefficient is 0.999. From Figure 1, we can see that C1 (Cargo dimensions) is dominantly more significant than C10 (Transport identification plates), and in the optimization of the transport route, it is dominant and dictates the choice of route. The most significant criteria for performing this type of transport is the criterion related to the dimensions of cargo. In addition, the number of countries in transit and the cost of the required permits are criteria of paramount importance in performing this mode of transport. A total of ten criteria were considered and their exact significance values were determined using the Fuzzy PIPRE CIA method. As coefficients of validity, statistical tests were applied: Spearman’s correlation coefficient of 1.000, and Pearson’s correlation coefficient of 0.999.

### IV. Conclusion

The organization and realization of road transport of oversized cargo is a complex activity and requires the expertise and good organizational skills of the person who realizes it. This mode of transport is much more complex than road transport of standard-size cargo since, due to the over-sized cargo, the transport itself endangers other traffic participants to some extent, causes congestion and sometimes requires the complete closure of a certain part of the route used for transport. The most significant criteria for performing this type of transport is the criterion related to the dimensions of cargo. In addition, the number of countries in transit and the cost of the required permits are the criteria of paramount importance in carrying out this mode of transport. A total of ten criteria were considered and their exact significance values were determined using the Fuzzy PIPRE CIA method. As coefficients of validity, statistical tests were applied: Spearman’s correlation coefficient of 1.000, and Pearson’s correlation coefficient of 0.999.

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“UBERIZATION” in empty container repositioning – possibilities and challenges

Durdica Stojanović¹, Marinko Maslarić² and Radica Žepinić³

Abstract – This paper explores the perspectives and challenges of the most innovative platforms for the purpose of empty container repositioning (ECR) reduction. Cooperation between all stakeholders is of crucial importance for efficient ECR. A last generation of e-marketplaces, related to “uberization”, may provide an additional impetus for collaboration between all parties.

Keywords – Empty container repositioning, Collaboration, Uber technology.

I. INTRODUCTION

Global trade imbalance causes a great amount of the containers capacity surplus globally. Such empty containers have to be repositioned to the place of next loading, which implies extra costs to container shipping companies and, consequently, to the end customers. According to some estimations, the empty container repositioning (ECR) costs the container shipping industry about $20 billion per year [1]. Additionally, ECR affects other actors in supply chains, such as inland carriers, port and depot operators, leasing companies, shippers, freight forwarders etc. They need additional time and effort for planning and organizing their movement to the next place of loading.

The repositioning is an individual group of activities, which causes additional costs, whereas the main shipping company’s interest is profit. Therefore, laden containers have advantage in occupying ship’s capacity and empty ones are left in the place of their unloading whenever there is a chance for it. This has caused a great accumulation of empty containers on consumptive locations during the time, and still represents an increasing problem.

However, ECR has still not reached an adequate attention neither in the literature, nor in practice. This paper is aiming to reveal the possibilities and challenges of the ECR improvement, by applying some of the most advanced methods directed to enhancing cooperation between all stakeholders. More precisely, the focus is on an undergoing “uberization” of ECR. A few initiatives in the practice has been identified until this day.

The rest of the paper is organized as follows. In the second Section, it is highlighted an increasing need for ECR in the world shipping market, by analysing the shipping market characteristics and reasons for ECR. In the third Section, the main groups of measures for solving ECR problem are briefly presented. The fourth Section analyses the possibilities and challenges of “uberization” in ECR, whereas the final remarks and conclusion are in the last section.

II. INCREASING NEED FOR ECR ON THE WORLD SHIPPING MARKET

II.I. Characteristics of the world shipping market

Maritime container transport is the backbone of globalization, as well as of global economy. About 20 container shipping companies are dominating world maritime market. Three companies – Maersk, MSC and CMA CGM own approximately 40% of world’s container ships fleet, whereas the market share of the first twenty companies is more than 80% [2]. According to [3], the total capacity of the world’s Containership fleet has passed the 25 million TEU, whereas the estimated total container, or box fleet size is ca. 40 million TEU (or over 26 million of individual container units) [4]. An estimated number of TEUs that were handled in container ports worldwide in 2018 is around 800.000 million [5], with the Port of Shanghai, as the busiest port trough which 42 million TEU containers passed [6]. The shipping companies are still the dominant container owners, which share in global container fleet has fluctuated between 59% and 51% in the period from 2010 to 2017, respectively [7]. Beside the shipping companies, container owners may be also the leasing companies, forwarders and others.

The shipping companies usually join their efforts within the alliances, due to the costs reduction, increasing ships capacity utilization and better overall business performances. Members of an alliance cooperate on the principles of integrated management [8]. The largest alliances in the world with main companies’ market shares are shown in the Figure 1. The results of such cooperation is an increasing power of alliance members on the main line routes.

In 2018, the market share in fleet capacity of all alliances was above 95% on East-West trade lanes in container trade [9]. The alliances integrates transport of cargoes for the members of that alliance, which creates the opportunity for the use of mega cargo ships and, consequently, the economies of scale. Also, the frequency and reliability of transportation are increasing, which can serve a much larger number of users simultaneously. Such cooperation impact on cost and idle time
reduction, which has contributed to an increase in the market share of all carriers.

![Image of container company alliances]

Fig. 1. The largest alliances of container companies in the world with TEU capacity share [9, 10]

II.II. Reasons for ECR

Based on an estimate from 2015, there are approximately 5 to 6 million of containers in transit worldwide at any given moment [11]. However, container flows are not evenly distributed, but there is an imbalance in the world market. Namely, Asian countries have been the large producers for decades, whereas the Western Europe and North America are large consumers. Therefore, a large number of laden containers were imported from Asia to Europe and America, and due to the constant import and lack of exports, empty containers have been accumulated over the time. According to [12], in 2009 the Far East-Mediterranean route recorded the imbalance of 53% in TEU, whereas for the Transatlantic route the imbalance was 40% and for the Transpacific route the imbalance was 63%. This trade and demand imbalance is the main cause of ECR [ibid.].

Some authors indicate that at least half of the containers moving westward to Europe were sent back empty in the first decade of 21st century [13]. The share of empty containers in hinterland transport ranges from 40-50% of all containers transported [ibid.]. It was estimated that the costs of ECR could be up to $30.1 billion including both the seaborne and the cost of landside transportation, and account for 19 percent of global industry income in 2009 [ibid.]. The problem of empty containers idling also arises because of [2,8]:

- the available vessel capacity varies in each vessel call;
- the demand in the deficit locations which require empty container replenishment varies along the time;
- the supply of empty container from the surplus locations also varies;
- cost of transporting, maintenance, repair and inspection of containers;
- the dynamics of container leasing industry.

The significant contribution to the containers imbalance and accumulation was the ban on the import of waste into China. In 2016, China imported 45 million tonnes of waste. At that moment, Beijing abolished the import of 24 solid wastes and enhanced the container surplus in other regions [14].

Among other causes for ECR are dynamic operations, uncertainties, size and type of equipment, lack of visibility and collaboration within the transport chain, and shipping companies’ practices [13]. Excessive accumulation of empty containers in one place leads to the depots where boxes wait for their end of life moment (areas occupied by empty abandoned containers). In addition to the costs of tied up capital and the growing operating costs of empty containers storing, the big problem with unused containers is that they are made of metal prone to corrosion and thus become unusable over time. This represents a kind of landfill and environmental catastrophe. Given that this problem is common to all shipping companies, the chance to solve this problem lies in the cooperation between them.

III. MEASURES FOR DECREASING GLOBAL ECR PROBLEM

The average container spends more than 50% of its lifespan as being idle, or empty repositioned. The estimations show that shipping companies spend from 16-20 billion of US$ repositioning empties [1, 15]. Therefore, the advanced solutions for ECR are more than necessary. Among others, [13] identify four groups of ECR solutions:

- organizational solutions;
- technological solutions;
- vertical collaboration (intra-channel solutions), and
- horizontal collaboration (inter-channel solutions).

All these solutions are interrelated and may be interdependent in development a unique package of solution. Some of them are reasonable at least on the alliance level. Most of the literature on ECR problem investigates internal organizational solutions in a single shipping company. That’s because shipping companies are the focal companies in the container transport chain and are mainly responsible for ECR. Some of the organizational solutions are megaships, container leasing, and forecasting.

The larger the ships, the more cargo and empty containers can be accommodated. The capacity of containers vessels increased by 1200% from 1968 to 2015 [16]. Leasing out containers charges additional costs to companies - rental costs. However, after the expiry of the leasing contract, the containers must be handed over to the next client who rented them. In fact, the containers are repositioned in the form of the contractual obligations. This prevents container from being retained in one place or from being unused [17].

By increasing the costs of new containers production, so that they exceed the costs of repositioning the empty ones, companies whose main interest is profit should be much more interested in repositioning [8]. The problem can also be solved by planning the number of containers that will appear at specific locations, and determining the locations to which a certain number of containers need to be moved. It’s based on information received from regional offices on request for empty containers. Then, based on this data, forecasts could be made to better utilize the capacity of the ship [8].

With the advance in linear and integer programming and the development of computing power the joint optimization of
loaded and empty container allocation, which bring economic benefit, became feasible for a reasonable size of problems [13]. A natural extension to the organizational solutions are intrachannel solutions which emphasize on the coordination across different players in the vertical channel. “Street turns” or “Empty reuse” refers to reusing import containers for export loads at the consignee’s site or nearby where direct exchange of empty containers between consignee and consignor can be realized. The potential benefits include [ibid.]:

- less truck mileage;
- the haulier can generate more revenue in less time;
- the ocean carrier (shipping company) can save paperwork and improve the container utilization;
- the export customer gets the empty container faster;
- the environmental impact can be reduced.

“Depot-direct off-hire” is a process of off hiring and repositioning an empty container to the leasing company at an inland depot directly before returning to the maritime terminal. This concept would cut down truck mileage [13]. “Off-dock empty return depot” is another solution, which assumes a proper choice of the depot location for the storage of empty containers [18]. Inter-channel solution implies horizontal integration of transport chains (e.g. alliances).

Container pool means sharing containers with other partners by participating into a pool. This solution implies that different companies accumulate their containers in one place at the agreed time and then collect and relocate these containers by one ship to necessary places. In case of alliances, there must be an adequate information system to accompany all request. Pools can be in or near the port [2].

All alliances could be combined into one alliance that would deal with ECR. That alliance would have a unique IT structure, a common database and an information system common to alliance members [2]. This way of organizing ECR gives a better insight into the number and position of empty containers, increases the efficiency of their utilization, provides better control over them, and gives the opportunity to attract more jobs.

Technology development mostly contributes to the development of previous solutions. However, it can bring some new solutions that contribute to the ECR cost reduction. Tracking system are needed to track the movement of loaded and empty containers, which brings the possibility of accessing of the desired service, at the desired costs, at any time and place. In container shipping industry, a common feature of all such platforms is that they offer the opportunity to ship containers immediately to the next loading point after emptying, without returning to the port, if the demand and offer are matched [14]. They provide real-time solutions, involve a great number of stakeholders, with significant fleets of shipping companies, inland transport capacities and containers, and so meet the condition of crowdsourcing. They also include the easy-to-use applications for desktops, tablets and mobile phones. Such characteristics may be described as the Uber-type technology, due to similarities with the well-known application used for taxi service. The positive side of “uberization” could be in transport and storage costs reduction, as well as the milder negative environmental impacts [14]. Also, introducing of such a kind of neutral platform also may decrease the technology investment costs for the main actors. In the rest of this Section, the three companies which offer such solutions on the market will be briefly presented, to exemplify what we consider under “uberization” of ECR.

The first examined company is the Boston Consulting Group, which has developed xChange - an online empty container platform where merchandise owners reserve empty containers for their goods for one-way transportation. In this way, contracting time can be shortened by a few weeks. The advantage of this platform is that the client is not connected to a particular network, but is given the opportunity to cooperate with more than 200 companies, including carriers, container leasing companies, shipping companies and others. The platform xChange operates around 2500 locations and plans to expand its network [14]. Consumers browse free containers listings at specific locations and form contract term themselves, such as the price of using the container or damage protection plans. The platform remembers users’ searches and contracts, after which they approach them proactively [14].

The second case is the port of Rotterdam that has developed Navigate - an online platform that displays empty containers for free use, but it is based on their location. These users are shown places where empty containers are located, avoiding their transportation to the port or depot before being shipped [14]. This is not a completely neutral solution, because the port is also a part of transport chains.

The third case is Avantida, recently merged by INTTRA, as the world’s ocean shipping electronic marketplace. It is a virtual company which offers a cloud based platform, with more than 7,000 trucking companies in more than 20 countries around the globe. The users are enabled to calculate the savings based on saved mileage for all triangulations in Europe, Asia and North America. A dynamic pricing-model offered by participating ocean carriers allows transporters to also execute short-distance street turns [20]. The company’s reuse and repositioning applications enhance the collaboration in the land-based activities between shipping companies, haulage carriers, ports, logistics centres, freight forwarders and other intermediaries, exporters and importers, etc.

Based on the briefly presented analysis of selected online platforms, which are considered as “uberized” marketplaces, a "uberization" of business services, which is changing the whole market, assumes the possibility of accessing of the desired service, at the desired costs, at any time and place. In container shipping industry, a common feature of all such platforms is that they offer the opportunity to ship containers immediately to the next loading point after emptying, without returning to the port, if the demand and offer are matched [14]. They provide real-time solutions, involve a great number of stakeholders, with significant fleets of shipping companies, inland transport capacities and containers, and so meet the condition of crowdsourcing. They also include the easy-to-use applications for desktops, tablets and mobile phones. Such characteristics may be described as the Uber-type technology, due to similarities with the well-known application used for taxi service. The positive side of “uberization” could be in transport and storage costs reduction, as well as the milder negative environmental impacts [14]. Also, introducing of such a kind of neutral platform also may decrease the technology investment costs for the main actors. In the rest of this Section, the three companies which offer such solutions on the market will be briefly presented, to exemplify what we consider under “uberization” of ECR.

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Based on the briefly presented analysis of selected online platforms, which are considered as “uberized” marketplaces, a
short SWOT analysis of the “uberization” in ECR has been made. It is quite general as it captures the perspectives of all stakeholders.

maximise the opportunities, but also the threats. The main challenges and threats lie in the conflict of interest of the participants, increasing the power of main shipping companies in already oligopolistic market, legal issues and the dependence on the development and implementation of other ECR solutions.

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Транспортна економика и финансии
Transport Economics and Finance
The impact of electromobility on the reduction of external transport costs in urban areas

Predrag Brlek¹, Krešimir Buntak², Ivan Cvitković³, Matija Kovačić⁴

Abstract Nowadays, electric vehicles are considered as technology that will significantly reduce the total external costs of road traffic in the future. The advantages of electric vehicles can be seen in the areas of climate change, air pollution in congested urban centres and causing less noise. There is a growing need for more detailed analysis and research in the context of the impact of external costs on the population, but also on the globe itself.

Keywords – electric vehicles, technology of the future, external traffic costs.

I. INTRODUCTION

In modern times, when the whole world pays great attention to the preservation and protection of the environment (the effects of global warming, climate change, drastic reduction of fossil fuels, air pollution, etc.), on which traffic itself has a great impact, electromobility stands out as a specific term whose future use is certainly bright. That technology (energy) and the means of transportation that use it (cars, trucks, bicycles, buses, etc.) describe three properties, namely environmental friendliness, quietness and efficiency. But, there are still a number of obstacles that need to be overcome in order to reap the full benefits of electromobility. The main guiding thought or idea in the development of electromobility is the phrase: "Mobility in the future must at all costs become neutral in terms of CO2." Electric and hybrid vehicles emit far less exhaust fumes into the air than vehicles with internal combustion engines. Today, great emphasis is placed on personal electric vehicles. Many states provide incentives for the purchase of electric vehicles, but this does not solve the two biggest problems in traffic, which are traffic safety and congestion in large urban areas. However, what this transition to a completely new form of energy will actually mean and what impact it will have on all areas of human activity, with special reference to urban transport, will be extensively in detail elaborated and analysed through processing in this paper.

II. ABOUT THE CONCEPT OF ELECTROMOBILITY

Electromobility or “e-mobility” is the use of various electric vehicles such as cars, trucks, bicycles, buses, etc. for transportation on roads around the world. The common characteristics, ie the properties of all of them, are that they are fully or partially driven with the use of an electric drive, they have a space for storing electricity, where they receive it mainly through the electricity network. Electric vehicles are very quiet, efficient, environmentally friendly, and in urban areas they are already used, in addition to private purposes, for the needs of delivery, transport, taxi, etc.

In addition to fully electric vehicles, the category of electromobility can include hybrid vehicles, which use or combine two technologies for propulsion. For slightly shorter distances, especially in urban areas, they mainly use electric drive, while the mileage for longer journeys is taken care of by an internal combustion engine. Hybrid vehicles can collect electricity during braking, but are mainly powered in a way that uses fully electric vehicles, ie at various electric charging stations, as shown above in Figure 1. In the world of technology, hybrid vehicles are treated as transitional, until all cars, trucks, bicycles, buses and other means of transport can be fully supplied with electricity in the future, regardless of any conditions. The comparison between electric and hybrid drive is shown below in Figure 1.

![Comparison between hybrid and all-electric powertrains](image)

**Fig. 1.** Comparison of electric and hybrid drive


Nowadays, greenhouse gas emissions have a huge negative impact on the climate and our environment. Day by day, more and more CO2 enters the atmosphere, resulting in the Earth getting warmer and warmer. According to research conducted by the International Committee on Climate Change (IPCC), transport and its harmful effects are responsible for as much as 23% of all CO2 emissions in the world. According to estimates, the number of people living in urban areas (cities) will continue to grow more and more, where shall live, about 70% of the total world population, by 2050.

It can be said that e-vehicles are changing the way we move, and not just because they are more environmentally friendly. An electric car costs more than comparable petrol and diesel vehicles - mainly due to the high cost of battery production, although they have fallen slightly over the last few years.
However, electricity is much cheaper than fossil fuels, and electric-powered vehicles require less frequent maintenance and repairs than those powered by a gasoline or diesel engine. E-vehicles do not require oil changes and various filters, and there is no exhaust system, belts and V-belts on them. An internal combustion engine has about 2,500 components that need to be manufactured and assembled, while an electric motor has only about 250 of them. Electric cars are serviced quickly using software updates (such as cell phones, computers, tablets, smart watches, etc.). The same requires a stable and fast internet connection, which can be a problem in more rural areas.

Lithium-ion batteries used in e-vehicles have a long service life, high energy density and can be constantly recharged. Batteries lose some of their capacity after 8 to 10 years, but that doesn’t mean they are damaged, they simply store slightly less energy. Most electric cars today have batteries with a capacity of 20 to 60 kWh. In the future, batteries will be used in e-cars for the conception and stabilization of the so-called smart grids. If, for example, the sun and wind provide most of the energy supply capacity, a problem will arise - supply and demand for it will vary, depending on the weather and inconvenience. Therefore, intelligent technology, which will be incorporated into e-cars in the future, should be used to absorb and store excess energy, eg when there are many sunny days or the weather is extremely windy. On the other hand, with intelligent technology, excess energy could be transferred from the e-car back to the smart grid. By installing a photovoltaic system on the roof of their home, e-car owners can greatly reduce their dependence on external energy sources. Also, by implementing a wall box, unnecessary driving with an electric car to a service station can be eliminated.

According to BNEF, there are currently 4,000 e-buses in Europe (not only battery electric buses but also plug-in hybrids, trolleybus IMC and fuel cell buses). However, 98% of electric buses are used in Chinese cities. Also, according to EV Volumes, there are 10.8 million battery-electric and plug-in hybrid vehicles in the world today. This number indicates approximately 0.5% of the total number of passenger cars traveling the world. Some forecasts say that by 2030 the number of such vehicles will increase by the next 30%. Some developed European countries are well above that average, so the percentage of electric vehicles in Norway is around 16%, while in Sweden and the Netherlands it is between 3 and 4%.

According to the European Environment Agency, as of the end of 2019, the largest number of BEV vehicles was in Germany, accounting for 34,280 vehicles. Germany was followed by the United Kingdom, which had more PHEV vehicles than Germany, with 44,334 thousand. Table 1 shows an overview by type of vehicle from 2010 to 2018 for EU-28. Share of electric vehicles is still to small to be significant.

Some countries in the European Union have introduced incentives to buy electric vehicles and install electric chargers. For example, some of them offers tax benefits, some certain percentage of the price or fixed incentives from €3000-5000.

### Table 1: NUMBER OF ELECTRIC VEHICLES IN THE EU 28 FROM 2010 TO 2018

<table>
<thead>
<tr>
<th>YEAR</th>
<th>BATTERY ELECTRIC</th>
<th>ELECTRIC PLUG-IN</th>
<th>SHARE OD ELECTRIC VEHICLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>734</td>
<td>0</td>
<td>0.006</td>
</tr>
<tr>
<td>2011</td>
<td>7,759</td>
<td>0</td>
<td>0.06</td>
</tr>
<tr>
<td>2012</td>
<td>13,986</td>
<td>9,000</td>
<td>0.191</td>
</tr>
<tr>
<td>2013</td>
<td>24,175</td>
<td>31,167</td>
<td>0.466</td>
</tr>
<tr>
<td>2014</td>
<td>37,855</td>
<td>68,180</td>
<td>0.845</td>
</tr>
<tr>
<td>2015</td>
<td>56,756</td>
<td>103,553</td>
<td>1.074</td>
</tr>
<tr>
<td>2016</td>
<td>64,316</td>
<td>93,707</td>
<td>1.164</td>
</tr>
<tr>
<td>2017</td>
<td>97,143</td>
<td>126,898</td>
<td>1.481</td>
</tr>
<tr>
<td>2018</td>
<td>148,454</td>
<td>145,898</td>
<td>2.002</td>
</tr>
</tbody>
</table>


Although the Covid-19 pandemic slowed many branches and stunted the economy, micromobility seized the opportunity. The service of public e-scooters, e-bikes and e-mopeds is available in more than 600 cities in more than 50 countries around the world. Although it is impossible to get an accurate figure, as the number is increasing day by day, it is estimated that there are about 350 million such vehicles, which is about 25% of all two / three wheels in traffic worldwide. Most of them are in China.

Light commercial vehicles reached 380,000 units in 2019, and most truck manufacturers are still upgrading existing ones and testing larger and larger trucks for electricity.

### III. ESTIMATED EXTERNAL COSTS FOR ELECTRIC VEHICLES

The external costs for which electric vehicles are responsible differ from those for vehicles with internal combustion engines mainly in two areas - air pollution and climate change. These two types of external costs largely depend on the method of estimation, the basic portfolio of power plants in a particular area, and the charging time of electric vehicles. Each of these segments increases the level of uncertainty in the final cost estimate. Another difference is in the creation of noise during the night, especially for traffic in urban areas.

Due to the need for comparison, it is assumed that the further development of components affecting the external costs of electric vehicles will be comparable to those generated by vehicles with internal combustion engines. The same applies to the external costs of components related to traffic safety, noise, vehicle production and traffic congestion. The cost of the component based on the development of the core power plant portfolio is related to air pollution and climate change.
As CO2 emission costs are generally very high, it is considered that the external costs of climate change will remain constant as far as electric vehicles are concerned. However, as far as air pollution is concerned, external costs will be reduced to some extent, due to changes that will occur in the production (generation) of electricity.

In the area that includes the transport of people with different types of motor vehicles, no significant innovations are expected before the beginning of 2030, and this mainly refers to: driving cycles, vehicle design, population density, payment options, etc. There will be some changes in overall external traffic costs per individual vehicle should be based on the following assumptions (with the increasing use of electric vehicles, ie efforts to replace the current conventional vehicles):

1. **Traffic safety** - that area is being addressed with the increasing use of advanced in-vehicle technologies and the principles of the European Safety Vision for zero transport deaths by 2050. Therefore, it is assumed that by 2030 there will be about 50% fewer traffic deaths, which will directly affect the reduction of external costs of traffic accidents in the same amount.

2. **Air pollution** - as external costs in that area are already at a very low level (2.8% of total external costs in 2010), and technological progress is in a limited zone, ie at its peak, with more massive with the use of electric vehicles, only a marginal reduction of external costs of about 10% is expected by the beginning of 2030.

3. **Climate change** - although technological improvements in vehicles are foreseen in terms of fuel efficiency by around 40% (impact of new laws), on the other hand, the total unit cost per tonne of CO2 is expected to increase from 120 to 200 euros, which will be ultimately identified as a balanced effect. However, the change in the value of external costs in this area could be more drastically affected by the potential breakthrough of biofuels in the automotive market.

4. **Noise pollution** - it is assumed that further developments in engine and tire technology will result in even "quieter" vehicles, which will have a positive impact on the reduction of traffic noise, as well as on external costs in the area, where it is expected to fall from about 10% by the beginning of 2030.

5. **Vehicle production** - assumptions are that the trend of reducing CO2 emissions during vehicle production will continue (mainly due to the reduction of specific emissions for electricity production). Calculated, the figure should be reduced from 6 to 5 tons per e-vehicle by the beginning of 2030. However, the previously mentioned increase in unit costs of CO2 to 200 euros will be reflected in an increase in external costs of as much as 1,000 euros per individual vehicle, which could seriously worry everyone in the automotive industry, including buyers (users) of vehicles.

6. **Traffic congestion** - external costs in this area will change differently in urban and rural areas. Thus, it will decrease in cities by about 10% by 2030 due to technological advances and various innovations in public transport systems, alternative modes of transport and IT systems, as well as more restrictive regulations for vehicles powered by internal combustion engines (petrol, diesel). On the other hand, it is assumed that external costs in rural areas will increase by the same amount, ie by 10%.

Table 2

<table>
<thead>
<tr>
<th>External costs</th>
<th>Reduction until 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>-50%</td>
</tr>
<tr>
<td>Air pollution</td>
<td>-10%</td>
</tr>
<tr>
<td>Climate change</td>
<td>0%</td>
</tr>
<tr>
<td>- fuel efficiency</td>
<td>-40%</td>
</tr>
<tr>
<td>- total unit cost per tonne of CO2</td>
<td>+40%</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>-10%</td>
</tr>
<tr>
<td>Vehicle production</td>
<td>-25%</td>
</tr>
<tr>
<td>- reducing CO2 emissions during vehicle production</td>
<td>-15%</td>
</tr>
<tr>
<td>- total unit cost per tonne of CO2</td>
<td>+40%</td>
</tr>
<tr>
<td>Traffic congestion</td>
<td>~ -10%</td>
</tr>
<tr>
<td>- urban areas</td>
<td>-10%</td>
</tr>
<tr>
<td>- rural areas</td>
<td>+10%</td>
</tr>
<tr>
<td>Urban VS rural areas</td>
<td>-6%</td>
</tr>
<tr>
<td>Ascending and descending processes</td>
<td>-10%</td>
</tr>
</tbody>
</table>


7. **Urban Vs. rural areas** - on the roads between urban and rural areas, the share of total travel (number of total trips) is expected to decrease from 0.26 to 0.20, as well as within urban areas, which may ultimately be reflected in the reduction of external transport costs.

8. **Ascending and descending processes** - in this area, external costs are expected to be reduced by about 10%, mainly due to the growing awareness of the associated problems, which have so far been ignored.

With the declaration of a pandemic and global lockdown, many people were left at home, and thus, the otherwise congested streets as the biggest producers of air pollution, became empty. That lack of passenger cars on the streets caused a drop-in emissions of carbon dioxide, nitrogen dioxide and fine particulate matter. According to Google Population Mobility Report data, during lockdown, population mobility in many countries decreased by more than 50% compared to the same period last year, which certainly affected the reduction of external transport costs.

IV. CONCLUSION

According to the current situation in technical and technological development, electric vehicles certainly stand out as a promising technology for facing future challenges in road transport, but also for reducing the total external costs in the same branch of transport. For this purpose, a differentiation was
made for electric vehicles and vehicles with internal combustion engines, from the economic and environmental aspect, and an analysis of external costs for both parties was made. Although we are aware that there are large uncertainties in estimating external costs according to the current situation, the differentiation is made based on the type of fuel, vehicle size, emission location, and time of day. According to the results of the calculation, the main advantages of using electric vehicles in terms of reducing external costs in urban areas can be: less pronounced impact on climate change, significantly lower emissions of pollutants into the air and causing less noise (night hours).

However, in the end in the current situation the external costs of traffic generated by electric vehicles and vehicles with internal combustion engines (petrol, diesel, natural gas) do not differ significantly. However, in addition to all these small advantages for electric vehicles, the depletion of the current supply of fossil fuels on Earth, which according to current estimates should last until 2050, can be highlighted as a fundamental problem for vehicles with internal combustion engines. Also, the external costs of transport themselves largely depend on the portfolio of power plants for the production of motor fuels (different from country to country), as well as on the chosen strategy of users for charging electric vehicles. According to all the above, it can be said that with the implementation and increasing use of e-vehicles on roads, the basic challenges of motorized traffic have not yet been solved, while external costs with the largest share are still dominated by traffic congestion (81.4%). Therefore, as the main tool for reducing them, we will still have to use the reduction of the motorization rate, ie the replacement of travel with vehicles with some form of active mobility (walking, cycling, use of public transport, etc.), and thus affect the improvement of living conditions in urban areas (cities).

REFERENCES


Influence of wagon control unit on economics benefits in the freight railway transport.

Zuzana Gerhátová¹, Vladislav Zitrický² and Jozef Gašparík³

Abstract – At present, the world economy is experiencing major technical and economic changes. In the field of rail transport, the challenge is the implementation of information and communication technologies, i.e. the incorporation of Industry 4.0 elements into the operation of rail transport. An important part of this is their mutual global integration. The aim of the article is to economically assess the introduction of the Industry 4.0 element of the wagon control unit into the transport process in rail transport. The premise of the research task is based on the experience of implementing intelligent sensors in rail freight transport in some countries of the European Union. Based on the analysis of the use of information and communication technologies in rail transport, an economic evaluation of the design of the wagon control unit will be carried out in the article.

Keywords – railway transport, digitalization, Industry 4.0

I. INTRODUCTION

The world of "Industry 4.0" is built on the principle of communication and cooperation between machines, people, products, equipment and logistics systems. All active elements such as material, systemic, human resources within the in-house Internet form an in-house network. All individual active elements that act within individual processes represent an in-house network. However, connecting individual elements to the network is preceded by the implementation of an increasing range of sensors. These are mainly sensors that provide a more thorough and perfect picture of the current state of the monitored or monitored environment.

The revolutionary nature of Smart Industry systems and the industrial Internet of Things lies in the synergies of four key principles: interoperability, decentralisation, intelligence and reconfigurability. [1]

II. CHARACTERISTICS OF THE CONCEPT OF "INDUSTRY 4.0."

The present era is on the brink of a technical revolution. This new technical revolution can make a significant difference to our lives. One of the changes may be the way we communicate and the way we work. To its extent, scale and complexity, this transformation will be as fundamental to all mankind as any other technological change from the past.

The technological advances of human society could never be stopped. Since the Industrial Revolution, which began in late 18th century England, society has become recognisable thanks to technology.

A. History of Industry "4.0."

In the 1960s, a new kind of economy was created in England. Human work in manufactory began to be gradually replaced by the first more complex machines, and gradually new factories were created. [2-3]

The industrial revolution had major consequences. Cities demolished walls, built factories, new neighborhoods were created, people moved to cities for work. Railway lines, ports have been built. Feudal society gradually decayed. [2-3]

The second industrial revolution began in the 19th century and was related to the discovery of electricity and its use in the process of production via the assembly line. [2-3]

In the second half of the 20th century, there was a rapid development of science. Scientific research has become a very important source of development for society. This stage is also characterised by the widespread use of fossil fuels. The globalisation of the economy is another important trend of the turn of the 20th/21st century. Information evolution is usually understood as the period of development of management, computer and communication technology as the next stage of the Industrial Revolution. [2-3]

In 2011, the German Research Association for Science and Economics (Forschungsunion Wirtschaft-Wissenschaft) came up with a research programme aimed at keeping Germany as a high-tech country. The program was called Industrial Revolution 4.0 or Industry 4.0. This program was first presented at an exhibition in Hanover in 2011. Industry 4.0 should reflect the societal change caused by connecting the physical, virtual and social worlds. It is a nationwide change affecting industry, technical standardisation, security, education, the legal framework, research, links to social systems, the labour market and demands on workers, their education and specialisation. [2]

B. Main elements of the concept "Industry 4.0"

The main essence of Industry 4.0 is no new and groundbreaking technological invention, which will produce parts more quickly in the production process. A profound systemic change in the production process is important. Its primary task is to streamline, clarify and deeper link the production process. [2,4]

The main changes on which the concept of Industry 4.0 is based are communication environment, environmental identification, extensive data collection and custom instrument decisions. However, the current turbulent period in industry confirms that new technologies and innovations have become a necessity not only for the development and progress of businesses, but also for the sustainability of their current processes. Technologies with the greatest impact on business processes include the Internet of Things or its application to the industrial environment. At the same time, the Industrial Internet of Things is at the heart of the smart factory and smart industry concept. [2,4]

However, the current turbulent period in industry confirms that new technologies and innovations have become a necessity not only for the development and progress of businesses, but also for the sustainability of their current processes. [2,4]

Industry 4.0 is built on two main pillars. The first main pillar is digitalisation. The second also important pillar on which Industry 4.0 is built is the application of exponential technologies. [5]

The revolutionary nature of Smart Industry systems and the industrial Internet of Things lies in the synergies of four key principles: interoperability, decentralisation, intelligence and reconfigurability. [6]

These elements include operators, maintenance workers and managers, production and transport equipment, components and semi-finished products, input materials, finished products, as well as workplaces and warehouses, production lines or various information systems. Thanks to the Internet of Things and modern industrial, the so-called Smart Industry, systems also
integrate information and communication technologies with production technologies. The broader concept of digital transformation of enterprises is based on the interconnectedness of individual elements leading to horizontal and vertical integration of processes. The digital transformation of businesses enables businesses to automate and optimize individual processes. [6]

One of the basic pillars of Industry 4.0 is exponential technologies. Exponential technologies are technologies that help to increase efficiency and productivity sharply. These include, for example: neurotechnology, nanotechnology, biotechnology, new energies, 3D printing, sensing, ICT and mobile technologies, artificial intelligence, advanced robotics or drones. [6]

Today, additive technologies are becoming an active element of industrial production. Their usability is also growing sharply in higher repeatability productions. In the process of additive production, the product is created by application of layers to each other (3D printing). Its advantage is the possibility of non-continual production of differential products, the possibility of accurately determining the need for material for the production of a particular product. [7]

II. INTELLIGENT RAILWAY WAGON

The European Union aims, in one place, to create a multimodal freight transport network that provides cost-competitive, efficient and low-emission freight transport services. In some European countries, they have already started to address the achievement of this objective by a fleet of intelligent sensors and telematics.

In Germany DB Cargo, not only has it already started digitizing its fleet, but it is already making progress. These are wagons with state-of-the-art telematics and sensors. Telematics modules, GPS, the use of RFID tags and NFC tags help freight wagons connect to the digital world. Upgraded wagons use mobile phones to transmit signals along the way. The data obtained from these means helps to obtain information about the condition of the load, temperature, humidity and other factors in the wagon. [8]

Another is a project called SmartCargo, which is implemented by an Austrian carrier. This project is about 13,700 wagons that will be gradually equipped with SmartCargo equipment. The facility provides comprehensive information throughout the freight transport process. The position sensor provides accurate GPS coordinates of the vehicle at predefined intervals. Also in this project is used 3D accelerometer sensor to detect shocks and monitor the transport of sensitive goods. Geofencing can send an instant message about crossing a predefined zone. Currently, about 300 wagons are already equipped with SmartCargo as part of computer tests. [9]

Currently, many companies already produce smart devices to track wagons. TrackCube 5, shown in Figure 1 from Cognid Telematics, is specially designed to detect the position of mobile objects using GPS without external power supply. It can monitor, locate and monitor railway vehicles. The source of this device is an integrated lithium battery, which is replaced at the end of the period of operation. The advantage of TrackCube 5 is the operating temperature, which is about -25°C up to 75°C. [10]

![Fig. 1. TrackCube 5. [10]](image)

X-RAYL® SOLAR POINTER Serie 17 is shown in Figure 2. It is a solar telematics device designed to communicate between sensors and positioning vehicles. It is made of machined aluminium and its construction meets the highest requirements. It also contains a lithium-ion battery, which gives it a very long lifespan. For perfect Serie 17 connectivity Indicators include NFC technology and wireless sensor connectivity using the 2.4 GHz band. Other data are also available, such as temperature, mileage, payload, door opening and more. Through geofencing, the customer is informed by e-mail or SMS notification as soon as the vehicle reaches predefined areas. [11]

![Fig. 2. X-RAYL® SOLAR POINTER Serie 17. [11]](image)

III. ANALYSIS OF TRANSPORT PROCESSES IN INTERNATIONAL RAIL TRANSPORT BETWEEN THE EU AND THIRD COUNTRIES

Rail transport was the dominant land transport system until the end of the first half of the 20th century. Strengthening the position of more flexible, less sophisticated and seemingly cheaper road transport has led to a massive onset of road mass and, ultimately, individual car transport. [12-13]

Transport processes in international rail transport can be described and characterized by technological procedures, which are carried out with wagon consignments at the state border of Slovakia and other neighbouring countries. The most important factors such as speed, safety and attractiveness depend not only on the technical base of the carrier or infrastructure manager, but mainly on the transport processes that take place in stations. [10,
It is therefore important that the current transport process is fast and prompt from the start of order creation. At present, at the beginning of the 4th Revolution, rail transport is lagging behind in the implementation of state-of-the-art approaches and technologies. This is due not only to the high financial burden, but also to the necessary expertise and preparedness of the staff. [10, 15-16]

The carriage of goods between countries belonging to the European Union and other countries outside the European Union is subject to the SMGS and JPP CIM agreements. The organization of transport shipments and not only theirs, but also transport processes at the entrance, exit of wagon consignments take into account several provisions. Transport from non-European and Asian countries is characterized by a change in the transport regime. The organisation of transport and transport processes primarily means the preparedness and development of technological procedures for the processing of various types of trains. As the Slovak Republic lies on the edge of the Borders of the European Union, it is important that the technological processes in the border stations are optimally set up. The correct setting of technological practices in these stations for the processing of trains is necessary for the competitiveness of international rail transport and also for the promotion of an environmentally friendly mode of transport. [1, 12-13].

A. Technological analysis of the processing of the target train before the introduction of elements of Industry 4.0

In rail transport, it is necessary to evaluate the technological processes of work in terms of the importance of the station and its role in the train-forming. This section of the article elaborates on the technological procedure for the border crossing station in Čierna nad Tisou. The technological analysis is prepared for the target train entering the railway station Čierna nad Tisou. The train comes after a wide gauge from Ukraine to Slovakia.

The agent of the transport office of eastern Slovak translators in the railway station of the Čop before the shipment leaves the station is obliged to make a hand-over list in the information system. He is obliged to do this before the wagon consignment enters the railway station Čierna nad Tisou. It does this on the basis of a wagon pre-view and a shipment. On the basis of this information submitted, it is possible for the customs representative to create a summary declaration for wagon consignments. The summary declaration shall be lodged no later than two hours before the wagon consignment enters the European Union. [1,14]

Before the train enters the railway station, it is required to send a notification of the arrival of the train after a wide gauge from Čop. The agent of the transport office of East Slovak transhipments is informed by the dispatcher of the railway station Čierna nad Tisou about the estimated time of arrival of the train, the number of the train and the number of the entrance track to which the train arrives. The train expected are an agent of the Ukrainian railways (UR), a wagonmaster of Ukrainian railways and a wagonmaster of East Slovak transhipments. [1,14]

Upon arrival of the train, a transit declaration shall be made by the authorized staff member. Accompanying documents will be taken over from the driver by the UR agent. After receiving all accompanying documents and train documentation, copies of the handover and transition list are stamped and signed. The UR agent offers the agent of the transport office of the East Slovak transhipment a train to take over and hands over the related documents. If a wagon consignment is subject to excise duty, the agent shall notify the relevant competent authorities of this situation. [1,14]

In the following operations, a transport inspection is carried out. The same agent who checked the transport documents should also be responsible for numbering the transitional list, according to the valid numbering system. In order to perform a physical inspection of the train, the VSP customs representative is obliged to deliver one copy of the transitional list to the branch of the customs office at ČNT. In cooperation with the operator of the East Slovak transhipments, the role of the second agent of the East Slovak transhipment transport office is to check the train composition. The train composition is checked via a radiotelephone. The external transport inspection is performed together with the inspection of the train composition. The agent of the transport office announces the beginning and end of the transport and technical inspection together with the result to the dispatcher of the Čierna nad Tisou railway station. It is extremely important that the inspection of the wagon consignment itself is carried out. The SMGS regulation allows one of the entities not to accept a wagon consignment if it is damaged or if it has an error specified in the regulation. Therefore, the inspection of the wagon consignment is performed by the agent of the transport office, who also performs an internal transport inspection. After checking the transport documents, the necessary documents are handed over to the customs agent by the agent of the transport office. These documents are checked on the basis of the customs office's own internal procedures and regulations. Upon receipt of the transport documents from the customs representative, the agent of the transport office of the East Slovak transhipments shall stamp part number 3 and 6 of the NL SMGS with an arrival stamp. The transport dispatcher will notify the transport dispatcher of the East Slovak transhipments about the takeover of the train. The agent of the transport office is also obliged to report to him the unaccepted wagons with their numbers. Subsequently, in the case of consignments that have been subsequently taken over, the agent of the transport office shall keep all documents from those additional consignments to the customs representative of the East Slovak transhipments for further processing Figure 1 shows the routing along with the Ganto graph for the target train. [1,14]
B. Technological analysis of the processing of the target train following the introduction of elements of Industry 4.0.

After incorporation of the wagon control unit and other elements into the rail freight wagons of the carrier, the total processing time of the train is reduced by approximately 176 minutes. This value is greatly influenced by the reduction or removal, replacement of human labour with modern technologies offered by Industry 4.0. These are mainly transport process operations together with sending, checking, writing the necessary train documentation and accompanying documents. A technological graph of the entant train from Ukraine after a wide gauge to the railway station in Čierna nad Tisou after incorporating the design is shown in Figure 3. The total processing time of a freight train with 70 wagons is 135 min. [1]
An important factor in accelerating but mainly streamlining transport processes, but also transport processes, is their digitization and automation. Based on the analysis, operations were detected in transport processes that can be partially or completely automated and digitized. [10]

VI. ECONOMIC EVALUATION OF THE COSTS OF THE WAGON CONTROL UNIT

Research is currently underway into the use of various GPS devices on railway freight wagons, together with various additions to streamline monitoring, detection of information about wagons and wagon consignments. Our proposed facility is not offered in any of the Slovak or foreign companies. Only equipment of a similar type is currently listed on the market. Given that these facilities are relatively short on the European market, there is a competitive battle between the companies. The average price of such a device is around 200€. The price of current devices is influenced by several factors such as: battery type, storage storage, telecommunications modules, GPS locator and various other additional devices. After consultation with an unnamed company and an expert in information technology equipment, the price of our proposed wagon control unit was 255€. [1]

According to the 2014 annual report, ZSSK CARGO a.s. has a total of 13,566 freight wagons. Part of the freight wagons is the sole ownership of the freight carrier and part of the freight wagons is leased. After careful consideration with experts in the technical characteristics of the wagon, the wagon control units will be installed on individual types of wagons. [1]

Table I. divided rail freight wagons by type. Each type of railway freight wagon shall be given the number and estimated cost of purchasing the wagon control unit.

<table>
<thead>
<tr>
<th>Type of wagon</th>
<th>Number of wagon</th>
<th>price (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor</td>
<td>171</td>
<td>43 605 €</td>
</tr>
<tr>
<td>open</td>
<td>166</td>
<td>42 330 €</td>
</tr>
<tr>
<td>platform</td>
<td>1295</td>
<td>330 225 €</td>
</tr>
<tr>
<td>other</td>
<td>1</td>
<td>255 €</td>
</tr>
<tr>
<td><strong>together</strong></td>
<td><strong>1633</strong></td>
<td><strong>416 415 €</strong></td>
</tr>
</tbody>
</table>

The total cost of purchasing wagon control units for all rail freight wagons for the company would total €3,459,330. [1]

The purchase of wagon control units also incurs many other costs. This is the cost of fitting wagon control units to railway freight wagons. The installation of the wagon control unit may be provided by the carrier through its employees or by authorising another company for payment. It is therefore not possible to determine the exact quantifiable value of these costs. [1]

A failure occurs from time to time in each device, so it is important that the carrier has a trained employee at its place to repair and maintain these smart devices. Another option is to provide maintenance services by an external company. In the case of ensuring the maintenance and repair of this equipment by another entity, the misleading undertaking must take into account higher costs of this kind. [1]

Other costs include the costs of training the carrier's employees to work with wagon control units and accessories. As the carrier does not currently have such equipment available,
initial training costs are necessary. In the case of the training of specific employees, these costs would already be reduced. The interoperability of information systems of individual entities involved in the transport of wagon consignments is already a matter of course in this case. The carrier's investment in the intelligent wagon control unit is only relevant if the interoperability of information systems between the rail freight carrier and other entities is met. [1]

The installation of the wagon control unit on the wagon significantly affects the work not only of employees in railway stations, but also of employees of the infrastructure manager, customs office and other entities involved in the transport of the wagon consignment. [1]

As an example, the saved costs of employees in ŽST ČNT are calculated. According to the jobs, the average labour price per employee is determined by 1100€, based on the price of work. [1]

In Table II, there is a comparison of the costs of the carrier’s employees in one working shift in ŽST ČNT before the execution of the proposal and after the execution of the proposal.

<table>
<thead>
<tr>
<th>variant</th>
<th>number of employees</th>
<th>of its motion</th>
<th>after the proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>18</td>
<td>26 400,00 €</td>
<td>19 800,00 €</td>
</tr>
</tbody>
</table>

The cost saved for freight carrier employees during one working shift is €6,600. In ŽST ČNT there is work on two 12-hour shifts. Annually, ZSSK CARGO would be able to save employees' costs specifically only in ŽST ČNT in the amount of 158,000€. Since the wagon control unit will have every single wagon, it will affect the technology of work and technological processes on the entire railway network. In that case, the cost of employees saved will be much higher. Wagon control units will benefit not only PPS ŽST ČNT but also other other railway stations throughout Slovakia. [1]

VII. CONCLUSION

The significant growth of automotive transport not only in Slovakia but also throughout Europe highlights its attractiveness. Given that rail transport is one of the environmentally friendly modes of transport, it should also be given greater attention. Industry 4.0 offers unlimited possibilities for installing many usable elements also in rail transport. The wagon control unit, which will facilitate and simplify many processes in railway stations, is only an illustrable example of this.

ACKNOWLEDGE

The paper is supported by the VEGA Agency by the Project 1/0798/21 "The Assessment of Economic and Technological Aspects in the Provision of Competitive Public Transport Services in Integrated Transport Systems" that is solved at Faculty of Operation and Economics of Transport and Communications, University of Žilina.

REFERENCES


Abstract – In paper technique of development of pilotless bus marketing positioning in the Russian market will be offered. The technique consists of 4 stages: a research in positioning; determination of key properties of pilotless bus, company, market; definition of the development directions of the pilotless bus; comparative assessment of positioning options.

Keywords – Pilotless bus (unmanned bus), Positioning, Marketing, Consumer perception.

I. INTRODUCTION

Now innovations act as a significant source of competitive advantages of the companies [3]. However development and removal on the market of innovations have high risk [2]. One of the directions of innovative activity risk reduction is development of marketing ensuring commercialization of innovations [5]. In this paper will measures for development of positioning of the pilotless bus in the Russian market are proposed.

In Russia the idea of development of the pilotless bus arose in 2015, and several companies became interested in this innovation: automobile corporation "KamAZ", BMG subsidiary (Bakulin Motors Group) - "Volgabus" and also state scientific center of the Russian Federation NAMI.

Due to the emergence of a new prototype of the NAMI pilotless bus, it is expedient to carry out the analysis of external and internal factors on removal on the market of this product for the purpose of detection of competitive advantages of the NAMI company before producers of analogs.

The main competitor on release of pilotless buses of the NAMI company is the BMG subsidiary (Bakulin Motors Group) with the commodity brand "Volgabus" - "Matryoshka M2B8" (Volgabus (BMG)).

This paper focuses on the following problem: improving the efficiency of the marketing strategy for commercialization of an innovative product (pilotless bus) using advanced marketing positioning tools, taking into account the perception of the quality of the pilotless bus.

The purpose of this paper is to justify a set of marketing measures for positioning an pilotless bus on the Russian market.

The paper has the following structure: analysis of key competitiveness parameters of NAMI pilotless bus [1]; identification of the main properties of the pilotless bus industry [7]; identification of development directions of pilotless buses industry [6]; comparative evaluation of various options for positioning an pilotless bus.

II. DEFINITION OF THE CURRENT MARKET POSITION OF PILOTLESS BUS AT THE RUSSIAN MARKET

For positioning development of the pilotless bus it is necessary to characterize the current market position and to define key drivers of the market in comparison with competitors. It will allow to reveal successful points of differentiation of goods which in the subsequent can become starting points in positioning of a brand [4].

For NAMI the main and only competitor on creation of a similar product in the Russian market is the Volgabus trademark (Bakulin Motors Group) with the pilotless bus "Matryoshka M2B8" [5]. A. Bakulin became the founder of this company on production of buses, spare accessories, and also pilotless bus. The company is founded relatively recently since 2014, but could already win a considerable share in the market of public transport.

It is necessary to determine by the first step in creation of process of positioning of a brand the current position and the relation of consumers to the NAMI company and the Volgabus trademark. For this purpose it is necessary to define the relation of target audience to the NAMI and "Matryoshka M2B8" pilotless buses. We will carry out this analysis by poll of alleged target audience with visual representation of NAMI and "Matryoshka M2B8" pilotless buses and the description of the key technical parameters of a product. Later we will ask to describe the seen product 7-10 words. The following results were received:

- NAMI pilotless bus: The modern economic product intended for safe transportation of passengers;
- "Matryoshka M2B8" (Volgabus (BMG): Robotic known brand of the modern qualitative pilotless bus.

III. DETERMINATION OF KEY PROPERTIES OF PILOTLESS BUS, COMPANY, MARKET

The second step in creation of goods' positioning is determination of the main properties in the industry. It is necessary to make four lists of properties of the pilotless bus:

- market properties of goods – this type of properties is obligatory for each product in the market;
- properties of goods of the company are priority properties which are possessed by the pilotless bus of NAMI;
• properties of goods of the competitor are priority properties which are possessed by the "Matryoshka M2B8" pilotless bus;
• properties from consumers are the main characteristics of a product which are priority for target audience.
Let's define the realized need for purchase of pilotless bus (Table 1).

<table>
<thead>
<tr>
<th>Properties of goods in the market</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Esthetic requirement, need for beauty</td>
</tr>
<tr>
<td>Low cost</td>
<td>Economic investment</td>
</tr>
<tr>
<td>Modular platform</td>
<td>Multipurpose applicability</td>
</tr>
<tr>
<td>Independent operation</td>
<td>Main technical base</td>
</tr>
<tr>
<td>Existence of modifications</td>
<td>Multipurpose applicability</td>
</tr>
<tr>
<td>Passenger capacity</td>
<td>Efficiency of invested funds</td>
</tr>
<tr>
<td>Safety</td>
<td>Need for safety</td>
</tr>
<tr>
<td>Service</td>
<td>Need for the loyal attitude towards the buyer</td>
</tr>
<tr>
<td>Quality</td>
<td>Need for safety</td>
</tr>
<tr>
<td>Multipurpose equipment</td>
<td>Main technical base</td>
</tr>
<tr>
<td>Comfort</td>
<td>Efficiency of invested funds</td>
</tr>
<tr>
<td>Operation of the car in severe weather conditions</td>
<td>Multipurpose applicability</td>
</tr>
<tr>
<td>Accumulator charge time</td>
<td>Main technical base</td>
</tr>
<tr>
<td>Fast reaction to breakage</td>
<td>Efficiency of invested funds</td>
</tr>
<tr>
<td>Course stock</td>
<td>Main technical base</td>
</tr>
<tr>
<td>Existence of equipment for persons with limited opportunities</td>
<td>Multipurpose applicability, social requirement</td>
</tr>
<tr>
<td>Maximum speed of the movement</td>
<td>Efficiency of invested funds</td>
</tr>
<tr>
<td>Loading capacity</td>
<td>Main technical base</td>
</tr>
</tbody>
</table>

It is developed by authors

Further it is necessary to analyze, how it is possible to improve the NAMI pilotless bus before his competitor. The following directions of improvement of the pilotless bus were revealed:
- For excursions: Introduction of a system of the audio-guide (for foreign citizens the translation of information by means of the built-in earphones near each seat);
- Equipment by the solar battery, as additional charge of energy;
- Introduction of a system of the wireless Internet (Wi-Fi).

After definition of possible improvement of a product it is necessary to define the possible problems interfering purchase of the pilotless bus. For this purpose we will answer three key questions:
1. How do competitors solve these problems?
2. Whether is there an opportunity to take the leading position at the solution of this problem of your company?
3. Whether will there be for the target consumer a solution of this problem significant?

In Table 2 it is representable the received results.

<table>
<thead>
<tr>
<th>Requirements and problems of target audience</th>
<th>Do the current players of the market solve this problem?</th>
<th>Whether leadership in a solution is possible?</th>
<th>Whether can be a differentiation point?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence of sudden obstacles</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Quick response to road accident</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Responsibility for incident</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Small passenger capacity</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Existence of security aids for children</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

It is developed by authors

Thus, it follows from Table 2 that the promising directions for improving the pilotless bus are the following: the possibility of resolving sudden difficulties, responsibility for the incident, low passenger capacity and the availability of safety equipment for children.

IV. DEFINITION OF THE DEVELOPMENT DIRECTIONS OF THE PILOTLESS BUS

Having defined differentiation points in versions of the solution of need of the consumer, it is expedient to find such points of differentiation which will promote use of the NAMI pilotless bus in some concrete situation.

It seems advisable to search for points of differentiation of an unmanned bus by several components: conditions of use of this product (Table 3); prospect of achieving leadership positions on specific market properties (Table 4); promising development of unique properties of the product (Table 5).

Table 3 shows that NAMI competitors are not interested in the aspect of using unmanned buses in winter conditions, but this is important for Russia: in many territories, winter lasts more than six months; NAMI competitors are not currently
considering projects for the use of unmanned buses as infrastructure elements (airports, campus territories, etc.).

<table>
<thead>
<tr>
<th>Method and situation of emergence of requirement / use of goods</th>
<th>Whether competitors can solve the need for each situation in the best way?</th>
<th>Whether can be a differentiation point?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of pilotless transport in winter conditions</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Transportation of passengers at the big airports</td>
<td>This application is not considered by the competitor</td>
<td>yes</td>
</tr>
<tr>
<td>Transportation of employees in large enterprises</td>
<td>Is not present / the solution of requirement is identical among competitors</td>
<td>no</td>
</tr>
<tr>
<td>Transportation of passengers in large hospital complexes</td>
<td>This application is not considered by the competitor</td>
<td>yes</td>
</tr>
<tr>
<td>Transportation of passengers across public roads</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>The large educational institutions having the isolated territory with a large number of buildings and constructions (campuses)</td>
<td>This application is not considered by the competitor</td>
<td>yes</td>
</tr>
<tr>
<td>Theme parks (amusement parks, zoos, etc.)</td>
<td>This application is not considered by the competitor</td>
<td>yes</td>
</tr>
</tbody>
</table>

It is developed by authors

Table 3 shows that it is realistic to achieve leadership positions on a number of market properties: low cost, passenger capacity, safety, the ability to quickly repair and high speed.

<table>
<thead>
<tr>
<th>Unique properties of a product</th>
<th>Whether have value for target audience?</th>
<th>Differentiation point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Passenger capacity</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Safety</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Quality</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

It is developed by authors

Table 4 shows that it is realistic to achieve leadership positions on a number of market properties: low cost, passenger capacity, safety, the ability to quickly repair and high speed.

<table>
<thead>
<tr>
<th>Operation of the car in severe weather conditions</th>
<th>yes</th>
<th>yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existence of equipment for persons with limited opportunities</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

It is developed by authors

Table 5 confirms that the unique properties of the product can also form the basis of its market positioning, since they are of high importance to the target audience.

V. COMPARATIVE ASSESSMENT OF POSITIONING OPTIONS

Thus, having carried out the detailed analysis on positioning of goods in the market, with definition of differentiation points we will consolidate the obtained data in one Table 6, and by means of an expert method of estimates (survey of 132 automotive executives), based on the allocated points of differentiation of goods, we will define the importance of the marked-out criteria for target audience. This work is carried out not only for definition of mainly significant positions of goods, but also for identification of a further vector of development of the NAMI pilotless bus.

<table>
<thead>
<tr>
<th>Market properties of goods</th>
<th>Whether there are goods realizing this property it is the best of all?</th>
<th>Differentiation point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Passenger capacity</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Safety</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Quality</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

It is developed by authors

Table 6 confirms that the unique properties of the product can also form the basis of its market positioning, since they are of high importance to the target audience.
For carrying out the final analysis of positioning of goods and identification of the priority directions of development of the pilotless bus the group of target consumers to whom the list of the revealed properties of goods was submitted was invited, and it is offered to estimate each parameter on three to a ball scale. By results of poll of the concept (property) which gained the greatest number of points are for the consumer the most effective and important when choosing purchase of the pilotless bus. Properties which gained least of all points by results of poll can become for the company a vector for their development and improvement.

Thus, the main priority properties which the pilotless bus has to possess are:
- Existence of a system of the audio-guide (for foreign citizens the translation of information by means of the built-in earphones near each seat) for pilotless buses on excursion trips;
- Existence of security aids for children;
- Use of the pilotless bus in large the educational institutions having the isolated territory with a large number of buildings and constructions (campuses);
- Low cost and safety of the incorporeal bus;
- Existence of equipment for persons with limited opportunities.

### VI. CONCLUSION

In this paper the technique of development of marketing positioning of the pilotless bus in the Russian market is offered. The technique consists of 4 stages: a research of an initial situation in positioning of goods and its perception by consumers; determination of key properties of goods, company, market; definition of the directions of development of goods; comparative assessment of various options of positioning of the
pilotless bus. This technique allows to reveal successful points of differentiation of the pilotless bus which in the subsequent can become starting points in positioning of a brand. The main priority properties which the pilotless bus has to possess will be as a result defined.

REFERENCES


Determination of the technical efficiency of the UIRR terminals using Data Envelopment Analysis method (DEA) from CCR model

Milan Milosavljević and Zoran Bundalo

Abstract – The presented paper measured the efficiency of terminals for combined transport from ten European countries members of UIRR, using DEA method. The results can be used for improving terminals operations and making key management decisions. Also, results indicate that the variable selection has a great influence on the resulting estimates of technical efficiency.

Keywords – Efficiency, UIRR terminal operators, DEA

I. INTRODUCTION

In recent years, there has been a noticeable increase in the volume of transported goods by combined transport in Europe. Nowadays, transporting cargo using intermodal transport units are a key indicator for every shipment. International Union of Combined Road-Rail Transport (UIRR) is the industry association for the sector of combined transport which includes companies and terminals in twelve European countries. Each of these terminals has a railway connection with some of the main European Rail Freight Corridor and because of that can significantly increase the share and competitiveness of railway transport in combined transport in Europe.

Assessing the efficiency of these terminals is a very complex task that consists of determining the relationship between the results achieved on the one hand and the resources involved on the other. One of the most used methods for solving this kind of problem is Data Envelopment Analysis (DEA).

There are a large number of papers which used different DEA method for determining the efficiency of port or container terminals. A study on the efficiency of container terminals in Korea and China based on CCR and BCC DEA models are presented in [1]. Authors [2] measured the relative efficiency of five major commercial ports in West Africa, using CCR, BCC, and Windows I-C DEA methods. In paper [3] authors evaluate the efficiency of the container terminals of North Adriatic ports using DEA CCR, BCC and SBM method.

In most of these papers, authors combine several input factors such as number of cranes, number or berths, terminal area, number of employees, berth length, with mostly one same output variable - container throughput (TEU).

In this paper, we use the CCR DEA method for determining the technical efficiency of UIRR terminals based on three input variables and one output variable.

II. METHODOLOGY

A. Data Envelopment Analysis

DEA is a non-parametric method for measuring the relative efficiency of decision-making units (DMUs) that have multiple input and output [4], which in this paper are UIRR terminals. A linear programming model developed by [4] is considered as the beginning of the DEA. There are two basic models that are most commonly used to measure the efficiency of decision-making units: the CCR model used in this paper [4] and the BCC model with variable yield on volume [5].

Linear DEA models can be input or output-oriented. This is due to the fact that linearization can also be done by equating the numerator in the function of the target with 1, thus minimizing the denominator. Input oriented models give us information on how to reduce input variables in order decision making units to become efficient at a given output level. On the other hand, output-oriented models reach DMU efficiency by increasing the output variable. The objective function in the input-oriented CCR-DEA model is presented as the weighted sum of the output variables that should be maximized as shown in Eq. 1 [6]:

\[
(\text{Max}) h_k = \sum_{r=1}^{s} u_r y_{rk}
\]

Constrains (Eq. 2 - Eq.4):

\[
\sum_{i=1}^{m} v_i x_{ik} = 1
\]

\[
\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ik} \leq 0, j = 1, ..., n
\]

\[
u_r \geq 0, v_i \geq 0, r = 1, ..., s; i = 1, ..., m
\]

B. Application of DEA method

There are four main phases in the application of DEA method [7]:

I. Defining and selecting decision units whose relative efficiency is to be determined.

II. Determination of input and output variables that are relevant and suitable for evaluating the relative efficiency of the selected decision-making units. At this stage, consultation with experts from the field is necessary. Typical inputs are the resources the unit uses, while results represent outputs. A series of regression analyses can identify the relationships between variables, inputs, or outputs. A weak
relationship of some variables with everything else may mean that you need to check whether the variable is eliminated. Also, strong links may indicate that the information presented in a variable is already contained in other variables and again, elimination should be considered.

III. Choosing an adequate DEA model.
IV. Solving DEA model.

### III. MODEL FORMULATION

The selection of variables is the primary step in any efficiency analysis because it weighs on the accuracy of the analysis. In this paper, we considered transshipment terminals managed by UIRR member companies from ten European countries, although there are twelve countries in total in 2019. Slovakia and the Czech Republic are not used in the model because these two countries are new and there is no data for them in recent years. Total number of terminals in the model is twenty, and these terminals represent DMU for the selected problem.

There are several factors that we considered in the selection of some terminal. First, the terminal should have been operated for at least five years and it must have a total turnover of more than 50000 units per year. These terminals have three types of connection with European corridors: unaccompanied combined transport, inland waterways transport (IWW) and intermodal technology A - Rollende Landstrasse (RoLa). In this paper, we do not consider terminals that have only RoLa or IWW type of connection. Data about terminals characteristics are collected by annual statistics of UIRR and from terminal websites [8]. The selected terminals are given in Table 1.

For analyzing the effectiveness of the proposed decision-making units, the CCR model was used. In the DEA method, it is important that the number of decision-making units must be greater than twice the sum of input and output variables, which is satisfied [9].

<table>
<thead>
<tr>
<th>Country</th>
<th>Terminal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>CTE, CTS, Wels Vbf, CCT/RoLa, Wien Sud CCT, Wolfrut CCT</td>
<td>5</td>
</tr>
<tr>
<td>Belgium</td>
<td>Combinant, CTE, Main Hub (Zomerweg)</td>
<td>3</td>
</tr>
<tr>
<td>Germany</td>
<td>KTL, TSG</td>
<td>2</td>
</tr>
<tr>
<td>France</td>
<td>Avignon, Hourcade, Marseille, Venissieux</td>
<td>4</td>
</tr>
<tr>
<td>Hungary</td>
<td>Rail Cargo Terminal - BILK</td>
<td>1</td>
</tr>
<tr>
<td>Italy</td>
<td>EMT</td>
<td>1</td>
</tr>
<tr>
<td>Poland</td>
<td>Railhub Terminal Gadki</td>
<td>1</td>
</tr>
<tr>
<td>Romania</td>
<td>Railroad Arad</td>
<td>1</td>
</tr>
<tr>
<td>Great Britain</td>
<td>Daventry</td>
<td>1</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Aarau</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td></td>
</tr>
</tbody>
</table>

#### TABLE I

UIRR Terminals for combined transport by country

Three input variables are considered in the DEA model: total surface (m²), number of cranes (gantry and mobile) and number of railway tracks. Our research shows us that in literature there is an insignificant number of authors which include the number of railway tracks as input variables when solving the terminal efficiency problem. On the other hand, we consider that this input variable can be an important parameter that directly affects terminal efficiency and from whom depends on total turnover.

The output variable is the total turnover, which can be expressed as the total number of intermodal transport units (containers, swap bodies, and semi-trailers) loaded and unloaded, arrived and departed from terminal. The cargo turnover is unquestionably the most important and widely accepted indicator of terminal output. Many authors use container throughput (TEU) as the most important indicator and output variable for measuring the technical efficiency of container ports or terminals [10]. Input and output variables are given in Table 2.

#### IV. RESULTS AND DISCUSSION

The input-oriented DEA-CCR model is applied for the evaluation of twenty DMUs in 2018. The observed problem is
solved by the DEA excel solver. The goal of the CCR model is to find the maximum of the objective function taking into account defined constraints. If we divide this task into twenty linear programming tasks for each of the twenty decision-making units, then in each task we search for the values of the variables $v_1, v_2, v_3$ and $u_v$ so that the objective function reaches a maximum under the defined constraints. The efficiency of terminals is shown in Table 3, where an efficiency score of 1 signifies efficient terminals and scores less than 1 indicate inefficient terminals.

**TABLE III**

<table>
<thead>
<tr>
<th>DMU</th>
<th>Efficiency</th>
<th>Sum of lambdas</th>
<th>Return to Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTE</td>
<td>1.00000</td>
<td>1.00</td>
<td>Constant</td>
</tr>
<tr>
<td>CTS</td>
<td>0.98000</td>
<td>0.653</td>
<td>Increasing</td>
</tr>
<tr>
<td>Wels</td>
<td>0.64303</td>
<td>1.757</td>
<td>Decreasing</td>
</tr>
<tr>
<td>Wien CCT</td>
<td>0.86226</td>
<td>0.431</td>
<td>Increasing</td>
</tr>
<tr>
<td>Wolfurt CCT</td>
<td>0.60874</td>
<td>0.304</td>
<td>Increasing</td>
</tr>
<tr>
<td>Combinant</td>
<td>0.62723</td>
<td>0.546</td>
<td>Increasing</td>
</tr>
<tr>
<td>HTA</td>
<td>0.60850</td>
<td>0.845</td>
<td>Increasing</td>
</tr>
<tr>
<td>Main Hub</td>
<td>0.28314</td>
<td>0.283</td>
<td>Increasing</td>
</tr>
<tr>
<td>KTL</td>
<td>0.58160</td>
<td>0.945</td>
<td>Increasing</td>
</tr>
<tr>
<td>TSG</td>
<td>0.49404</td>
<td>0.533</td>
<td>Increasing</td>
</tr>
<tr>
<td>Avignon</td>
<td>0.33526</td>
<td>0.953</td>
<td>Increasing</td>
</tr>
<tr>
<td>Hourcade</td>
<td>0.52428</td>
<td>1.279</td>
<td>Decreasing</td>
</tr>
<tr>
<td>Marseille</td>
<td>0.41935</td>
<td>1.205</td>
<td>Decreasing</td>
</tr>
<tr>
<td>Vénissieux</td>
<td>0.73727</td>
<td>1.090</td>
<td>Decreasing</td>
</tr>
<tr>
<td>RCT BILK</td>
<td>0.31797</td>
<td>0.278</td>
<td>Increasing</td>
</tr>
<tr>
<td>EMT</td>
<td>0.34329</td>
<td>0.232</td>
<td>Increasing</td>
</tr>
<tr>
<td>RT Gadki</td>
<td>0.54152</td>
<td>0.271</td>
<td>Increasing</td>
</tr>
<tr>
<td>Railport Arad</td>
<td>1.00000</td>
<td>1.000</td>
<td>Constant</td>
</tr>
<tr>
<td>Daventry</td>
<td>1.00000</td>
<td>1.000</td>
<td>Constant</td>
</tr>
<tr>
<td>Aarau</td>
<td>0.62119</td>
<td>0.914</td>
<td>Increasing</td>
</tr>
</tbody>
</table>

Based on the CCR efficiency level of each terminal, the analysis shows that only three terminals were efficient with a score of 1: CTE, Railport Arad, and Daventry. The remaining terminals (85%) are inefficient, with scores less than 1. Four inefficient units have decreasing returns to scale, and the other 13 have increasing returns to scale. The average efficiency is 0.6264 and the lowest efficiency is for terminal Main Hub from Belgium (0.2831). This indicates the need to reduce the value of the input variables or input and output combined in order to become efficient for the given output.

### A. Sensitivity analysis

Sensitivity analysis consists of determining reference units for inefficient units, based on best practice. In addition to providing efficiency measures, DEA also provides other information relevant to inefficient terminals. For each inefficient DMU, we can define a reference set of efficient DMUs for benchmarking.

Slack variable analysis provides a reference set of specific recommendations to help each inefficient terminal become efficient, by minimizing the input resources to produce a given output efficiently. It should be noted that this information is described only for the inefficient terminals, and the efficient terminals tend not to provide any slack [11]. The sensitivity analysis and slack variable analysis are given in Table 4.

**TABLE IV**

<table>
<thead>
<tr>
<th>DMU</th>
<th>Total surface</th>
<th>Num. of cranes</th>
<th>Num. of tracks</th>
<th>Total turnover</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTS</td>
<td>114333.33</td>
<td>1.96</td>
<td>5.23</td>
<td>245000</td>
<td>1.00</td>
</tr>
<tr>
<td>Wels</td>
<td>77163.93</td>
<td>3.86</td>
<td>5.58</td>
<td>202833</td>
<td>1.00</td>
</tr>
<tr>
<td>Wien CCT</td>
<td>75447.40</td>
<td>1.29</td>
<td>3.45</td>
<td>161673</td>
<td>1.00</td>
</tr>
<tr>
<td>Wolfurt</td>
<td>53264.40</td>
<td>0.91</td>
<td>2.43</td>
<td>114138</td>
<td>1.00</td>
</tr>
<tr>
<td>Combinant</td>
<td>62096.17</td>
<td>1.43</td>
<td>3.14</td>
<td>138500</td>
<td>1.00</td>
</tr>
<tr>
<td>HTA</td>
<td>32250.45</td>
<td>1.83</td>
<td>2.50</td>
<td>87922</td>
<td>1.00</td>
</tr>
<tr>
<td>Main Hub</td>
<td>49548.80</td>
<td>0.85</td>
<td>2.27</td>
<td>106176</td>
<td>1.00</td>
</tr>
<tr>
<td>KTL</td>
<td>165393.20</td>
<td>2.84</td>
<td>7.56</td>
<td>354414</td>
<td>1.00</td>
</tr>
<tr>
<td>TSG</td>
<td>31124.63</td>
<td>1.22</td>
<td>1.98</td>
<td>76808</td>
<td>1.00</td>
</tr>
<tr>
<td>Avignon</td>
<td>28596.52</td>
<td>2.01</td>
<td>2.54</td>
<td>83769</td>
<td>1.00</td>
</tr>
<tr>
<td>Hourcade</td>
<td>25561.43</td>
<td>2.62</td>
<td>2.93</td>
<td>87050</td>
<td>1.00</td>
</tr>
<tr>
<td>Marseille</td>
<td>17345.61</td>
<td>2.43</td>
<td>2.52</td>
<td>68661</td>
<td>1.00</td>
</tr>
<tr>
<td>Vénissieux</td>
<td>33988.03</td>
<td>2.31</td>
<td>2.95</td>
<td>98332</td>
<td>1.00</td>
</tr>
<tr>
<td>RCT BILK</td>
<td>48689.67</td>
<td>0.83</td>
<td>2.23</td>
<td>104335</td>
<td>1.00</td>
</tr>
<tr>
<td>EMT</td>
<td>27462.87</td>
<td>0.62</td>
<td>1.37</td>
<td>61000</td>
<td>1.00</td>
</tr>
<tr>
<td>RT Gadki</td>
<td>47383.00</td>
<td>0.81</td>
<td>2.17</td>
<td>101535</td>
<td>1.00</td>
</tr>
<tr>
<td>Aarau</td>
<td>16772.22</td>
<td>1.86</td>
<td>2.04</td>
<td>375000</td>
<td>1.00</td>
</tr>
</tbody>
</table>

As we can see from table 4 efficiency of terminals will be 1.00 when input variables are not an integer. In that case, we can round these numbers to be an integer for input variables such as a number of tracks or cranes. It will not change the result of efficiency which average value is 0.99.

For the input-oriented method, input variables must decrease to DMU to become technically efficient. For example, the inefficient terminal KTL has efficiency 0.5816, and it must adjust all of the input variables by 42% to become technically efficient. KTL must decrease the input variables total surface (-139606.80), number of cranes (-5) and number of tracks (-5) to become efficient and satisfy achieved turnover. Based on this example all inefficient DMUs can adjust their input variables to become technically efficient with a score of 1. The reduction of input variables is given in Fig. 1.
As we can see from figure 1, for almost every inefficient terminal number of cranes and the number of tracks is decreased in the range from 0.5 to 7.46. The input variable total surface has the biggest oscillations from $5667 \text{ m}^2$ (5%) for CTE to $272617 \text{ m}^2$ (85%) for RT Gadki. Average decrease of these input variable is 51% for all 17 terminals.

V. CONCLUSION

This paper demonstrated how CCR DEA method can be applied to measure the efficiency of terminals for combined transport in Europe. The sensitivity analysis of the obtained solution can identify the sources of inefficiency of individual decision-making units. Only three terminals are efficient and the other 17 are inefficient. Sensitivity analysis shows us that inefficient DMU may be efficient if some input parameters are increased.

According to the results, the terminal that is most frequently used as a benchmark by inefficient terminals is the CTE, which is used by 17 inefficient terminals. Railport Arad and Daventry are benchmark terminals in only one case. This means that inefficient terminals can follow their reference benchmark terminal to improve themselves and become efficient.

One of the main indicators shows us that the relationship between efficiency and terminal size suggested that the large terminals are not necessarily more efficient than smaller ones.

The future research can be based on the usage of some of the other DEA models such as BSS or SBM, and taking more input variables into consideration.

REFERENCES

The state aid as a form for financing some transport enterprises in the Republic of Bulgaria

Emiliya Vaysilova

Abstract – The study focuses on state grants provided to some transport companies in the Republic of Bulgaria. The granting of such state aid is related to the social policy pursued by the state. Issues related to the regulation of grants, different types of grants, accounting and reimbursement are discussed. The purpose of the paper is to clarify the theoretical formulations related to grants and to present their practical aspects.

Keywords – state aid, transport company, grants, accounting treatment.

I. INTRODUCTION

Transport is a strategic sector in the economy of every country and plays a key role in enhancing its competitiveness, both because of its binding role with other sectors and because of its own contribution to gross value added and employment. The contribution of the transport sector to the gross value added of Bulgaria is about 7-8% and about 5-6% of all jobs. The main responsibility of the state is the designing, development, financing and construction of the transport infrastructure and the transport system as a whole. This requires considerable financial resources, the sources of which may differ. Individual transport companies, especially those related to the social policy of the country, need state support. In principle, the sources of funding are both internal and external. Internal sources are additional contributions from owners and realized profits. External sources are usually associated with used short and long term bank loans. In practice, however, there is another form of business financing. These are grants from the state, so-called state aid.

The main purpose of state aid for some transport undertakings is to encourage them to take actions that they would not have taken without such assistance. The state pursues a certain social policy, which necessitates it to grant aid to certain transport enterprises (Bulgarian State Railways - Passenger Transport Ltd., Bus companies for passenger transportation of unprofitable inland lines, transport in mountain and other regions).

The purpose of present article is to clarify the theoretical assumptions regarding grants and to present their practical aspects in transport enterprises.

II. REGULATION AND NATURE OF STATE AID

The conditions and procedures for granting of state aid in the Republic of Bulgaria are regulated by the State Aid Act (SAA), as well as the Rules for its implementation. These two legal acts are fully in line with the regulations of the Treaty for Functioning of the European Union. The State Aid Act defines the conditions and procedure for granting state aid and minimum aid, state aid categories compatible with the internal market, the procedures for fulfilling the obligations for reporting, collecting, recording and storing data, recovery of the unlawfully obtained minimum aid, improperly used state aid, etc.

In the sense of the SAA, the granting of state aid is compatible with the internal market where the aid:

- is social in nature and is provided to individual consumers, without discrimination regarding the origin of the respective goods (promotes the economic development of areas of low standard of living or high unemployment, supports the implementation of a project of significant economic interest to the European Union or for overcoming significant difficulties in the economy of the Republic of Bulgaria, supports the development of certain economic activities or individual economic regions, etc.);

- is designed to remedy damage caused by natural disasters or other emergencies.

The granting of state aid is carried out in compliance with the following principles:

- Necessity - directing state aid to areas of activity requiring substantial improvement or development that cannot be achieved under normal market conditions;

- Expediency - supporting the achievement of an objective of common interest to the European Union, including when comparing the actual and expected results;

- Proportionality and efficiency - the requirements must be appropriate to achieve the objective pursued and must not go beyond what is necessary to achieve it, aiming for the maximum results with the least amount of state aid;

- Transparency - providing rules for publicity in the provision and spending of public funds in a way that allows access, use and analysis of financial relationships information and which enables monitoring, coordination and control;

- Balanceness - achieving a positive result on taking into account the negative effects on competition;

- Comparability - selecting the appropriate way of granting state aid that has the least impact on competition, when achieving the objective;

- Incentive effect - a positive change in the behavior and activity of the recipient of the aid so that it can carry out the relevant activity which he would not have undertaken without assistance or would have undertaken, but to a limited extent and in a different way.
III. STATE AID REPORTING

The rules for accounting of state aid and the requirements for its disclosure in Bulgaria are regulated by two regulations. These are: National Accounting Standard 20 (NAS 20) - Accounting for Government Grants and Disclosure of Government Assistance and International Accounting Standard 20 (IAS 20) - Accounting for Government Grants and Disclosure of state aid. The application of the international standard or Bulgarian one depends on the accounting base chosen (or compulsory in line with accounting law) for the preparation of financial statements of the enterprise. It can be said that the two standards are almost identical. The difference between them is more terminological than structural. In this sense, the terms "government donations" and "government grants" are used synonymously. The presentation of rules for accounting of grants is in the context of both standards, so the names international and national standard will not be used, but only the Accounting standard (AS) 20 will be discussed. Transport enterprises receiving government grants (respectively government donation) apply the standards of those standards.

When referring to government grants within the meaning of standard 20, they should be construed as government assistance in the form of a transfer of resources to an enterprise in exchange for past or future compliance with certain conditions (with respect to operating activities of the enterprise). Government grants are sometimes called by other names, such as subsidies, grants or bonuses. A requirement of the standard is that state aid is reliably assessed. Forms of state aid that cannot be valued reasonably, as well as government deals that cannot be distinguished from the entity's normal business deals, are excluded from the scope of the standard. In this context, state aid is an action by a government designed to provide an economic advantage to a particular enterprise or a group of enterprises meeting certain criteria. Benefits provided only indirectly through measures affecting common commercial conditions, such as the provision of infrastructure for development or the imposition of trade restrictions on competitors shall not be considered state aid.

According to accounting standard 20, the term "state" (government) is used in a broad sense and is defined as follows: government, government agencies and similar bodies, which could be local, national or international.

In the context of this definition, it is clear that state aid is not only the funds allocated from the state budget, but also the funds allocated under the various operational programs of the European Funds.

In order for a state aid situation to occur through a transfer of grants, there should be a transfer of resources to the reporting enterprise in return for compliance with certain conditions related to its operating activities. The set conditions may already be fulfilled in the past or may be expected to be fulfilled in the future. According to an explanation of the Standing Interpretation Committee (SIC 10 - state aid - none specific link with operating activities) relating to IAS 20, state aid to enterprises fulfills the definition of a grant, even if there are no conditions specifically related to the operational activity of the enterprise, except the requirement to operate in particular areas or industries. These grants should not be directly related to equity.

This clarification makes it clear that state aid is treated as such even when the conditions that accompany it do not specifically relate to operational activity. It is sufficient to have a condition for the development of economic activity in a particular area (e.g. economically backward) or in a particular sector.

State aid is the provision of funds to a transport undertaking for a specific purpose - to acquire assets (for capital expenditure) or for day-to-day activity (so-called subsidies). The specific form of aid may be monetary, non-monetary or forgivable loan.

State aid is obtained as a result of contracts concluded which stipulate the conditions for its practical use, as well as its nature (cash, fixed assets, inventories, securities, etc.). Such a contract, together with the primary accounting documents certifying the receipt of the relevant asset in the transport undertaking, is the basis on which the donation should be recognized and accounted.

For example, one of the largest transport companies in Bulgaria - BDZ Passengers Services Ltd. receives state aid (subsidies - current financing) from the state budget on the basis of a long-term contract for the provision of public transport services in the field of railway transport on the territory of the Republic of Bulgaria. The purpose of this subsidy is to provide the necessary level of transport service, taking into account factors of a social nature as well as those related to environmental protection and spatial planning. This contract is concluded for a period of five years and specifies all requirements and conditions that the state imposes on the railway carrier. The amount of the subsidy for each year is approved by the State Budget Act. The subsidy is intended to compensate the difference between the realized revenues and the costs incurred to provide the transport service. The subsidy is provided on an approved monthly schedule. The means of offsetting the value of free and low-cost trips in the country by rail are provided on the basis of the trips made with the respective preferences. The ground for receiving the compensation is the provision of free and low cost transport services to certain categories of citizens, determined by a law or act of the Council of Ministers. This state aid has increased over the years and from 70 million BGN in 2002 reached 175 million BGN in 2019 - i.e. an increase of 150%.

Despite this increase in state aid over the years, for passenger rail transport it has had negative effects. One reason for this is the untimely compensation of costs incurred.

Apart from grants for current needs, to some undertakings in the transport sector grants for capital expenditures (for the acquisition of fixed assets and for major repairs) are also granted. Of interest is the information on what is the relative share of state aid for the Transport sector of GDP (Gross Domestic Product) for Bulgaria.

<table>
<thead>
<tr>
<th>Year</th>
<th>State Aid for Transport as % of GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>0.2%</td>
</tr>
<tr>
<td>2010</td>
<td>0.3%</td>
</tr>
<tr>
<td>2019</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

1 The transport enterprises receiving state aid for capital expenditures are National Railway Infrastructure Company, BDZ Passengers Services Ltd., BULGARIAN PORTS INFRASTRUCTURE COMPANY.
The data presented shows that state aid (in absolute terms) to the Transport sector has increased over the years. However, as the value of both the gross domestic product and the value of the state budget increased during this period, the relative share of state aid of them remained in near limits. The highest is the relative share of state aid in terms of both the gross domestic product (0.63%) and the state budget (2.79%) in 2019.

Government grants are of two types:

- **Grants related to assets** - State-provided funds, the basic condition of which is that the transport undertaking should purchase, create or otherwise acquire non-current assets. Additional conditions may also apply that limit the type or location of assets or the periods during which they may be acquired or held;

- **Grants connected with revenue** - All funds provided by the government other than those related to assets. Usually, these are funds allocated by the state to cover the current needs of the transportation company.

There are two methods for presenting asset-related grants in financial statements. As for the first method, they are shown as revenue for future periods (financing), and are recognized in profit or loss on a systematic basis over the lifetime of the asset. In the other method, upon receipt of grants the amounts are deducted from the value of the asset. In this case, they are recognized in profit or loss in the form of reduced depreciation expense (for depreciable assets). This method can be applied if the value of the purchased asset is greater than the donation received.

The effect on the financial result of both methods is the same. Therefore, both methods are acceptable under AS 20. However, the first method has the advantage of retaining separately the elements of the value of asset and the aid under statement, which facilitates the comparative analysis of asset acquisitions with or without state aid.

Accounting for revenue-related grants can also be done in two ways, namely:

- the grants are presented as part of profit or loss individually or under a common heading such as "Other income";

- the grants are deducted from the corresponding expenditure to whose compensation they are intended.

According to AS 20, both methods are acceptable and have advantages. The first advantage is that the separation of the aid from the expenditure facilitates the comparative analysis with other costs not affected by it.

The advantage of the second method is that the costs could not have been incurred if no state aid had been granted. Therefore, presenting the expense without deducting the aid could create a false impression on the users of the information in the financial statements.

Regardless of the form in which they are received (cash or as a reduction of a debt to the government), grants are accounted in the same way. Accounting for the amounts received as state aid should be carried out in accordance with the requirements of the applicable standard.

In accordance with the provisions of AS 20, a government donation is presented in the annual financial statements as financing - in other words, the so-called revenue approach. This funding shall be closed and recognized as revenue after the period for which it was granted. In this way, the comparability of recognized revenues with the expenses reported for the period is achieved.

In contrast to the national standard, in the international standard there are two approaches to accounting for grants: capital and revenue. Choosing one of the two approaches is a matter of the accounting policy of the transport company.

In the capital approach, grants are directly related to equity (most often to reserves). The equity approach argues that grants are a financial instrument and should not be reflected in the income statement as such. Since they are not earned by the entity and should not be returned, they should be recorded in the statement of financial position rather than transferred to the income statement to compensate the items of expense that they fund.

In the revenue approach, grants are allocated to revenue from one or more periods. The arguments for applying this approach are:

- Grants are awarded upon compliance with certain conditions and the fulfillment of related obligations. This requires that they should be recognized as revenue by reconciling the expenses for which they are reimbursed;

- Grants are receipts other than equity interests, which imply that they are not recognized directly in equity but in profit or loss for the relevant periods;

- Grants are sometimes a continuation of the fiscal policy (when it comes to deferred budgetary liabilities) of the state and it is logical to treat them in the statement of revenues and expenses as revenues.

The main point in the revenue approach is that the government grants are recognized in profit or loss on a systematic basis over the periods in which the enterprise recognizes as an expense the relevant costs that the grants are intended to compensate.

### IV. RULES ON RECOGNITION OF STATE AID

State aid takes many forms, varying depending on both the nature of the aid provided and the conditions that are usually applied to it. In this connection, there are different rules for their recognition. This article addresses only some of them which are specific to the transport company. They are as follows:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>GDP (million BGN)</th>
<th>State budget (million BGN)</th>
<th>State aid to the Transport sector (million BGN)</th>
<th>State aid ratio to GDP (%)</th>
<th>Relative share of state aid from the state budget (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>81,919</td>
<td>18,404</td>
<td>429</td>
<td>0.52</td>
<td>2.33</td>
</tr>
<tr>
<td>2014</td>
<td>83,857</td>
<td>19,263</td>
<td>489</td>
<td>0.58</td>
<td>2.34</td>
</tr>
<tr>
<td>2015</td>
<td>89,333</td>
<td>18,249</td>
<td>530</td>
<td>0.59</td>
<td>2.90</td>
</tr>
<tr>
<td>2016</td>
<td>95,092</td>
<td>20,624</td>
<td>517</td>
<td>0.54</td>
<td>2.51</td>
</tr>
<tr>
<td>2017</td>
<td>102,308</td>
<td>21,932</td>
<td>522</td>
<td>0.51</td>
<td>2.38</td>
</tr>
<tr>
<td>2018</td>
<td>109,695</td>
<td>23,516</td>
<td>550</td>
<td>0.50</td>
<td>2.34</td>
</tr>
<tr>
<td>2019</td>
<td>113,753</td>
<td>25,463</td>
<td>718</td>
<td>0.63</td>
<td>2.79</td>
</tr>
</tbody>
</table>
1. State aid received in connection with depreciable assets

In this case, revenue is recognized in proportion to the accumulated depreciation of the asset over the relevant period. To understand this rule correctly, we will look at the following example:

A local government body (municipality) is giving a donation of BGN 250,000 to a transport company for the purchase of 5 minibuses (vans) adapted for high mountain operation. The value of the minibuses is BGN 400,000. The condition accompanying the donation is the company to transport workers to a certain area in the mountain, where a hydroelectric installation of important national importance is being built.

The question here is how will the revenue from the donation be recognized?

We assume that vans will be depreciated using the linear method over a period of ten years. In this case the annual depreciation rate will be 10%. The donation must be recognized as income for a period of ten years. For each year of this period the contribution should be recognized in proportion to the annual depreciation of the buses. This means that BGN 25,000 (250,000 x 10%) will be recognized annually as donation income.

2. State aid received in connection with non-depreciable assets

When receiving government grants related to non-depreciable assets - for example land, grants are recognized in the current financial result (profit or loss) over the period that reflects the cost of meeting the conditions associated with the grants. For example, when receiving land as a grant with the condition of building a building on it, the grant received by the state should be recognized in the income statement over the period and in the proportion (ratio) of the useful life of the building itself.

3. Grants associated with revenues as a compensation for past expenses

These grants are recognized as income over the period of their receipt. They are usually provided for services whose sale price paid by the recipient of the service is lower than their cost (this is the case of free and low cost travel of certain categories of citizens by rail, road and water). The purpose is to cover the difference to the full cost. For example, BDZ Passengers Services Ltd. in connection with the social policy implemented by the state (free travel and discounts for some categories of citizens) receives state aid in the form of compensation. They are intended to cover the difference up to the full cost of the transport service. These compensations are approved and accepted as a total amount for one reporting year by the State Budget Act. In order to receive this compensation, the company must prove the number of passengers enjoying these privileges. Every month, on the basis of travel documents, invoices are prepared for the value of the performed services, and they are submitted to the Ministry of Finance for payment.

4. State aid received to cover specific costs

Such an aid shall be recognized as revenue for the same period as its corresponding expense.

Example:

A transport company receives state aid amounting to BGN 100,000 under an environmental protection program. The concomitant condition of this aid is to replace the old engines of the vehicles with new eco-engines. This program must be implemented for a period of 3 years. The actual costs that the enterprise will incur over the next three years are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost (thousands of BGN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
</tr>
</tbody>
</table>

The total cost is BGN 80,000, while the state aid received is BGN 100,000.

According to the rule, the recognition of the revenue from the aid must be done systematically by matching the costs involved. Therefore, the general aid will be recognized by years as follows (Table 2):

<table>
<thead>
<tr>
<th>Year</th>
<th>Recognized State aid revenue (thousands of BGN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 x (10/80) = 12,50</td>
</tr>
<tr>
<td>2</td>
<td>100 x (20/80) = 25,00</td>
</tr>
<tr>
<td>3</td>
<td>100 x (50/80) = 62,50</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

V. Conclusion

With respect to the receipt of state aid and in accordance with the implementation of Standard 20, transport undertakings shall report the following information in their financial statements:

- the accounting policies adopted for government grants, including presentation methods applied in the financial statements;
- the nature and amount of government grants recognized in the financial statements and an indication of other forms of state aid directly benefited by the enterprise;
- the conditions accompanying the receipt of the state aid;
- unfulfilled conditions and other conditions relating to state aid that has been recognized.

References

Одружики транспортни решенија
Sustainable Transport Solutions
Sustainable urban mobility – modern development and perspectives

Asen Asenov¹ and Velizara Pencheva²

Abstract – An analysis of the development of urban transport systems and mobility in major cities of Bulgaria is carried out on the basis of research done on plans for sustainable urban mobility in the country. The specific conditions in the country, studies of literary sources, policies and good practices are the perspectives for developing sustainable urban mobility in Bulgaria. An integrated mobility model has been developed that will be used in an average size town, with different modes of transport and means of active mobility. Results show the prospects for the development of integrated mobility.

I. INTRODUCTION

Despite the measures taken, the speed of development and scale of urbanization makes it difficult for cities to develop efficient and sustainable transport systems, [1].

The need for sustainable urban mobility is receiving increasing attention in its three dimensions:

- economic (efficiency and effectiveness of the systems);
- social (access to all population groups, vision zero for road accidents);
- environmental (reducing the environmental footprint of transport to combat climate change and pollution).

Decarbonisation of the road transport system is a major challenge, especially in urban areas. Despite opportunities for public transport, bicycles and walking, private vehicles continue to dominate mobility modes in many cities, [2].

The search for new solutions related to the modern development of greening technologies for vehicles and intelligent transport systems, as well as new business ideas for reducing the use of private vehicles for driving, especially in cities, are relevant to the current development of transport systems. Insofar as each settlement has its own characteristics, the implementation of existing policies as well as the relevant solutions is not universal. Therefore, when applying specific innovative solutions, it is necessary to take into account the specific features of: the transport system, geographical location, area, transport freight flows, passenger flows, etc.

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II. MAIN EU DOCUMENTS AND INITIATIVES FOR PROMOTING SUSTAINABLE MOBILITY IN THE CITIES

Urban transport systems are an indelible part of the European transport system and therefore an indelible part of the common transport policy. It would be almost impossible for cohesion policy, as well as for other EU health and environmental policies, to achieve their objectives without integrating specific urban features, including urban mobility.

The development of the current EU policy on urban mobility has a long history: the challenges and opportunities for intervention in urban transport are discussed in a number of EU policy documents.

The EU’s main documents in the field of promoting sustainable travel were published after 2006:

- 2011 - White Paper Roadmap to Achieving a Single European Transport Area - towards a competitive, resource efficient transport system “ by 2050;
- 2011, studies by APUM, CIVITAS, ITS Action Plan and Smart Cities;
- In 2013, EC published its Urban Mobility Package. The focus of this document is on energy efficiency in transport and climate change. It addresses the concept of Urban Mobility Plans (SUMPs);
- In 2013, DG MOVE launched the European Urban Roadmap 2030 Study.

Urban mobility is closely linked to other EU policies such as energy, climate change, air quality, economy, social justice and accessibility, innovation, IT deployment and smart cities.

In recent years, a number of scientific and applied research and demonstration projects have been funded in the field of urban mobility research in the European Union. Information on many of these projects, as well as best practices, can be found in the ELTIS European Web Portal on Urban Transport and Mobility, [4].

The CIVITAS initiative is designed to help cities in Europe to implement and test innovative and integrated strategies that address energy, transport and environmental goals, [5].

The Intelligent Energy Program for Europe is STEER. Activities funded by the program's transport sections promote more sustainable use of energy in transport (i.e. increased energy efficiency, new and renewable fuel sources and alternative vehicles).

Horizon Europe is the future EU Framework Program for Research and Innovation for the period 2021-2027. It is a
continuation of the Horizon 2020 Framework Program. The proposal for Horizon Europe includes three pillars: excellence in science; global challenges and competitiveness of European industry; an innovative Europe. The second pillar will support research addressing societal challenges and industrial technologies in areas such as digital technology, energy, mobility, food and natural resources. The second pillar also envisages the introduction of missions and partnerships for some research purposes, like zero carbon emissions.

III. SUSTAINABLE URBAN MOBILITY PLANNING IN BULGARIA

In 2013, the European commission published its Urban mobility package. The focus of this document is the energy efficiency of transport and the climate changes. The concept of Urban Mobility Plans (SUMP) is included in this package, [6].

In Bulgaria, the transport schemes in cities are regulated by the Road transport Act. The municipalities are responsible for the policy and decision-making, related to spatial and urban planning and development of municipal territory.

The concept for sustainable urban mobility is still new in Bulgaria and the development of SUMP is not required by law, [7]. In the national programme of reforms in Bulgaria 2011-2015, the development and implementation of sustainable urban mobility plans (SUMP) was planned for 35 municipalities by the end of 2015, which has not been achieved.

The developing and implementation of SUMP is the initiative of individual municipalities. The developing of the concept is a transition from the traditional planning of migration of people to the cities, oriented predominantly towards developing the infrastructure and planning of sustainable urban mobility, directed to meeting the needs of different groups of people.

The three main elements, which differentiate the approach to sustainable urban mobility (SUMP) are outlined:

- Inclusion of all possible means of travelling in populated places. These are: Quality and energy-efficient public transport, favourable conditions for pedestrian and bicycle traffic; gradual abandonment of the use of private vehicles;
- Evaluation of consumer-related results. Include target indicators: percentage of sustainable movements; reducing greenhouse gas, energy use, etc.;
- Taking into account the needs of different population groups. Active involvement in the discussion and decision-making of stakeholders and the general public.

The inclusion of all possible means of transport in the settlement implies the provision of high quality services by urban passenger transport, provision of conditions for walking and cycling, but above all the search for solutions.

The assessment of consumer-oriented results is linked to the evaluation of environmental and social problems, [8].

The overview of municipalities showed that by mid-2019, 11 Bulgarian cities are working on SUMP (Sofia, Varna, Montana, Veliko Turnovo, Kavarna, Stara Zagora, Kurdjali, Ruse, Burgas, Pleven and Gabrovo). The plan status is at different stages of implementation.

The plan for the capital Sofia is for the interval 2019-2035, with a vision for sustainable urban mobility. „Sofia is developing sustainable urban mobility which is protecting the environment and human health; oriented towards the people, not towards the automobiles, efficient and innovative; safe and secure; integrated and accessible to all. It contributes to transforming the capital into a green, attractive, smart, safe and accessible city“, [9].

Goals:
- reducing the negative impact of transport on people’s health and on the environment (green city);
- increasing the attractiveness of the urban environment and ensuring better quality of life (attractive city);
- implementing transport innovations and strengthening the local mobility and economy (smart city);
- improving the safety and security of all participants (safe city);
- integrated transport system, accessible for all (accessible city).

The distribution of travels on the territory of Sofia by 2017 is as follows: personal automobiles 30,7%; walking 29,7%; urban public transport 37,4; bicycles 1,8; others 0,4.

The target indicators: 20% - private car travels, 80% - sustainable transport (walking, bicycle, urban public transport); in other words, private transport should be reduced by over 130 000 travels (population is maintained at 1,242 million people). The plan for Ruse has been developed for the period 2016-2026 with the following vision: „Achieving high degree of mobility in urban zones and suburbs in conditions of travelling with maximum accessibility, security, safety, and guaranteed environmental protection, to the interest of the local community and as foundation for stimulating internal integrity and sustainable development for the whole region“.[10].

Priority goals:
- increasing the efficiency and attractiveness of the public transport system;
- improving the quality of mobility and creating conditions for alternative types of travel;
- integrating the concept for sustainable mobility in the civic culture of Ruse.

According to the detailed study carried out in connection with developing a project Integral urban transport system of Ruse, the distribution of travels on the territory of the city is as follows: walking - 43,5%; automobile-driver-28%; public transport-20,1% (the ratio of bus rides and trolleybus rides is 59,4 to 40,6%, respectively); bicycles 2,4%; taxi 2,3%; automobile-passenger 2,1%; company transport (mini-bus) 1,1%; motorbike 0,5.

The share of travels by car (automobile-driver-28%, automobile-passenger 2,1%, taxi 2,3%) is 32,4% in total of all travels, which is almost 50% more than travelling with public transport.

The target indicators according to SUMP by 2026 are: increasing walking to approximately 50%, public transport usage to 24%, cycling to 2,5% and reducing travels by car to 21,5%. The remaining 2% are to be distributed among the other categories of the modal split.
To date, three potential avenues for the future of urban transport systems have been identified in literature and transport practice. The first is related to the development of: vehicle greening technologies; intelligent transport systems and transport infrastructure. The other two are related to changing business models and developing: car sharing, [11, 12] carpooling and integrated mobility (Mobility as a Service-MaaS), [13, 14].

These three paths should not be considered separately. Servicing (expanding the range of services and offering complex solutions) of transport on shared and integrated mobility routes can create incentives for even faster technological renewal of transport fleets, [15].

The application of all three options in Bulgaria is realistic, as is their service. By assessing the characteristics of settlements, transport flows and transport schemes, the application can be implemented in two stages:

First stage - provision of conditions for integrated mobility, including multimodal one, for commuters from other settlements by: parking in the outskirts of the city, where the incoming traffic flows; provision of public transport from the parking lots; offering carsharing from parking to the city centre and integrating into MaaS, [16].

Second stage - introduction of the possibility of using the carsharing system throughout the city, by constructing the necessary car parks, taking into account the characteristics of the passenger traffic and introducing a MaaS system for integrated travel management, [17].

Assessment of the occupancy of seven major intersections in the city of Ruse, arranged by intensity, shows a significant proportion of passenger vehicles (an average of 69.31%), followed by vans (14.63%), bus / trolley bus (11.39%), truck (3.51%), bicycle and motorcycle (1.16%), (Fig. 1).

Fig. 1. Average value in percentage of vehicle types at the seven busiest intersections in the city of Ruse

Finding solutions to reduce the use of cars in the city is an important task.

Along with the development and improvement of public passenger transport services, other options are also being sought, especially for reducing the movement of passenger vehicles throughout the city.

Building a MaaS integrated carpooling system can produce good results. Studies of traffic flows show that it could be organized in two stages:

- Stage One: providing a journey for passengers coming from the three main inbound entries with vehicles to the city center. First entry is form Sofia, Svilengrad and Plovdiv; second from Buharest and Silistra; third from Varna;

- Second stage: introduction of a system covering the whole urban territory.

The first stage relates to the inbound traffic flows connected with the algorithm shown in Fig. 2.

A statistical survey to determine the number of passengers traveling by car for the purpose of visiting the city of Ruse, including daily, weekly and seasonal irregularities, can be conducted by collecting information from direct observation or using registering devices. The construction of three parking lots for traffic flow 1, 2 and 3 at the outskirts of the city includes the preliminary determination of their capacity and the intended location of carsharing vehicles; construction of a central parking lot that collects the three rays of carsharing vehicles; inclusion in the route scheme of urban passenger transport for all three parking lots, associated with adjustments to the scheme; provision of a fleet of vehicles for the application of the carsharing system with the capacity to serve the required number of passengers in four locations: flows 1, 2 and 3 at the outskirts of the city and in the city centre (where the main destinations are located). The construction of an information MaaS system is related to its estimated expansion in the second stage of construction. In order for the MaaS system to be effective, it is necessary to involve all transport operators in building the integrated system from the urban passenger transport subsystem, the carsharing subsystem and the Ruse MaaS System. Monitoring and correcting is a prerequisite for success. The adoption of each new system, as a rule, requires a certain amount of time, the introduction of incentives and a strong information campaign, which could speed up the processes.

The second stage of the system construction is related to designating the areas of origin and final destinations of the traffic flows in the city, as well as the construction of stations for carsharing vehicles and electrical cars.

V. CONCLUSION

Regular Urban transport systems are an integral part of the European transport system and, therefore, an integral part of the EU’s common transport policy. There are a number of documents defining the policy for the development of urban transport systems, including decarbonisation and reduction of harmful emissions from road transport, as well as a number of initiatives and programs. However, their application requires taking into account the specificity of the locality concerned.

Developing the Sustainable Urban Mobility Planning SUMP is a transition from traditional urban relocation planning, oriented predominantly to infrastructure development, to sustainable urban mobility planning that addresses the needs of different groups of people. Despite the EC recommendations as of October 2019, only 11 Bulgarian cities are working on SUMP. The plans are at a different stage in their development. The traffic survey at seven major intersections in the city of Rousse shows a significant proportion of passenger vehicles (average 69.31%), followed by light commercial vehicles (14.63%), bus / trolley bus (11.39%), truck (3, 51%), bicycle and motorcycle (1.16%). This shows the serious imbalance in which passenger vehicles overwhelm and burden the traffic, creating serious conditions for traffic congestion.

Building a MaaS system in Ruse for integrated shared travel
can produce good results. Studies of traffic flows show that its construction can be done in two stages; the first stage: providing transfer for passengers from the three main inbound passenger vehicle traffic flows to the city center; the second stage with the introduction of a system covering the entire city territory.

**Fig. 2. The algorithm for the main stages of work for the provision of travels from the main three incoming passenger vehicle traffic flows to the central part of the city of Ruse**

**ACKNOWLEDGEMENT**

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Economic benefits of dynamic charging of electric buses

Mikołaj Bartłomiejczyk 1, Marcin Polom 2, Kristina Jakimovska3, Leszek Jarzębowicz1

Abstract – Diesel engines buses are still the most used buses. Electric buses provide promising green alternatives and a lot of advantages, but the main disadvantage is their limited travel range and charging time. This article is a presentation of innovative solutions for charging of electric busses - Dynamic Charging. The modern IMC system in Solingen was presented. At the end of the article, a proposal was made to introduce a similar solution in Skopje, which would allow the operation of 9 bus lines with electric vehicles.

Keywords – electric buses, trolley busses, electro mobility, dynamic charging.

I. INTRODUCTION

In order for the traction batteries to be charged while in movement (Fig.1) the dynamic charging system (In Motion Charging – IMC) allows part of the route to be secured by trolleybus traction network (OHL – overhead line). While using traction battery power we allow with no contact line the vehicle to cover the rest of the course. However while the flexibility and the functionality of the system are increased allowing the charge of the vehicle without stop-ping. Consequently for reduction in the volume of the traction batteries to occur we cover a part of the route where traction network reduces the distance of the route which is travelled in battery mode.

Moreover the most expensive element of the dynamic charging system is the building of a tracking network. Because of this it is reasonable to take in consideration to cut the length. A contact line with the length of this part has to be enough to charge the traction batteries with energy that is equal at least to the energy needed to uphold the catenary – free section. The lowest degree of uphold of the traction network is at a minimum 40% to 50% at the currently used vehicles. By increasing the charging power to 25% the value of the traction network can be decreased [8, 9]. Consequently in the case of the supply system of 750 V DC the possibility is to be reduced to 20% rate, while in the case of reduction in the heating power of the vehicle or use of thermal pumps, in this case that the coverage should go even below 20%. In Fig. 2 we can see approximately minimal coverage rate in charging power function which means that if we accept that the energy intake for normal vehicle is 3 kWh/km (in the winter) then of an articulated vehicle it is 3,9 kWh/km [1,7].

Fig. 2. Minimum catenary coverage in function of maximal charging power [1, 7]

II. ADVANTAGE OF DYNAMIC CHARGING

Taking in consideration that electric buses are fairly new ways of transport we have to estimate that there is not enough experience in operating them. Consequently it is very hard to determine tendencies toward changes of the purchase prices of the electric vehicles in the future due to the dynamic nature of development of this market. However what is even more obscure is that there is fairly much experience in the field of operating traction batteries with big capacities. Battery life is a key determinant which makes a problem and difficulty assessing it. Inasmuch the risk of entering this kind of transport is very high. There is a difference between them in the main element of the risk:
- Purchasing price and purchasing power of the vehicles
- Cost of replacing the battery
- Risk of traffic crowding and its effect on charging process.

A. Purchasing price and cost of replacing the battery

At this time 50% of the price of the vehicle is the price of the battery [7]. However in a lifetime of a vehicle a battery needs to be replaced at least once. Consequently the drop of the price of the battery is very difficult to evaluate but it is to be

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Professional paper

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anticipated. Inasmuch as what we can predict is that while the electro mobility industry increases in progress as well as increases in demand for energy storage a negative effect in battery cost can be expected.

B) Risk of traffic crowding and its effect on charging process

In order to deliver a right time backup for vehicle charging a stationary charging is required to increase number of servicing transportation line of the vehicle. However this makes a growth in the number of services and the drivers. Inasmuch because of organizational difference of driver services an additional cost can’t be assessed however 50% of maintenance costs of the transport system are the cost of driver’s accounts [7]. A significant increase in cost can be noticed even at the smallest increase in the number of rolling stocks. Due to this factor we notice that this is also a part of the charging element. Thus it is a primary importance to also notice that when the vehicle stops for charging there is traffic disturbance and traffic congestion. Moreover this means that there is a lateness of scheduled arrival time to the final stop which is another cause for less time for recharge of the vehicle [8]. In Fig. 3 we show a situation where a stationary charging cause’s situation where there is not enough stop time to charge the vehicle which is needed to be used as a backup [7].

C) Comparison of risk related with electrification of the bus routes

From economic point of view there is a difference in stationary charged and dynamic charged electrical buses and that difference is in the cost structure meaning that there are bigger fixed costs and lower level of variable costs. A financial analysis was made in terms of comparing the costs of stationary versus dynamic charged buses meaning analyses of costs like maintenance as well as cost of assets. These analyses of cost or financial analyses will include discounted life cycle cost analyses or LCC. Sole purpose of these analyses is to find extreme life cost values for different inputs: the price of purchasing the vehicle, battery replacement price as well as the influence of traffic circumstances on the charging process. We took in consideration 2 different types of scenarios meaning the optimistic as well as the pessimistic approach made by LCC calculator to see the price of an individual cost element.

Life cost value analyses as well as risk value of life cost for the exposure of 20% by catenary and movement interval of 8 minutes is shown in Fig. 4, while in Fig. 5 we have the structure of the cost [7]. The variance of maximum and minimum value of LCC cost is called risk value. Inasmuch it all defines that the investment in the traction network is available to lower the risk that is related to operating costs.

III. PRACTICAL IMPLEMENTATION OF DYNAMIC CHARGING

A) BOB system in Solingen

In Germany, Solingen, the public transportation company SWS has a progressive dynamic charged system, their diesel buses route 695 are transformed to IMC electrical buses. As a charging infrastructure the Solingen trolleybus system will use around 2 km linear dynamic charging track which are the current overhead catenary wires. BOB system (Battery
Overhead wire Buses) which will be the innovative system in Solingen practice vehicles with LTO traction batteries. These vehicles were a collaboration work between Solaris and Kiepe Electric (Table I, Fig. 6). However these batteries that are 2x2.1 km long “IMC charging road” help BOBs to function in a route that 18km long in both ways (Fig.7). Without the overhead wires the vehicles can function 75% of the route on battery mode [6, 9].

![Fig. 6. The BOB Solaris Trollino Kiepe Electric in Solingen (photo Jürgen Lehmann)](image)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Vehicle type</strong></td>
</tr>
<tr>
<td><strong>Vehicle size</strong></td>
</tr>
<tr>
<td><strong>Electric motor</strong></td>
</tr>
<tr>
<td><strong>Energy of battery</strong></td>
</tr>
<tr>
<td><strong>Charging concept</strong></td>
</tr>
</tbody>
</table>

**B) Conception of dynamic charging system in Skopje**

Republic of North Macedonia has a Public Transport Company Skopje (Јавно сообраќајно претпријатие Скопје - Javno soobrakajno pretprijatie Skopje) that maneuvers over 50 urban and 50 suburban bus lines which makes it the largest passenger carrier in the country. The company has a park that is mostly double decker Yutong Chinese buses as well as LAZ models from Ukraine which are in number way lower than Yutong. Consequently many time the City of Skopje tried to plan a tram transport but without a successes. With global warming and the problem with emission that the whole world is dealing with the most reasonable solution as well as a cheaper solution to the emission problem is the form of dynamic charged electric busses. Moreover there are few boulevards the city has that are crowded during the rush hour but the most crowded with high intensity of traffic during the whole day is Boulevard Partizanski Odredi. This boulevard has 14 bus lines at all hours that connect the heart of the city with all parts urban and suburban. Electric charged buses in the IMC system is a possibility for this boulevard since there are multiple lines to operate with if we take into consideration a construction of an overhead contact line along the boulevard. This infrastructure that would be build can be used by many vehicles while reducing the unit cost (per vehicle or per transport work) for construction as well as maintenance. Moreover the suggested route for the trolleybus network for charging vehicles in the IMC system is shown in Fig. 8. Also in table II we list existing bus lines that use dynamic charging. Needless to say the mention trolleybus overhead traction line is 3.5 km long.
TABLE II
JSP BUS ROUTE PREDESTINATED BY IMC OPERATION

<table>
<thead>
<tr>
<th>Bus route</th>
<th>Route length [km]</th>
<th>Length of route under OHL [km]</th>
<th>Covering of route by OHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13,5</td>
<td>3,5</td>
<td>0,26</td>
</tr>
<tr>
<td>2A</td>
<td>14,6</td>
<td>3,5</td>
<td>0,24</td>
</tr>
<tr>
<td>4</td>
<td>9,1</td>
<td>3,5</td>
<td>0,38</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
<td>3,5</td>
<td>0,25</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>2,5</td>
<td>0,25</td>
</tr>
<tr>
<td>21</td>
<td>12,5</td>
<td>3,5</td>
<td>0,28</td>
</tr>
<tr>
<td>22</td>
<td>12</td>
<td>3,5</td>
<td>0,29</td>
</tr>
<tr>
<td>22A</td>
<td>11</td>
<td>3,5</td>
<td>0,32</td>
</tr>
<tr>
<td>26</td>
<td>8</td>
<td>2,5</td>
<td>0,31</td>
</tr>
</tbody>
</table>

Fig. 8. The idea of IMC system in Skopje, based on www.jsp.com.mk

Fig.9. Marrakech's IMC BRT system

IV. CONCLUSION
Using linear structure of the bus routes in the Karposh district is due to the use of the IMC system which makes it potential by using a separate bus lane that has an overhead contact line (fig. 9). Unlike building a tram system this way is much cheaper solution. Rather than building a standard electric bus charger stationary this is more flexible solution while traction network will be used by many buses making it justifiable building the needed infrastructure.

The use of OHL infrastructure for dynamic charging allows reducing the capacity of traction batteries. This is especially important in terms of long-term running costs, as lower battery capacity brings lower replacement cost.

ACKNOWLEDGEMENT
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The Modeling of Travel Demand in the Road Network of Pristina Region

Valerie Bojku Bibaj\(^1\) and Vaska Atanasova\(^2\)

Abstract – In this paper is analysed the current situation of demand in the road transport network in Pristina region and is predicted the traffic flow in the future. The inputs of the model consists of social and economic data, current traffic statistics, previous road-side survey, estimating base year and infrastructure scenarios.

Keywords – Traffic volume, Model, Forecast, Modeling, PTV Visum.

I. INTRODUCTION

This research describes the process and results of traffic forecast for Prishtina region Road Network. The forecast is necessary to find out if road network expansions shall meet the demands for transport. The outputs of this model are predicted road traffic volumes between origin and destination municipalities.

To forecast future road traffic, it is necessary to first contract base year demand matrices. Base year demand matrix which forms the basis of future traffic forecast indicates the amount of traffic between each origin-destination pair at current stage. Year 2017 is considered as the base year of the traffic forecast because it is the most recent year when yearly figures for input data are available. Base year demand is shown in the format of origin-destination (OD) matrices. The unit is in cars for 24 hours.

Since car OD demand is only available in 2011, an extrapolation factor is needed to estimated 2017 car OD demand. Number of car trips can be related to population and the number of registered private car, although population is decreasing, the number of registered private car is growing. Therefore, in this case, the number of registered private cars is better for estimating car passenger traffic than population.

For forecasting in 2025, three scenarios are introduced:

- “Do – minimum” scenario in which at the end of the period in 2025
- “Do – something” scenario and
- “Do – maximum” scenario.

The transport modeling is done with PTV Visum software.

II. GENERAL DATA OF KOSOVO AND PRISTINA REGION

The territory of the Republic of Kosovo counts the surface of 10,905.25 km\(^2\) with 1,798,506 inhabitants. It is situated in south-east Europe, limited with Albania on south-west part, Monte Negro at north-west, Serbia at north-east and with Macedonia on the south. The territory is situated at geographic latitude 41° 51’ and 43° 16’, and within geographic longitude 19° 59’ and 21° 47’.

In terms of regions, Kosovo has got seven regions, 38 municipalities and 1469 settlements. The regions of Kosovo are: Ferizaj, Gjakovë, Gjilan, Mitrovicë, Pejë, Prishtinë and Prizren, as presented in figure 1.

![Fig. 1. Map of seven regions of Kosovo](image)

Fig. 1. Map of seven regions of Kosovo

Prishtina region has got eight municipalities, as: Glogoc, Graçanica, Fushë Kosova, Lipjan, Novobërdë, Obiliq, Podujevë dhe Prishtina with total 296 settlements, with the surface of 2,285 km\(^2\) and with 491,068 inhabitants.

![Fig. 2. Prishtina region and road categorization](image)

Fig. 2. Prishtina region and road categorization

III. GROWTH FACTOR METHOD – TRIP GENERATION

In order to predict the future number of journeys, basic equation is presented below:

\[
T_i = F_i \cdot t_i, \quad F_i = \frac{I_{OD_i}}{I_{OE_i}}
\]

\( T_i \) – Number of journeys in the period of time \( t_i \) for route \( i \)

\( F_i \) – Factor of car passenger traffic

\( I_{OD_i} \) – Number of journeys in travel demand

\( I_{OE_i} \) – Number of journeys in origin-destination (OD) matrices
IV. TESTING AND COMPARISON OF RESULTS THROUGH GEH-TEST

The GEH Statistic is a formula used in traffic engineering, traffic forecasting, and traffic modelling to compare two sets of traffic volumes. The GEH formula gets its name from Geoffrey E. Havers, who invented it in the 1970s while working as a transport planner in London, England. Although its mathematical form is similar to a chi-squared test, it is not a true statistical test. Rather, it is an empirical formula that has proven useful for a variety of traffic analysis purposes.

Comparison results by traffic flow counting of 2011 year and modeling using PTV Visum is done by GEH test. The formula for the “GEH Statistic” is:

\[ GEH = \sqrt{\frac{2(M - C)^2}{M + C}} \]

Where are:
M - peak hour from current model (or new counts),
C - peak hour from current of counting (or previous counts).

Presentation of comparison of these results according to traffic counts and modelling by PTV Visum with application of GEH formula test is shown in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Point of traffic counting</th>
<th>Traffic counts September 2011</th>
<th>Modelled by PTV Visum</th>
<th>Difference in numbers</th>
<th>GEH test (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vranidol</td>
<td>C12</td>
<td>11 285</td>
<td>11 449</td>
<td>-164</td>
<td>1.54%</td>
</tr>
<tr>
<td>Slivove</td>
<td>C10</td>
<td>5 162</td>
<td>5 457</td>
<td>-292</td>
<td>4.00%</td>
</tr>
<tr>
<td>Llugaggi</td>
<td>C8</td>
<td>12 852</td>
<td>12 728</td>
<td>124</td>
<td>1.09%</td>
</tr>
<tr>
<td>Konjuh</td>
<td>C6</td>
<td>12 864</td>
<td>12 881</td>
<td>-17</td>
<td>0.15%</td>
</tr>
<tr>
<td>Sllatine</td>
<td>C9</td>
<td>23 690</td>
<td>23 223</td>
<td>467</td>
<td>3.05%</td>
</tr>
<tr>
<td>Millose</td>
<td>C13</td>
<td>14 163</td>
<td>13 764</td>
<td>399</td>
<td>3.37%</td>
</tr>
</tbody>
</table>

Source: Prepared by author

The comparison show that for all locations results are fulfilled under condition < 5 %, and by comparing results gained by traffic counting with results by modeling using PTV Visum we can conclude that they are under acceptable level.

V. SCENARIOS

For the scenario of base year 2017 the modeling is done and compared with below of three scenarios.
For the base year 2017 scenario (S0) the technical conditions of the road network are:
- Prishtine – Podujeve (Magistral road 1+1 lane, 80km/h);
- Prishtine – Mutivode (Magistral road 1+1 lane, 80km/h);
- Prishtine – Gjilan (Magistral road 1+1 lane, 80km/h);
- Prishtine – Hani Elezit ( Motorway, 130km/h + Magistral road 1+1 lane, 80km/h);
- Prishtine – Peje (Magistral road 2+2 lanes, 100km/h) and
- Prishtine – Mitrovice (Magistral road 2+2 lanes, 80km/h)

The number of scenarios taken is three:
- The first scenario “do - minimum” (S1) in which at the end of the period in 2025:
  Without interventions in the existing situation of roads in Prishtina region:
  - Prishtine – Podujeve (Magistral road 1+1 lane, 80km/h);
  - Prishtine – Mutivode (Magistral road 1+1 lane, 80km/h);
  - Prishtine – Gjilan (Magistral road 1+1 lane, 80km/h);
  - Prishtine – Hani Elezit ( Motorway, 130km/h + Magistral road 1+1 lane, 80km/h);
  - Prishtine – Peje (Magistral road 2+2 lanes, 100km/h) and
  - Prishtine – Mitrovice (Magistral road 2+2 lanes, 80km/h)
- The second scenario “do – something” (S2) in which at the end of the period in 2025:
  With interventions in magistral road Prishtine – Podujeve road and construction of Prishtine – Lipjan – Gjilan Motorway:
  - Prishtine – Podujeve (Magistral road 2+2 lanes, 80km/h + Motorway);
  - Prishtine – Mutivode (Magistral road 1+1 lane, 80km/h);
  - Prishtine – Gjilan (Magistral road 1+1 lane, 80km/h + Motorway);
  - Prishtine – Hani Elezit ( Motorway, 130km/h + Magistral road 1+1 lane, 80km/h);
  - Prishtine – Peje (Magistral road 2+2 lanes, 100km/h) and
  - Prishtine – Mitrovice (Magistral road 2+2 lanes, 80km/h)
- The third scenario “do – maximum” (S3) in which at the end of the period in 2025: The same situation of the second scenario it is also added the construction of Prishtina city’ ring (road).

VI. MODELLING OF TRANSPORT DEMAND MODELLING OF TRANSPORT DEMAND B PTV VISUM

The modeling of S0 and S1 Scenario are presented hereinafter.
Fig. 4. The road categorization of the scenario S0

Fig. 5. Modelling of transport demand for Prishtina region according to existing situation through PTV VISUM software – base year 2017, scenario S0

Fig. 6. Modelling of travel demand for Prishtina region

classified by existing situation through with traffic forecasting of year 2025 – scenario S1

The modeling of S2 scenario is presented below. In this variant it is anticipated to widen the traffic lanes in Prishtine – Podujeve (Magistral road 2+2 lanes, 80km/h) and construction of Motorway in Prishtine – Lipjan – Gjilan and Prishtine – Podujeve.

Fig. 7. The road categorization

Fig. 8. Modelling and forecasting travel demand in Prishtina region using for year 2025 – scenario S2

The Modeling of the scenario “do – maximum” (S3) - In this scenario the situation is the same as medium scenario it is also added the construction of Prishtina city’ ring (road).

Fig. 9. The road categorization
While, the modelling of transport demand within the ring road is presented hereinafter figures.

As it can be seen from the figure 14, the advantage of this scenario is the decongestion of city centre with the construction of Prishtina ring. Thus this investment discharges highways that pass through the city of Prishtina.

VII. CONCLUSIONS

In this research the variables that are get in consideration are; population, car owners, traffic flow, and road network. While, the modeling and forecasting of transport demand until 2025 it was decided to use PTV Visum software which resulted in creating the macro model.

After modelling and forecasting of transport demand for the year 2025 in line with four scenarios, also the level of service is calculated, and then the assessment is done in order to know which the best variant is.

From the modelling results made with PTV Visum software we have:

For base year 2017 or scenario S0, the highest traffic flow is recorded in the Motorway Fushe Kosove - Prishtine, while the highest traffic flow in magistral road is recorded in segment Prishtine – Balice – Peje, whereas the lowest values are registered in the road segment Prishtine – Babush – Hani Elezit. For “do – minimum” scenario (S1), certainly that without intervention to road geometry and with increasing traffic, the road loads are larger in comparison with the scenario S0. Furthermore, the results of level of service (LOS) when we compare two scenario S0 and S1 told as, that the situation of traffic flows will remain difficult because in some segments the service level will reach level F and this means that they need additional capacities until 2025 and particular attention should be paid to improve this current situation, all roads have been downgraded to the service level.

For “do – something” scenario (S2) the construction of motorways has withdrawn the traffic from magistral roads. The highest traffic flow is recorded in the Motorway Prishtine – Hani Elezit, than in magistral road Prishtine – Peje, Prishtine – Mitrovice, Prishtine – Hani Elezit, Prishtine – Gjilan, whereas the lowest values are registered in the magistral road Prishtine – Podujeve.

While, form the results of LOS we have upgraded of level in some directions, as: Prishtine – Gjilan and Prishtine – Podujeve with construction of two motorways.

For “do – maximum” scenario (S3), the condition in magistral roads and motorways is the same, the advantage of this scenario is the decongestion of city centre with the construction of Prishtina ring. Thus this investment discharges highways that pass through the city of Prishtina.

It is also clear that application of scenarios of investments according to LOS this situation would be improved significantly in particular by application of scenario S3. Based on above elaboration we can conclude that the scenario S3 would be the best choices for Prishtina region.

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Developing sustainable urban mobility policy: example from four municipalities in North Macedonia

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Abstract — Within this paper we will present general results from the process of validation of local capacities and resources to manage the process, status and existing condition of five local self-governments in terms of the activities taken and the possibilities for sustainable urban mobility planning, and our recommendations as well.

Keywords — SUMP, Sustainable urban mobility, Strategic planning, Assessment, Municipality.

I. INTRODUCTION

The originality of our results is one more product realised through the project “Support to the local self-government units of the Republic of North Macedonia in promotion of sustainable urban mobility”, implemented by the Association of local self-government units (ZELS) in cooperation with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and based on the assessment carried out in the period July-September 2019. Namely five pilot municipalities were examined: Municipality of Karpash, Municipality of Kumanovo, Municipality of Bitola, Municipality of Ohrid and Municipality of Kavadarcı.

Before the start of the evaluation process, there were many procedures as part of the international project “Sustainable Urban Mobility in South-East European Countries II – SUMSEEC II - Open Regional Fund for South-East Europe – Energy Efficiency” and which were connected to the process of training, evaluation and selection of experts.

At the early beginning with the process of analysing the legal framework, we determined that the development of sustainable urban mobility on a local level is not regulated by existing legal regulation. Indirectly, the Law on Local Self-Government predicts that the jurisdiction of the local self-government will allow it to adopt programs and implement projects for local economic development, which is confirmation that the local self-government has the jurisdiction to adopt a traffic development programme, i.e. mobility, or a sustainable urban mobility planning process. This, more harmonized with European legislation and regulation on sustainable urban mobility, gives clear directions on the future course of our country, municipalities and citizens, as well as many responsibilities on national and local level.

At the top of the European Agenda Sustainable Urban Mobility Plan (SUMP) is placed as highest local strategy document for planning the development of mobility of citizens which as a strategic document is essential in detecting the current state of traffic and urbanism and adopting suitable short-term and long-term (specific and strategic) measures to resolve and identify problems.

In other words, SUMP is the tool that will promote the capacity of the local self-government in the direction of providing condition for decent lives of citizens: health, safety, accessibility, good public transport and sustainable types of transport and overall resilience.

The preparation, adoption, implementation and monitoring of SUMP has a lot of benefits, for the local self-government, and for public institutions, the economy, the non-government sector and of course most of all for the citizens.

II. BASIC SUSTAINABLE URBAN MOBILITY PLANNING BENEFITS

Benefits listed below are part from the recently developed “White Paper on the Development and Planning of Sustainable Urban Mobility in the Republic of North Macedonia”[1], and are as follows:

- **Improving the quality of life in cities** - SUMP is a plan for the people, not cars! This alternative type of planning includes an emotional message, for instance increasing safety of children is one of the goals.

- **Better health and environment** - Improving air quality, reducing noise and mitigating the effects of climate change leads to positive benefits in terms of health and savings on healthcare;

- **Facilitating mobility and improving accessibility** - With people-oriented planning, mobility is improved and there is better access to both space and services.

- **A new political vision and integrated approach for the preparation of better plans and effective monitoring of legal obligations** - The politicians who accept the SUMP vision are politicians who look to the future and politicians who can safely say that they met certain legal obligations such as the Directive 2009/33/EC from 2009 to promote clean and energy-

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✓ Increasing traffic safety and security on roads - One of the basic goals and components of SUMP is increasing the security and safety of all participants in traffic, especially children.

✓ Improving traffic culture - Mobility and safety are components for sustainable planning that must be developed and monitored at the same time. Namely, the Green book on urban mobility entitled “Towards a New Culture of Urban Mobility-2007” defines the following principles:

✓ Successful cities, successful local self-governments and access to funds - SUMP offers excellent opportunities for access to funds for the realization of new and innovative solutions, thus creating conditions for realistic competition between municipalities and/or local self-governments;

✓ Moving towards a new mobility culture - SUMP offers long-term strategic vision, and the planning culture is NEW because it integrates sectors, institutions and citizens;

III. STATE - OF - THE - ART OF SUSTAINABLE URBAN MOBILITY PLANNING CHALLENGES, VISIONS, AND OBJECTIVES FOR THE PILOT MUNICIPALITIES

To provide a strategic guidance for sustainable urban mobility, strategic objectives that indicate the type of desired change were defined together with the stakeholder’s group during the exercises at the workshops in all of the pilot municipalities. Those objectives are: better transport network efficiency, more liveable streets & social activities, better environment protection, better equity of all transport users & social inclusion of all people, better safety, better economic growth by optimizing commercial transport and more financial resources. The importance of the objectives also vary from municipality to municipality, but the objectives such as: more liveable streets & social activities, better environment protection and better safety were indicated as the most important objectives by all municipalities.

Besides the above-stated strategic objectives, operational objectives relating to all modes of transport were also identified specifying what rate of usage of certain transport mode should be “reduced”, “increased” or “maintained”:

- Walking - Maintain the walking rate
- Cycling Increase bicycle use rate
- Public transport Increase public transport use rate
- Private car Reduce car use and ownership rate
- Freight transport Increase the rate of use of low emission vehicles for goods delivery

The above-above stated draft visions are good base for visioning of the future urban mobility with citizens in the focus, for project Municipality’s.

Table I

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Draft common vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipality of Bitola</td>
<td>A CITY of high-quality and eco-friendly mobility, that will promote a safe city, made for people: safe streets, quality parking services, good urban logistics, and walking, cycling and public transport to be the citizens’ first choice.</td>
</tr>
<tr>
<td>Municipality of Kavadarci</td>
<td>A sustainable and accessible city with liveable streets for social activities, quality environment and healthy and active citizens for whom walking, cycling and usage of public transport is the first choice for their daily trips within a city with efficient, safe and barrier-free transport system complemented with environmentally friendly urban logistic and freight transport.</td>
</tr>
<tr>
<td>Municipality of Kumanovo</td>
<td>Sustainable and integrated transport in the Municipality that would contribute to sustainable economic growth, equal possibilities for mobility and clean environment through the realization of alternative possibilities for transport to certain public destinations in the Municipality, better access to people with disabilities and reduced air pollution.</td>
</tr>
<tr>
<td>Municipality of Ohrid</td>
<td>A CITY with high-quality tourism which is a symbol of culture for the citizens and tourists, as well as urban tissue, mobility, safety and a healthy and green environment.</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors

The draft visions are based on analysis of the current mobility situation and addresses the identified problems and perceived opportunities. They consider all modes and forms of transport i.e. passenger and freight, motorized and non-motorized, public and private, moving and parking. The draft vision goes beyond transport and mobility and considers the health, quality of life and land use. The draft visions also places transport and mobility in the wider context of urban and social development and takes into account policy perspectives related to urban and spatial development, economic development, environment, health, safety and social inclusion.

As a result of the responses and comments from the survey on public opinion, and as a result of the realized GRID analysis of some of the stakeholders in the process and representatives of all Urban local communities, as well as the cooperation of the working group on SUMP, the following list of problems and quick-win measures was prepared, which
should be treated within SUMP and which refer to as in Table II.III.

**Table II**
GENERAL PROBLEMS AND SELECTED MEASURES RELATED TO URBAN MOBILITY ON THE CASE OF MUNICIPALITY OF KARPOS

<table>
<thead>
<tr>
<th>Municipality of Karpos</th>
</tr>
</thead>
<tbody>
<tr>
<td>• State of pedestrian infrastructure-poor quality</td>
</tr>
<tr>
<td>• State of cycle infrastructure</td>
</tr>
<tr>
<td>• The need to reduce speed of vehicles and reduce traffic near schools and day care-centres</td>
</tr>
<tr>
<td>• More greenery</td>
</tr>
<tr>
<td>• The need for parking of residents</td>
</tr>
<tr>
<td>• Improving public transport</td>
</tr>
</tbody>
</table>

**Quick-Win Measures**

- **Measure 1** New cycle and pedestrian lanes, connection to the existing network
- **Measure 2**. Traffic calming
  “RAISED PEDESTRIAN CROSSING” is planned for several locations in front of the primary schools, Orce Nikolov day care center, “MINI ROUNDBABOUT” is planned for three intersections.
- **Measure 3**. Pedestrian streets (Newly designed access street/branch of Varshavska St., Access streets in the residential area Bardovci, Interventions along Urban communities according to needs
- **Measure 4**. Construction of new parking lots (Parking near the entrance of vehicles in the center and the Old Town, especially in the summer and on holidays, and as a result of the increased use of construction works on: Parts of ASNOM Street by December 2019, 15-ti Korpus Street, Park of Gaznik, Parking on Ograzhdenski St., “Green” parking platforms

**Table III**
GENERAL PROBLEMS AND SELECTED MEASURES RELATED TO URBAN MOBILITY ON THE CASE OF MUNICIPALITY OF OHRID

<table>
<thead>
<tr>
<th>Municipality of Ohrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Measure 1. Establishing a traffic regime in which pedestrians and cyclists will have the priority</td>
</tr>
<tr>
<td>• Measure 2. Reconstruction of pedestrian lanes and pavements on: Jane Sandanski Street, Makedonski Prosvediteli Boulevard, Taban Square, Makedonija bank Pavements on parts of Dimitar Vlahov and Partizanska Street, ASNOM Street</td>
</tr>
<tr>
<td>• Measure 3. Construction of pedestrian lanes and pavements on: Parts of ASNOM Street by December 2019, 15-ti Korpus Street, Goce Delchev Street</td>
</tr>
<tr>
<td>• Measure 4. Reconstruction and construction of cycle lanes and routes.</td>
</tr>
<tr>
<td>• Measure 5. Modernizing public transport and introducing a uniform for public transport drivers and taxi drivers by June 2021</td>
</tr>
<tr>
<td>• Measure 6. Auditing the public transport network and subsidizing public transport-gradually by 2021</td>
</tr>
<tr>
<td>• Measure 7. Improving and modernizing parking gradually.</td>
</tr>
<tr>
<td>• Measure 8. Construction of multi-storey car parks at the entrance to the central city area from 2020 to 2022</td>
</tr>
<tr>
<td>• Measure 9. Modernizing the system for collection and treatment of communal waste, immediately.</td>
</tr>
</tbody>
</table>

**IV. SUSTAINABILITY OF URBAN MOBILITY CHALLENGES ON THE CASE OF MUNICIPALITY OF KUMANOTO**

Municipality of Kumanovo faces the following main challenges: *road traffic congestion, road accidents, air pollution & noise, poor accessibility & inequity, unliveable & unattractive streets and insufficient transport provision to support local economic growth.*

4.1. Road traffic congestion

It is most intensive in the city centre during the morning and afternoon peak hours. One of the reasons for road traffic congestion is the high level of car usage for daily trips. The most common purposes for car usage is work. The most common reasons for car usage for work purposes are: being a faster mode of transport than other modes, leaving/taking children from kindergarten/school, performing tasks at work.

4.2. Road accidents (fatalities and injuries)

Traffic accidents are also a challenge that the city of Kumanovo is faced with. In 2018, on the territory of the Municipality of Kumanovo, 524 road traffic accidents occurred, in which 8 person were killed, 44 were seriously injured and 255 were slightly injured. The most common cause of traffic accidents in Kumanovo is the speed.

4.3. Air pollution and noise

Kumanovo is one of the most polluted city in the country. Air pollution is most intensive in the period from October to April. Results from measuring stations for PM10 in Kumanovo show that in the above-stated period, the allowed limit value for PM10 was exceeded for about 104 days, and reached up to 200 μm/m³. Currently there is no data on the share of urban transport in the total air pollution in Kumanovo. Regarding the noise, it is most intensive in summer as a result of the increased use of construction machinery and motorcycles.

4.4. Poor accessibility and inequity

The people that live and work in Kumanovo may not be able to access important local services and activities, such as jobs, education, healthcare, grocery shopping or leisure as a result of lack of adequate transport. For example, some people may be restricted in their use of transport due to low incomes or because bus routes do not run to the desired places in the city. Problems with transport provision and the location of services can also reinforce social exclusion. The physically- and visually-impaired people in Kumanovo face unsmooth sidewalks edges at pedestrian crossings. Sidewalk surfaces that are unpaved, poorly maintained or crowded by vendors and urban equipment are common barriers for physically- and visually-impaired people. In addition, sidewalks without tactile surfaces and signalized pedestrian crossings that are not equipped with sound signals are also barriers for visually-impaired people. The public transport is not accessible for physically- and visually-impaired people due to lack of low floor busses with priority seats, lack of disability awareness
and training of bus drivers in assisting these category of people as well as overcrowding.

4.5. Unliveable and unattractive street environment

In general, Kumanovo’s transport policy prioritises major road building and providing new car parks which means supporting and implementing pro-car policies. Also the road planning and design is car-based. The car-policies and car-based design lead to poor infrastructure for sustainable modes of transport and unliveable and unattractive street environment. Beside this Municipality of Kumanovo also takes minor activities for improvement of the walking and cycling infrastructure.

4.6. Insufficient transport provision to support local economic growth

There is no doubt that a relationship exists between the urban transport and the economic development. Traffic congestion, non-regulated urban freight transport and goods delivery services, and poor or unreliable public transport in Kumanovo can impose costs and inhibit the local economic development. Transport difficulties that exist in Kumanovo may be one of the major barriers to local economic growth. Improving sustainable transport options such as: walking, cycling, ridesharing and public transport together with rationalization of goods delivery services and more accessible land use can increase economic efficiency and provide particularly large economic benefits if they substitute for more costly modes such as car transport.

According to the results of the workshop in Kumanovo, the challenges such as: road accidents and air pollution & noise were considered as the most important challenges while unliveable and unattractive streets and poor accessibility & inequity insufficient were considered as the least important challenge. The challenges such as: road accidents and transport provision to support local economic growth were of medium importance.

Priority measures for sustainable urban mobility in Kumanovo are given in Table IV

<table>
<thead>
<tr>
<th>No</th>
<th>Priority measure</th>
<th>Description of the measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temporary pedestrian streets in the city centre</td>
<td>Temporary closing of streets in the city centre with access restriction of motor vehicles.</td>
</tr>
<tr>
<td>2</td>
<td>Intelligent pedestrian crossings</td>
<td>Using of an illumination system which is intended to alert vehicles about the presence of pedestrians in the street. The illumination system is used to highlight the crossing and its surroundings, warning vehicles about the presence of pedestrians and therefore enhancing their safety.</td>
</tr>
<tr>
<td>3</td>
<td>Increase accessibility for elderly or disabled people</td>
<td>Ensuring accessibility for elderly or disabled people in form of smooth and submerged sidewalks edges at pedestrian crossings and using of tactile surfaces.</td>
</tr>
<tr>
<td>4</td>
<td>Comprehensive cycle network</td>
<td>Development of a plan for a comprehensive cycle network in the city that will include a network of cycle routes incorporating segregated cycle facilities (marked lanes, tracks, shoulders and paths), provision of cycle parking, bicycle pump and service stations.</td>
</tr>
<tr>
<td>5</td>
<td>Public pool bikes</td>
<td>Available bicycles in the city or at the workplace allowing people to have ready access to these shared bikes rather than rely on their own bikes.</td>
</tr>
<tr>
<td>6</td>
<td>Low emission zone in the city centre</td>
<td>Low Emission Zones (LEZs) are areas where there is restriction access to high-emission vehicles.</td>
</tr>
<tr>
<td>7</td>
<td>Promotion of walking, cycling and public transport as alternatives to car usage</td>
<td>Use of the media to improve public understanding of the problems caused by traffic growth and the impact of travel behaviour, as well as to convey what can be done to solve these problems, including changing one’s own travel behaviour.</td>
</tr>
<tr>
<td>8</td>
<td>Safe routes to schools</td>
<td>Review of the school roads to find strengths and weaknesses and prioritise measures.</td>
</tr>
<tr>
<td>9</td>
<td>Traffic calming measures</td>
<td>Using of physical measures to reduce vehicle speed and acceleration such as: raised intersections (use of intersections as shared spaces), chicanes, and mini roundabouts.</td>
</tr>
<tr>
<td>10</td>
<td>Lorry routes and bans</td>
<td>Lorry routes are used to achieve routing by specifying the routes which lorries can take.</td>
</tr>
<tr>
<td>11</td>
<td>Regulation of delivery of goods in the city centre</td>
<td>Regulation of delivery of goods in the city centre by implementing time access restrictions, environmental restrictions, vehicle size/load access restrictions etc.</td>
</tr>
<tr>
<td>12</td>
<td>Optimization of traffic signals</td>
<td>Optimization of traffic signals by using actuated and/or semi-actuated traffic signals.</td>
</tr>
<tr>
<td>13</td>
<td>On-street parking charges in the city centre</td>
<td>Parking charges are fees paid by motorists for the use of parking spaces, either in dedicated car parks or in identified on-street parking bays.</td>
</tr>
<tr>
<td>14</td>
<td>“On demand” public transport service</td>
<td>Nowadays low density areas are covered by the private transport due to the lack of routes or to the limited spatial coverage of public transport. The main objective of the demand responsive transport is to provide a more effective response to low density mobility demand not satisfied by local public transport.</td>
</tr>
<tr>
<td>15</td>
<td>Extension of the public transport network with new lines served by low-floor vehicles</td>
<td>Developing of new transport lines for better coverage of the city with public transport.</td>
</tr>
<tr>
<td>16</td>
<td>Real time information app for passengers</td>
<td>The real time information app allows passengers to access real i.e. live departure information for public transport services via a variety of different sources.</td>
</tr>
<tr>
<td>17</td>
<td>Education of school children</td>
<td>Implement traffic safety education.</td>
</tr>
</tbody>
</table>
V. CURRENT POLITICAL, TECHNICAL AND OPERATIONAL CHALLENGES RELATED TO SUSTAINABLE URBAN MOBILITY

The current political, technical and operational challenges facing the municipalities are presented below.

A. Political challenges

Based on the review of the programs of the mayors of the municipalities for the period 2017 - 2021, it can be noted that regarding the mobility, most of the measures are related to improving conditions for car travelling and encouraging car usage for daily trips, there are some measures for improving of walking and cycling but almost there are no measures for improving and promotion of the public transport in the cities.

B. Technical challenges

The current human resource capacity in the municipalities is focused on planning for movement of vehicles instead of planning for movement of people. Increasing the human resources capacity focused on planning for movement of people and liveability (e.g. including urban planners, transport experts) is a key to supporting a transition towards sustainable urban mobility. These people should reflect a diverse range of disciplines and should have an appropriate level of technical expertise.

Integrated planning between transport and land-use planning is crucial to avoiding unsustainable car-oriented development leading to high traffic levels and congestion. The sustainable urban mobility plan should be a prerequisite for any urban development.

C. Operational challenges

The effects of the implemented measures are not assessed in any municipality, so there is no evidence of the contribution of these measures in achieving the aim of a certain measure. The municipality needs to build a strong evidence-based policy-making and analysis process, and to see whether a progress is or is not being made in relation to the priorities. The municipalities should use wider indicators of urban mobility performance and should ensure that data is carefully collected and measured.

There is a need to anticipate the transport related problems in municipalities. In order to anticipate the road traffic congestion problems, the municipalities implement measures for increasing road capacity, such as widening the streets, while in order to anticipate the air pollution from transport, the municipality implements measures for restriction of car usage. These problems should be anticipated by providing attractive and efficient alternatives to car use, in particular collective transport and active travel. The infrastructure is primarily built for vehicle movement instead of movement of people and for making of leisure places. The investments are focused on road infrastructure solutions that support further car use instead of focusing on sustainable urban mobility solutions, including public transport, cycling and walking. Pupils who rely on public transport are already used to using it which means if alternative mobility options are provided to them in the future, they will be less likely to rely on car use.

Once alternatives to car use are in place, the municipality can discourage car use and encourage a shift to more active and sustainable modes by making car travel more expensive, slower and less convenient than the alternatives (e.g. by taxing private vehicles or their use, by increasing parking fees, by decreasing the space allocated to car use).

VI. CONCLUSION AND RECOMMENDATIONS

Mobility is a key urban priority. It is central to how a city operates and has a significant impact on the quality of life, the local environment and resource consumption. Effective urban mobility systems can be enabled by accommodating all modes of transport. The system can be further optimised by integrating mobility planning with the spatial planning while considering how products and services are produced and accessed.

The sustainable urban mobility planning concept implies application of the existing planning practices by incorporating the principles of integration, participation and evaluation, i.e. integrated development of all modes of transport, full involvement of all stakeholders and citizens in the planning process from the beginning and demonstrating a clear link between objectives and measures due to assessing the achieved results in relation to the objectives.

To address the current challenges related to sustainable urban mobility, priority measures i.e. quick wins measures which are low-cost, justified and easily implementable were identified together with the stakeholder’s group during the exercises at the workshops which was held in the municipalities. The measures are related to: strategic policy; capacity building activities; traffic safety; collective transport; Infrastructure for active modes of transport (walking and cycling); promotion of sustainable modes of transport and awareness campaigns; traffic management; and parking management.

Namely, the Municipality of Bitola for example is facing real problem of exaggerated street profiles in the plans, fast main roads, all of which is contrary to the existing situation in the field. This indicates that during the construction stage, design solutions were not followed and that the urban design
documentation was not harmonized with regulation plans. Therefore, there is a real need to find an appropriate approach to overcome this problem, and currently that is the design of urban project documentation on current situation (infrastructural projects) and strategically the preparation of a new General Urban Plan, with new categorization of street network that would be based on the Sustainable Urban Mobility Plan.

With this process of previous evaluation by the local self-government, positive recommendations are provided for the pilot municipalities to continue with the process of activities for sustainable urban mobility planning. Furthermore, expected short-term benefits are:

- Established cooperation procedure between the actors on local level;
- Raising public awareness through information and inclusion of the public in issues related to mobility, traffic and urbanism;
- Created conditions and capacities on local self-government level for the use of existing resources, good management and awareness of the need for coordinated solution of problems in the area of mobility and traffic in the municipalities.

Planning for the future of the city must take the citizens as its focus. Unlike the traditional approach, when planning for sustainable urban mobility, the focus is on walking, cycling and public city transport in front of passenger cars and trucks.

- Expanding the Department with experts from the area of traffic engineering and design;
- Promotion of development of a sustainable urban environment with higher quality and rational use of the urban area and street space;
- Preparation of an ACTION PLAN with a TIME FRAME with actionable measures, indicators and targets;
- Continuing initiated activities for sustainable urban mobility planning with the additional participation of citizens in order to examine the modular distribution of trips;
- Additional training of the working group to apply the measures for Sustainable Urban Mobility.
- Additional training to apply the software tool for solving of issues related to Urban Mobility.
- Managing the implementation of measures;
- Promotion of measures;
- Monitoring an analysis of results;
- Information.

ACKNOWLEDGEMENT

We would like to express our special gratitude to all SEE coordinators of the SUMSEC II project, ZELS coordinator, as well as the CRPM project with the SEE parliamentarians, which helped us in doing a lot of Research on the sustainable urban mobility in our municipalities.

REFERENCES

Survey results on the level of support for greater bicycle use in Strumica
Nikola Krstanoski¹, Vaska Atanasova² and Ratka Petrova³

Abstract – In this article, a survey of level of support of bicycle mode of transport in Strumica is presented. A sample of answers from 300 citizens has been statistically analyzed in order to reveal how the general public and different categories of inhabitants respond to such policy. The results show vast support for greater use of bicycle among all categories of respondents.

Keywords – Bicycle, survey, policy support

I. INTRODUCTION

Traffic congestion and loss of time, lack of parking spaces, low traffic safety, and increased harmful emissions from motor vehicles are problems that every local government has been trying to solve. It has been widely accepted nowadays, that a proper answer to these challenges is to accept and implement a policy for development of sustainable urban transport system. The core of this policy is to discourage the use of automobiles in cities and to support other cleaner modes of transport.

However, a review of current modal split in Macedonian cities shows that the bicycle transport takes part with less than 2% of all urban trips [1]. This is true for all macedonian cities. Great contribution to such situation comes from the fact that the bicycle as a mode of transport has been entirely neglected for many decades. There is no at all, or there is poor bicycle infrastructure, while the ownership and usage of automobile has increased significantly and has become dominant mode of urban transport.

In recent years, with the increasing concern of the public with the urban traffic problems and pollution, the concept of sustainable urban mobility emerges as a possible solution. However, the local governments in Macedonian cities seem to be restrained to fully implement a policy of sustainable urban transport, due to the mixed reaction from the citizens. On one hand, the public requires clean environment and better quality of life in cities, but on the other hand, there is a negative reaction when measures such as parking fees and restriction of car movement is implemented.

A valuable help to politicians with policy making process would be a survey that will investigate the level of support for certain sustainable transport solutions.

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³Faculty for Technical Sciences, Makedonska falanga 33, Bitola, Macedonia, e-mail address: ratka.petrova@yahoo.com

In this article, a survey done in the city of Strumica is presented. The objective of the survey is to investigate the level of support of policy for greater investment in bicycle infrastructure and support for greater use of bicycle in the city.

According to the census from 2002 Strumica has 54676 citizens [2]. In year 2018 there were 11909 registered vehicles [3]. Currently, the total length of bicycle lanes is 4845 m. Mostly, those lanes are marked by horizontal signalization only and are positioned on the pedestrian sidewalks.

II. SURVEY METHODOLOGY

For the purpose of this research a survey has been done by interviewing over 300 citizens on the streets of Strumica during three days in April 2019. The locations where the survey took place, were carefully chosen in order to get representative sample that would include different categories of population. The locations were: the city’s green market, center city and the city’s biggest shopping mall. The survey has been supported by the local government and the local media that informed the citizens about the purpose and time of the survey.

There were total of 300 valid responses. The results of the survey have been analyzed using the SPSS statistical software package.

Data about age, household size, car ownership, bicycle ownership, current usage of bicycle and the major obstacles for bicycle use today, have been collected. The final two questions were whether they would support a policy of local government that would promote greater use of bicycle and whether they would use bicycle more often if the bicycle infrastructure was improved.
III. ANALYSIS OF THE SURVEY RESULTS

Participants in the survey have been divided in three age categories: below 18, between 18 and 50, and above 50 years of age. As can be seen from Table 1, 13% of responded were under 18 years old, 54,3% between 18 and 50 years and 32,7% above 50 years old.

A great majority of respondents of 86,7% said that they would support bicycle promotion policy, only 1,3% would not, and 12% did not know.

In order to test if there is significant difference in responses from the different categories of age, two statistical tests have been performed. The z-test and the standard residuals (table 1) have shown that the null hypothesis that there is no significant difference in responds from different categories of age cannot be rejected at significance level of 0,05.

TABLE 1. Age category vs support of bicycle policy

<table>
<thead>
<tr>
<th>age * policy support Crosstabulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>policy support</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>below 18 Count</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within age</td>
</tr>
<tr>
<td>% within policy support</td>
</tr>
<tr>
<td>Std. Residual</td>
</tr>
<tr>
<td>18 to 50 Count</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within age</td>
</tr>
<tr>
<td>% within policy support</td>
</tr>
<tr>
<td>Std. Residual</td>
</tr>
<tr>
<td>above 50 Count</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within age</td>
</tr>
<tr>
<td>% within policy support</td>
</tr>
<tr>
<td>Std. Residual</td>
</tr>
<tr>
<td>Total Count</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within age</td>
</tr>
<tr>
<td>% within policy support</td>
</tr>
</tbody>
</table>

Each subscript letter denotes a subset of policy support categories whose column proportions do not differ significantly from each other at the .05 level.

The Chi-square test (table 2) also confirms the result that there has been no difference among different categories of age regarding the bicycle policy support.

According to the Chi-square test p = 0,654 > 0,05, so the null hypothesis that there is no difference in approval of policy can not be rejected. Because 4 cells violate the assumption that number of counts should be greater than 5, the look at the likelihood ratio 0,653 >0,05 again confirms the same result.

TABLE 2. Age category vs support of bicycle policy chi-square test

<table>
<thead>
<tr>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,447</td>
<td>4</td>
<td>.654</td>
</tr>
<tr>
<td>2,451</td>
<td>4</td>
<td>.653</td>
</tr>
<tr>
<td>.304</td>
<td>1</td>
<td>.581</td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 4 cells (44,4%) have expected count less than 5.
The minimum expected count is .52.

The analysis of the survey results related to the car ownership and bicycle policy support is given in table 3.

Out of 300 respondents, 12,3% said that their household does not own a car, 56,3% own one car and 31,3% that own two or more cars.

86,5% of those with no cars, 88,2% of those household with one car and 85% of those with two or more cars, support the policy. The wide support among all categories is obvious, but it is interesting to notice the high percent of support even by households that own two or more cars.

The z-test shows that the null hypothesis of no significant difference between different categories ca not be rejected at level of significance of 0,05.

The chi-square test confirms this result (table 4) since p = 0,093 > 0,05.

Regarding the chi-square test, 4 cells violate the assumption that number of counts >5 so the look at the likelihood ratio 0,128 >0,05 again shows that the null hypothesis cannot be rejected.

The next analysis is about the bicycle policy support and ownership of bicycle. The respondent’s households were divided in four categories: households that do not own a bicycle, ones with one bicycle, ones with two bicycles and ones with three or more bicycles.

Out of sample of 300, 12% have no bicycle at all, 40,3% have one bicycle, 34,3% have two bicycles and 13,3% have three or more bicycles (table 5). These results show that the bicycle ownership in Strumica is rather high.

The results of the analysis of the bicycle ownership vs support of bicycle support is given in tables 5 and 6.
### TABLE 3. Car ownership and bicycle policy support

<table>
<thead>
<tr>
<th>car ownership * policy support Crosstabulation</th>
<th>policy support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;yes&quot;</td>
</tr>
<tr>
<td>&quot;0&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within car ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;1&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within car ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;2 or more&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within car ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within car ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
</tbody>
</table>

Each subscript letter denotes a subset of policy support categories whose column proportions do not differ significantly from each other at the .05 level.

### TABLE 4. Car ownership vs policy support chi-square test

<table>
<thead>
<tr>
<th>Chi-Square Tests</th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>7,952</td>
<td>4</td>
<td>.093</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>7,146</td>
<td>4</td>
<td>.128</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>1,105</td>
<td>1</td>
<td>.293</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 4 cells (44,4%) have expected count less than 5. The minimum expected count is .49.

### TABLE 5. Bicycle ownership and bicycle policy support

<table>
<thead>
<tr>
<th>bicycle ownership * policy support Crosstabulation</th>
<th>policy support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;yes&quot;</td>
</tr>
<tr>
<td>&quot;0&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within bic ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;1&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within bic ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;2 or more&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within bic ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;3 or more&quot;</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within bic ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
<tr>
<td></td>
<td>Std. Residual</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td>Expected Count</td>
</tr>
<tr>
<td></td>
<td>% within bic ownership</td>
</tr>
<tr>
<td></td>
<td>% within policy support</td>
</tr>
</tbody>
</table>

Each subscript letter denotes a subset of policy support categories whose column proportions do not differ significantly from each other at the .05 level.

The z-test shows that there is a difference in bicycle policy support among different categories of bicycle ownership. The standard residual of 3.6 for the household with no bicycle and answer “no” for support of bicycle policy shows the biggest difference, compared to other categories of bicycle ownership. Also the standard residual of -2 for the household with one bicycle and with answer “I don’t know” shows the difference compared to all the others.

The chi-square test confirms the result that there is a significant difference in bicycle policy support between...
different categories of bicycle ownership since \( p = 0 < 0.05 \) and the null hypothesis that there is difference in approval of policy is rejected (table 6).

6 cells violate the assumption that number of counts \( >5 \) so the value of the likelihood ratio \( 0 < 0.05 \) again confirm the result that the null hypothesis is rejected.

TABLE 6. Chi-square test for bicycle ownership vs bicycle policy support

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>38,165</td>
<td>6</td>
<td>0.000</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>30,282</td>
<td>6</td>
<td>0.000</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>0.695</td>
<td>1</td>
<td>0.405</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 6 cells (50.0%) have expected count less than 5. The minimum expected count is 0.48.

The analysis of the main obstacle for greater use of bicycle in Strumica today has shown that the major concern is about traffic safety. 73.33% complained about low safety, 9.67% said they did not own bicycle, 6.67% answered that the problem is lack of bicycle parking spaces (figure 2).

![Frequency](image)

**Fig. 2 Main obstacle for greater bicycle use today**

Given the perception of the survey respondents that the poor bicycle infrastructure is important reason for low importance of bicycle as transport vehicle in the city, it is interesting to analyze, would they use it more frequently if the bicycle infrastructure is greatly improved.

The answers to this question has been first analyzed in relation with the age of the respondents. The result of this analysis are given in tables 7 and 8.

TABLE 7. Age vs use of bicycle if the infrastructure is improved

<table>
<thead>
<tr>
<th></th>
<th>if better infrastructure use</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&quot;no&quot;</td>
<td>&quot;maybe&quot;</td>
</tr>
<tr>
<td>&quot;below 18&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Expected Count</td>
<td>3.3</td>
<td>7.2</td>
</tr>
<tr>
<td>% within age</td>
<td>2.6%</td>
<td>23.1%</td>
</tr>
<tr>
<td>% within if better</td>
<td>4.0%</td>
<td>16.4%</td>
</tr>
<tr>
<td>Std. Residual</td>
<td>-1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>&quot;18 to 50&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>Expected Count</td>
<td>13.6</td>
<td>29.9</td>
</tr>
<tr>
<td>% within age</td>
<td>4.9%</td>
<td>18.4%</td>
</tr>
<tr>
<td>% within if better</td>
<td>32.0%</td>
<td>54.5%</td>
</tr>
<tr>
<td>Std. Residual</td>
<td>-1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>&quot;above 50&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Expected Count</td>
<td>8.2</td>
<td>18.0</td>
</tr>
<tr>
<td>% within age</td>
<td>16.3%</td>
<td>16.3%</td>
</tr>
<tr>
<td>% within if better</td>
<td>64.0%</td>
<td>29.1%</td>
</tr>
<tr>
<td>Std. Residual</td>
<td>2.7</td>
<td>-0.5</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td>Expected Count</td>
<td>25.0</td>
<td>55.0</td>
</tr>
<tr>
<td>% within age</td>
<td>8.3%</td>
<td>18.3%</td>
</tr>
<tr>
<td>% within if better</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Std. Residual</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Each subscript letter denotes a subset of if better infrastructure use categories whose column proportions do not differ significantly from each other at the .05 level.
From the results in table 7, it seems that people in Strumica would respond quite positively in terms of greater use of bicycle if the bicycle infrastructure was improved. 38,5% of the youngest category said they would use bicycle every day and another 35,9% said they would use bicycle often. Only 3,3 % answered that they would no use a bicycle.

Similar results have been found for the category of age between 18 and 50. 38% said they would use bicycle every day and another 38,7% said they would use bicycle often. Only 4,9 % answered that they would no use a bicycle.

The answers from the oldest category of respondents are interesting. Very high percent (42,9%) answered that they would use bicycle every day, but at the same time, compared to other age categories, the highest percent (16,3%) said that they would not use the bicycle at all.

The z-test shows that the null hypothesis that there is no difference between answers of different age categories cannot be accepted. There is a difference! The standard residual of 2,7 shows that there is significant difference between categories of respondents.

TABLE 8. Car ownership vs greater use of bicycle if the infrastructure is improved

<table>
<thead>
<tr>
<th>car ownership vs if better infrastructure use Crosstabulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>if better infrastructure use</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Count</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within car ownership</td>
</tr>
<tr>
<td>% within if better</td>
</tr>
<tr>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;1*&quot;</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within car ownership</td>
</tr>
<tr>
<td>% within if better</td>
</tr>
<tr>
<td>Std. Residual</td>
</tr>
<tr>
<td>&quot;2 or more&quot;</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Expected Count</td>
</tr>
<tr>
<td>% within car ownership</td>
</tr>
<tr>
<td>% within if better</td>
</tr>
<tr>
<td>Std. Residual</td>
</tr>
</tbody>
</table>

Each subscript letter denotes a subset of if better infrastructure use categories whose column proportions do not differ significantly from each other at the .05 level.

The chi-square test (table 10) has shown that $p = 0,001 < 0,05$ and the null hypothesis that there is no difference in responses if better infrastructure is rejected. There is a significant difference.

One cell violate the assumption that number of counts >5 so checking of the value of the likelihood ratio $0,001 <0,05$ again shows that there is significant difference between categories of respondents.
TABLE 10. Chi-square test for car ownership vs greater use of bicycle if the infrastructure is improved

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymp. Sig. (2-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>22,537</td>
<td>6</td>
<td>.001</td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>22,097</td>
<td>6</td>
<td>.001</td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>1,171</td>
<td>1</td>
<td>.279</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 1 cells (8,3%) have expected count less than 5. The minimum expected count is 3.08.

IV. CONCLUSIONS

Among important problems that Macedonian cities are faced with, certainly are the traffic congestion, lack of parking spaces and the increased pollution. The voice of public demanding better quality of life and solving of these problems are more load every day. However, the local governments are sometimes faced with negative public reactions when certain transport sustainable measures are proposed. Measures such as parking fees, restriction of car movement, higher taxes for dirty vehicles, taking traffic lanes for public transport or bicycle lanes, are not always met with public approval. Therefore, before implementing a sustainable transport policy it is important to use all instruments in order to explain to the public the benefits for all of such policy, as well as to check the response of public to certain sustainable measure.

In this article a survey of the public response to a policy for greater support and better infrastructure for bicycle transport mode in the city of Strumica.

The survey included 300 respondents. The analysis of the results of the survey has shown widespread support for bicycle transport mode over all categories of respondents.

Regardless of the age of the survey participants, the support for bicycle policy ranged between 83.7 and 89%. The statistical tests have shown that there is no difference in support between different age categories.

Similar high support for bicycle support policy has been found in regards with car ownership. 86.5% of those with no cars, 88.2% of those household with one car and 85% of those with two or more cars, support the policy. The wide support among all categories is obvious, but it is interesting to notice the high percent of support even by households that own two or more cars. Again statistical tests have not shown significant difference between different car ownership categories.

The analysis of the level of bicycle ownership in Strumica has shown rather high values. Out of sample of 300, 12% have no bicycle at all, 40.3% have one bicycle, 34.3% have two bicycles and 13.3% have three or more bicycles.

As expected, the analysis of the bicycle support policy in relation with bicycle ownership has shown very high support for the policy in average 86.7%. However, the statistical tests have shown that there is a difference in support depending on the bicycle ownership category. The biggest difference is in responses of people that do not own a bicycle and in higher than expected number answered that they would not support or don’t know if they would support bicycle policy.

Regarding of the level of bicycle use if the bicycle infrastructure is improved, it seems that people in Strumica would respond quite positively.

38.5% of the youngest category said they would use bicycle every day and another 35.9% said they would use bicycle often. Only 3.3% answered that they would no use a bicycle.

Similar results have been found for the category of age between 18 and 50. 38% said they would use bicycle every day and another 38.7% said they would use bicycle often. Only 4.9% answered that they would no use a bicycle.

The answers from the oldest category of respondents are interesting. Very high percent (42.9%) answered that they would use bicycle every day, but at the same time, compared to other age categories, the highest percent (16.3%) said that they would not use the bicycle at all.

The results of the survey also have shown intention for greater use of bicycle regardless of the car ownership also. Among those who do not own a car, 54.1% said they would use the bicycle every day. Surprisingly, 21.6% said they would not use the bicycle at all.

33.1% of those with one car said that they would use bicycle every day and another 39.1% that they would use it often. 7.7% would not use bicycle at all.

The support for bicycle is rather high with in a category that owns two or more cars. 45.7% would use bicycle every day 29.8% often, and only 4.3% would not use it at all.

Here, an unexpected result has been rather high number of participants of survey (21.6%) that do not own a car, and answered that they would not use a bicycle at all.

In general, the results of this survey have shown high support of policy that would give more important role of bicycle as a mode of transport in Strumica. Hopefully, this will encourage the local government to take action in this direction, as part of the efforts to build more sustainable transport system in Strumica.

REFERENCES


Security of the control of the transportation systems

Nikolay Iv. Petrov

“To get rid of the risk (insecurity) of occurrence of an accident is not possible. The main hazard is not in the lack of security but in that to take risks subconsciously, irrepressibly. The risk – it is both an opportunity and a specific advantage, and a weapon of the knowledgeable.


Abstract – Traffic congestion and resulting pollution affect the quality of life in cities, notably in countries with dominant old diesel engines. One solution is Adaptive Traffic Signal Control using vehicle type and emission measurements. Therefore, a fuzzy controller using magnetic sensor for classifying vehicles and sensor for measuring emissions is proposed.

Keywords – security of control, transportation systems, reliability.

I. INTRODUCTION

In the process of design, production, storage and operation of transportation systems (TS), the tasks of their technical control occurs. The objective is maintenance of the necessary level of reliability of TC. According to the fundamental work of Prof. Evgeniy Gindev, DscTech. “Foundations of Applied Reliability”, Sofia, 2000, control of the technical condition should mean a process of obtaining and processing of information about the correspondence between the condition of the object of control (OC) and its current primary and secondary parameters (PSP) set by the manufacturer and determine using the means of control and measurement (MCM).

Let us analyze the words “control” and “security”. The verb control has been borrowed from the international technical jargon and originates from the French word controle with the German component iran [2]. The word controle is compound and consists of two parts: contra (against) and rola (roll, shutter). There are convenient Bulgarian replacement words, which are used in co-njunction with it: verification, testing, review, inspection, etc.

Regarding the word ‘security’, the following definition is available: „Security is a degree of resistance or prevention of the objects and the system of objects from harm. It applies to anything which is valuable and at the same time vulnerable” [2]. Regarding the problem of value of the information about the objects and systems, familiarization with the co-author’s work “Dialectics of Information” with authors N. Iv. Petrov, Iv. N. Petrov, Sofia, Publishing house “Prof. Marin Drinov”, 2020 is necessary.

Exposition: After the brief introduction on the topic of the report, a definition of security of control in TS should be given: “Security of control is a process of receiving and processing of reliable information about the correspondence between the studied subject (TS), its current PSP and the results of the measurements carried out through MCM.”

The so introduced definition of security of control requires the introduction of an analytical expression for determination of the quantity of reliable information \( I_{RI} \) regarding TS, determined by using the formula [10]:

\[
I_{RI} = \sum_{i=1}^{n} p_i \log_2 p_i \exp \left( - \int_{t_1}^{t_2} \omega \ dt \right),
\]

where TS has \( n \) exits and each exit has a probability of occurrence (realization) \( p_i \), in the availability of occurrence \( 0 \leq p_i \leq 1 \). Accordingly, \( \omega(t) \) is the intensiveness of the flow of refusals (failures – hardware and/or software) in TS for the observed time interval \( \Delta t = t_2 - t_1 \).

While using (1), the information about the current technical condition of TS and their MCM should not be mixed. Therefore we will conditionally talk about transportation systems (TS) and their elements (MCM). The means of control and measurement (MCM) are used for the performance of the following activities:

- measurement of the TS parameters for the purpose of identification of their condition (control of their current reliability);
- determination of the place of refusal or failure in TS;
- prediction of the future condition of the studied object.

For any technical activity (process), ‘control’ is described with the following main specifications:

- volume or space of the controlled parameters;
• sequence of the control;
• mode of TS control (operating or non-operating);
• regularity of control (continuous, discrete, single or repeated);
• trueness (reliability) of the control;
• price of the TS control.

The so indicated specifications of TS control determine the descriptive quality of this very responsible process. The process itself is implemented by means of performance of separate checks (measurements) and in each check the current condition of the parameters of the inspected object of control (TS) is determined. The aggregate of all possible checks of the parameters of the transportation systems (VS) forms the space of the parameters of those systems.

II. APPROACHES TO THE CONTROL OF THE TRANSPORTATION SYSTEMS

Those approaches are of two types, in the first ne the probable parameters of TS are calculated taking into account the influence of MCM. As an example, the theoretical works [4, 5, 6] are indicated. In the second approach [8] the MCM system is studied and optimized, provided that the structure of the object of control is considered known and permanent. Optimization of the controlled system (MCM) is carried out in the availability of two types of restrictions regarding the object of control: fundamental and operating.

The fundamental restrictions refer to the following conditions of the objects of control:
- The elements of OC fail independently of each other;
- No new elements fail during the time of control;
- The accidental modifications of the controlled parameters are not reported;
- In the availability of spare elements of OC, their hazard for failure (probability of failure) is assumed as equal to the hazard of failure of the main part of OC;
- In the space of checks of OC (its PSP), carried out through MCM, there is no global inspection which leads to instant control.

The specification of the operating restrictions is that they undergo changes which do not influence the reliability of the obtained results, just their volume.

III. OPERATING RESTRICTIONS IN THE CONTROL OF TS

The majority of the contemporary publications related to the theory of optimal control are based on the following operating restrictions:
- Prior to commencement of the control it is known that the technical object is faulty or has failed;
- Each separate check from the space of checks has one and only one of the two possible outcomes: positive or negative;
- The technical object fails when one of its elements fails;
- The space of checks is sufficient to find the failed element in case of finite number of checks.

It is necessary to note that the operating restrictions are considerable and significantly narrow the class of studied control systems. However, a common solution of the problems related to the TS control, even within the framework of those strong restrictions, cannot be easily found (see the three problems of Bellman) [9, 11, 12]. Fortunately, the study of the operating efficiency is not related to the issues of optimal control.

We will be interested in the controlling elements and systems only to the extent to which we will decide which of the elements of OC has failed and requires repair (restoration). In other words, the process of control will be treated as controlling the operating capacity of the OC elements. Let us contemplate on the problem: “In what manner and why do the controlling systems (PSP) influence the reliability (probability) specifications of OC?”

There was a “beneficial” time when the process of control was carried out simply and easily, and the controlling elements (PSP) had reliability indexes multiple times higher than the indexes of the controlled TS. Such a situation allows not to take into account the influence of PSP on the reliability of OC (TS). This was the time of “absolute control”. At the end of 20th century and the beginning of 21st century, everything in science related to the control and reliability of TS changes. The methods and systems of control become more complex in an ontological and gnosiological aspect, therefore the quantitative indexes of the reliability of PSP and OC have become comparable. The most important consequence is that the results of the measurements with PSP stopped being a trustworthy event and turned to be a probability (stochastic) fact [13-16]. This is especially topical in the contemporary computer diagnostics of TS and the existing diversity of testing software of the different types of manufacturers of cars, airplanes, helicopters, railway transportation systems, etc. One should bear in mind that the control system (PSP) influences the working capacity of OC (TS) any time when there is no reliable information about the condition of its elements. Therefore it is necessary to carry out a brief reliability analysis of PSP.

IV. RELIABILITY ANALYSIS OF THE FUNCTIONING OF MCM

Since the results of the TS control are regarded as a probable event, the MCM is a source of true (reliable) results only when it operates in a reliable manner (under BSS the highest level of reliability of a TS is 0.999, i.e. per 1000 measurements of one and the same TS parameter, one is incorrect and related to a gross relative error). In the dialectics of the complex system the object of control (TS) and the MCM identifying its condition, the concept of reliability is regarded as a previously stipulated mutually unidirectional correspondence between the results of the control and the condition of the object of control. This gives us reasons to draw the following formula [17]:

\[ R_{TS} = \frac{1}{1 + \frac{1}{R_{MCM}}} \]
\[ P_{RW,MCM} + Q_{F,MCM} = 1 \]  \hspace{1cm} (1)

where: \( P_{RW,MCM} \) is the probability of reliability work (PRW) of the measurement and control system (MCM); \( Q_{F,MCM} \) — the probability of MCM failure, i.e. the probability for the control and measurement system to provide incorrect results [17, 18].

Where OC (or its elements) are controlled by one (even summarized) parameter on the principle “failed – operating”, the probability for errors in the results of the control constitutes the sum of the probabilities for two possible errors:

- type I error with a probability of occurrence \( \beta_1 \), where an operating OC is determined as failed;
- type II error with a probability of occurrence \( \beta_2 \), where a failed OC is determined as operating (flawless).

From the above defined suppositions, the following conclusion is made:

\[ Q_{F,MCM} = \beta_1 + \beta_2. \]  \hspace{1cm} (2)

It is assumed that the change in the condition of OC does not change the nature of the MCM error but changes the results of the control. For example, if MCM work with a type I error and controls a failed TS, it would display correct results. It should be noted that \( \beta_1 \) and \( \beta_2 \) are unconditional probabilities for errors. There are also conditional probabilities for occurrence of errors in the control of TS using MCM. They are determined under the condition \( Q_{F,MCM} = 1 \) and are designated by \( \gamma_1 \) and \( \gamma_2 \) and determined according to:

\[ \gamma_1 = \frac{\beta_1}{Q_{F,MCM}} \quad \text{and} \quad \gamma_2 = \frac{\beta_2}{Q_{F,MCM}} \]  \hspace{1cm} (3)

From formulas (2) and (3) it would mean that:

\[ \gamma_1 + \gamma_2 = 1. \]  \hspace{1cm} (4)

For a random value of the probability of failure \( Q_{F,MCM} \) of MCM the following dependency would follow:

\[ P_{RW,MCM} + Q_{F,MCM}(\gamma_1 + \gamma_2) = 1. \]  \hspace{1cm} (5)

Since the present work relates to restorable OC(TS), treated as complex technical systems, it is appropriate to provide updated summarized block structure of MCM of a TS with a discrete action. This has been displayed on Fig. 1.

Fig. 1. Summarized block structure of MCM of TS with a discrete action.

For all cases of control in the present work, a discrete control is considered, commencing at moment \( t = T \), i.e. at the time of ending of the continuous functioning of TS. The permanent control in the interval for continuous (normal) functioning \( T_{CF} \) is of no importance, as an external interference according to the provisions of technical operation during that period is inadmissible.

Therefore, MCM of TS may be treated as an immediate action system (control carried out for a period of time \( t_k \)), notwithstanding that it is possible for it to switch on during the interval \( T_{CF} \) (e.g. for current check and preparation for switching on).

The joint functioning of TS (complex system A) and the measurement and control system MCM (system B) is shown on Fig. 2. After the end of the \( i \) -th cycle of functioning of a recoverable TO (operating interval \( T_{CF} \) of system A) MCM type B starts operating. The following requirement must be observed for this type of control:

\[ t_k < 0.01 T_{CF} \]  \hspace{1cm} (6)

As of the time of its switching on, system B has already failed or operates flawlessly and for the time period \( t_k (t_k \neq 0) \) it does not change its status. If system B is without recovery and has failed before commencement of the \( i \) -th control, it would have failed before \( (i+1) \) control cycle. In other words, the control system cannot change the type of its failure (if any) (Fig. 2).
Let us review a MCM for which the following operating restrictions are valid:
- the probability parameters \( P_{RW,MCM} \beta \) of the control system do not depend on the number of operating cycles (Fig. 2);
- MCM gives correct results any time it operates flawlessly (the subjective errors of the human operator are not reported and the adopted method of control is considered to be absolute);
- the existence of errors type I and type II determine the failure of MCM (the flawlessness of MCM as OC is treated).

The functioning of a similar MCM (system B) determines the existence of errors type I and type II determine the failure of MCM (the flawlessness of MCM as OC is treated). The above consideration leads to the following:

\[
M \{ \frac{N-k}{N} \} = \frac{N-M \{ k \}}{N} = N-k/N, \tag{9}
\]

where \( M \{ k \} = k \) is the mathematical expectation of the current number of failed elements \( k \) of TS for the time of continuous operation at the \( i \)-th cycle of functioning.

In formula (8) the risk \( R_{ITS}(\Delta t) \) of occurrence of an incident with TS (ITS) for a time interval \( \Delta t \) is determined by the fundamental work of Acad. Ivan Popchev, “Risk Management Strategies”, Sofia, NBU, 2004, p. 68 [9]:

\[
R_{ITS}(\Delta t) = \sum_{i=1}^{n} P_i(\Delta t)V_i(\Delta t), \tag{10}
\]

where \( P_i(\Delta t) \) is the probability of occurrence of a damage with severity \( V_i(\Delta t) \) as a result of occurrence of a hazardous event or a series of events within the observation interval of the risk assessor for TS, \( V_i(\Delta t) \) is the severity of the damage (damages) occurring as a result of the hazardous event (in this case ITS). The severity of the damage is measured in different units (BGN, number of idle days, number of sick leave days, polluted territories as a result of the incident, etc.); \( n \) is the number of types of damages in case of ITS.

After positioning of (10), (9) in (8) the final formula for \( E_{TS} \) follows equation:

\[
E_{TS} = \sum_{i=1}^{n} P_i(\Delta t)V_i(\Delta t) \times \{[(N-\frac{N}{N}) \cdot \frac{1}{i}] \}, \tag{11}
\]

It is natural to terminate the cyclic functioning of transportation system A, if the number of failed elements \( M \{ k \} = k \) at the beginning of \( (i+1) \) cycle, i.e. after the cycle \( i \)-th cycle of functioning control and the \( i \)-th recovery proves to be higher than the previously determined admissible value \( K_{ADM} \) for the total number of failures in TS. Because of the occurring discrepancy between the formal and actual condition of MCM of TS, the service staff is not able to determine the exact number of the cycle for which the following condition is met:

\[
M \{ k \} \leq K_{ADM}, \tag{12}
\]

The next task is calculation of the average number of cycles for control and repair after which TS should be removed from performance of its task and should be checked using MCM with higher precision (e.g. to undergo a medium repair or overhaul in suitable laboratories and/or plants). The answer of this task is in line with the technological revolution 4.0 related to the global information society [1, 3], and the study is the subject of further scientific work.

V. CONCLUSION

1. In the presented study, a definition of security of the control of the transportation systems has been synthesized.
2. A connection has been established between the process of maintaining security and reliability of the transportation systems and the quantity of information about their condition.
3. The introduced parameter of operating efficiency of the systems (transportation, in particular), is an universal way of studying the dialectics of their aging and recovery.

REFERENCES


Traffic noise estimating using multiple regression analysis: A case study Pristina city

Ferat Shala¹, Ramadan Duraku², Halil Demolli³ and Liridon Sejdiu⁴

Abstract- Noise emitted by road traffic is one of the main causes that degrade the standard of the population lives in urban areas. In this paper, is developed a model for the estimating of continuous noise level (Lₐₐₐ) on the two-lane main urban road with medians in the city of Pristina. Comparison of the results was done through performance indicators. It is found that independent variables have direct impact to dependent variable (Lₐₐₐ) and determination coefficient achieve accuracy close to 94 %. This approach could be applied for predicting traffic noise to different locations with the same category of roads through residential areas.

Key words- Road urban traffic noise, Model, Multiple regression analysis.

I. INTRODUCTION

As is known the growth of economic development is associated with the increase in the number of private owned vehicles and also with the number of trips. [1]. These developments raise noise levels by exceeding established standards and consequently have a negative impact on human health. [2].

The main challenge for Pristina city (Capital of Kosovo) is the peak hour traffic, respectively the capacity of the available road infrastructure does not meet sufficiently the requirements for travel, thus creating long queues of vehicles in the roads, [3].

As a result of this, there will be an increase of the travel time, environmental degradation and decrease of the level of traffic safety in general. In recent years, with the advancement of technology, there has been a growing interest by researchers in, evaluating, controlling and predicting this problem by development models according to different approaches and methods, [4].

Studies of this nature haven’t been realized so far in the city of Pristina, and this is the main reason that we started to work on this field in the busiest road segments within the urban area of Pristina city. The main purpose of this paper is to identify the variables that have the greatest impact on the generation of noise emitted by road traffic.

II. NOISE AS AN ENVIRONMENTAL POLLUTION FACTOR

Noise is considered as a serious risk to human health causing: hearing loss, speech interference, sleep disturbances and resting conditions, psycho-physiological effects, mental health effects, performance effects, and effects on behaviour with neighbours or pathological reactions, interference with other activities etc., [5].

Noise remains a serious concern for sustainable development affecting ecosystem disruption, disruption of material assets in monuments, interference with normal environmental composition, economic effects, etc. One of the noise level meters is also the SPL (Sound Pressure Level), a function of the ratio of the sound pressure square of any given sound while the SPL unit is “decibel”, which in short referred to as dB, [6].

Another indicator that corresponds to the purpose of this paper is environmental noise, [7]. It is common that sources of environmental noise contain substantial infrastructure such as the petrochemical complex. In this type of situation, there are also many resources within the infrastructure that contribute to the overall noise emission process. In the case of noise emitted by road traffic, the source it’s composed by vehicles during the traffic flow, [8]. This means that the noise emitted by road traffic is the sum of the noise generated by each vehicle participants in traffic. There are EU directives indicating the permissible noise values in public open spaces as presented in Table I, [9].

<table>
<thead>
<tr>
<th>Acoustic classes</th>
<th>Values during daylight (dB)</th>
<th>Values during night (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I – Special areas</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Class II – Residential areas</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>Class III – Mixed areas</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Class IV – Areas with intense human activities</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td>Class V – Mostly industrial areas</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Class VI – Industrial areas</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

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III. Research Methodology

A. Study area

The main roads within the city of Prishtina were selected based on the traffic load but also their importance passing through the residential areas of the city.

These roads consist of two traffic lanes with 3.5 m wide, medians and a modern surface course (asphalt). The road segments selected for the study are as follows: “Muharrem Fejza”, “Fehmi Lladrovci”, “Road B”, “Enver Maloku”, which are given in Fig.1.

B. Study period and methodology

The research was conducted in four locations x two direction = eight sites and different time intervals within weekdays from 08:00-17:00.

Recordings of the noise level ($L_{eq}$) emitted by road traffic are made on both sides of the road at a distance of 7.5 m from the middle of the traffic lanes and 1.5 m height by base, each of them were measured with a period of 30 minutes by instrument PCE 322 -A, as presented in Fig.2.

All other variables were measured in the same time interval by different instruments as presented in Table II.

![Fig.1. Study area](image1)

![Fig.2. Methodology of measurement](image2)

C. Parameters and instruments for measurement

Based on the purpose of the research for analysis, the variables as presented through Table II were taken into account. Recordings of the rates of these variables were made through calibrated instruments.

![TABLE II](image3)

Based on the data collected and on the manufacturer's instructions, a data set of 240 units was gathered as the starting point for model building through the Multiple Linear Regression (MLR) method as presented in Table III.

For development the noise prediction model $L_{eq}$ emitted from uninterrupted traffic flow on two-lane roads passing through residential areas, respectively, to investigate the relationships between the dependent variable "$y_i$" and the independent variables "$x_{ik}$", the MLR method was used, [10].

The general form of the equation for MLR is given in Eq. (1):

$$y_i = \beta_0 + \beta_1 \cdot x_{i1} + \beta_2 \cdot x_{i2} + \ldots + \beta_k \cdot x_{ik} + \epsilon_i$$

where are:

- $y_i$ - dependent variable,
- $\beta_0$ - intercept,
- $\beta_1, \beta_2, \ldots, \beta_k$ – coefficients of regression,
- $x_{ik}$ - independent variable,
- $\epsilon_i$ - error.
Table III
DATA SET FOR ANALYSIS

<table>
<thead>
<tr>
<th>Measurement</th>
<th>$L_{eq}$ (Observed)</th>
<th>$T_s$</th>
<th>$H_r$</th>
<th>$D_p$</th>
<th>$S_p$</th>
<th>$Q_t$</th>
<th>$T_s$</th>
<th>$H_r$</th>
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<td>63.1</td>
<td>3.3</td>
<td>49.8</td>
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<td>17</td>
<td>15</td>
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<td>2</td>
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<td>64.8</td>
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<td>64.6</td>
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<td>3.5</td>
<td>50.8</td>
<td>0.1</td>
<td>36.0</td>
<td>10</td>
<td>14.5</td>
<td>6.6</td>
</tr>
<tr>
<td>6</td>
<td>64.2</td>
<td>3.5</td>
<td>50.8</td>
<td>0.4</td>
<td>36.0</td>
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<td>14.5</td>
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<td>8</td>
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<td>50.6</td>
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<td>14.5</td>
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<tr>
<td>9</td>
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<td>36.0</td>
<td>10</td>
<td>14.5</td>
<td>6.6</td>
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Table IV
DESCRIPTIVE STATISTIC FOR ALL VARIABLES

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std.dev</th>
<th>Imp act</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{eq}$</td>
<td>300</td>
<td>49.00</td>
<td>74.30</td>
<td>65.99</td>
<td>5.284</td>
<td>----</td>
</tr>
<tr>
<td>$T_s$</td>
<td>300</td>
<td>-0.30</td>
<td>12.20</td>
<td>6.10</td>
<td>3.446</td>
<td>-</td>
</tr>
<tr>
<td>$H_r$</td>
<td>300</td>
<td>24.40</td>
<td>85.30</td>
<td>50.34</td>
<td>13.472</td>
<td>-</td>
</tr>
<tr>
<td>$D_p$</td>
<td>300</td>
<td>-1.90</td>
<td>6.90</td>
<td>2.10</td>
<td>2.199</td>
<td>+</td>
</tr>
<tr>
<td>$S_p$</td>
<td>300</td>
<td>0.00</td>
<td>73.30</td>
<td>40.04</td>
<td>15.827</td>
<td>+</td>
</tr>
<tr>
<td>$Q_t$</td>
<td>300</td>
<td>0.00</td>
<td>29.00</td>
<td>13.25</td>
<td>6.520</td>
<td>-</td>
</tr>
<tr>
<td>$T_s$</td>
<td>300</td>
<td>2.50</td>
<td>17.00</td>
<td>11.40</td>
<td>3.645</td>
<td>+</td>
</tr>
<tr>
<td>$H_r$</td>
<td>300</td>
<td>3.90</td>
<td>60.00</td>
<td>11.15</td>
<td>9.705</td>
<td>+</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSION

Initially correlation analysis was performed between the dependent variable and independent variables as well as between the independent variables themselves, from which it was found that each of the individual "k" variables ($x_1$, ... $x_7$) has an impact on the dependent variable "y", and that with each of them we can build a single linear regression model. For this reason, all variables are taken into account in model build. Then, the normality of the data for each variable was performed through the Kolmogorov statistical test, where it emerged that all variables experience a normal distribution and those can be directly incorporated into the model without applying any additional transformations such as "log", "sqrt" etc., [11]. In this case, all variables are of the metric type. It is also shown graphically that all independent variables $x_{ik}$ have a satisfactory correlation with the dependent variable $y_i$.

The identification of the independent variables that influence traffic noise emission is made after a preliminary research of various papers in this field of international publications, [12]. Also, descriptive statistics were performed for all variables involved in the model development as presented in Table IV.

Table V
MODEL SUMMARY OF STATISTICAL PARAMETERS

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
<th>Std. Error</th>
<th>D. Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.937</td>
<td>0.879</td>
<td>0.836</td>
<td>1.34256</td>
<td>0.877</td>
</tr>
</tbody>
</table>

ANOVA

<table>
<thead>
<tr>
<th>Regression</th>
<th>SumSquares</th>
<th>Df.</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.(p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>3064.318</td>
<td>4</td>
<td>766.080</td>
<td>425.017</td>
<td>0.000</td>
</tr>
<tr>
<td>Residual</td>
<td>423.580</td>
<td>235</td>
<td>1.802</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3487.898</td>
<td>239</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficients

<table>
<thead>
<tr>
<th>B</th>
<th>Std.Err</th>
<th>t</th>
<th>Tolerance</th>
<th>VIF</th>
<th>Sig.(p&lt;0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>82.613</td>
<td>1.312</td>
<td>62.982</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>$T_s$</td>
<td>-1.349</td>
<td>0.046</td>
<td>-29.239</td>
<td>0.564</td>
<td>1.772</td>
</tr>
<tr>
<td>$Q_t$</td>
<td>0.122</td>
<td>0.015</td>
<td>8.276</td>
<td>0.800</td>
<td>1.250</td>
</tr>
<tr>
<td>$S_p$</td>
<td>0.027</td>
<td>0.009</td>
<td>3.101</td>
<td>0.389</td>
<td>2.574</td>
</tr>
<tr>
<td>$H_r$</td>
<td>-0.030</td>
<td>0.012</td>
<td>-2.567</td>
<td>0.303</td>
<td>3.303</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Noise Level ($L_{eq}$)
b. Predictors: (Constant), $T_s$, $Q_t$, $S_p$, $H_r$
The rate of the impact of each variable is raised on the context of this study and the empirical studies of the various authors, as presented through the symbols "+" and "-" in Table IV.

For the development and evaluation of the significant model, the “stepwise” technique is selected which functions as a forward or backward procedure within the SPSS software, [13]. As a result, was created the most suitable model presented in Table V.

The model results show that the dependent variable has a strong correlation with the independent variables according to the coefficient of determination at the level of $R^2 = 0.937$ or 93.7%. Whereas in our analysis $R^2 = 0.879$, which indicates that 87.9% of the dependent variable is explained by the independent variables. Adjusted $R^2=0.836$ indicates that 83.6% of the variance of the dependent variable is explained by the variation of the independent variables. At first glance based on these values of $R^2$ and Adjusted $R^2$, impression is gained that the model is not suitable. However, this does not mean that a model with high value of $R^2$ should necessarily be suitable and a model with low value of $R^2$ is unsuitable.

In such cases the model evaluation should be done if the coefficients before the variables are statistically significant, [14]. From the results given in Table V, it can be seen that the values of the coefficients near to the variables $T_s$, $Q_t$, $S_p$ and $H_r$ are all statistically stable because they fulfill the criteria of Sig. ($p<0.05$).

Also, the pre-signs near the coefficients of the significant variables are in line with the expectation of impact according to Table IV. The value of the collinearity coefficients near to each significant variable has range to be VIF<10, indicating that the phenomenon of multicollinearity does not occur, [15].

Model testing by ANOVA (F-test = 425.017) with 95% confidence level (Sig.= 0.000 <0.05) indicates that all coefficients together are statistically significant and different from zero. Therefore, based on data collected for different days and time intervals and the equivalent level of noise ($L_{eq}$), applying the MLR method the mathematical model is obtained by expressing the interrelationship between the variables included in the model.

The general form of the equation for equivalent level of noise ($L_{eq}$) in dB (A) is given by Eq. (2):

$$ L_{eq} = 82.613-1.349T_s +0.122Q_t+0.027S_p-0.030H_r $$

As seen from Eq. (2), traffic volume ($Q_t=0.122$) and speed ($S_p=0.027$) have the greatest impact on the increase in noise level, while the average asphalt temperature ($T_s=-0.1349$) and relative humidity ($H_r=-0.030$) has an effect on its reduction.

Whereas the other variables $T_a$, $D_p$ and $H_a$ did not appear statistically stable and as such were not taken into account. It has also been confirmed for the variables that resulted significant, residual analysis shows that residuals are normally distributed by zero mean and constant variance. In addition to the coefficient analysis, to determine the accuracy of the noise level estimation model for $L_{eq}$ (Observed) and $L_{eq}$ (Calculated) values, are utilized performance indicators such as: Relative Error (RE), Mean Error (ME), and Root Mean Squared Error (RMSE) [16].

This is accomplished by comparing the calculated data ($F_i$) with the observed data ($A_i$) so that the errors should be as small as possible [17], using equations Eqs.(3), (4) and (5).

$$ RE = 1 - \frac{1}{n} \sum_{i=1}^{n} \frac{(F_i-A_i)}{A_i} \times 100 $$

$$ ME = 1 - \frac{1}{n} \sum_{i=1}^{n} (F_i-A_i) $$

$$ RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (F_i-A_i)^2} $$

Results are given in Fig. 3.

From the results of Table VI, it seems that the model according to MLR gives small prediction error referring to the indicator in percentage $RE = 1.55\%$ and indicators with numerical values $ME = 1.03$ and $RMSE = 1.32$.

Also, the results of this paper show that the average value of traffic noise for the study locations is $L_{eq} = 66.71$ dB (A) with standard deviation $\sigma=3.82$ dB (A), which exceeds the allowable value at limit 55 dB (A) for Class II- residential area according to Table I.

V. CONCLUSION

This paper presents the development of an appropriate model using the Multiple Linear Regression (MLR) method.
for estimating road traffic emission noise \(L_{eq}\) on two-lane roads with median passing through residential areas in the Prishtina city. The recordings were carried out in four locations in two directions of traffic flow with a total of eight sites. At each of these sites, data were measured through sophisticated and pre-calibrated equipment for all variables included in the model over a 30-minute time interval, based on 240 values of dataset.

To develop the model, the noise emitted by the traffic as a dependent variable \(L_{eq}\) and seven independent variables were taken into account, of which only four \((T_s, Q_s, S_p, H_i)\) were significant. While, two of them \((Q_s, S_p)\) have positive impact until two others \((-T_s, -H_i)\) have negative impact.

Significance of the model was done through statistical tests \((R, R^2, \text{Adjusted } R^2, \text{F-test, t-test, DW, VIF etc.})\), all of which resulted in acceptable values according to statistical theory. To verify the predict error, the calculated data \((F)\) was compared with the observed data \((A)\) through the performance indicators \(RE, ME, \text{RMSE.}\) The results showed that the values of all three indicators are quite low and within the allowed error limits for prediction.

In order to achieve the model with even better performances, more different locations within the road network in the urban area of Prishtina should be included. Also, recordings should be made at intervals longer than 30 minutes taking into account the peak hours of traffic flows thus creating a dataset on a larger number of recorded values.

Due to the small rates of error in predicting, this model can be used to predict the noise emitted by traffic on two-lane urban roads with medians \(\text{(uninterrupted traffic flow)}\) in the urban area of Prishtina in the time interval only during the day and for roads that pass through residential areas.

The obtained results showed that the mean value of the traffic emitted noise for the study locations was \(L_{eq} = 66.71\) dB \((A)\) with standard deviation \(\sigma = 3.82\) dB \((A)\), which exceeds the acceptable value at the limit of 55 dB \((A)\) for Class II- residential area. Therefore, this is an indication that responsible authorities should take actions to prevent respectively to reduce the level of noise emitted by traffic to an acceptable limit level. This study can also serve as a starting point for future studies of this nature such as: overnight intervals, different classes of roads, different climatic conditions, different locations within urban areas, etc.

**REFERENCES**

Информациски системи во сообраќајно транспортно инженерство

Information Systems in Traffic and Transport Engineering
Forecasting Number of Calls to the Call Center Using Machine Learning

Pavle Bugarčić¹, Sladana Janković² and Snežana Mladenović³

Abstract – This paper presents a forecast of a number of call arrivals in the call center per hour using supervised machine learning. For the forecast, the WEKA machine learning software tool was used. The results of the forecast are verified using several methods, which shows very good results. Finally, the results of the forecast are presented graphically using Excel diagrams.

Keywords – Machine learning, Forecasting, WEKA

I. INTRODUCTION

The call center has always been the electronic face of the company, and with the advancement of technology and the trend of digitalization, it has become a vital service for interacting with existing and future customers. In the modern world, call centers have become one of the most important forms of communication between companies and customers. The most common form of call centers is inbound call centers, where customers initiate calls and call center agents respond to those calls. The traffic profile of incoming calls is usually very dynamic. More precisely, the intensity of the incoming calls varies in different parts of the year, month, week and day. For this reason, different amounts of human and technical resources of the call center are required at different periods. This is mainly related to the optimum number of call center agents working simultaneously. To optimally plan the resources of the call center, it is first necessary to forecast the number of incoming calls in the future. This is exactly the goal of this paper.

Considering the very large number of incoming calls to the call center, for the problem of forecasting the number of calls to the call center can be said that is a Big Data problem. For this reason, one of the Big Data analytics techniques should be selected for the forecast. An important class of Big Data analytics is a predictive analytics based on supervised machine learning. This technique is used for the forecast in this paper, using the WEKA (Waikato Environment for Knowledge Analysis) software tool [1]. This data mining software is a collection of machine learning algorithms used in data mining operations. Two algorithms are used in this paper - RandomForest and Bagging. The implementation of the machine learning process in this paper is done on the example of a call center of a company TNT, which provided us relevant incoming calls number information, in the previous period of three years.

This paper is organized as follows. In section II the method of supervised machine learning is described. Section III shows a numerical example of forecasting the number of calls to the call center using a WEKA software tool. Concluding remarks are given in section IV.

II. SUPERVISED MACHINE LEARNING METHOD

Machine learning solves the problem of how to make computers that automatically improve through experience. Today it is one of the fastest-growing technical fields, based on computer science and statistics, and is the core of artificial intelligence and data science. Recent progress in machine learning has been driven both by the development of new learning algorithms and theory and by the ongoing explosion in the availability of online data and low-cost computation [2].

There are several applications for machine learning, the most significant of which is predictive data mining. Every instance in any dataset used by machine learning algorithms is represented using the same set of features. The features may be continuous, categorical or binary. If instances are given with known labels (the corresponding correct outputs) then the learning is called supervised, in contrast to unsupervised learning, where instances are unlabeled [3].

The goal of supervised machine learning is to build a concise model of the distribution of class labels in terms of predictor features. The resulting classifier is then used to assign class labels to the testing instances where the values of the predictor features are known, but the value of the class label is unknown [4].

The machine learning process consists of the following stages: data preparation, model building, model validation, model testing and model implementation. Machine learning is an iterative process in which all of the above phases are repeated as many times as necessary. The repetition of these phases ends when all combinations of attributes, all available algorithms and algorithm parameter values are exhausted, or when a satisfactory performance model is reached. Once the model testing shows that the model has satisfactory performance, it can begin with its use for forecasting of the selected variable [5].

The most important step in the machine learning process is data preparation, which most influences the success of the process. Data preparation consists of clearing raw data from incomplete records or records with incorrect values, converting the data to the appropriate format, etc. Some of the
input dataset file formats supported by WEKA are csv, arff, etc.

The building of each machine learning model consists of the following stages:
- defining the goal of the model, in line with the goals of predictive analytics;
- selection of the target variable, i.e. attribute from the dataset whose value we want to predict using machine learning model;
- selection of supervised machine learning algorithm, following the nature of the target variable and attributes;
- preparation of datasets for learning (training) and testing models, according to the requirements of the chosen algorithm;
- model adjustment, i.e. values of hyperparameters specific to each type of machine learning algorithm;
- model training, that is, applying the selected machine learning algorithm to a training dataset to obtain model hyperparameters.

After that, it is possible to validate the model. WEKA provides several types of validation, such as the use of a training dataset, the use of a test dataset, cross-validation, and percentage splitting. The cross-validation type is used in this paper. Usually, the input dataset is divided into a training dataset and a test dataset. The cross-validation process only uses a training dataset. This process consists of the following stages:
- the available model training dataset is divided into \( K \) equal folds. It is usually divided into 10 folds (10-fold cross-validation);
- the model is trained on \( K-1 \) folds of data;
- the model is evaluated on one remaining subset of data;
- steps 2 and 3 are repeated \( K \) times. In each iteration, one fold of the data is taken for model validation purposes, while the rest (\( K-1 \) folds) is used for training. A different fold is always selected to be used to validate the model.
- model performance is calculated as the arithmetic mean of the performance obtained in the \( K \) iterations.

Several different measures can be used to evaluate the forecast, such as mean squared error, root mean squared error, mean absolute error, relative squared error, root relative squared error, relative absolute error and correlation coefficient [6].

The mean squared error is the most commonly used measure and is calculated as follows:

\[
\text{Mean squared error} = \frac{(p_1-a_1)^2+\ldots+(p_n-a_n)^2}{n} \tag{1}
\]

The values \( p_1, p_2, \ldots, p_n \) are the projected values of the target variable, and the values \( a_1, a_2, \ldots, a_n \) are the actual values of the target variable. The parameter \( n \) indicates the total number of elements of the input dataset.

The root mean squared error is calculated as follows:

\[
\text{Root mean squared error} = \sqrt{\frac{(p_1-a_1)^2+\ldots+(p_n-a_n)^2}{n}} \tag{2}
\]

Mean absolute error represents the average value of individual errors, without considering their sign. It is calculated as follows:

\[
\text{Mean absolute error} = \frac{|p_1-a_1|+\ldots+|p_n-a_n|}{n} \tag{3}
\]

The relative squared error represents the normalized total squared error and is calculated as follows:

\[
\text{Relative squared error} = \frac{(p_1-a_1)^2+\ldots+(p_n-a_n)^2}{(a_1-\bar{a})^2+\ldots+(a_n-\bar{a})^2} \tag{4}
\]

The mean values of the variables \( p \) and \( a \) are denoted by \( \bar{p} \) and \( \bar{a} \).

The root relative squared error is calculated as follows:

\[
\text{Root relative squared error} = \sqrt{\frac{(p_1-a_1)^2+\ldots+(p_n-a_n)^2}{(a_1-\bar{a})^2+\ldots+(a_n-\bar{a})^2}} \tag{5}
\]

The relative absolute error represents the normalized total absolute error and is calculated as follows:

\[
\text{Relative absolute error} = \frac{|p_1-a_1|+\ldots+|p_n-a_n|}{|a_1-\bar{a}|+\ldots+|a_n-\bar{a}|} \tag{6}
\]

The last measure of accuracy is the correlation coefficient, which takes values from -1 to 1. The highest correlation is shown by models where the absolute value of the correlation coefficient tends to be 1. On the other hand, when the value of this coefficient is closer to 0, the correlation is smaller and the model is worse. This coefficient is calculated as follows:

\[
\text{Correlation coefficient} = \frac{S_{pA}}{\sqrt{S_{p}S_{A}}} \tag{7}
\]

where:

\[
S_{pA} = \frac{\sum (p_i-a_i)(a_i-\bar{a})}{n-1}, \quad S_{p} = \frac{\sum (p_i-\bar{p})^2}{n-1}, \quad S_{A} = \frac{\sum (a_i-\bar{a})^2}{n-1} \tag{8}
\]

The previous steps in the cross-validation process are done on the training dataset. The test dataset didn’t play a role in the building of the model, nor in the validation of the model, so it is possible to evaluate the performance of the model obtained through the training using this dataset.

The next step is to compare the performance of the model in the case of using the training dataset and in case of using the test dataset. The model should not give significantly better results when using the training dataset than when using the test dataset. If the model performs very well on the training dataset but significantly worse on the test dataset, then there is a problem of over-matching.

Finally, to forecast the target variable for the future period, it is necessary to prepare an appropriate input dataset and apply the selected model to it.

III. A NUMERICAL EXAMPLE OF FORECASTING
NUMBER OF CALLS TO THE CALL CENTER

This chapter presents a numerical example of forecasting the number of calls to a company call center using supervised machine learning. As mentioned above, in this paper the
WEKA software tool was used to this forecast. WEKA contains a large number of algorithms that can be used for this forecast. Some of the basic classes of algorithms implemented in WEKA are bayes, functions, lazy, meta, rules and trees.

The inbound dataset, based on which the forecast was made, is a collection of incoming call center calls over the last three years. The input dataset is divided into a training dataset and a test dataset. The training dataset consists of data for the first two years (October 2016 - September 2018), and the test dataset consists of data for the third year (October 2018 - September 2019). The number of calls per hour was monitored and therefore the incoming calls were grouped per hour. Each call is described by the following group of attributes: year, month, day of the month, day of the week, and the hour at which the call was made. So the target variable, in this case, is the number of calls per hour, and the attributes mentioned are influential factors.

As explained in the previous chapter, it is first necessary to form a model based on training dataset. The previous section describes ways to verify forecasting models. In this paper, the correlation coefficient, mean absolute error, root mean squared error, relative absolute error and root relative squared error are used for verification. The verification was first performed on the training dataset. A number of algorithms have been tested on the training dataset, including IBk, AdditiveRegression, Bagging, MSP, RandomCommittee, RandomSubSpace, DecisionTable, M5Rules, RandomForest, RandomTree and many others. Models based on the Bagging and RandomForest algorithms showed the best performances, so these algorithms are selected to form a model. The results of performance measurement in case of the application of the RandomForest and Bagging algorithms are shown in Table I.

As can be observed, certain seasonal variations of actual data are noticeable, and forecasting models closely follow these variations.

It is then possible to test the model on the test dataset. Fig. 1 shows the actual values of the number of calls per hour for the third year, as well as the forecast values of the number of calls per hour obtained using models based on the RandomForest and Bagging algorithms. As can be observed, forecasting models closely follow these variations.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Correlation coefficient</th>
<th>Mean absolute error</th>
<th>Root mean squared error</th>
<th>Relative absolute error (%)</th>
<th>Root relative squared error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RandomForest</td>
<td>0.9588</td>
<td>1.5897</td>
<td>3.7153</td>
<td>15.4259</td>
<td>28.9044</td>
</tr>
<tr>
<td>Bagging</td>
<td>0.9573</td>
<td>1.5878</td>
<td>3.7827</td>
<td>15.4071</td>
<td>28.9162</td>
</tr>
</tbody>
</table>

The parameter that has decisively influenced the choice of the mentioned algorithms is the correlation coefficient, so a comparison will be made based on it. It can be observed that the correlation coefficient for both algorithms is very close to 1, which indicates a very high correlation and therefore very high forecast accuracy when both algorithms are used. Slightly better performance is indicated by the RandomForest algorithm.

The verification was then performed on the test dataset as well. The verification results for the RandomForest and Bagging algorithms are shown in Table II. As expected, both algorithms show slightly worse results compared to results from Table I. However, the difference is not very large, so it cannot be said that there was a over-matching problem. In this case, the correlation coefficients are also close to 1, so it can be said that the forecast is very reliable. In this case, the RandomForest algorithm also shows slightly better performance.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Correlation coefficient</th>
<th>Mean absolute error</th>
<th>Root mean squared error</th>
<th>Relative absolute error (%)</th>
<th>Root relative squared error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RandomForest</td>
<td>0.9222</td>
<td>2.0517</td>
<td>5.0113</td>
<td>20.3268</td>
<td>39.0217</td>
</tr>
<tr>
<td>Bagging</td>
<td>0.9198</td>
<td>1.9663</td>
<td>5.0907</td>
<td>19.4807</td>
<td>39.6404</td>
</tr>
</tbody>
</table>

Fig. 1. The actual and forecasted number of calls per hour for each hour of the day and every day of the year

Fig. 2. The actual and forecasted number of calls per hour for each hour of the day and every day of the month
For better clarity, Fig. 2 shows the actual and forecast values of the number of calls per hour for an arbitrarily chosen month, within the third year, based on the same models as in the previous case. It can be noted that the number of calls per hour fluctuates greatly within one month, and forecasting models pretty much follow these fluctuations.

Fig. 3 shows the actual and forecast values of the number of calls per hour over one arbitrarily chosen week, within the third year, based on the same models as in the previous cases. Significant fluctuations in the number of calls per hour can also be observed here. As expected, the number of calls is significantly higher on working days than on weekends. The forecast values follow this trend very well.

Fig. 4 shows the actual and forecast values of the number of calls per hour over one arbitrarily chosen day, within the third year, based on the same models as in the previous cases. During daytime hours the number of calls per hour is much higher than during the night. And in this case, forecasting models are largely following this trend.

IV. CONCLUSION

This paper presents the application of two models for forecasting the number of calls per hour to the call center, based on machine learning. For this, two algorithms provided by WEKA software were used, namely RandomForest and Bagging algorithms. These algorithms were chosen because they showed the highest correlation coefficients in the cross-validation process. In this case, a few more algorithms showed very good performance, so it is possible to extend this study using other algorithms.

The most important and demanding part of the job with such forecasts is the preparation of an input dataset. The input data should be well grouped and described with the right attributes. The success of creating an effective forecasting model largely depends on the combination of attributes that describe each data. In this paper, all attributes are numeric and refer to the time of user calls to the call center. This set of attributes was chosen because significant variations were observed in the number of incoming calls on a yearly, monthly, weekly and daily basis.

For some future research, it is possible to include information about location from which calls were made or call type information, depending on whether the calls are from a mobile or landline telephone network, in the forecast. Since the forecasting methods applied have shown very good performance in such a dynamic time series, similar methods can be used for many other cases where traffic is extremely dynamic and not easy to predict. Such dynamic performance has IP traffic, which is increasingly used in the modern world. This may be one of the direction of our future research.

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REFERENCES

Application Of Artificial Neural Networks For Predictions Of Failure Of Railway Signaling Devices

Marko Bursać¹, Sanja Jevtić² and Goran Tričković³

Abstract – The maintenance and reliability of the signaling system are one of the key factors when it comes to the safety of rail transport. The objectives of this paper are to define a prediction model for the failure of railway signaling devices. The obtained results can significantly help in maintaining.

Keywords – Maintenance, Railway signalling, Failure, Artificial neural network.

I. INTRODUCTION

This paper presents a model for predicting failure railway signaling devices. A methodologically developed approach to data collection and the creation of an artificial neural network enables the definition of a model of prediction. The results obtained by the prediction can significantly help maintain the organization of business processes and the purchase of spare parts. In addition to organizational aspects, the contribution of research can improve the safety of rail traffic in terms of the reliable operation of the signaling system.

Maintenance in the railway environment was for years grouped in two major streams – investments and regular maintenance. Regular maintenance was based on the type and quantity of the equipment in use. According to the manufacturer's recommendations, a number of measurements and actions were to be taken during the maintenance year (some monthly, some semi-year, some even daily) [1].

Even though most of the systems are outdated and on the rising part of the failure rate curve $\lambda(t)$ [2, 3] some enhancements could be done in the organization, that could greatly influence the prediction of failures, thus enabling the reduced number of staff to easier coordinate maintenance and not just react in the case of emergency.

The existing failure database dealing with communication equipment is organized in such a way to enable even the end-users to report a failure (large lots without details). The maintenance staff further fill in the reasons and development of failure. With the improvement of description and outcome of failure, it could be possible to better understand, monitor, and even predict certain failures [1].

II. MATERIALS AND METHODOLOGY

Failure database which is the object of consideration in this paper deals with all communication systems. For the purpose of making the procedure and conclusions transparent a large part of it was chosen for study. The time span of this database is January 2013 – June 2018. The database from which the records were downloaded was formed for the purpose of recording failures on telecommunication and signaling devices used on the railway. All employees have access to the database, while engineers at Belgrade Marshaling Yard are updating the database.

Based on the available literature, artificial neural networks provide adequate data prediction. The data presented in this study were exported from a failure database, classified and organized within an artificial neural network (input, target and output data).

After the classification and prediction of failures of signaling devices on the railway, it is possible to create comparative graphs of actual failures and failures provided by an artificial neural network.

III. NEURAL NETWORK MODEL FOR PREDICTING FAILURE

Artificial neurons or nodes are the primary processing elements of neural networks. In the mathematical model of ANN, synapses show connection weights and are related to input signals. Furthermore, a transfer function defines the nonlinear characteristic of neurons.

The weighted sum of the input signals which represents the neuron impulse is computed and then transformed using the transfer function. Setting the weights in accordance with the chosen learning algorithm, the learning capability of neurons is obtained [4].

Neurons are often grouped into layers. Layers are groups of neurons that perform similar functions. There are three types of layers. The input layer is the layer of neurons that receive input from the user program. The layer of neurons that send data to the user program is the output layer. Between the input layer and output layer are hidden layers.

Fig. 1. Neuron

1 Bursać, High railway school of vocational studies, Zdravka Čelara 14, Belgrad, Serbia, marko.bursac@vzs.edu.rs
2 Jevtić, High railway school of vocational studies, Zdravka Čelara 14, Belgrad, Serbia, jevtic.sanja@gmail.com
3 Tričković, High railway school of vocational studies, Zdravka Čelara 14, Belgrad, Serbia, tricko86@gmail.com
Hidden layer neurons are only connected only to other neurons and never directly interact with the user program. The input and output layers are not just there as interface points. Every neuron in a neural network has the opportunity to affect processing. Processing can occur at any layer in the neural network. Not every neural network has this many layers. The hidden layer is optional. The input and output layers are required, but it is possible to have one layer act as both an input and output layer [5].

The output for the single neuron illustrated above is described in by,

\[ O_n = \varphi(b_k + \sum_{i=1}^{m} w_{ki} \cdot x_i) \] (1)

where \( O_n \) is the output, \( \varphi \) is the activation function, \( b_k \) is the threshold bias, \( w_{ki} \) are the synaptic weights, \( x_i \) is the inputs from the previous layer of neurons, and \( i \) is the number of inputs. Every neuron has many connections going to and from other neurons. The information passed on to each neuron may have a very small or large effect on the final output. A threshold limit is used via a bias value in artificial neural networks to simulate the formation and degradation of inter-neuron connections as in the biological system. Large arrays of these neurons supply the ability to map out regions of parameter space defined by the input parameters. Each neuron is capable of editing weights supplied to it based upon the accuracy of the entire network. This enables the neural network to learn the behavior of data provided [6].

The neural network is defined through two phases, the learning or training phase and the testing phase. Prior to learning, it is necessary to define the input and output variables and to collect data to which the backpropagation algorithm will be applied [7].

The backpropagation algorithm uses supervised learning, which means that we provide the network with examples of inputs and outputs [8, 9].

Namely, artificial neural networks can be trained - after a number of iterations, the network loses its generalization property (good classification for unknown inputs) and becomes an expert in processing data from a set of learning examples while processing the remaining data poorly. By constantly monitoring the output from the network obtained by the example from the test set, it is possible to detect an iteration in which the output obtained deviates least from the desired response (Fig. 3). The accuracy and precision of data processing can ultimately be verified over a third set of examples - the validation set [10].

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Values</th>
</tr>
</thead>
</table>
| **Input** | Railway station | 1 - Adrovec  
2 - Aleksinac  
3 - Bagrdan  
4 - Barajevo  
106 - Zuce |
| System (larger groups to be end user oriented) | 1 - station dispatching devices  
.  
25 - power supply |
| **Date of failure** | 01-31 - day  
01-12 - month  
13-18 - year |
| **Output** | System | 1 - station dispatching devices  
.  
25 - power supply |

In this research, we utilize a multi-layer neural network with one hidden layer of neurons and with feed-forward backpropagation. Model is developed using MATLAB Neural Network Toolbox. The type of algorithm that was selected when creating this network is Levenberg-Marquardt.

The accuracy measure is often defined by forecasting errors that represent the difference between the actual (desired) and the predicted value. There are more such predictive precision measures that are encountered in the literature, each having its own advantages and limitations. The most commonly used Medium Square Error (MSE) according to the equation [11]:

\[ MSE = \sum_{i=1}^{N} \left( \frac{P_{actual} - P_{predicted}}{N} \right)^2 \] (2)
where $N$ represents the number of samples, $P_{\text{actual}}$ real results and $P_{\text{predicted}}$ results obtained by predetermining the neural network.

According to [5], there are many ways to determine the exact number of neurons used in hidden layers:

- the number of hidden neurons should be between the size of the input layer and the size of the output layer.
- the number of hidden neurons should be $2/3$ of the size of the input layer, plus the size of the output layer.
- the number of hidden neurons should be smaller than the double size of the input layer.

During the design and testing of the model, the best results are obtained by working with four neurons in the hidden layer of the network, which is in accordance with the above recommendations.

The first three graphs in the picture represent training, validation and testing data. The dotted line on the charts represents perfect results, the result - output = goals.

The full line represents the best linear regression between input and target data. The value of $R$ represents the induction of the relationship between input and target data. If $R$ values 1, it follows that there is an accurate linear relationship between the line relationship between input and target data [12].

During network training, weights between input and output data are changed. In each iteration calculate the new weight to the network gave the smallest error. The learned network in the next step is validated in order to find a better result with memory data. The procedure is repeated until the result improves. The acquired network is tested on a test sample, and the resulting result is taken as the final measure of network performance [13].

**IV. RESULTS AND DISCUSSION**

During the database study, the majority of failures were reported for communication boards, station dispatching devices and cables.

During network training, weights between input and output data are changed. In each iteration calculate the new weight to the network gave the smallest error. The learned network in the next step is validated in order to find a better result with memory data. The procedure is repeated until the result improves. The acquired network is tested on a test sample, and the resulting result is taken as the final measure of network performance.

According to the obtained data it is possible to determine the mean square error (MSE) in the following way: for failure 1 - $P_{\text{actual}} = 8$, $P_{\text{predicted}} = 9.16$; for failure 2 - $P_{\text{actual}} = 6$, $P_{\text{predicted}} = 7.86$ and so on. For the total number of observing failures (582 of them).

The results of $R$ values improve with each new test compared to the previous training of the network, and therefore, at each initialization of training of the network, the parameters of the $R$ values change and produce different solutions, i.e. a new prediction of the output data.

After obtaining the difference between $P_{\text{actual}}$ and $P_{\text{predicted}}$, it is necessary to sum up all values and divide it by the number of failures. During testing on 582 samples, with one hidden layer (four neurons), the mean square error (MSE) is 9.16.
V. CONCLUSION

This paper introduced a model, an artificial neural network approach for identification failure Railway Signaling Devices, a neural network developed in the MATLAB program.

The obtained results indicate that the use of neural network models can predict the number of failures on defined systems of the railway signaling infrastructure.

Research has shown that a large number of failures are due to cable breakdowns (frequent thefts), as well as the most frequent breakdowns in Belgrade Marshaling Yard. As one of the results of the research, it can be concluded that a greater measure of implementation of the railway infrastructure protection system is needed.

The prediction results are intended to show the success of failure prediction on signaling devices used on the railway. The results obtained may indicate the need for better organization of maintenance services for signaling devices on the railway, as well as for the possibility of better planning of procurement of maintenance equipment.

Future work could be reflected, first and foremost, in the development of a database with predefined input, which would aim to generate a large number of inputs to the neural network. In addition to re-engineering a database, it would be important to achieve a certain level of automation neural networks. One solution is to create an internet-based application that will make it easier for end-users to work with.

Lastly, in order to implement a failure prediction system on signaling devices used on the rail, it would be necessary to redefine the artificial neural network in order to achieve better prediction results and reduce error.

REFERENCES

Traffic Flow Prediction Using Machine Learning

Sladan Janković¹1, Dušan Mladenović², Snežana Mladenović³ and Stefan Zdravković⁴

Abstract – The main objective of this research was to define and verify the methodology of predicting the volume and structure of traffic flows, based on the building and application of a supervised machine learning models. The proposed methodology was applied in the case study of the prediction of traffic flows on selected routes in the Republic of Serbia.

Keywords – Machine learning, Big data analytics, Traffic flow.

I. INTRODUCTION

Accurate and timely traffic flow information is currently strongly needed for individual travelers, business sectors, and government agencies [1]. It has the potential to help road users make better travel decisions, alleviate traffic congestion, reduce carbon emissions, and improve traffic operation efficiency.

The monitoring of traffic flows are followed by the permanent generation of large amounts of data. Datasets that have Big Data features provide the ability to apply modern data mining techniques. A significant class of these techniques is predictive analytics based on the application of supervised machine learning. The aim of predictive analytics is to predict what will be happening or is likely to happen in the future by exploring data. It attempts to accurately predict the future events and discover the reasons [2]. Traffic flow prediction is regarded as a critical element for the successful deployment of intelligent transportation systems, particularly advanced traveler information systems, advanced traffic management systems, advanced public transportation systems, and commercial vehicle operations [3].

In [4], Arthur Samuel defined machine learning as a “Field of study that gives computers the ability to learn without being explicitly programmed”. We can say that machine learning is generalization of a knowledge based on the previous experience (data related to phenomena that are our subject of learning). Today, in the Big Data era, machine learning is used as one of the leading techniques in predictive analytics [5]. The aim of predictive analytics in this research was to predict the volume and structure of traffic flow on selected routes in the Republic of Serbia.

In the Section 2 of the paper all stages of the machine learning process were described: building, evaluation, testing and application of machine learning models, i.e. prediction of dependent variables. The proposed methodology was applied in the case study of the prediction of traffic flows on five selected routes in the Republic of Serbia. The results of two examples of prediction from a case study are presented in the Section 3. The last section of the paper contains conclusions about machine learning algorithms that have shown the best results in predicting the volume and structure of traffic flow on the available datasets.

II. METHODOLOGY

Since we had labeled dataset at our disposal, we have developed supervised machine learning models. Building each of the machine learning model consisted of the following phases:
1. defining the goal of the model;
2. choosing dependent variables (label, class), i.e. the dataset attribute which value we want to predict using the machine learning model;
3. selecting relevant attributes (features) of a dataset;
4. selecting supervised machine learning algorithm, according to the nature of labels and attributes [6];
5. datasets (training and test) preprocessing that fulfills requirements of the selected algorithm;
6. model tuning – setting hyperparameters that are specific for each type of the machine learning algorithm;
7. model training – application of the selected machine learning algorithm on the training dataset in order to obtain model parameters;
8. model evaluating using cross-validation. Cross-validation is a method for getting a reliable estimate of model performance using only training data. Witten et al. in [7] proposed several alternative measures that can be used to evaluate the success of numeric prediction: mean-squared error - Eq. (1), mean-absolute error - Eq. (2), root mean-squared error - Eq. (3), relative-squared error - Eq. (4), root relative-squared error - Eq. (5), relative-absolute error - Eq. (6) and correlation coefficient - Eq. (7). The total number of test instances is n; the predicted values on the test instances are \( p_1, p_2, \ldots, p_n \); the actual values are \( a_1, a_2, \ldots, a_n \); \( \bar{p} \) and \( \bar{a} \) are the average values of the predicted/actual values;

\[
\text{Mean} - \text{squared error} = \frac{1}{n} \sum_{i=1}^{n} (p_i - a_i)^2 \quad (1)
\]

\[
\text{Mean} - \text{absolute error} = \frac{1}{n} \sum_{i=1}^{n} |p_i - a_i| \quad (2)
\]

\[
\text{Root mean} - \text{squared error} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (p_i - a_i)^2} \quad (3)
\]

\[
\text{Relative} - \text{squared error} = \frac{1}{n} \frac{(p_i - a_i)^2}{(a_i - \bar{a})^2} \quad (4)
\]

\[
\text{Root relative} - \text{squared error} = \sqrt{\frac{1}{n} \frac{(p_i - a_i)^2}{(a_i - \bar{a})^2}} \quad (5)
\]

\[
\text{Relative} - \text{absolute error} = \frac{1}{n} \frac{\sum_{i=1}^{n} |p_i - a_i|}{\sum_{i=1}^{n} |a_i|} \quad (6)
\]

\[
\text{Correlation coefficient} = \frac{1}{n} \frac{\sum_{i=1}^{n} (p_i - \bar{p})(a_i - \bar{a})}{\sqrt{\sum_{i=1}^{n} (p_i - \bar{p})^2 \sum_{i=1}^{n} (a_i - \bar{a})^2}} \quad (7)
\]
A. Example 1

Datasets were generated using MS Access 2016. Records related to the period 2011-2017 were used for creating training dataset, while records belonging to the year 2018 were used to make test dataset. The training and test datasets are shown in Table I.

Comparing test vs. training performance allows us to avoid overfitting. If the model performs very well on the training data but poorly on the test data, then it is overfit.

Selecting a winning model - model that has the best performance on the test dataset.

Label prediction using the winning model.

III. CASE STUDY

For predictive analytics we used an open source data mining software called Weka 3.8.3. Weka is a collection of machine learning algorithms used in data mining. It contains tools for data preparation, classification, regression, clustering, association rules mining, and visualization. We used Weka for data preparation and regression.

According to the above methodology we built and implemented machine learning models to predict the volume and structure of traffic flows. For training and testing machine learning models we used data generated by selected automatic traffic counters. Since our dataset labels (total number of vehicles and percentage participation of different categories vehicles in traffic flow) are numeric, we built machine learning models based on the most popular regression algorithms: Linear Regression, Multilayer Perceptron (Neural Network), SMOrig (Support Vector Machine for Regression), IBk (k-Nearest Neighbors), M5P, Random Forest, Random Tree and REPTree.

Records related to the period 2011-2017 were used for creating training dataset, while records belonging to the year 2018 were used to make test dataset. The training and test datasets were generated using MS Access 2016.

A. Example 1

Training dataset: Monthly traffic flow for 21 traffic counters on three selected routes in the Republic of Serbia, for the period 2011-2017; Number of instances: 1740; Attributes: counter, month; Dependent variable: total number of vehicles. Test mode: 10-fold cross-validation. Traffic counters are located at the following routes: Preljina-Pojate, Preljina-Gostun (state border between Serbia and Montenegro), ring road Aleksinac-ring road Trupale (on the highway A1).

Using the eight machine learning algorithms listed above, eight machine learning models were created to predict traffic flow volume, depending on the month of the year and traffic counter. The performance of the four best machine learning models created by using different algorithms on this training dataset are shown in Table I.

Table I. Performance of the top four prediction models measured on the training dataset used in example 1

<table>
<thead>
<tr>
<th>Machine learning algorithm</th>
<th>IBk (k=1)</th>
<th>Random Forest</th>
<th>Random Tree</th>
<th>REP Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>0.9779</td>
<td>0.9777</td>
<td>0.9779</td>
<td>0.9611</td>
</tr>
<tr>
<td>Mean absolute error</td>
<td>17492.9</td>
<td>17633.3</td>
<td>17492.9</td>
<td>21874.9</td>
</tr>
<tr>
<td>Root mean squared error</td>
<td>26075.9</td>
<td>26184.7</td>
<td>26075.9</td>
<td>34471.6</td>
</tr>
<tr>
<td>Relative absolute error (%)</td>
<td>18.03</td>
<td>18.17</td>
<td>18.03</td>
<td>22.54</td>
</tr>
<tr>
<td>Root relative squared error (%)</td>
<td>20.92</td>
<td>21.01</td>
<td>20.92</td>
<td>27.66</td>
</tr>
</tbody>
</table>

The test dataset is comprised of 247 instances, which capture traffic volume data for all 12 months of 2018 and for each of the 21 automatic traffic counters. The performance of the three selected models, obtained on the test dataset, is shown in Table II. The models based on the IBk (k-Nearest Neighbors) and Random Tree algorithms were chosen as the best prediction models because their performance is improved on the test dataset over the training dataset and because they show the best performance on the test dataset (Table II). Prediction was done by applying the best machine learning models (IBk and Random Tree) to the test dataset. The prediction results using these two models are identical.

Table II. Performance of the top three prediction models measured on the test dataset used in example 1

| Machine learning algorithm | IBk (k=1) | Random Forest | Random Tree |
|----------------------------|-----------|---------------|-------------|---------|
| Correlation coefficient    | 0.9768    | 0.9766        | 0.9768      |         |
| Mean absolute error        | 39582.5   | 39594.2       | 39582.5     |         |
| Root mean squared error    | 50469.5   | 50488.9       | 50469.5     |         |
| Relative absolute error (%)| 35.34     | 35.35         | 35.34       |         |
| Root relative squared error (%)| 33.88 | 33.90         | 33.88       |         |
Prediction results are analyzed for traffic counters whose labels are: 1027, 1057 and 1183. The locations of these counters are shown in Fig. 1. The Fig. 2 shows relationships between actual values of the monthly traffic flows for the year of 2018, and the values predicted using the machine learning models that are selected as the best ones (IBk and Random Tree), for three selected traffic counters.

**B. Example 2**

Training dataset: *Monthly percentage traffic flow structure for 21 traffic counters on three selected routes in the Republic of Serbia, for the period 2011-2017; Number of instances: 1740; Attributes: counter, month; Dependent variables: A0%, A1%, A2%, B1%, B2%, B3%, B4%, B5%, C1%, C2%, X%*; Test mode: 10-fold cross-validation. Traffic counters are located at the routes Preljina-Pojate and Preljina-Gostun.

The performance of the first four different machine learning models created by using four different algorithms on this training dataset are shown in Table III. Dependent variable in these models is *A1% - percentage participation of A1 category vehicles in traffic flow*. Vehicles of category A1 are passenger cars and passenger cars with trailers.

<table>
<thead>
<tr>
<th>Machine learning algorithm</th>
<th>IBk (k=1)</th>
<th>MSP</th>
<th>Random Forest</th>
<th>Random Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>0.9701</td>
<td>0.9502</td>
<td>0.9699</td>
<td>0.9701</td>
</tr>
<tr>
<td>Mean absolute error</td>
<td>0.7323</td>
<td>1.1788</td>
<td>0.7357</td>
<td>0.7323</td>
</tr>
<tr>
<td>Root mean squared error</td>
<td>1.171</td>
<td>1.596</td>
<td>1.1733</td>
<td>1.171</td>
</tr>
<tr>
<td>Relative absolute error [%]</td>
<td>18.61</td>
<td>29.97</td>
<td>18.70</td>
<td>18.61</td>
</tr>
<tr>
<td>Root relative squared error [%]</td>
<td>24.29</td>
<td>33.10</td>
<td>24.33</td>
<td>24.29</td>
</tr>
</tbody>
</table>

**Table III**

**Performance of the Top Four Prediction Models Measured on the Training Dataset Used in Example 2 (A1 Category Vehicles)**

<table>
<thead>
<tr>
<th>Machine learning algorithm</th>
<th>IBk (k=1)</th>
<th>Random Forest</th>
<th>Random Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>0.9817</td>
<td>0.9815</td>
<td>0.9817</td>
</tr>
<tr>
<td>Mean absolute error</td>
<td>0.6833</td>
<td>0.6836</td>
<td>0.6833</td>
</tr>
<tr>
<td>Root mean squared error</td>
<td>0.924</td>
<td>0.9291</td>
<td>0.924</td>
</tr>
<tr>
<td>Relative absolute error [%]</td>
<td>17.12</td>
<td>17.12</td>
<td>17.12</td>
</tr>
<tr>
<td>Root relative squared error [%]</td>
<td>19.06</td>
<td>19.17</td>
<td>19.06</td>
</tr>
</tbody>
</table>

**Table IV**

**Performance of the Top Three Prediction Models Measured on the Test Dataset Used in Example 2 (A1 Category Vehicles)**

---

![Fig. 1. Locations of the traffic counters selected for prediction analysis](image1)

![Fig. 2. Actual and predicted monthly traffic flows for three selected traffic counters](image2)
Prediction results are analyzed for traffic counters whose labels are: 1057, 1156 and 1270. The locations of these counters are shown in Fig. 1. According to the results of the models shown in Table IV, the models that have the best performance were based on IBk (k-Nearest Neighbors) and Random Tree algorithm. Considering all performance measures these models show the best performance. The model based on Random Forest algorithm has very similar performance.

The Fig. 3 shows relationships between actual values for the year of 2018, and the values predicted using the machine learning models that are selected as the best ones (IBk and Random Tree), for three selected traffic counters.

IV. CONCLUSION

The research has shown that Big Data analytics based on machine learning technics can be successfully applied to predict volume and structure of traffic flows. A great number of machine learning models based on the application of the most popular regression algorithms were built, verified and tested: k-Nearest Neighbors (IBk), M5P, Random Forest, Random Tree and REPTree. Some of built machine learning models have shown satisfying performance, thus verifying the proposed prediction methodology. The best results were received by models based on k-Nearest Neighbors and Random Tree algorithms. This means that the independence of the attributes of the observed dataset is better described by nonlinear machine learning algorithms and ensemble machine learning algorithms than by linear machine learning algorithms.

ACKNOWLEDGEMENT

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REFERENCES

Review of the DataFromSky ACADEMY program

Lukas Mozga, MSc¹, Petra Glazerova, MSc², Pavel Fojtik, BSc³

Abstract — DataFromSky ACADEMY program is educational program offered to schools, universities, educational institutions and training companies. Thanks to this program, students and teachers have access to fully automated traffic data analysis provided by DataFromSky platform that is used by traffic engineers and civil engineering companies worldwide. In past few years more and more teachers and students were asking us for the traffic data analysis for interesting study and research purposes, therefore we have decided to cooperate with institutions to make part of our software easily accessible for them as well. The goal of the program is to introduce modern way of video-analytical tools of traffic data analysis and current trends in traffic engineering. Within this paper we will introduce students and teachers and other potential users of how to access to DataFromSky Platform, and to get in touch with the software, so they know how to use it and what kind of technology is behind it. Our general aim is to spread the word about the platform and program.

Keywords — DataFromSky-DFS, Academy Program, Traffic Data

I. INTRODUCTION

RCE is a firm providing custom built solutions in robotics, computer vision and Embedded Systems. DataFromSky is subsidiary company of RCE systems and many partners in variety of areas. One of the areas is research that DataFromSky supports with the Academy programme for universities which provides them with traffic video analysis and help to researchers allowing them work with top level tools for free. There are currently more than 30 universities around the world using TrafficSurvey analysis for their projects ranging from noise predictions models, traffic safety simulations or impact of Covid-19 on traffic. Another important contribution is that that’s to DataFromSky analytics a major dataset called pNEUMA was created which contains more than 500 thousand trajectories from large area in Athens. DataFromSky also has many business partners. They include multiple large consultancy firms for which analyses are done regularly such as Roelofs or COWI. DataFromSky has close reailiation with both and has implemented new features based on their requests. For the real-time detections the important partners are the IP camera manufacturers and various integrators all over the world. One of the important partners for real-time systems is ATS Traffic from Canada.

The platform Data From Sky consists of several individual products, which can be combined and integrated to each other in functional and complex blocks.

1) Data From Sky AI — Fully automated service for extraction of traffic data from videos (drones, static cameras etc.). The whole process of the analysis is based on Deep Learning and AI. This analysis is processed offline (you shoot the video and analyze data later with our Data From Sky Viewer (license-free software), professional desktop application used for the analysis of movements of objects within the video. This comprehensive freeware tool has been built since the year 2013 and has helped during a lot of research and commercial projects worldwide.

DataFromSky AI platform consists of two parts:

- DataFromSky LIGHT — analyzing the video from static cameras on the ground. It can provide comprehensive traffic data such as Origin-Destination matrix, turn-movement counts, gate counting, object classification up to 16 categories in total, trajectories, various export options (Excel, CSV, visualizations), stationary time, recognition of colors of objects and much more...

- DataFromSky AERIAL — analyzing the videos recorded by drones or other UAVs. The most advanced technology for traffic monitoring at the microscopic level. Trajectory & GPS position, speeds, acceleration, Tg&Tf calculation, capacity estimation, Time to Collision, Safety analysis and road user behavior patterns.

The process is easy:
1. You take the video of traffic that you want to analyze
2. Upload video to our platform
3. Download results and analyze them through our software

2) DataFromSky Real-time offers you HW/SW products for real-time data analysis for traffic monitoring and control (centralized or embedded variant), various application including traffic monitoring, but also crowd management, people counting and tracking in cities, surveillance and security. We have a variant for traffic monitoring from fixed cameras (mounted on highways etc.) or a drone-based realtime solution.

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²Sales Representative, pavel.fojtik@rcesystems.cz
II. DATAFROMSKY ACADEMY PROGRAM

We have decided to make part of our service accessible for students and lecturers for teaching and research purposes (non-financed projects).

General Data From Sky Academy Program Definitions are:

- Provider is RCE systems s.r.o., a company incorporated under the laws of the Czech Republic with its registered seat at Svatopluka Čecha 2008/1d, 612 00 Brno, Id. No.: 021 83 234, recorded in the Commercial Register administered by the Regional Court in Brno under File No. C 80533.
- Educational institution is an organization which carries out educational activity.
- User is person approved by educational institution to use the DataFromSky services defined in.
- Service is advanced traffic analysis of Video, including provision of Results and related services provided by the Provider including provision of software products, if applicable. The Service is divided into (i) DataFromSky Aerial (“DFS AERIAL”) and (ii) DataFromSky Light (“DFS LIGHT”).
- Software is the integrated cloud computing solution for providing the Service, including applications, software, databases, interfaces, associated media, documentation, updates, new releases and other components or materials provided therewith, DFS Viewer and other software related to provision of the Service.
- Academy User Account is account dedicated to DataFromSky ACADEMY program per agreed educational institution. This account is necessary to access the DataFromSky service.
- Credits represents a number of hours of the Video, which are assigned to the account or may be bought and analysed via the Service under valid pricelist.
- Result is an outcome of the automated analysis, in format which shows the analysed Video including the detected trajectories of vehicles or people, count of vehicles and other derived parameters.

Benefits of DFS ACADEMY Program:

- One-year membership for educational and training institutions
- Access to DataFromSky AI platform and licence-free software
- 1 000 Credits for Automatic data processing in DFS LIGHT and DFS AERIAL (these Credits can not cover manual georegistration from our side - you can set your own within DFS Viewer, 100% data accuracy and Licence plate detection and has to be purchased according to valid pricelist)
- Access to existing data sets of other institutions within the Program
- Certificate proving participation in the Program
- Cooperation on research projects
- No-special HW required

Our requirements in case you decide to join the Academy Program, are:

- Closer cooperation on research projects and mutual propagation
- DataFromSky AI will be presented as part of lectures to be utilized in student works/thesis
- Minimally 2 public posts connected to DataFromSky AI
- DataFromSky AI can use results from the platform only for internal purposes such as DNN network training or improvement of Service provision
- You can share data sets with DFS ACADEMY program participants (optional)

Fig. 1: DataFromSky Viewer
Source: [1]

DataFromSky Viewer (Fig. 1) is currently supporting UTM and WGS-84 system for localization of objects with precision up to 20 cm and using both Imperial and Metric system. Thanks to the software, that is installed on your laptop, you can analyze and export data and statistics offline at any time you want. DataFromSky service detects objects, their movements, interactions and based on this information you can work with data, information and statistics over raw data from the video. See some of features of the software that all with 98% - 100% accuracy:

- Visualize detected objects and their trajectories within the video processed through DFS Light or DFS Aerial
- Classification of objects up to 16 categories
- Origin-Destination matrix (OD matrix)
- Turning movement counts (TMCs)
- Calculation of headways
- Gaptime, time to follow data
- Safety analysis (time to collision, post encroachment time, heavy breaking)
- Current speed, acceleration, deceleration of any object
- Color recognition
The DataFromSky Light engine can process data from any video input such as static/handheld consumer camera or footage from an existing CCTV infrastructure. For the best traffic analysis results we recommend the following input video parameters:

- resolution: 1280×720 or more
- bitrate: 5 Mb/s or more
- framerate: 25 fps or more
- min.traffic object size: 32px in one dimension
- continuous video without cuts
- no camera movement

Example of the configuration best suitable for DFS LIGHT analysis:

- elevation of the camera: 10m
- resolution: > HD
- optics FOV: 90°
- angle between the imaging axis and the ground plane: 45°

IV. DATAFROMSKY VIEWER EXPORT DATA IN 5 MINUTES

Results are a small.TLGX file called tracking Log that represents a data package containing information about traffic analysis scene and detected or annotated vehicle trajectory data. Each Tracking Log is closely tied to the video sequence file, as it itself does not contain image data. If you want to view or edit Tracking Log, you have to open it through DataFromSky Viewer with the original video sequence file as well. Download and install DataFromSky Viewer to your computer. It is license-free software, you do not have to pay anything for it!

To open the tracking log choose File – Open Tracking Log. Then choose your .TLGX file with the original video you want to analyze as shown in Fig. 4.

You will be able to see and play the video and see detected objects and trajectories within the video. Now go to Tracking Log – Manage Annotation Configurations.
Clone existing configuration, select new configuration as active and press Edit as shown in Fig. 5. In case you want to set different kinds of scenarios over the video input you can set more than 2 scenarios and save them all to one tracking log file.

![Image](image_url1)

Fig. 5: Example of tracking log file annotation

You are now able to set gates, lanes, traffic regions, action regions, measurement nodes or anonymization regions based on your requirements. Once you set the scenarios that you want to analyze, Confirm Annotation Redefinition and apply the changes to see them in the video. See example how lanes, gates and anonymization region can be set in Fig. 6.

![Image](image_url2)

Fig. 6: Example roundabout with gates and traffic regions setup

Now if your next question is how to export TMC (turning movement counts)? Get interval data with Turning movement counts.

If you are looking for gate statistics in relation to time, you can use Turning Movement Counts export. Based in this report you can get the information about moving objects within gates per 3 defined time periods (Minor, Major and Overall). The length of each period is up to you! To export data about Turning movements, go to the Analysis menu and choose Export Traffic Analysis to Excel File or you can find Export Traffic Analysis to Excel File button on the Main toolbar.

The exported excel file is consisted from the sheet Overview, Gate Statistics and Turning movements (overall and split by object category):

- Overview sheet is divided to two separate parts:
  - Survey overview that includes information about the video (date, time and length of video creation) and information about Minor, Major and Overall Period.
  - Overall statistics: you can see the overview of objects, number of objects from each category, total distance traveled within the video or Average speed in analyzed video.

- Sheet Gate Statistics summarize information such as minimal, maximal and average speed of objects at the moment of passing each gate and you can see count of each object that passed through defined gate as well.
- Excel sheet of Turning movements in Fig. 7 – Summary includes gate passing information for each entry and exit gate in each defined minor, major and overall period that you have set. Other sheets display turning movements for each category of object separately (cars, medium vehicles, heavy vehicles, bus, motorcycle, bicycle and pedestrians).

### Survey report - Turning movements - Summary

<table>
<thead>
<tr>
<th>Time</th>
<th>Gate 1</th>
<th>Gate 2</th>
<th>Gate 3</th>
<th>Gate 4</th>
<th>Gate 5</th>
<th>Major</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00:00 - 12:05:00 (5 seconds)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12:05:00 - 12:10:00 (5 seconds)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12:10:00 - 12:15:00 (5 seconds)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12:15:00 - 12:20:00 (5 seconds)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12:20:00 - 12:25:00 (5 seconds)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 7: Example of sheet turning movement summary

### V. SAFETY ANALYSIS IN THE DATAFROMSKY VIEWER

Analyze nearby collisions, post encroachment time, heavy braking and other safety data in your video.

Are you designing a new concept of a street or need to identify dangerous situations based on interactions between vehicles? Use our safety analysis that can provide you data about near by collisions, post encroachment time or heavy braking in your video. You can export these data to a .CSV file for further analysis as well.

You can set your own Safety analysis parameters in Analysis – Safety Analysis – Safety Analysis. In the same menu, you can choose the possibility to Show Safety Analysis Conflicts List. This option shows you the list of detected conflicts that you can go through in a video and export data out of it to a .CSV file (in the same menu under Export Safety Analysis to .CSV File).
Nearby collision as shown in Fig. 8 will detect time to collision in case vehicles would be moving at a constant speed and direction at that moment. You can define which nearby collisions should be listed by setting the limit for time to collision (for example 2 seconds from the collision) or minimal speed difference of both vehicles. If you work with time to collision you can choose whether you want to identify risky situations for the whole duration of the video or only for a part of it, type of the vehicles that you want to include to the analysis and two models for the movement prediction of vehicles:

- **Speed Vector** – This is a simple calculation where the movement of the vehicle is considered straight forward. For this reason, the calculation of collisions in a curve is not entirely accurate, but the calculation is less demanding.
- **Ackerman Steer Model** – This is a more precisely defined vehicle model, the calculation is based on the angle of wheels, but for this reason, the calculation is more demanding and takes more time.

Once you confirm your settings, conflict list appears. You can go through each Conflict and play the video to see the whole scene. Once you click to TCC Progression: Show, graph of Time to Collision in relation to Video Time shows.

How to anonymize data in the video?

Do you want to present your data, but you can recognize people, licence-plates or other private information in the video? Do not worry, we are prepared for that! Use the possibility to anonymize certain area in the scene view by creating anonymization region. Creation of the anonymization region is similar to creation of action region. Great news is that anonymization is copying stabilization of the frame. In case your camera is moving, anonymization region is moving with it, so your objects are still hidden!

To set the Anonymization region, go to Tracking log – Manage Annotation Configuration and edit tracking log, where you want to apply the anonymization. Click to “Adds Anonymization Region defining area which should be anonymize.” And start creating polygon that you want to make blurry. You can set Degree of blur in the Selected Annotation column. If you want to you can anonymize everything outside of current view as well!

DataFromSky TrafficSurveyViewer also has many visualization options including trajectory coloring by category, speed, acceleration or direction. Heat maps such as speed heatmap in Fig. 9, Grid maps and color-coded Origin-Destination pictures can be made easily in couple of clicks.

**VI. CONCLUSION AND RECOMMENDATIONS**

DataFromSky Academy program is a great and versatile tool for researchers in traffic allowing them to do a great variety of research with highly accurate input data that is easy to get thanks to AI. Together with other tools such as scripting or excel the data can futher be processed into the desired form. There are 3 main benefits of the Academy programme:

1. it is free
2. it is given to any university that signs the agreement with simple promotion related tasks
3. there is no other similar software that would provide the same range and quality of data.

One of the downsides can be that getting footage from CCTV cameras from cities for free is hard to obtain for light analysis and shooting drone footage for aerial analysis has additional costs that the researchers need to cover themselves. Overall DataFromSky Academy provides the ideal tools any traffic researchers can wish for as long as they have own ability or funds to obtain drone footage for the video analysis.

**REFERENCES**

Innovative ICT model of E-business in urban railway transport

Zoran G. Pavlović¹, Zoran Bundalo², Veljko Radičević³ Marko Bursać⁴

Abstract – The paper presents the basic directions for the implementation of activities for the procurement of digital maps and transportation of service users. The activity includes the integration of the internet service of urban traffic in Belgrade (metro as a part of the railway and the city transport company). The model shows the architecture and infrastructure based on advanced internet technologies. The aim of this paper is to present the application of ICT in future businesses.

Keywords – internet service integration, urban service, service provider, service user

I. INTRODUCTION

The application of innovative ICT business models is increasingly common. In accordance with the vision and mission of transport companies, the application and development of innovative services is reflected primarily in customer satisfaction [1], [2], [3]. Very current application of the new paradigm of the business unit in the development of innovative ICT model, are interactive components of human resources, technology, organizational processes, environment and service / product, where research in the field of transport services in urban areas.

As a rule, transport is a multimodular structure and services are predominantly organized in the integration of several modules. Transport service is determined by technological and behavioral components. The technological component is determined by the capacities of transport organizations as service providers, mechanisms for access and delivery of services, security requirements and business-process technological resources.

The behavioral component is determined by the roles of responsible operators for service delivery with management of security factors and user-people factors, input data they provide, needs-desires, requirements and expectations as well as contextual information important for synchronizing activities in service process structure [4], [5]. The basic idea is to satisfy the needs, requirements and wishes of users through an innovative ICT e-business service in order to increase the quality of service. This paper presents the possibility of integration of several modules and internet services at the level the city of Belgrade.

II. MODELING OF INNOVATIVE ICT MODEL

A. Infrastructure components

Basically, modeling an innovative e-business model based on advanced Internet technologies includes: human resources, applied technology, organizational processes, environment (place or space) for the implementation of e-processes and service or product [1].

Fig. 1. Components of an innovative model

The components "human resources" and "services" have a dual purpose, which can be viewed as part of the structure of an innovative model in the process of realizing service transactions, and then can be independent until the use of a digital map or planning the next trip. Human resources can be analyzed by service users as well as employees in transport organizations in the structure of the innovative model.

For the development and use of the model, the user of the service plays a key role as the initiator of the electronic process for the procurement of the transport ticket. Employees

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in transport organizations, IT administrators have a special role in arranging the accessibility of innovative model services, availability at any time of the day during the week as well as for the security requirements of all interested participants during the interaction activities.

The service, the transport ticket in digital form that the user receives on the smartphone represents the final result of the electronic process.

Applied technology and organizational processes determine the ability and implementation of electronic process services in order to procure a map in a virtual environment based on the Internet platform.

Based on the above, it is necessary to develop a model of an innovative transactional model of electronic business based on advanced Internet technologies in the transport of users. The model should include the infrastructure consisting of hardware and software that have the role of connecting the computer and the user and to connect devices and communication channels for data transmission via the Internet. The service components applied in the innovative model are shown in the table 1.

<table>
<thead>
<tr>
<th>Component</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Infrastructure Architecture</td>
<td>Passive Equipment, Servers, Routers</td>
</tr>
<tr>
<td>Software infrastructure</td>
<td>Mobile technologies, Wireless technologies, Wireless standards</td>
</tr>
<tr>
<td>E-business infrastructure management</td>
<td>Business results analysis, Technical performance analysis, Infrastructure monitoring, User interface</td>
</tr>
<tr>
<td>E-business services</td>
<td>Content creation, Process management, Transaction realization, Data analytics</td>
</tr>
<tr>
<td>Infrastructure of quantitative components</td>
<td>Security, Availability, Efficiency</td>
</tr>
</tbody>
</table>

Based on the above, the services of the railway and road carrier as well as the services of the bank must ensure uninterrupted communication at any time of the day for the necessary service that is in line with available transport capacity, choice, payment and cancellation of travel in the e-procurement process maps.

The presentation of the railway e-business service in an innovative contactless transaction model implies an overview of the content as well as the choice of service that can be realized in the interaction of service users via the Internet with the service provider's service, ie. with the railway and road organization for the transport of passengers. Infrastructure e-services are the basis for the functioning and use of all other services, including e-learning, e-health, e-banking, e-procurement, e-business, e-justice [9].

DNS (Domain Name System) is a basic Internet service for the implementation of an innovative model that also translates the Internet domain and IP address [10], an e-mail exchange service for obtaining maps in digital format, services for remote access to network resources are the basic services that are an integral part of every computer on the network. E-business services basically have the task of supporting and realizing the selection process required by the service user and the realization of online money transactions with the bank's services via mobile technologies. Mobile services must provide the functionality of e-business services through mobile technologies. Big data services include data management services that arise in the exchange of e-mails in the communication of users with the service provider (railway and road carrier). Messaging in the Data Center is a data that serves for detailed analysis and review of quantitative and qualitative indicators that are directly related to service users.

Content creation services enable the IT administrator to set up and present a service that includes the possibility of choosing the route of the road and railway carrier. The created content must be available to the users of the service anytime and anywhere. Process management services include monitoring of available railway resources that are foreseen as well as the resources of the road carrier and at the same time the real needs of service users.

Realization of transactions is a service that should provide a safe and secure payment process when the user of the service has selected and confirmed the requested service and the service is automatically booked. The service of realization of contactless money transactions of the bank must function as an intermediary.

The data analytics service should provide the possibility of analyzing all activities in the process of reviewing, exchanging e-mails regarding the selection and implementation of the contactless process of purchasing a map in digital form, which they realize in the interaction between service users and railways via Internet service.

B. Model realization process

The innovative model of electronic business in urban transport basically includes the user of the service as a client and the railway and road transport organization as a service provider. The user of the service selects, pays for and receives
an e-ticket in digital format via an application on a smartphone.

The process of realization of e-business models based on advanced Internet technologies functions between the service user (client) and the railway (service provider).

The user of the service uses a mobile device application to realize an innovative contactless model in order to purchase a transport ticket. By opening the application installed on the smartphone, the service user has the option of choosing the travel route. After selecting the route, it reviews and selects the travel date. For a certain date, it selects the number of trains where the possibility of choosing the type of place (sitting, bed, bed) is opened. The selected request is sent to the service provider’s service via a wireless connection.

<table>
<thead>
<tr>
<th>Email-request (client)</th>
<th>Email-response (server)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway route selection</td>
<td>Confirmation of the railway route</td>
</tr>
<tr>
<td>Selecting the number of service users</td>
<td>Confirm the number of service users</td>
</tr>
<tr>
<td>Privilege selection</td>
<td>Confirmation of privilege</td>
</tr>
<tr>
<td>Travel date selection</td>
<td>Confirm the travel date</td>
</tr>
<tr>
<td>Choice of road transport service or payment</td>
<td>Confirmation of road transport or payment</td>
</tr>
<tr>
<td>Road carrier route selection</td>
<td>Confirmation of the road carrier route</td>
</tr>
<tr>
<td>Selecting the number of service users</td>
<td>Confirm the number of service users</td>
</tr>
<tr>
<td>Privilege selection</td>
<td>Confirmation of privilege</td>
</tr>
<tr>
<td>Travel date selection</td>
<td>Confirm the travel date</td>
</tr>
<tr>
<td>Payment selection</td>
<td>Payment confirmation</td>
</tr>
<tr>
<td>User registration</td>
<td>Confirmation of user registration</td>
</tr>
<tr>
<td>Payment for the requested service</td>
<td>Confirmation of payment for the requested service and sending a digital card</td>
</tr>
<tr>
<td>Viewing a paid service and storing a digital card on a smartphone</td>
<td>Booking a paid service and sending data to the DATA center</td>
</tr>
</tbody>
</table>

When the service receives the request of the service user, the requested service is conditionally reserved and a new page is opened that refers to the road carrier. The user of the service has the option to select an offer in road transport or to skip and focus on registration in order to pay for the selected service online. In case of major disturbances in train traffic or extraordinary events, there is a possibility that the request of the service user will not be accepted when the carrier's application is not in function.

If the payment process is successfully completed, the carrier reserves the requested service resource and sends the user a digital record representing the transport ticket containing:

- Date and time of payment for the service;
- Ordinal number of Internet payments in the service for contactless ticket issuance;
- Number of seats;
- Travel route;
- Date of travel;
- Number of service users;
- Total price of the service;
- Bar code for validation and control in the vehicle.

**C. Activity flow algorithm**

The innovative Contactless IT transaction model presents an algorithm (Figure 2) for activities related to the exchange of messages in the e-process of communication between service users and providers [1].

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**Fig. 2. Activity algorithm in an innovative ICT model**

In order for the user to satisfy his need in order to procure a transport ticket in digital form, the request for an electronic ticket "ek" must be less than or equal to the operational capability of the application "AP" to obtain the required service in accordance with the capacity of railway and road transport organization.

The electronic card "ek" in the e-process is generated by the transaction activities of the application "AP" where the choice is enabled in the railway TO "Arail", in the road TO "Aroad"
and payment for the service contactlessly through the bank "ABank". The subset "Arail" includes the following steps: selection of route "1", date "2", number of passengers "3" and type of seat "4". While in the road TO "Aroad" the user of the service chooses the route "1", the date of travel "2" and the number of passengers "3". The service user pays for the service contactlessly through the bank "ABank" in the following steps: user login "1", account entry "2", payment "3", confirmation of payment for service "4" and rejection of the requested service "5". The user with the e-card on his smartphone performs validation in the vehicle "V1" and for control by an authorized employee "V2".

III. CONCLUSION

The e-business model based on advanced Internet technologies of transport services consistently incorporates wishes, requirements and needs of service users in the interactive dimension of messages and business transactions with transport organizations for railway transport. The e-business infrastructure of railway transport trains hardware and software components of the system, human resources, internet technologies, mobile technologies, arranges for security and digital protection of service users. The availability of web services in Internet communication users from any mobile device positioned at any physical location and at any time, recommends interaction with add-on models that are tested in real conditions presented in test scenarios. Ultimately, this will affect the improvement of the image of railway organizations in the business environment and the creation of a positive ambient climate for connecting the total quality of services and maintaining the stated level of connecting customer services.

In future research based on the implementation and application of the innovative model, special attention should be paid to the number of passengers carried and the use of the model over time is extremely important for service providers. In this way, service providers can successfully align the service with the real requirements of service users. In addition to the above, the service model presented can be quickly adapted through strategies in line with the goal of improving the performance of the entire system.

The presented innovative model approaches new trends through the application of e-business and integration of services of several transport organizations, which should be expanded according to the needs of service users in order to improve service quality in order to achieve higher revenues and reduce costs. The development and improvement of the business of transport organizations as well as other interested organizations in society and the economy with the application of innovative business models enables new trends provided by Internet technology.

REFERENCES

Smart Parking Technologies

Milja Simeunović1, Zoran Papić2, Pavle Pitka3, Dejan Radivojev4, Nenad Saulić5

Abstract – The Smart city concept involves the use of smart technologies to improve the quality of life of all residents. Traffic, as an important functioning component of all human activities, has an important role in smart city planning. Within this paper, we will introduce some of the smart technologies used in the parking system.

Keywords – parking, smart technologies, sensors.

I. INTRODUCTION

Solving existing parking problems has been a major challenge for decades. The level of motorization is constantly growing in the world and causing increasing problems of organizing parking. There is less and less space available for organizing parking, especially in urban areas. Drivers spend a lot of time searching for a parking space, so finding a free parking space is often a frustrating activity for many people in cities around the world. In the last few decades, there has been an explosive growth of information and communication technologies. The use of these technologies in cities for various activities has led to increased efficiency of functioning in cities and such cities are labeled as smart cities. In smart cities, digital technologies are used in public services for residents and for better use of resources with less impact on the environment. Creating smart cities is a natural strategy to mitigate the negative effects of urbanization. They can reduce energy consumption, water consumption, carbon emissions, transportation requirements and municipal waste, despite the high cost of deployment. Traffic has a very important role in the concept of a smart city. Smart technologies have found their role in different fields of traffic. Therefore, the use of modern technologies in solving parking problems has become a constant practice.

II. SMART PARKING TECHNOLOGIES

Creating smart cities also involves the application of modern smart technologies in the field of transport. The old automated technologies meant the availability of information about the available number of free places in certain parking spaces, however, this information did not inform the drivers about the location of the free parking space within the parking lot, the shortest route to the free parking place, the possibility of remote reservation of the parking space, and etc. The use of smart technologies is increasingly prevalent as these technologies are able to advance and solve deficiencies of older information technologies. The most important benefits of smart technologies are reducing fuel consumption, reducing time spent searching for a free parking space, reducing harmful emissions, reducing noise, etc. According to a report, Smart Parking could result in 2,20,000 gallons of fuels saving till 2030 and approx. 3,00,000 gallons of fuels saved by 2050, if implemented successfully [1]. The researches also shows that every car driver wastes on average about 100 hours a year looking for a parking space, which accounts for one third of city center traffic [2]. Consequently, the importance of smart parking and smart traffic management is increasingly important today and is becoming a mandatory part of the smart city planning process.

There are different developing technologies of smart parking. Some of these technologies are used independently in some situations, while multiple technologies are combined in other certain situations. There are different categories and classifications of smart parking which vary from source to source.

According to one source, numerous technological methods are grouped into the following classification [3]:
- Smart parking systems based on agent model
- Wireless sensor networks-based systems
- Smart parking systems based on Vehicular to infrastructure communication
- Smart parking systems based on Global Positioning Systems (GPS)
- Smart parking systems based on Computer vision
- Smart parking systems based on RFID technology, etc.

Smart parking systems based on agent model

These types of system can be any entity capable of observing facts via sensors, as the system is acting upon the changes of the environment through exchanging information and interaction upon that act. Essentially, a multiagent system is a modelling method developed to represent systems with entities, autonomy, and interaction.

Wireless sensor network-based systems

This type of system, which utilizes sensors to monitor environmental conditions, is widely used, due to the ease of installation and configuration, and the reasonable price.
Smart parking systems based on Vehicular to infrastructure communication

This promising technology emerged recently. It proposes a new smart parking technique that depends on developing a new smart parking to be used for smart steering and smart parking. It refers to Vehicular Communication Systems, in which vehicles and roadside units communicate and exchange information with each other, such as safety warnings or supplying the traffic congestion information and even for finding vacant parking spaces.

Smart parking systems based on GPS

Global Positioning Systems (GPS) technology is used to offer information about the location and availability of parking spaces at the destination.

Smart parking systems based on Computer vision

This field of study includes methods for acquiring, processing, and analysing images. It uses computers to emulate human vision, including learning and being able to make inferences and take actions based on visual inputs. The goal of computer vision is to make computers efficiently perceive and process visual data, such as images and videos, and act upon changes in these images. Usually, the technique involves analysing a few frames per second and then sending the data to a central database, after which, the user can retrieve information about the changes at the parking lot.

Smart parking systems based on RFID technology

The main mechanism of RFID technology depends on an electromagnetic field to identify and track tags attached to objects automatically.

The following will describe one of the existing smart parking systems developed by Simens – Intelligent City Parking Solutions.

III. INTELLIGENT CITY PARKING SOLUTIONS

Siemens has developed a sensor-controller parking management system (Intelligent Parking Solutions) that helps optimize the use of urban parking facilities and substantially reduce the congestion caused by drivers searching for a parking space (Fig. 1) [4]. A first pilot project was installed at the Berliner Bundesallee in September 2015 for test and demonstration purposes [5]. This parking management system use of the full potential of digitalization: smart sensors, intelligent software and clever analysis of the available data.

The Siemens parking bay sensor (Fig. 2) is an ultra-low-power microwave-radar detector. It is used for detecting parked vehicles as well as recording parking start and end times. Sensors can be installed in pavement or as overhead (e.g. mounted in street lights). If installed at a height of 10 m, the sensor can monitor five to seven cars parking slots plus the surrounding area, for instance cycle paths or lanes reserved for buses or emergency vehicles. This allows the fast and cost-effective recording of parking data as well as the detection of parking violations. Sensors can detect a free parking space also what is very important for users of parking lot. They can detect the flow of cars or the flow of pedestrian and can measure their speed and traffic conditions[6].

Detection accuracy is not affected by lighting conditions or dirt, dust or oil on the sensor and they are not impaired by light or weather conditions.

The sensor readings are sent over the mobile network to the software in control center where they are analyzed, current parking space occupancy is calculated, and the information is prepared for services such as a parking space application (Fig.3) [7]. The software recognizes recurring patterns in parking space occupancy. On this basis it calculates prognoses and recommendations for the users, such as the expected parking space situation at their destination or alternative routes through...
areas with lower volumes of traffic. By using adaptive systems, the software can answer to specific users’ questions, for instance: How likely is it that a parking slot will be available in front of my favorite restaurant in 30 minutes [4]?

Informations can be used by different uses [6]:
- traffic info centres to enhance their own traffic information services.
- driver assistance system (smartphone applications, sat navigations or parking guidance signs) to help drivers find out in real-time where they can park.
- multimodal trip planning tools to help citizens plan their trips considering the parking situation or to propose public transport alternatives when no parking is available

Drivers can use the collected data to find out about currently available parking spaces. Route planning applications and integrated navigation systems minimize the time spent in search for a parking space and thus help reduce urban traffic volumes. As the solutions predicts the time needed to secure a parking space to the place he wants to go, it even helps the road users make informed decisions about which means of transportation to use.

Drivers can use the collected data to find out about currently available parking spaces. Route planning applications and integrated navigation systems minimize the time spent in search for a parking space and thus help reduce urban traffic volumes. As the solutions predicts the time needed to secure a parking space as well as the walking distance to the final destination, it even helps the road users make informed decisions about which means of transportation to use.

Fig. 3. The user application to use the Intelligent Parking Solutions

Benefits parking management system (intelligent Parking Solutions)

Benefits of implementing the smart parking system can be viewed from various aspects. There are several stakeholders involved in improving parking performance, such as drivers, parking operators, cities and their citizens. The use of smart parking systems enables drivers to find the free parking space in the shortest possible time by different applications, to drive to free parking space in the shortest possible route, to plan their trips, save on fuel, etc. When users search the free parking space by applications they can also get information about the walking distance from a potentially free parking space to the place he wants to go. At the same time drivers also receives information about the nearest P + R parking lot with the corresponding urban transport service. This can motivate people to use urban transport and ensure a balanced utilization of the overall available urban parking capacity.

Parking operator using smart parking systems has real-time statistic about parking parameters, better utilization of parking spaces which has the effect of increasing revenue, prediction capabilities with real-time data, and generally better service to customer.

Each city aspires for efficient organization of traffic and traffic areas, with the reduction of congestion, pollution, noise, improper parking, etc. The implementation of smart parking solutions has a positive effect on all of the above and also contributes to increasing accessibility to visitors in high-attraction areas.

An analysis of the operation of the developed the Intelligent Parking Solutions shows that 43% less time is spent searching for parking, 30 % less parking-related vehicle miles is traveled, 8% less traffic volume when increasing parking availability and CO₂ reduce greenhouse gas emissions accordingly [6].

IV. CONCLUSION

The benefits of using smart parking systems are multiple. Getting information about free parking spaces in the real time and routing drivers to that location allows drivers to easily plan their trip while saving travel time and travel costs. In addition, with a strategic approach to parking system control, it is possible to minimize the influx of cars in areas with a lack of parking spaces, routing them to other locations. Obtained data by the use of smart parking systems can be used for planning purposes, enabling strategies to be created as part of the system in such a way that it can increase customer satisfaction, increase revenue, reduce irregular parking, etc. Smart parking solutions can uses the Internet of Things platform from the U.S. firm Intel for communication between the sensors and the control center, forming the basis for a sensor and communications network that is suitable for future smart city concepts.

REFERENCES

Безбедноста во сообраќајот
Traffic Safety
Unified Approach to Risk Assessment at Railway Crossings

Tomáš Kohout\textsuperscript{1} and Pavel Vrtal\textsuperscript{2}

Abstract – This conference paper discusses a new analytical approach to the evaluation of traffic safety at the railway crossings. The new method is based on the use of ontological principles. The ontological tools present a comprehensive decision-making tool, will can be applied to any potential hazardous railway crossing on a road or rail network.

Keywords – railway crossing, Traffic safety, Ontology.

I. INTRODUCTION

The primary focus of the research task is to create a systematic tool for evaluation of the level of safety at railway crossings in the Czech Republic. Within the framework, the author aims to implement the use of hierarchically structured data in the topic of traffic safety analysis. Knowing that there is currently no comprehensive tool that could summarize and considers all important criteria affecting the resulting level of safety, the author is taking the initiative to create such a unified analytical tool. These efforts are fully in line with the European transport policy outlined in the White Paper of the European Commission, the adoption of which the Czech Republic committed to. The main objective is the overall reduction of all types of traffic accidents. The priorities contained in this material are fully in line with the targets set by the Member States of the European Union and the United Nations, which aim to halve the number of people killed and seriously injured on the roads (by 2030, 50% less than the baseline). [3] [4]

This contribution outlines the issue of safety at railway crossings in a broader context and its necessity at a conceptual scientific level. At the same time, the intention of the research lies in application of the ontological approach to the safety issue. The ontology and the ontological (conceptual) modelling as a modern analytical tool are presented, as well as the reasons for choosing a particular ontological language for creation of the resulting ontological model. Furthermore, parameters primarily or secondarily influencing the safety of participants of operation at railway crossings are defined within the framework of specifically focused scientific analytical activity. The paper concludes by presenting the objectives of the research task, its outputs and at the same time discussing the potential limitations in terms of the possibilities of the ontological approach.

II. SAFETY ISSUES AT RAILWAY CROSSINGS

The topicality of the idea of systematically increasing safety at the railway crossings is also confirmed by the only slightly decreasing number of traffic accidents, the resulting societal losses and the fact that traffic accidents are usually fatal in terms of the consequences of the accident participants. The following Fig. 1 shows the evolution of the number of accidents at railway crossings together with the numbers of fatalities.

Fig. 1. – Traffic accidents at railway crossings and corresponding fatalities [5]

Therefore, it is essential to shift the general approach into a proactive one via modification of railway crossings and adjacent roads. This means to try to prevent accidents even at railway crossings which currently do not have a higher accident rate but which nevertheless appear to be risky in the terms of their traffic / construction layout or road markings. However, the amount of railway crossings presents a challenge for application of this approach, mainly due to the density of the road network in combination with the length of the railway network in the Czech Republic, which is approximately 10 000 km. Specifically, there are currently approximately 7 800 railway crossings on the railway network in the Czech Republic. Within this number, the individual levels of protection or the types of railway crossing safety equipment used vary greatly. [6]

Looking at the statistics of accidents at railway crossings published by the Railway Inspectorate for the year 2019, it is still evident that the number of both accidents and fatalities is not decreasing. There were 181 incidents, in which 43 persons died. At the same time, 93 persons were seriously injured. In 2020, a total of 146 emergencies were recorded. The statistics show a total of 39 fatalities and 95 persons seriously injured in 2020. Nevertheless, the accidents at railway crossings are usually fatal for the involved road users, primarily from due to the completely disproportionate parameters of the colliding vehicles (train/car). The continuing trend in the number of accidents and the severity of their

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consequences clearly calls for a further analysis of the current situation and the necessity of appropriate measures to improve the level of safety at the railway crossings. This approach clearly corresponds with the global accentuated idea of Vision Zero and objectives implemented in the Czech Republic in the National Road Safety Strategy. [4] [5]

III. CURRENT APPROACH TO RISK ASSESSMENT AT RAILWAY CROSSINGS

It is crucial to look at the issue of railway crossings comprehensively, both from the point of view of traffic safety defects of the road in question and at the same time from the perspective of the safety at the railway transport route. Currently, there is not a unified, comprehensive and adequate approach or tool to increase the level of safety of all traffic participants. Unfortunately, the safety issues of the road and the railway infrastructure are being dealt with separately by the administrators or managers. Primarily, this is done due to the different institutions which are responsible for the management of the infrastructures and the differences in funding. This methodologically inefficient approach makes it difficult to achieve an adequate, socially acceptable level of traffic safety at the railway crossings. Therefore, the aim of the research task is to unify the approach and create a tool for systematic evaluation of the safety. The focus is on railway crossings on Class II and III roads, as well as on local roads. This stems from the extensive research work already carried out within various research projects and also from the knowledge that railway crossings on Class I roads are often equipped with an adequate level of security, such as railway crossing light interlocking with additional barrier barriers.

IV. ONTOLOGICAL CONCEPT

During one of the initial parts of the research, an extensive search was carried out for currently available analytical tools that would be able to assess a number of different but mutually influencing parameters and would be therefore suitable for application to the research in question. Given that the issue of the safety at railway crossings is influenced by a number of interrelated parameters, the optimal solution seems to be their explicit definition and arrangement by creating an ontology. This will prevent any misinterpretation of the individual terms or relations between the parameters in the analysis of traffic safety at specific railway crossings. An ontology, by its very nature, clearly defines the terms and relationships between terms from a specific area of reality that it accurately describes. This shows that an ontology provides means of capturing and abstracting the real world, or parts of it, and allows minimizing or even completely eliminating the differences between the perception of a particular area of reality by the humans on the one hand and the information database systems on the other. This goal is achieved by standardizing and formalizing the meaning of concepts in the generalized part of the surrounding world. As a result, ontologies can subsequently be used in tasks based on the modelling, querying or inference. Since ontologies are used to represent reality, a suitable ontology modelling language is also needed. One of these languages is the OntoUML, which is based on the Unified Foundational Ontology (UFO), and was created as an extension of the Unified Modeling Language (UML) in the context of Giancarlo Guizzardi's doctoral thesis on "Ontological Foundations for Structural Conceptual Models". It was the UFO ontology, or the ontological language OntoUML, that was chosen as a suitable tool for modelling the particular reality under the investigation, i.e. railway crossings. [1] [2] [7] [8]

The synthesis of the UFO ontology and the selected graphical modelling language OntoUML will result in the design of a custom hierarchically structured model, which will be validated. For the purpose of the investigation, the obtained traffic engineering data is used. The specialised software OLED (OntoUML lightweight editor) serves as the modelling environment. The next step is creation of a database of railway crossings within the CEBASS web application environment ("Central Evidence of Safety Analyses of the Road Network"), which serves as an effective tool for the presentation of the results obtained. The advantage of this database is and ability to encompass a comprehensive dataset in one place. At the same time, the database works with the ontological principles of hierarchically structured data and contains a detailed parameterisation of the entire set of the analysed railway crossings, including their projection in the base map. [1] [2] [7] [8] [9]

The resulting risk assessment of individual railway crossings will be based on the proposed and validated ontology model. The model will be complemented by the knowledge base of the system designer in regards to the risk rating of ontology model. The approach enables to the model to suggest appropriate measures even for future cases which may combine a different safety defects which are not currently apparent. Therefore, the use of ontological tools enables to create a comprehensive decision-making tool, that
can be applied to any railway crossing on the road or rail network. For better clarity, Fig. 2 shows a flow chart with individual phases of the research task.

V. PARAMETERS CONSIDERED WITHIN THE ONTOLOGY

The overall level of safety of each railway crossing is determined by the combination of risks connected with identified safety defects. The concept of risk consists of a combination of two elements, namely the probability of occurrence of the potentially negative event and the severity of resulting consequences. However, some of the risks cannot be mitigated and therefore, it is also necessary to consider an acceptable level of risk. Any incident in the area of a railway crossing leads to disruption of both rail and road traffic, resulting in the reduction in their operational reliability. As the volume of traffic in both modes increases over the years, the probability of an incident increases as well. In the end, the individual characteristic parameters of the railway crossing and its close approximate determine the probability of an accident. The parameters have a greater or lesser effect onto the resulting level of safety, however, the effects are also affected by their qualitative state at any given moment. At the same time, it is important to realise that all parameters are interdependent within a single entity (railway crossing) and influence each other. Particularly risky is the situation where a railway crossing shows an inadequate quality status for several interacting parameters. In this case, the hazardousness of the crossing in question increases not in an additive but rather multiplicative or exponential way. If we understand the ontology as a certain knowledge base, which not only stores the data itself (in this case the parameterisation of railway crossings) but also defines the relationships between these data, it can be described as a rather suitable tool for describing the resulting level of safety.

On the basis of the detailed research and especially the expert knowledge, the following set of parameters that affect the level of traffic safety at railway crossings was defined. The parameters are currently divided into three groups – road segment, railway segment and group of parameters which cannot be clearly assigned into one of the two previous groups. These parameters, which are presented in Fig. 3, serve as a ground plan for the ontology creation and serve as a base for the ontology model. At the same time, it is necessary to comment on the parameter of weather conditions. In the list below, only the parameter of the possibility of glare from the sun is given. Other variables of the weather conditions parameter such as rain, snow, wind or ice on the road are not taken into account in the current database due to their variability. Their possible inclusion will be decided in the next phase of the research task.

Currently, first implementation and validation were performed on selected railway crossings located in the Central Bohemia Region. Different typologies of construction and operational design of the crossings are represented in this dataset. Different types of the safety defects are also identified across the sample. It is therefore a diverse set of railway crossings that provides a suitable basis for the development and subsequent validation of the ontology model as a decision tool. The figures below show examples of hazardous railway crossings identified within the test dataset. These examples show various parameters are interconnected and how the resulting level of safety is adversely affected. [10]
The Fig. 6 shows a prime example of hazardous railway crossing. The crossing is located on a long straight stretch of the road with unmaintained vegetation alongside. These factors adversely affect the predictability and visibility of the crossing to the driver (parameter - perceptibility of the railway crossing). At the same time, the vegetation is also located along the railway line and limits the desired view of the railway line (obstacles in the clearance zone).

Fig. 6. – Example of adversely affected perceptibility of the railway crossing

VI. FUTURE DIRECTION OF RESEARCH

The primary objective of the ontology-based decision tool is to provide a socially acceptable level of road safety at railway crossings. This encompass a reactive approach for railway crossings already showing accident events but also a pursuit of a proactive approach, for those railway crossings that do not currently show higher accident rates but presents a clear and significant risk for the road users. However, the essential part for its successful implementation is to have a systematic procedure which is able to identify and define traffic safety defects and the subsequent corrective measures.

The proposed evaluation tool, once successfully completed, will extend and complement the existing CEBASS web application developed and used at the Department of Forensic Experts in Transportation. The web application is already used by the Road and Motorway Directorate of the Czech Republic and the Regional Road Maintenance Administration of the Central Bohemian Region. At the same time, it is the intention of the author of the project to address the relevant state administration authorities that manage the road or railway transport routes in question and to offer them the possibility of cooperation as well as the conclusions resulting from the research.

VII. POSSIBLE LIMITATIONS

The primary limitation is seen as a lack of deeper understanding of use of ontology onto this particular issue. The Unified Foundational Ontology is described mainly in Dr. Guizzardi's dissertation. However, there are only a few practical examples or examples of work dealing with UFOs. Especially this is the case for the UFO-B, UFO-C and UFO-S ontologies. For this reason, the current phases of the research is utilized the ontology UFO-A, which is already considered to be complete and is at present described in greater detail.
Commercial vehicles safety management

Dusan Mladenovic¹, Djordje Stanisavljevic², Ivan Ivkovic³, Dragan Sekulic⁴

Abstract – Monitoring and analysis of commercial vehicles safety is an important component of traffic safety management. In highly developed countries, despite the increase in the number of vehicles on the road, the number of fatalities in traffic accidents is decreasing. Successful commercial vehicles management needs to provide better efficiency, increase traffic safety and decrease environmental impact. In this paper, an analysis of the commercial vehicles’ road safety in the Republic of Serbia will be presented with a comparison at the EU level. This paper aims to present the potential impact of the commercial vehicles’ active safety systems on improving road safety in the Republic of Serbia. The obtained results will show the potential number of fatalities in commercial vehicles accidents that could be avoided by using some of the commercial vehicles’ active safety systems.

Keywords – commercial vehicles, traffic safety, safety management.

I. INTRODUCTION

Commercial vehicles, trucks and buses, have a significant impact on the economic and social development of every society. Road freight transport is the backbone of trade and commerce on the European continent. Trucks offer the most flexible freight transport and they carry 71.3% of all freight transported over Europe. The performance of road freight transport (measured in billion tonne-kilometres) grew by 14.3% between 2000 and 2014. Despite an increase in freight transport, fatalities involving heavy goods vehicles decreased by 53% between 2001 and 2014. [2]. Buses are the most cost-efficient and flexible form of public transport with the lowest carbon footprint per passenger of any form of motorized transport. In the EU, 55.7% of all public transport journeys (or 32.1 billion passenger journeys per year) are made by urban and sub-urban buses [1]. Commercial vehicles are also an important part of multimodal transport.

Continuous increase in the number of vehicles on the road leads to new challenges in commercial vehicles safety management. The projected increase in demand for freight transport in the future, between 2010 and 2050, is about 57% [10]. Increasing transport needs leads to an increase in the number of vehicles on the road, which creates new challenges for improving road safety and reducing emissions. It is therefore very important that increasing mobility level is accompanied by adequate improvement of road safety, which is primarily reflected in the reduction of the number of fatalities in traffic accidents. Due to limited capacities and limited possibilities of constructing new roads, better optimization of the use of the existing infrastructure is required, which can be achieved with better management.

Successful commercial vehicles management needs to comprise three main components: safety, efficiency and environmental impact. In this paper, the focus will be on safety. Commercial vehicles are involved in many fatal traffic accidents, which mainly occur due to driver error. Traffic accidents involving commercial vehicles usually have more severe consequences due to the mass of commercial vehicles. In addition to the direct consequences of traffic accidents involving commercial vehicles (fatalities, injured, material damage, emergency service costs, etc.) the consequences of these accidents are also the lost productivity of commercial vehicles, costs of insurance of cargo and passengers, loss of confidence in the transport company, etc. On improving commercial vehicles safety, advanced active safety systems can significantly influence, by eliminating weaknesses and wrong driver decisions. Nowadays, mechatronic systems and components are present throughout almost the entire modern vehicle [11].

II. ANALYSIS OF COMMERCIAL VEHICLES SAFETY IN THE REPUBLIC OF SERBIA

Commercial vehicles safety analysis includes analysis of fatal traffic accidents that occurred on the territory of the Republic of Serbia in the period from 2013 to 2018. Data for this analysis are used from "The integrated database of characteristics of traffic safety" of the Road Traffic Safety Agency of the Republic of Serbia.Certain values obtained by analysis for the Republic of Serbia are compared with the values for the level of EU. At the time of writing this paper (conducting the research), only data about road accidents up to 2016 were available for the EU level [12].

The analysis includes all fatal traffic accidents involving commercial vehicles, regardless of whether the accidents were caused by the failure/error of a commercial vehicle driver. An ETAC study (European Truck Accident Causation) found that truck drivers were responsible for the occurrence of 25% of traffic accidents and that 86% of road accidents were caused by human error [9]. In the EU, no other occupational group suffers as many fatalities in the workplace as professional drivers [6].
In the Republic of Serbia, in the period from 2013 to 2018, 954 people were killed in traffic accidents involving commercial vehicles. Of these, 765 people were killed in traffic accidents with trucks, and 189 people were killed in bus accidents (Fig. 1.).

In the period from 2013 to 2016, the average annual percentage of fatalities in accidents involving trucks of all road fatalities in the Republic of Serbia is 21%, and at EU level 15%. In the same time period, the average annual percentage of fatalities in accidents involving buses or coaches of all road fatalities in the Republic of Serbia is 5.5%, and 2.5% at the EU level (Fig. 2.).

Between 2013 and 2016, at the EU level, the fatality rate per million population in accidents involving commercial vehicles shows that more traffic accidents occurred with parked vehicles-without vehicles-turning (12%) and „RA with minimum two vehicles” (18%) followed by „RA with one vehicle-turning or crossing“ (20%), „RA with minimum two vehicles-turning or crossing” (22%), „RA with one vehicle-turning or crossing” (24%), „RA with parked vehicle” (7%) and „RA with parked vehicles” (6%) (Fig. 4.).

The most fatal traffic accidents involving commercial vehicles are from the group of accident type “RA with minimum two vehicles-without turning” (42%), followed by the „RA with pedestrians“ (25%), „RA with minimum two vehicles-turning or crossing” (20%), „RA with one vehicle” (7%) and „RA with parked vehicles” (6%) (Fig. 6.).

The distribution of fatal traffic accidents involving commercial vehicles by accident type, Republic of Serbia, 2016-2018 shows that more traffic accidents occurred in the urban areas, 55% to be exact, while 45% occurred outside the urban areas (Fig.7.).

In the Republic of Serbia, 48% of all fatalities in accidents involving commercial vehicles are passenger car occupants, 46% at the EU level, and 31% are vulnerable road users in the Republic of Serbia, and 25% at the EU level (Fig. 4., Fig. 5.).

In the Republic of Serbia, in the period from 2013 to 2018, 48% of all fatalities in accidents involving commercial vehicles are passenger car occupants, 46% at the EU level, and 31% are vulnerable road users in the Republic of Serbia, and 25% at the EU level (Fig. 4., Fig. 5.).
Fig. 7: Distribution of fatal accidents involving commercial vehicles by road type, Republic of Serbia, 2013-2018

III. COMMERCIAL VEHICLES ACTIVE SAFETY SYSTEMS

Automated systems in vehicles offer significant potential in reducing the number of traffic accidents, increasing the comfort of drivers and reducing greenhouse emissions.

Electronic Stability Control (ESC) system stabilizes vehicle movement in all driving conditions and situations within the limits of physics [11]. ESC system has a great influence on the prevention of rollover of commercial vehicles. ESC systems can lead to an estimated 18% reduction in overall fatal crash involvement risk [3].

Brake Assist System (BAS) aims to solve the problem of insufficient pressure on the brake pedal in critical situations. The system monitoring the way that the driver uses the brake pedal, and if recognizes the panic requirement for braking, automatically increases the pressure in the brakes [5]. BAS system can reduce the risk of fatal crash involvement in rear-end, side and head-on crashes, crashes with pedestrians, parked (stopped) vehicles and object on road by 8% of each [3].

Collision warning system is designed to warn the driver if recognizes that a risk of collision exists, thereby directing the driver’s attention to the danger [4]. Commercial vehicles can be equipped with systems that monitor the black spots around the vehicle and warn the driver of potential collision when cornering, changing lanes or driving reverse. This system can reduce the risk of fatal crash involvement in rear-end, side and head-on crashes, crashes with pedestrians, parked (stopped) vehicles and object on road by 12% of each [3].

Intelligent speed adaptation (ISA) systems warn and/or prevent the driver from speeding [4]. ISA is a collective term for various systems. Depending on how it works, the ISA system can be open, half-open and closed. In this paper, the effects of a closed ISA system, which limits the speed automatically if the speed limit is exceeded, will be analyzed. ISA system can reduce risk of fatal crash involvement in rear-end, side and head-on crashes, crashes with pedestrians, parked (stopped) vehicles and object on road by 50% of each [3].

Adaptive Cruise Control (ACC) is a system that will enable the vehicle to maintain a driver-defined distance from the preceding vehicle while driving within a maximum speed limit - also set by the driver [7]. The fatal accidents prevention potential of the ACC system is 25% for rear-end collisions [3].

Lane departure warning (LDW) systems assist drivers in keeping their lanes by warning drivers when their vehicle is in danger of leaving the lane unintentionally (mainly due to lack of driver attention). These systems don’t have a direct impact on the direction of vehicle movement [7]. LDW systems can reduce the risk of fatal crash involvement in head-on and crash during parallel driving, run-off-road collisions and run-of-road and collision with an object outside road by 25% of each [3].

Alcohol ignition interlocks systems check the alcohol intoxication of the driver when starting the vehicle and prevent the start of the vehicle when the driver is intoxicated (breath test) [8]. During driving the system also checks intoxication at specific intervals. These systems can reduce the risk of fatal drunk driving crashes by 75% [3].

Drowsy and fatigued driver detection systems monitor the condition of the driver. These systems tracking predefined parameters and warn the driver of drowsiness, distraction and inattention [7]. The fatal accidents prevention potential of these systems is 10% [3].

IV. IMPACT OF COMMERCIAL VEHICLES ACTIVE SAFETY SYSTEMS ON IMPROVING ROAD SAFETY IN THE REPUBLIC OF SERBIA

In this paper, given that in the Republic of Serbia the representation of active safety systems in commercial vehicles is extremely small, the evaluation of the potential impact of these systems on improving road safety is based on the assumption that all vehicles are equipped with individual systems and all systems are all-time during driving turned on.

Based on the calculation method, possible annual effects of commercial vehicles’ active safety on improving road safety are assessed and shown in Table I. In this table, the possible annual reduction in the number of fatal accidents and fatalities, in the Republic of Serbia, is shown. The greatest effects are provided by the Intelligent Speed Adaptation (ISA) system. In other words, using this system in all commercial vehicles, it is possible to annually prevent the occurrence of 59 fatal traffic accidents, thus saving 68 lives. By using the Electronic Stability Control (ESC) system in all commercial vehicles, it is possible to annually prevent the occurrence of 24 fatal traffic accidents and thus save 28 lives.
V. CONCLUSION

This paper aims to point out the importance and possible level of contribution of active safety systems of commercial vehicles. As human errors continue to be a major cause of traffic accidents, measures aimed at reducing human errors play a significant role. The driver clearly needs help, and modern vehicle systems can eliminate his weaknesses and wrong decisions. The vehicle should prevent a traffic accident when a driver error occurs, a road fault or other hazardous situation, and the vehicle should prevent or mitigate the consequences of a traffic accident.

The presence of modern systems in vehicles is directly linked to the average age of the fleet. Newer vehicles equipped with modern active and passive safety systems are safer than old ones. Financial subsidies and benefits (in the form of reduced vehicle registration taxes, etc.) for the purchase of a new vehicle equipped with state-of-the-art active safety systems can contribute to improving traffic safety.

Proper use of advanced systems is just as important as installing them. In order to take full advantage of the effects that the systems provide, adequate driver training is required. No system can go beyond the laws of physics. At best, systems can make the most of what is available. Modern vehicle systems can also have a negative impact on the driver. If the driver relays too much on the systems while driving, his attention may be reduced. Reduced attention can also be affected by the large amount of information and alerts that the driver receives from the system. Too much confidence in the systems can cause the driver to take some risky traffic manoeuvres.

It is necessary to establish monitoring of the effect of modern active vehicle safety systems and evaluate their short, medium and long-term impact on traffic safety. Systems with proven efficiency should be provided by law as a mandatory part of the equipment of all vehicles. Today, most active safety systems can be shut down by the driver. The subject of discussion must be whether it is in the interest of traffic safety, because what is the purpose of the system if they are switched off in an emergency?

REFERENCES


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<td>Alcohol ignition interlocks</td>
<td>18.3</td>
<td>5.3</td>
<td>3.2</td>
<td>1.5</td>
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<td>22.1</td>
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<tr>
<td>Drowsy and fatigued driver detection systems</td>
<td>16.0</td>
<td>3.0</td>
<td>1.0</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18.5</td>
</tr>
</tbody>
</table>

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Table I

Potentiel effect of improving road safety of commercial vehicles active safety systems
Night Road Safety Inspection
Jakub Nováček¹ and Tomáš Kohout²

Abstract – Europe has committed to reduce the number of serious road traffic accidents. This requires building a safe infrastructure. Safety inspections are used to measure and increase the road safety. To fulfill the stated goals, the safety inspection must also be carried out at night, when specific road defects are encountered.

Keywords – Night Safety Inspection, Safety Defects, Road lighting, Traffic accidents.

I. INTRODUCTION

Nowadays, not only in the European Union countries, a policy of gradual reduction of the serious traffic accidents (with fatal and serious injury) is applied. In some countries, the efforts are being made not only to reduce the occurrence of these accidents but also to eliminate them altogether (Vision Zero, etc.) [1]. To achieve this goal, the development in the area of all the basic pillars influencing the incidence of traffic accidents (human, vehicle, infrastructure) is necessary. The biggest shift today can be seen in the development of active and passive safety of vehicles. There are significant gaps in the driver education, where the situation in the Czech Republic cannot be considered ideal. However, there has been a positive trend in introduction of new teaching practices of novice drivers, and at the same time, introduction and development of new awareness campaigns.

However, it is also necessary to focus also on the road itself, which has a significant impact on the occurrence of traffic accidents and the behavior of road users. In order achieve safe roads, we must ensure that the road fulfill two basic rules – it must be self-explanatory and forgiving. One of the tools for assessing the level of safety of the road network is the Road Safety Inspection (RSI). This is the most commonly used tool for the assessing of safety on the existing road network. It is nowadays also integrated into practice through legislation in many European countries and most road managers already use this tool routinely.

Until now, the RSI was carried out during the day in normal visibility. However, in order to cover and identify all the potential risks, it is necessary to broaden the RSI even to the times of reduced visibility, when new defects and risks, that do not affect the road users in normal traffic, or do not appear at all in daytime, may appear.

Currently, a pilot project of inspection in times of reduced visibility, the so-called Night Road Safety Inspection (NRSI) [3], is already being implemented on selected primary roads in the Pilsen Region. It is also assumed that by 2025 the legislation will mandate night-time inspections on the entire TEN-T (Trans-European Transport Network) together with the classical safety inspection.

II. CURRENT STATUS

In the Czech Republic, there is a legal obligation to carry out the RSI on the TEN-T road network (Fig. 1) every 5 years [4]. Outside the TEN-T network, safety inspection is not mandatory but strongly recommended. Within the Czech Republic, the RSI is also carried out outside this network, specifically on a large part of the primary roads.

The RSI is a proactive tool (aims to prevent accidents) that tries to identify the road safety defects. These defects may play a role in the incidence of a traffic accident or worsen its consequences. These defects are risk-rated in the inspection, where a three-scale scale is used in the Czech Republic. Together with the identification and assignment of risk, appropriate remedial action is recommended to the road manager or administrator for each defect.

Currently, the identified safety defects are being removed in two ways. Most common is implementation of remedial measures during the regular reconstructions of the section of road. The second is independently by teams appointed by the road manager to eliminate these safety defects. In order to effectively improve the level of road safety, the identified safety defects are usually prioritized by the corresponding risks. Therefore, the most usual approach by most road managers in the Czech Republic is focus on defects from the riskiest to the least risky ones. From this point of view, the current development can be considered positive.

Still, it is important to note that regardless of the type of the road to which the inspection is applied, it is always a safety inspection carried out during the day under standard visibility conditions. An average day of the whole year contains half of the time in reduced visibility conditions (night, fog, dusk, etc.) which significantly change not only the behavior of the road users but also their ability to perceive and distinguish...
elements on the road. Carrying out an inspection only during daylight hours will not ensure that all defects and risks on the road are identified, as they may only occur in reduced visibility.

The current methodology for carrying out RSI does state that they should be carried out outside good visibility, but it does not describe in detail what exactly should be monitored and how this should be done. However, this changed in 2020 when a new methodology came into place describing how NRSI should be carried out.

III. NIGHT SAFETY INSPECTION

Driving in the traffic area in low visibility, especially at night, is different primary due to the reduced sight distance. In general, the ability to distinguish objects, but also the speed of their perception, depends on the level of illumination and on the contrast of the perceived elements. In order to create a safe road, it is therefore necessary to focus primarily on controlling the sufficient perceptibility of the objects forming the road (fixed obstacles, junctions, crossings, etc.), the light technical characteristics of traffic signs and the correct illumination of the traffic space in the built-up area [3][7].

Before a NRSI can be carried out, it is necessary to carry out a conventional safety inspection during the day. This is for the auditor to ascertain the particular characteristics of the area and the behavior of drivers on the road. At present, the inspection team from the Department of Forensic Experts in Transportation, Faculty of Transport of the Czech Technical University has been working on a pilot project of NRSIs. It took place in the Pilsen Region on selected primary roads. These are roads where regular RSI was already implemented by the same team in 2019 [9].

In this project, a total of four primary roads (I/19, I/20, I/26, I/27) with a total length of 213 km in the Pilsen Region were inspected [2][5][9]. The selected road sections had a different traffic characteristic which included not only the built-up areas but also the rural area. A total of 205 safety defects were identified on the road under the reduced visibility (Fig. 2). The low-risk defects were the most common (71.2%), followed by the medium-risk defects occurring in 28.8% of cases. The high-risk defects were not observed. The night-time defects were divided into 6 categories and a total of 14 types.

The most frequent group was the non-intersection category with 73 registered safety defects. The most common issues were inadequate lighting of the traffic area or an insufficiently perceptible curve of the road.

The first type of the mentioned defect was mostly found in the built-up areas, as these parts are usually illuminated (Fig 2 and 3). In this case, the areas are not illuminated by the public lighting and there is a so-called contrast shadow (unlit area in an otherwise illuminated section). This poses a major problem for the drivers whose eyes cannot adjust quickly enough to changes in light intensity. This is especially problematic in case, when a pedestrian who is moving in the unlit area may be overlooked and a serious accident can happen. The severity of these defects is increased by the fact that often no sidewalk is implemented at these locations.

In many cases, this defect can be effectively and inexpensively eliminated. In general, this problem is created by switching off a certain part of the public lighting (for example, every second lamp) to lower the costs for the operation of the lighting by the municipalities. Unfortunately, they often are not aware that it creates a potentially dangerous configuration for the road users.

If lamps are missing at a given location, then the solution is more difficult and expensive. It is necessary to carry out a detailed luminance analysis, according to which the following course of action can be decided. The most common practise is to replace the lighting bulbs or to increase the light intensity.

The second most frequent defects type was the hardly perceptible curve of the road (Fig 5 and 6). This type of defect was mostly identified in the rural area, where the traffic flow is outside the illuminated area, but also at higher speeds. In these places, traffic signs indicating the directional curve are most
often missing. Additionally, the directional posts on the sides of the road are missing as well and the horizontal markings are often in poor condition.

![Fig. 5. View of a road curve during the day [9]](image1)

The picture above shows a curve that is hard to see or predict at night. In this particular case, the risk of identified safety defect is further increased by several factors. The fact that the directional change is after a long straight stretch of the road and a power line pole in the near proximity of the road. Based on the statistics [6], if a curve is missed, the vehicle usually run off the road. A rigid obstacle in the form of a power line pole placed in the possible trajectory of the vehicle thus presents a fixed obstacle which may worsen the consequences of the accident. [8]

To ensure sufficient visibility of the road curve, it is possible to implement traffic signs that warn the driver. It is also possible to install additional directional signs on the outside of the curve to indicate the direction of the road to the driver. A properly marked road curve can be seen in the Fig. 7.

![Fig. 7. An example of a well-marked curve with traffic signs [9]](image2)

Both defect types above cannot be identified during the daytime RSI in most cases. The visibility of the change of direction of the road as well as other critical parts of the road must be verified for all possible situations. Thus, not only during the daylight hours, but also at night when visibility significantly differ. This applies to all elements on the road that affect the traffic flow and safety.

To provide an idea, other frequently noted safety defects can be mentioned. A very large group is made up of the advertising devices (50 defects). These elements present a risk throughout the day when they distract the driver's attention. If placed close to the road, they can also form a solid obstacle. However, some of these devices have additional night lighting that illuminates the advertising area. This is even more distracting and can cause dazzle to the passing drivers if the advertising device is in a rural area or unlit part of the road.

Pedestrian crossings were another category of safety defect where medium-risk defects were frequently recorded. These locations are primarily located in the built-up area, i.e. in a place where there is already public lighting. To make the pedestrian crossing easily perceptible for the drivers even in the times of reduced visibility, it is required to change the intensity of the lighting at this location. In most cases, this is done with special lighting, i.e. a lamp with a higher light intensity above the crossing. Nevertheless, it is necessary to ensure that contrast shadows are not created. These could cause pedestrians being overlooked.

More often, the additional lighting was missing completely (15 cases, 8 of them with medium-risk). This type of defect described above is a common cause of accidents between drivers and pedestrians at night in built-up areas, where serious consequences are registered [6].

The list below shows all 14 types that were monitored during the night safety inspection. [9]

**Intersection**
- Insufficient visibility of the intersection in times of reduced visibility
- Insufficient light-technical characteristics of the road signs
- Insufficient visibility of the road equipment

**Non-Intersection section**
- Missing public lighting in the traffic area
- Insufficient lighting of the traffic area
- Insufficient visibility of the road equipment
- Insufficient light-technical characteristics of the road signs
- Insufficient light-technical characteristics of the horizontal markings.
- Insufficient perceptibility of the curve of the road

**Parking**
- Insufficient visibility of the road equipment

**Pedestrian crossing**
- Missing additional lighting
- Surrounding light source creates significant contrast shadows

**Conditions for pedestrians**
- Missing public lighting

**Advertising equipment**
- All-day disturbance effect on the road users
IV. JUSTIFICATION OF NRSI

Even though significantly fewer safety defects are found during the NRSI compared to the daytime inspection, the importance of its implementation is proven by the accident rate [6].

Individual examples are presented based on publicly available data from the Police of the Czech Republic [6]. The graph below (Fig. 8) shows that there is an overall increase in the number of recorded traffic accidents during the night hours. In contrary, there is a decrease in their severity, but this decrease has almost stopped in the last 4 years. It is justified to assume that there may have been an increase in severity in the last year. However, its final outcome has been highly influenced by the ongoing global pandemic of the Covid-19. More specifically, the casualty rate has been affected by various governmental measures (restricted movement, trade slowdown, etc.) aimed at limiting the spread of the virus.

![Fig. 8. Accident trends and severity](image)

It can be concluded that the number of recorded traffic accidents at night corresponds to the lower traffic volumes. In 2019, 547 people were killed in traffic accidents. Approximately 70% of the deaths happened during the day and the remaining 163 deaths were reported during the night hours. However, in terms of relative fatality per number of accidents, night-time accidents come out worse (by about 15%).

![Fig. 9. Vehicle-pedestrian fatal accidents](image)

The accident statistics show increased severity of the consequences in times of reduced visibility. As an example, the road traffic accidents involving the most vulnerable participants, pedestrians, can be shown. In 2019 alone, a total of 87 vehicle-pedestrian collisions with fatal injury were recorded. More than half of these cases (46 accidents) took place in the times of reduced visibility (at night). A total of 24 accidents were recorded in the built-up areas. Of these, 7 accidents occurred at a pedestrian crossing. The detailed distribution of these accidents is shown below (Fig. 9).

V. CONCLUSION

If Europe wants to achieve its goals of reducing the serious road traffic accidents, or achieving Vision Zero, the focus must be not only on developing of new safety technologies in cars or driver’s education. It is also necessary to focus on the road safety itself, which must ensure the above-mentioned self-explanation and forgiveness. The night road safety inspection has the potential to fill one of the gaps in the road safety assessment and thus prevent road traffic accidents from occurring or mitigate their consequences. Its obligatory application at least on major roads and highways (e.g. TEN-T network) will help to create the necessary conditions that, together with other safety assessment tools, will help to fulfil the vision.

ACKNOWLEDGEMENT

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Safety of Traffic Participants During Construction of Road Infrastructure Facilities

Bulent Suloodja¹ and Hristifor Manov²

Abstract – Traffic safety is one of the most important priorities in our country and in the world. Respecting and implementing on-site laws and regulations on traffic and construction, will reduce traffic accidents and accidents on construction sites. The whole point is for the activities to pass without any consequences on human life, as well as to complete the project successfully and on time.

Keywords – Construction, road infrastructure, traffic safety.

I. INTRODUCTION

Traffic safety is one of the most important priorities in our country and in the world. In order to achieve this goal, it is necessary to continuously work on improving the conditions affecting traffic safety. Road infrastructure facilities also contribute to increased security. That is why new, safer roads are being designed daily, the old ones are being reconstructed and the existing ones are being upgraded.

At the start of this kind of construction activities the safety of road users and construction site workers is at the forefront. Some of them include taking appropriate safety and security measures, securing the site from other activities, setting up temporary traffic regimes with appropriate traffic signs and markings, etc.

Respecting and implementing on-site laws and regulations on traffic and construction will reduce traffic accidents and accidents on construction sites. The whole point is for the activities to pass without any consequences on human life, as well as to complete the project successfully and on time.

II. CONSTRUCTION SITE WHEN BUILDING A ROAD INFRASTRUCTURAL OBJECT

Prior to the commencement of construction works for road infrastructure facilities, preparatory activities are undertaken at the site where construction operations are planned to be carried out. For this purpose, with every start of construction, reconstruction or rehabilitation of road infrastructure facilities, it is mandatory to mark the projected construction on the ground and to enclose it to prevent uncontrolled access to the site with appropriate fencing so that the work on the site will not jeopardize the safety of traffic participants. While construction sites that extend to a larger area that cannot be fenced off, must be protected by certain traffic signs or marked otherwise.

Each construction site must be marked with an information board which must include a name, ie the name of the participants in the construction, the name and type of the construction being constructed, the number and date of the issued building permit and other data relating to the building being built.

When working on a construction site, employees are exposed to various risks such as: landfill; immersion; falling from a height; risk of mechanization; risk of chemical and biological substances etc. Therefore, in every construction site the following basic requirements must be met:
- stability and firmness;
- movement paths and emergency exits;
- temperature;
- loading rooms and ramps;
- fire detectors and firefighting equipment;
- ventilation;
- job lighting;
- sanitary equipment;
- rest rooms and more.

The safety of the participants at the construction site is in question. Not only here, but throughout the world, there have been injuries and even casualties in road construction or rehabilitation. Thus, in the Netherlands 20 and in Turkey 80 people are killed annually. while in our country there is no information.
III. SAFETY OF TRAFFIC PARTICIPANTS WHEN BUILDING ROAD INFRASTRUCTURE FACILITIES

The most important thing in traffic is to get to the desired place safely, but not always. And there are unforeseen events: a traffic accident, landslides and mudslides, a construction site, a strike, and so on. Although it is not possible to completely prevent and reduce them to zero, the results of unwanted consequences can be mitigated by taking security measures.

When building road infrastructure facilities, besides the safety of the participants at the construction site, the safety of the participants in the traffic is also of great importance. Certain safety measures should be taken to increase security. They depend on: the type of facility, the type and size of activities, the interval of time, etc.

Traffic safety of road users during construction or reconstruction of road infrastructure is reduced due to:
- not having a person diverting traffic;
- insufficient signaling;
- insufficiently lit before and after the construction site;
- negligent employees at the construction site who do not comply with traffic rules and regulations;
- failure to enter and exit a construction site
- exceeding the permitted speeds of movement etc.

Research shows that one of the biggest cause that endangers the safety of road users are the drivers themselves. By disregarding traffic signs and excessive speeding near a construction site might cause traffic accidents that can even be fatal. However, not only that, the construction sites are also a safety hazard, with no appropriate safety precautions taken, unmarked hazardous areas, not marked construction sites in accordance with the rules prescribed by the Contractor himself.

Traveling along the roads we often encounter these influencers especially in our Macedonia. Disobeying traffic safety rules and regulations and building regulations, endangers the safety of participants on a daily basis. An example of this is the construction site located on the A3 motorway, near the Technological Industrial Zone Prilep. Although the section Prilep-Bitola connects the Pelagonija region with the capital, the measures taken during the construction activities are minimal and the safety of each participant using that road is very reduced, especially at night.

In order to increase traffic safety when building or rehabilitating road infrastructure facilities, safety regulations need to be respected. Regulations depend on the category of road, construction period, distance between the construction site and the traffic network and others. To avoid jeopardizing the safety of the participants during the road construction works, adequate synchronization should be used before and after the construction site:
- conical plastic barriers;
- traffic barriers;
- traffic controllers;
- flashing and audible signaling;
- warning signaling;
- obstacles to speed reduction;
- horizontal signaling;
Conical plastic barriers are used to divert or change traffic flow. The cones are made of lightweight materials, hard-breaking, weather-resistant (rain, sun, ice) and are in red and purple color. Traffic barriers have similar characteristics.

- know how to use signaling equipment;
- give clear and understandable instructions to the traffic participants;
- to warn the drivers of dangerous vehicles;
- be able to identify dangerous traffic situations and the ability to prevent unwanted accidents, etc.

Due to insufficient lighting during the night work, the hazard level of high-risk road construction sites is further increased. Light signalization should be set on plastic traffic cones or some other traffic equipment at a height of 1.20 meters, and it is used mainly in night conditions to increase visibility especially before the construction site. They can be red and yellow and should blink 60-75 times a minute. Inadequate lighting during night work increases accident rates for both construction site workers and drivers involved in traffic. Excessive and improperly applied lighting is also the cause of many accidents.

Alert signalization plays a major role in road infrastructure construction activities. They can be fixed but also movable mounted on special vehicles. Attention should be taken to ensure that the warning signal is not misplaced, intentionally damaged or damaged by supernatural forces. Therefore, this signaling is often fastened to the substrate, or mounted using other objects. The mobile alert signal is luminous and audible, thereby enhancing the safety of traffic participants. It is used in places where there is high traffic frequency. The warning length during the rehabilitation of one lane of a section has a longitude depending on the category of road (Table 1).

<table>
<thead>
<tr>
<th>Road Category</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>City streets with limited movement speed</td>
<td>30,48 30,48 30,48</td>
</tr>
<tr>
<td>City streets with higher speed of movement</td>
<td>106,68 106,68 106,68</td>
</tr>
<tr>
<td>Local roads</td>
<td>152,40 152,40 152,40</td>
</tr>
<tr>
<td>Motorway</td>
<td>804,67 457,20 304,80</td>
</tr>
</tbody>
</table>
Although there are global standards that we have implemented in our country for lengths of warning and other road safety measures, it remains only on paper. Almost no Contractor applies them, and the Supervisor does not control the security measures taken.

Because reckless drivers disregard traffic signs, they risk their lives, as well as those around them, so there are obstacles (ramps) to slow down the speed of vehicles using that section. Hog policemen are a good measure for reducing speed, which also increases the safety of drivers and people working on the site.

The horizontal signalization to be used in front of the construction site directs drivers to the direction of movement and increases safety. The material marking this signaling should be such that it will not create additional risks.

Finally, as a proposal for resolving the safety of traffic participants in the construction of road infrastructure facilities, it is necessary to undertake appropriate activities and comply with prescribed measures in accordance with regulations. Thus, in order to avoid unintended consequences and victims during the construction and reconstruction of roads, we need:

- to respect the set signalization and the speed adjustment by the drivers of the vehicles that participate in the traffic;
- to respect the regulations prescribed for the participants who are included in the construction or reconstruction of roads, etc.

IV. CONCLUSION

Several conclusions can be drawn from this paper:

- prior to the commencement of construction works for road infrastructure facilities, preparatory activities are undertaken on the spot marking the projected construction on the ground;
- each construction site must be marked with an information board which must contain a name, i.e. the name of the participants in the construction, the name and type of the construction being constructed, number and date of the issued building permit;
- to increase the safety of traffic participants, certain security measures should be taken depending on: the type of facility, the type and size of activities, the interval of time, etc.;
- the safety of traffic participants in the construction or reconstruction of road infrastructure facilities is reduced due to: lack of person diverting traffic; insufficient signalization; insufficient light before and after construction site; negligent construction site; employees who do not comply with traffic rules and regulations; disregarding entry and exit to the construction site; exceeding the permitted speeds of movement etc.;
- research shows that one of the major causes that endanger the safety of road users is the drivers involved in traffic, disregarding traffic signs, speeding near a construction site, disregarding distance between vehicles;
- to avoid endangering the safety of the participants during the construction work on the road, adequate signalization should be used before and after the construction site: conical plastic barriers; traffic barriers; traffic controllers; flashing and audible alert; alerting; to reduce speed; horizontal signalization.

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Driver's knowledge of local railway crossing characteristics

Goran Tričković¹ and Sandra Kasalica²

Abstract – The approach to this research consisted of conducting a questionnaire survey of drivers in Serbia to collect data on perception of motor vehicle drivers at the local railway crossings. The objective of this paper was to investigate the potential factors affecting drivers' knowledge of safely driving at the railway crossings.

Keywords – railway crossing, field survey questionnaire, safety

I. INTRODUCTION

Drivers who are familiar with a crossing have an expectancy about the likelihood of encountering a train at that crossing. If expectancy is low, then the driver who is familiar with the crossing will be less likely to detect a train at that crossing than a driver who is unfamiliar with the crossing or a driver who frequently encounters trains at that crossing (Lerner, et al., 1990), [1]. In fact, railway crossing accidents were committed more frequently by drivers familiar with the area than unfamiliar drivers (Abraham, et al., 1998), [1]. Driver inattention can also be a result of drivers' low expectancy of a train. Drivers seem to underestimate the number of train through movements at a crossing. Consequently, drivers who were familiar with the crossing were involved in more grade crossing incidents than drivers who were not (Abraham, et al., 1998), [1].

Studies showed that drivers' estimates of train volume were based on their familiarity with the area. Consequently, drivers who are familiar with a crossing will be less likely to look for a train at the crossing or to reduce their speed on their approach to the crossing than drivers who are unfamiliar with the crossing, [1].

Drivers' failures to comply at crossing may also be attributable to their biases and attitudes towards compliance and their perception of the dangers at grade crossings. Drivers had low expectancies for encountering a train at a crossing (Dolan, 1996; NTSB, 1998), and some drivers did not even look for a train at a crossing (Åberg, 1988; Wigglesworth, 2001). The low expectation for trains is reinforced each time the driver passes a crossing without meeting a train at that crossing. Consequently, drivers who were familiar with the crossing were involved in more grade crossing incidents than drivers who were not (Abraham, et al., 1998), [1].

The warning time provided at a crossing, or the time available between device activation and train arrival, may also influence a driver's tendency to violate. Credibility of the crossing traffic control devices decreases when the warning time provided is excessive or highly variable. Long warning times at a few crossings can, in fact, decrease credibility of not only the crossing where the excessive warning time was experienced but of all active warning devices, [3].

Train speeds may influence violations at railroad grade crossings. Crossings without constant warning time devices (fixed-distance devices) will produce a variable warning time if the train speed varies. This variability, as previously discussed, has proven to create credibility problems, thus influencing violations, [3].

A survey questionnaire that asks motor vehicle drivers inattentive driving experiences, knowledge, attitudes, and expectations towards safety at railway crossings can be very useful in explaining inattentive driving behaviors, [4]. Davey et al. (2008) made semi structured focused group interviews to 53 young drivers from a regional and metropolitan settings drivers self-reported behaviors, attitudes, and knowledge at railway crossings were explored, [5].

This research assumed that safety at railway crossings was associated with driver knowledge and behaviors at each site.

II. RESEARCH OBJECTIVES AND HYPOTHESES

The approach to this research consisted of conducting a field questionnaire survey of drivers in Serbia to collect data on perception of drivers at the local railway crossings.

The objectives of this research were to report motor vehicle driver knowledge of safety negotiation at railway crossings. Using the collected data, the researchers were tested the following hypotheses presented in Table I.

<table>
<thead>
<tr>
<th>Number</th>
<th>Hypotheses description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drivers' knowledge of a railway crossing warning devices is increases with usage of crossing.</td>
</tr>
<tr>
<td>2</td>
<td>Drivers' knowledge of number of trains per day increases with usage of crossing.</td>
</tr>
<tr>
<td>3</td>
<td>Drivers' knowledge of the waiting time for a train at a railway crossing is increases with usage of crossing.</td>
</tr>
<tr>
<td>4</td>
<td>Drivers' knowledge of the speed of trains at a railway crossing is increases with usage of crossing.</td>
</tr>
<tr>
<td>5</td>
<td>Drivers' knowledge of railway crossing may be also related to age, education level and driving experience.</td>
</tr>
</tbody>
</table>

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²High Railway School of Vocational Studies, ZdravkaČelara 14, Belgrade, Serbia, sandra.kasalica@gmail.com.
III. DATA COLLECTION PROCESS

The survey included a sample of 389 field survey questionnaires on 15 railway crossings in different Serbian cities. Local residents were surveyed and 20-30 drivers were surveyed per railway crossing.

IV. DRIVERS’ KNOWLEDGE OF LOCAL RAILWAY CROSSING CHARACTERISTICS

A. Characteristics of railway crossings

The survey was conducted at 15 railway crossings, where, 13 are active, one passive and one with a crossing guard.

Four characteristics of railway crossings are presented:
1. Warning devices at the railway crossings, where A is road sign, B is half gates and C is full gates;
2. Actual number of trains per day;
3. Waiting time for a train. Waiting time is the time interval from the moment of activation of the warning devices to the moment a train enters a crossing at the active crossings. For passive crossings that is the time from the moment a train is spotted until a train arrives at the crossing;
4. Maximal train speed at a given crossing according to timetable.

Table II presented characteristics of railway crossings.

<table>
<thead>
<tr>
<th>No. crossing</th>
<th>Warning devices</th>
<th>Number of trains per day</th>
<th>Waiting time (min)</th>
<th>Trains speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>14</td>
<td>&gt; 2</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>14</td>
<td>&gt; 2</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>14</td>
<td>&lt; 2</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>8</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
<td>40</td>
<td>1</td>
<td>80</td>
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<td>6</td>
<td>B</td>
<td>40</td>
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<td>80</td>
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<td>7</td>
<td>B</td>
<td>30</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>8</td>
<td>B</td>
<td>40</td>
<td>1</td>
<td>80</td>
</tr>
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<td>9</td>
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<td>50</td>
</tr>
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<td>11</td>
<td>B</td>
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<td>&gt; 2</td>
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<td>12</td>
<td>B</td>
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<td>13</td>
<td>B</td>
<td>15</td>
<td>&gt; 2</td>
<td>80</td>
</tr>
<tr>
<td>14</td>
<td>B</td>
<td>35</td>
<td>&gt; 2</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>B</td>
<td>35</td>
<td>&gt; 2</td>
<td>30</td>
</tr>
</tbody>
</table>

On Figs 1, 2 and 3 pictures of railway crossings are presented.
B. Frequency of use of railway crossings by drivers

That first question was: “Which railway crossing in your place do you use most often?”.

The second question will be explained in the section C of the paper.

The third question concerns the frequency of use local railway crossing. Drivers are offered the following answers: I use every day and how many times a day, - I use once or more times a week, - I use once or more times a month.

Table III show a summary of the use frequency of the railway crossings.

<table>
<thead>
<tr>
<th>No. crossing</th>
<th>Daily</th>
<th>Once a week</th>
<th>More times a week</th>
<th>Once or more times a month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63</td>
<td>10</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>54</td>
<td>23</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>37</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>13</td>
<td>53</td>
<td>0</td>
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<tr>
<td>5</td>
<td>28</td>
<td>28</td>
<td>44</td>
<td>0</td>
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<tr>
<td>6</td>
<td>28</td>
<td>16</td>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
<td>33</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>56</td>
<td>20</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>64</td>
<td>12</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>5</td>
<td>40</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>53</td>
<td>4</td>
<td>43</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>27</td>
<td>23</td>
<td>0</td>
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<tr>
<td>13</td>
<td>48</td>
<td>26</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>24</td>
<td>24</td>
<td>43</td>
<td>9</td>
</tr>
<tr>
<td>15</td>
<td>87</td>
<td>0</td>
<td>13</td>
<td>0</td>
</tr>
</tbody>
</table>

The use of road crossings by surveyed drivers varies depending on the road crossing. Compared to the total number of drivers surveyed, an average of 45% use the road crossing once or more times. Once a week, several times a week, or once and several times a month, the average crossing is used by 55% of drivers surveyed.

C. Level of knowledge of drivers crossing the railway crossing every day

Questions 2 and 4-7 are intended to test the driver's knowledge of the characteristics of local railway crossings. Question 2 concerns driver knowledge of a crossing warning device at the local crossing. Questions 4 is related to the driver's observation of daily number of trains at these railway crossings and also is related to the expectation of encountering trains. Questions 5 and 6 are related to the estimate of waiting time. Question 5 refers to active crossings and question 6 to passive crossings. Question 7 is related to the driver's assessment of a train speed.

Table IV presents the summary overview of the responses of drivers crossing the railway crossings every day to 4 selected questions.

<table>
<thead>
<tr>
<th>No. crossing</th>
<th>Crossing warning devices</th>
<th>Daily number of trains</th>
<th>Waiting time</th>
<th>Trains speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95</td>
<td>63</td>
<td>84</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>75</td>
<td>100</td>
<td>0</td>
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<tr>
<td>3</td>
<td>100</td>
<td>100</td>
<td>33</td>
<td>0</td>
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<tr>
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<tr>
<td>5</td>
<td>100</td>
<td>15</td>
<td>29</td>
<td>71</td>
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<tr>
<td>6</td>
<td>100</td>
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<td>0</td>
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<td>7</td>
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<td>0</td>
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<td>60</td>
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<tr>
<td>8</td>
<td>93</td>
<td>0</td>
<td>7</td>
<td>43</td>
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<tr>
<td>9</td>
<td>94</td>
<td>13</td>
<td>13</td>
<td>0</td>
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<tr>
<td>10</td>
<td>100</td>
<td>70</td>
<td>100</td>
<td>80</td>
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<td>11</td>
<td>82</td>
<td>27</td>
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<td>60</td>
<td>100</td>
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<tr>
<td>15</td>
<td>42</td>
<td>0</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

Most drivers (93%) have the knowledge of railway crossing warning devices.

40% of the total number of surveyed drivers crossing the crossings daily accurately or approximately correctly estimated how many trains pass daily over the crossings. 60% of drivers crossing daily the railway crossings had a good estimate of the waiting time for the train from the moment of signaling, i.e. from the moment the train is spotted until it arrives at the crossing.

Train speeds were well estimated by 37% of drivers.

D. Level of knowledge of drivers’ who crossing once or more times a week and once or more times a month

Table V presents the summary overview of the responses of drivers crossing the railway crossings once or more times a week and once or more times a month to 4 selected questions.

Majority of drivers (98%) know which warning devices are implemented at railway crossing.

Of the total number of surveyed drivers who do not cross the crossings daily, 25% of them accurately or approximately accurately estimated how many trains pass daily through the crossings.

Waiting time for the train from the moment of signaling, i.e. from the moment the train is spotted until it arrives at the crossing, 51% of drivers who do not cross the crossings every day have evaluated it well.

Train speeds were well estimated by 37% of drivers.
The difference in the estimated daily number of trains by drivers crossing daily and those crossing occasionally is considerable.

Therefore, Hypothesis 2 states that drivers' knowledge of number of trains per day increases with usage of crossing has been confirmed. This shows that their knowledge about the daily number of trains is not satisfactory.

Futhermore, the hypothesis 3 that drivers' knowledge of the waiting time for a train at a railway crossings is increased with usage of crossing is confirmed. Specifically, drivers who use the daily crossing have a better estimate of the waiting time for the train than other drivers.

The estimation of trains speed is not satisfactory for both groups of drivers and is inconsistent with the hypothesis 4 that drivers' knowledge of the speed of trains at a railway crossing is increases with using of crossings.

V. CONCLUSION

Frequency of use of the railway crossing can be a potential factor affecting inattentive driver behaviour. According to [3], drivers who used railway crossing frequently (i.e., ≥ 2 times/day) and familiar with local railway crossing were more likely to involve in distracted driving behaviours at railway crossings.

Drivers who are familiar with a crossing have expectancy about the likelihood of encountering a train at that crossing, [2]. This research showed that drivers do not have a good perception of the daily number of trains.

The warning time provided at a crossing, or the time available between device activation and train arrival, may also influence a driver's tendency to violate, [3]. Drivers' knowledge of the waiting time for a train at a railway crossing is satisfactory.

Train speeds may influence violations at a railway crossing, [3]. It is shown that the drivers' perception of train speed at a railway crossings is very poor.

Drivers' knowledge of railway crossings characteristics may be also related to age, education level and driving experience, which will be the subject further research.

REFERENCES

Traffic Accident Prediction Based on Comprehensive Data Comparison

Pavel Vrtal¹ and Jakub Nováček²

Abstract – The project aims to improve the road safety by identification of potentially risky locations on roads that show similarities to known accident locations. This contribution presents an algorithm that is combining the commonly used methods and the road characteristics identified through the road network analysis and road passport. It is able to search for potentially risky locations on the road network and alert the road managers to the potentially risk prone sites.

Keywords – Traffic accident prediction, Road safety, Comparison algorithm, Accident sites

I. INTRODUCTION

The issue of the road accidents is a long-standing and ongoing issue that requires constant attention. The Czech Republic (CR), like any other European Union country, is obliged to adopt a plan to reduce the consequences of the road accidents, the so-called White Paper [1]. This document serves as the base for a number of national strategic documents, including the National Road Safety Strategy in the CR [2], [3]. One of the main objectives of the current practices is to promote the idea of "Vision Zero". This idea ideally represents a transport system without fatalities or serious injuries. Achieving such a goal is so far only utopia, but it is still assumed that it will be possible to achieve or at least come very close to this result in the future.

It can be said that there is a number of factors by which this objective can be met. One of the potential solutions is the development of modern technologies and systems that will not only contribute to reduction of accidents, but also help to prevent them. Essentially, these elements are already being used as support systems for vehicles, where the last stage is completely autonomous driving without human assistance. Progress in this issue is considerable and a lot of time and money was invested in the development. However, to effectively achieve Vision Zero, another key condition must be met. A shift or a transformation of the transport infrastructure to such a state that it does not pose a risk by itself. A number of procedures are currently used to proactively help to improve this condition. Road safety inspections can be seen as a typical example [4], where the acquired knowledge directly improves the quality of the existing roads. Another effective tool is the implementation of road safety audits, which in turn highlights the road design deficiencies and risks already at the design stage. Although the quality of the road network is constantly being improved in this way, the overall progress is not sufficient. There is still a number of places that are risky in design and dangerous for road users, however, not addressed.

The current approach of identification of accident sites in the CR is based on certified methodologies that use various classifications. Currently, the most widely used approach is to identify the accident sites by three key criteria. By a definition, the accident site is a site where occurred at least 3 accidents with personal consequences within 1 year, at least 3 accidents with personal consequences of the same type in 3 years, or at least 5 accidents of the same type during 1-year period [2]. Another approach is based on identification of the accident sites through mathematical models that predict the locations by the traffic volumes [5]. It is also possible to determine the accident sites by the relevant road managers on the basis of their practical experience. Nevertheless, independently on the chosen approach, the identification of accident site is usually only retrospective and the approach is therefore not proactive.

The aim of this contribution is to highlight the fact that there are a number of locations on the road network that show a number of similar characteristics to already identified accident sites and could therefore present a potential risk for the road user. The only difference is that no significant accident event or a larger number of accidents has yet taken place. By identifying such potentially risky sites, it would be possible to achieve the desired proactive approach and avoid unnecessary injuries. Therefore, an algorithm for identification of new, potential accident-prone locations based on predefined input information is presented. The algorithm is based on the principle of conditional probability.

The following chapters set out how this outcome can be achieved. The first part of the text describes the way in which the input parameters concerning the directional and elevation characteristics of the road can be appropriately identified. The next section focuses on the creation of a database of the individual features necessary to identify a match to already known accident locations. Last but not least, a procedure how to apply it in practice is outlined.

II. METHODS

The initial idea was to create a test algorithm that would be able to detect and search for similar sections in other parts of the road network based on predefined road parameters (directional and elevation guidance). All outputs are designed to correspond with a particular probability match to a pre-identified location. However, it is necessary

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to consider the non-uniform characteristics of the road section. At the same time, there is also a problem with the different orientation of the cardinal points of the individual roads. Furthermore, it is also not possible to simply find the mathematical properties of a road curve defined by previously known equations. For this reason, it was necessary to use a procedure that could effectively identify a specific road section with high accuracy without any additional information about the specific properties. The ideal way was to use a common geodetic coordination system, such as the single trigonometric cadastral network (S-JTSK) used in the CR, to determine the position and elevation of any point of the road in the terrain. Additionally, it was necessary to obtain approximate information on the curvature of the analysed roads using the high quality data from the map portal of the Czech Office of Surveying and Cadastre [6] and the web portal Mapy.cz [7]. The current research is in its initial and testing phase, so in the future, it will be necessary to use the axes of individual lanes. However, the export of the position coordinates of road axis points directly from map applications is not entirely usable. The output of individual points is not with a constant spacing and the recorded position of points changes dynamically depending on the curvature of the road.

Therefore, in order for the comparison algorithm to work properly, it was necessary to split the roads into fixed lengths. In this way, it was possible to obtain a sufficiently detailed coordinate description of the selected roads (Fig 1). The road segment length should be short enough to enable the determination of low curvature radius, yet, not too small due to the overall length of the road network.

The position point comparison algorithm is constructed in such a way that the individual section lengths between adjacent points are taken as a specific parameter. The difference between the previous and subsequent X and Y coordinates is then calculated. It enables to obtain the positional differences of the X and Y coordinates and thus the road spatial layout. An illustrative example is shown in Fig 2.

Completing the elevation map for the road sections in question is considerably more complicated. The freely available map documentation is not sufficiently accurate to determine an adequate match. In order to achieve the most accurate result, it was necessary to use models of aerial laser scanning of the elevation in the CR. These models are digital terrain models which captures the natural or human activity-modified surface in digital form. The models are in the form of heights of discrete points in an irregular triangular area network (TIN). Digital models used for the purposes of this study are the 1st and 5th generation models (DMR 1G and 5G). According to the authors' assessment, these models contain the most suitable data for the purposes. The mean error of DMR 1G is 0.4 m in open terrain, without obstacles, and 0.7 m
in forested landscape [8]. It can be seen that the achieved accuracy is not quite ideal, however, the advantage of using this scanning is in the possibility to identify bridge objects, which are not so accurate or completely missing in the following generations. The reason is that subsequent generations have a more aggressive error filtering approach, which lead to omission of these objects. The use of the latest, 5th generation surface scanning, on the other hand, have a significantly smaller mean error. The DMR 5G is stated to have an accuracy of 0.18 m in open terrain and 0.3 m in forested landscapes [9]. By combining the aforementioned models together with directional location of road network, it was possible to determine the vertical alignment. However, due to the differences in heights of the DMR, it was necessary to develop an algorithm that estimated the correct heights. The approach works by the prediction of subsequent points through calculation of the trend of the height values. As a base information was taken the DMR 5G model. If the subsequent height from the model corresponded with the predicted value, it was possible to consider that the subsequent height was correct. If the prediction of the next point height significantly differed, it was evaluated as an incorrect by the algorithm and replaced by the 1st generation height information. In case, that both models’ heights showed values which differed significantly, the predicted height information was used. The model of the particular road vertical alignment was thus created by iterative evaluation of the most suitable points. The road was then divided into sections of constant length, similar to the directional alignment. In order to further minimize the effects of local errors, the resulting vertical alignment was smoothed with use of the simple moving average. The idea is that the changes in the vertical alignment of the road are gradual and continuous. At the same time, to check the error rate, maximum and mean errors were evaluated and this information was used for new iteration to improve the resulting quality of the model. The test output from the vertical alignment of road can be seen in the following Fig 4 and 5. In the first case the road is routed under the bridge structure, in the second case the road is routed over the bridge.

After obtaining general information on the directional and vertical alignment, a detailed assessment of the individual elements on and near the road must be provided. The principle for the identification of typologically similar sections within the road network is based primarily on a sufficiently detailed database containing various segments. Fig 6 shows the initial layout of the database structure, which can subsequently be used for the filtering. This part is still under development and it is likely that there will be subsequent modifications to evaluate all aspects crucial for an accurate determination. The database is designed in such a way that each road section "Road element" is supplemented with different groups of attributes that modify the resulting correspondence of the selected section with other road sections. In general, the sub-categories of the "Road element" can be divided into elements that will contain basic information on geometric parameters, information related to the traffic characteristics, road infrastructure or facilities in close proximity to the road. At the same time, each section is supplemented with information related to traffic accidents statistics. This database will also include the use of data obtained in the context of road safety inspections aggregated in the CEBASS (Central Evidence of Road Safety Analysis) database [10].
III. POSSIBLE LIMITATIONS

The accuracy of the resulting forecast of potentially risky road sections will depend mainly on the quality of the input data, which significantly influence the result. At the same time, it is necessary to establish a scale of significance for individual attributes, which can be used to prioritize sub-elements of the database over others. If the thresholds of the matching is set too high in the final stage, the algorithm will not be able to find any similar results. For this reason, it is necessary to test the possibilities of how accurate the matching performs and to find a compromise between identical and errant solutions.

If the results are sufficiently valid, desirable step is a creation of a simple and intuitive web interface that will contain the above-mentioned principles. Through filter windows or by directly marking of an area on the map, it will be possible to find places with similar character from a pre-selected location. The graphical representation in the map base will then be discussed as to how best to interpret these results in order to make them as user-friendly as possible for wide range of potential users (such as road administrators, safety experts, road managers).

IV. FUTURE DIRECTION OF THE RESEARCH

The future steps lies mainly in adding new elements to the database, which will characterize the roads in more detail. At the same time, in this way, elements of a different nature will be collected that can develop the passport of the roads in more detail. Another way to use the new solution is, for example, to implement information in car navigation systems in such a way that the system would inform the driver that he is in areas where increased caution is needed. Last but not least, it is possible to look at the result of this project as a database that can be used to search for very similar places on the roads and thus suggest, for example, the reconstruction of selected elements or sections of the road.

V. CONCLUSION

The search for new ways to effectively address and prevent traffic accidents is a necessity for the future development and improvement of the traffic safety. This article illustrates one possible step to make a comprehensive use of the available data and to look at accident rates in a different way than has been done so far. If the full functionality of the proposed solution is achieved, it will be possible to effectively predict a potentially hazardous locations where significant socio-economic loses could occur. It also has the benefit of informing the road managers that there are areas on the road network that need to be addressed as a priority and enables to take a proactive approach.

ACKNOWLEDGEMENT

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ПРИЛОЗИ
ATTACHMENTS
Electric vehicle as an optimal delivery vehicle

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"St. Kliment Ohridski" University, "HM of May"
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Introduction

The increasing growth and development of cities lead to increased traffic congestion, which has a negative impact on the environment. It is a serious problem, not only in the countries of the European Union, but also in the countries of the former republic of Yugoslavia. The increase in the number of vehicles in the cities has a negative impact on the environment, as well as on the health of the population. The traffic congestion in the cities also leads to an increase in the fuel consumption and the emission of pollutants.

The electric vehicle (EV) is a vehicle that is powered by an electric motor, which is driven by an electric energy source. The electric vehicle is a clean and environmentally friendly vehicle, which is becoming increasingly popular in the world. The electric vehicle is a vehicle that is powered by an electric motor, which is driven by an electric energy source. The electric vehicle is a clean and environmentally friendly vehicle, which is becoming increasingly popular in the world.

Electric vehicles can be classified into different categories, based on the type of electric energy source. The electric vehicle can be classified into different categories, based on the type of electric energy source. The electric vehicle can be classified into different categories, based on the type of electric energy source.

Electric vehicle as a delivery vehicle

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In addition to the environmental benefits, electric vehicles also have other advantages, such as lower operating costs, lower maintenance costs, and lower fuel costs. The electric vehicle is a vehicle that is powered by an electric motor, which is driven by an electric energy source. The electric vehicle is a clean and environmentally friendly vehicle, which is becoming increasingly popular in the world. The electric vehicle is a vehicle that is powered by an electric motor, which is driven by an electric energy source. The electric vehicle is a clean and environmentally friendly vehicle, which is becoming increasingly popular in the world.

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Analysis of street design on traffic safety on the reconstructed boulevard “Goce Delchev” Prilep

Introduction

The municipality of Prilep is located in the central part of the Republic of North Macedonia. The current network of the reconstructed street “Goce Delchev” is composed of the following components: Prilep, Topolcicica and Vr Problemi. The municipality also includes the Prilep city, which covers the western part of the city with the streets and roads that make up the city’s fabric.

The municipality has the challenge of differentiating Andrej Markov and the other parts of the city, as well as facilitating the circulation of traffic in the city. The municipality has identified “Goce Delchev” as a central road for the city and has initiated a project to reconstruct it.

Reconstruction of “Goce Delchev” Blvd. in Prilep

In the period from February to December 2020, a complex reconstruction of the road was performed. The road was reconstructed in several locations, starting from the area of the “Farmers’ Market” to the “Old Town.”

Analysis of design inconsistencies and non-compliance with traffic rules and regulations

In the period from February to December 2020, a complex reconstruction of the road was performed. The road was reconstructed in several locations, starting from the area of the “Farmers’ Market” to the “Old Town.”

What measures can be taken to improve traffic safety

Over the last few years, the number of accidents has increased, with more accidents occurring at intersections. The municipality has identified several measures to improve traffic safety, including:

1. improving the visibility of road signs and traffic lights
2. improving the pedestrian crossings
3. improving the road surface and road markings

Conclusion

The purpose of the study is to identify the deficiencies and weaknesses in the current road network. The study was conducted in several phases, including the collection of data on traffic accidents and the analysis of the road network. The results of the study will be used to improve traffic safety and reduce the number of accidents in the city.

Bibliography

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**Introduction**

Traffic signs are an essential component of road transport infrastructure. They enable orderly and efficient movement on roads and highways. The importance of traffic signs in traffic management and road safety cannot be overstated. They provide critical information to drivers and pedestrians, helping to prevent accidents, ensure traffic flow, and reduce the risk of collisions.

Traffic signs are classified into different categories based on their function and purpose. They are integral to the safe and efficient operation of a transportation system. The types of traffic signs include regulatory signs, warning signs, and informational signs.

**Cadastre content**

The digital inventory of road signs system is designed to address the following requirements:

- Identification
- Location
- Status
- Geographical coordinates
- Type and class
- Position and installation

The objective of implementing this system is to ensure that the inventory of road signs is up-to-date and accurate. This helps in maintaining the safety and efficiency of traffic management.

**Data collection system**

The data collection process involves the systematic gathering of information on road signs. This includes their location, type, and condition. The data collected is used to update and maintain the digital inventory of road signs.

**Software solution**

The software solution used in the system is designed to facilitate the process of data collection and management. It enables the efficient and accurate update of the digital inventory of road signs.

**Conclusions**

The digital inventory of road signs system is a valuable tool in traffic management. It helps in maintaining the safety and efficiency of road transport. The system can be further improved by integrating it with other traffic management systems to achieve better results.

**Bibliography**

Introduction

Artificial neural networks are computing systems vaguely inspired by the biological neural networks in the human brain. Such systems are usually trained by a process called backpropagation. During training, the network is presented with a set of training data, and the weights of the connections are adjusted to minimize the error. A widely used technique for doing this is the backpropagation of error. Backpropagation of error is a method of training artificial neural networks that adjusts the weights of the neurons in the network in order to minimize the difference between the network's output and the desired output. The process is repeated for each example in the training set, and the weights are adjusted after each example is presented. The process is repeated until the network converges to a solution, or until a maximum number of iterations is reached.

Methods

After proper training of the network, the generalization performance of the network is evaluated. Several methods are used to test the network, including the mean squared error (MSE) and the root mean squared error (RMSE). The MSE is the average squared difference between the predicted values and the actual values, while the RMSE is the square root of the MSE. The network is also tested on a set of unseen data to evaluate its performance on new data.

Results

The results obtained from the testing show that the network is able to accurately predict the traffic flow on the road. The MSE and RMSE values are both very low, indicating that the network is performing well.

Conclusions

The presented results confirm the applicability and feasibility of using artificial neural networks for traffic flow forecasting. The low error rate, average delay and fuel consumption are achieved using neural networks, and the results obtained from the testing show that the network is able to accurately predict the traffic flow on the road.

Bibliography

ПРИЛОЗИ
ATTACHMENTS
Electric vehicle as an optimal delivery vehicle

Introduction

The commercialization of electric vehicles (EVs) has gained significant traction in recent years due to growing environmental concerns and the increasing focus on sustainable transportation. This paper explores the potential of EVs as delivery vehicles, highlighting their benefits over traditional gasoline-powered vehicles. The study aims to assess the feasibility of using EVs for delivery services, focusing on factors such as energy efficiency, environmental impact, and operational costs.

Methodology for selecting the optimal electric vehicle

1. **Comparative Analysis**: Evaluate EVs against gasoline-powered vehicles in terms of efficiency, cost, and environmental impact.
2. **Simulation Modeling**: Use simulation software to model delivery routes and scenarios to understand the performance of different EV models.
3. **Cost-Benefit Analysis**: Calculate the total cost of ownership for EVs, including purchase, maintenance, and fuel costs, comparing them to gasoline vehicles.
4. **Energy Efficiency**: Assess the energy consumption and range capabilities of various EV models.
5. **Environmental Impact**: Analyze the CO2 emissions and other environmental effects of using EVs for delivery services.
6. **Regulatory and Policy Considerations**: Evaluate the impact of current and potential future regulations on the use of EVs in delivery services.

Results

- **Energy Efficiency**: EVs demonstrate a significant reduction in energy consumption compared to gasoline vehicles, making them more cost-effective in the long term.
- **Environmental Impact**: The use of EVs reduces greenhouse gas emissions, contributing to a cleaner environment.
- **Cost-Benefit Analysis**: EVs can offer cost savings, particularly in the long term, due to lower maintenance and fuel costs.

Conclusion

The use of EVs for delivery services presents several advantages over gasoline-powered vehicles, including lower operational costs, reduced environmental impact, and improved energy efficiency. Further research and development are needed to address concerns such as range and charging infrastructure, but the potential benefits make EVs a promising option for delivery services.

Bibliography

Introduction

The municipality of Prilep is located in the central part of the Republic of North Macedonia. The current master of the municipality of Prilep is composed of the former municipalities of Prilep, Tepelenik and Vrhovce. The municipality also includes the following: road which connects the northern part of Prilep and the road that connects the southern part of Prilep.

The municipality also includes the municipalities of Cerova and Dolenje in the north, Mrakinje in the south, Vrševci and Vrševci in the west, Gruevci in the east, Divčibare and Doljevci in the north and Govče in the south. The municipality of Prilep is served by an urban bus service that is free of charge and operating during the week.

Reconstruction of “Goce Delchev” Blvd. in Prilep

In the period from February to November 2020, a complete reconstruction of the boulevard “Goce Delchev” was performed in the central part of the city. The reconstruction was conducted at several locations on the boulevard along the main traffic routes. The reconstruction was realized by expanding the boulevard to accommodate the flow of traffic, and also by improving the safety conditions.

Analysis of design inconsistencies and non-compliance with traffic rules and regulations

The total length of the reconstructed sections is 345 meters. The new boulevard is designed to accommodate vehicles in the urban environment, and it is planned to be realized in the immediate vicinity of the existing buildings.

What measures can be taken to improve traffic safety

As a consequence of the above, some traffic violations are recorded, such as:

1. Filing checks for drivers of vehicles on the road.
2. Filling the traffic lights on the road.
3. Monitoring the quality of the road.
4. Monitoring the efficiency of the road.
5. Monitoring the speed of the road.
6. Monitoring the safety of the road.
7. Monitoring the compliance with traffic rules and regulations.

Conclusion

The purpose of the research was to identify the implications and challenges of the traffic on the boulevard. To achieve this, the research was conducted by collecting data on traffic volumes, traffic violations, and traffic accidents. The results of the research showed that the traffic on the boulevard is characterized by high traffic volumes, frequent traffic violations, and a high number of traffic accidents. Therefore, it is necessary to implement measures to improve traffic safety and ensure a safe environment for all road users.

Bibliography

**Introduction**

Traffic signs are an accepted and one element of road transport infrastructure. They enable drivers through understanding in road transport systems. Traffic signs are a vital function of road safety regulations. All signs are organized in a hierarchical manner as a road traffic, and the signs are also organized in order to reduce the potential and severity of road accidents which is among the most important reasons for creating traffic sign systems.

A traffic sign system is an example of an emergency and it is defined as the result of effectively managing and successfully improving the road network and creep of the road network. Therefore, traffic signs are an important public transport infrastructure and the network of emergency, building and preventing the road safety, the road with the sign "dead" in positions that are not addressed in the question of "slow, regular, and steady".

The introduction of the traffic sign system involves the following aspects:

- Managing the network of the road network.
- Developing and financing the traffic signs and equipment.
- Data collection and automated data on traffic systems.
- Data processing and data transmission and control of digital data.
- Establishment of a digital platform for traffic systems.

**Data collection system**

The data collection system consists of a traffic network and a traffic flow classification of traffic signs and equipment.

- Data collection and automated data on traffic systems.
- Data processing and data transmission and control of digital data.
- Establishment of a digital platform for traffic systems.

**Software solution**

The data collection system can be used for the following recommendations:

- Identifying traffic signs.
- Traffic signs.
- Traffic sign network.
- Data collection.
- Data transmission.
- Data processing and data transmission.
- Establishment of a digital platform for traffic systems.

**Conclusion**

Mobile mapping systems represent an interesting alternative to traditional methods for collection, analysis and maintenance of road data, especially for urban areas. The use of mobile mapping systems provides a number of advantages, such as cost-effectiveness, flexibility, and data availability. The integration of mobile mapping systems with other data sources, such as LiDAR and thermal imaging, further enhances their utility for road network management and urban planning purposes.

**Cadastre**

Advantages of the proposed system include:

- The ability to use the data for various purposes, such as urban planning, traffic management, and emergency response.
- The ability to collect and maintain a comprehensive database of road data.
- The ability to access and use the data in real-time, which is essential for decision-making.
- The ability to use the data for various purposes, such as urban planning, traffic management, and emergency response.

**Bibliography**

PLANNING AND EXPLOITATION OF FAST CHARGERS FOR ELECTRIC CARS IN THE URBAN AREA - BITOLA

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**ELECTRIC VEHICLES**

- Any vehicles that use an electric power for propulsion
- Most popular in the mid-19th and early 20th centuries
- They contribute to cleaner air because they do not create harmful pollution from the built-in energy source
- Due to the limited range, an infrastructure system is needed to provide charging points

**CHARGING EV**

- High voltage and alternating current is used as a power supply
- Charging infrastructure is used to ensure EVs are charged
- EVs can be charged at different types of charging points

**Charging infrastructure**

- Components of EV
- Connection of fast chargers in NEPLAN

**Fast charging stations**

<table>
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**Projected Infrastructure of fast chargers in Bitola**

**Schedule of fast chargers in Bitola**

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**BIBLIOGRAPHY**
Introduction

Short-term load forecast is very essential for power system operation and economic dispatch. The significance of designing an improved load forecast system on several issues. Increased penetration of non-predictable, renewable sources, electricity markets deregulation, power plants, and an energy system's overall state are some of the factors, which has significantly increased the unpredictability level of load forecast. The load forecast is a major input in the energy systems' operation, which affects the energy system's economic performance. The use of a more accurate load forecast improves the economic performance of the entire power system. A more accurate load forecast also reduces the loss of generation and helps in the optimal allocation of the grid's assets. The load forecast can be done using several techniques, which are widely used in the industry today.

Methods

Artificial neural networks are computing systems vaguely inspired by the biological neural networks. Such systems perform a task by forming a network of simple processing elements. Artificial neural networks are used in许多实际应用, including the prediction of load forecasting. The data used for the prediction is obtained from the power system's actual load data. The network is trained using a training dataset, which is a set of input patterns and corresponding output patterns. The input patterns are the historical load data, and the output patterns are the predicted load data. The network is trained using a backpropagation algorithm, which adjusts the weights of the connections between the neurons in the network. The network is then tested using a test dataset, which is a set of input patterns that the network has not seen before. The network's performance is evaluated using various metrics, such as the mean absolute error (MAE) and the root mean square error (RMSE).

Results

After training the network, the generalization performance of the network is evaluated. Figure 2 shows the learned load forecasting performance. The results are presented in terms of MAE and RMSE, which are calculated for each time step and for the entire time period. The network achieved a high accuracy in the load forecasting, which is evident from the low MAE and RMSE values.

Conclusions

The presented results confirm the applicability and effectiveness of using artificial neural networks for load forecasting. The results show that artificial neural networks can provide accurate load forecasts. The network has been trained and tested on historical load data. The results show that the network is capable of accurately forecasting future load. The network's performance is evaluated using various metrics, such as MAE and RMSE. The network achieved a high accuracy in the load forecasting, which is evident from the low MAE and RMSE values. The network is suitable for real-time load forecasting and can be applied to power systems to improve their performance.

Bibliography


Figure 1: Structure of neuron

Figure 2: Load forecast for the year X

Figure 3: Vehicle volume forecasting for 15, 20, 25, 30, 35, 40

Table 1: MAE and RMSE of Load Forecasting for Several Time Steps

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Table 2: MAE and RMSE of Vehicle Volume Forecasting for Several Time Steps

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Figure 4: MAE and RMSE for several time steps