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- Promote and exchange information and knowledge in the transportation research arena and its application
- Explore the new trends in development and invention related to the efficiency, reliability, safety and economically and ecologically sustainable transportation.

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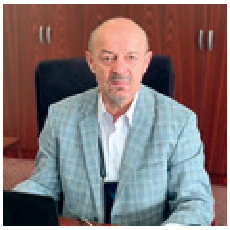

EDITOR'S WORD

Dear readers,

It is my pleasure to present the eleventh, printed and electronic edition of the magazine "Traffic and transport theory and practice - TTTP", which successfully resists the challenges set in the field of modern processes of traffic and transport engineering. It is important that we have established the continuity of the regular edition of two issues on an annual level, with a high criterion of choice and discretion in the relationship between the reviewer and the author of the papers.

I am pleased to inform you that "Traffic and Transport Theory and Practice - Journal for Traffic and Transport research and Application - TTTP" has been included in the European database of scientific works Erih Plus and according to the Ministry of Scientific - Technological Development and Higher Education of the Republic of Srpska, categorized as a magazine of the highest rank.

Erih Plus "The European Reference Index for the Humanities and the Social Sciences" is one of the largest index databases of scientific journals in the world, focused on journals in the humanities and social sciences. It is a reference for the first category of international journals and is applicable in the selection of university degrees. It is a database containing bibliographic data on academic journals in the social sciences and humanities.The aim of the database is to increase the visibility, demand and availability of journals in the field.

Therefore, from the Copernicus database, we stepped into a higher-ranking database, thus obtaining the conditions for the status of the first category of international journals at the national level. The works published in our journal will especially benefit scientists.

The journal has ensured open access to older issues on its own website (https://apeiron-uni.eu) which enables a wider population of researchers to publish and protect their author's works.

Editor-in-Chief
Prof. Danislav Drašković, PhD Eng.

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ORIGINAL SCIENTIFIC PAPER

Visibility at intersections in the city of banja luka

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Abstract: Visibility at intersections in road traffic plays a key role in ensuring the safety and efficiency of the traffic flow. Insufficient visibility at intersections can significantly increase the risk of traffic accidents. This paper investigates the importance of visibility at intersections and its impact on the safe merging of vehicles into traffic. The state of visibility at intersections in the city of Banja Luka is analyzed in order to identify factors that lead to a lack of visibility. Research results are presented that indicate insufficient visibility at certain intersections, which can lead to an increased risk of traffic accidents. Recommendations and opportunities for improving visibility at intersections are also discussed, including proper placement of traffic signs, signage and removal of obstructions that impede visibility. The importance of driver awareness of the importance of visibility and timely reaction at intersections is emphasized. This paper provides insight into the problem of lack of visibility at intersections and highlights the need to take measures to improve road traffic safety.

Keywords: visibility, traffic safety, intersection, traffic accidents

INTRODUCTION

Traffic accidents and their consequences are one of the main indicators of traffic safety. A large number of traffic accidents occur at intersections, and insufficient road visibility is a very common cause.

Intersections with insufficient visibility, especially in urban areas, must be timely marked with traffic signage and road equipment in order to enable the safe flow of traffic A major problem presents the fact that a large number of intersections are not marked with traffic signage, and that the signage is being installed without the main traffic design.

The driver receives more than 95% of the information by the sense of sight. At intersections, sufficient visibility needs to be ensured so as to enable the driver of the vehicle without the right of way, to safely perform the action of merging onto a road with the right of way. Drivers should have a clear view of the intersection and be able to see other vehicles, pedestrians and cyclists prior to deciding to perform any action by their vehicle.

Maintaining visibility at intersections encompasses regular cleaning and maintenance of greenery, horizontal and vertical signage (road markings and signs), as well as proper parking of vehicles in the vicinity of the intersection in order to ensure sufficient visibility.

The paper describes the methodology of determining the necessary visibility at intersections and connection points in accordance with the rulebooks and guidelines that are being applied in Bosnia and Herzegovina.

LEGAL REGULATIONS IN THE AREA OF ROADS AND TRAFFIC SAFETY ON ROADS IN BIH

The Law on Public Roads regulates the legal status of road manager, the manner of utilization of public and uncategorized roads; management, financing, planning, construction, reconstruction, maintenance and protection of roads; concessions on public roads; implementing public-private partnership and supervising implementation of this law (Official Gazettes of the Republic of Srpska No. 89/13 and 83/19). This law stipulates, among other things, that the management of the main (arterial) and regional roads is performed by the PE "Roads of the RS", while the management of local roads, streets in settlements and road facilities on them is performed by the competent authority of the local self-government unit, which in this case is the City of Banja Luka.

The Law on the Basis of Traffic Safety on Roads in BiH (Official Gazettes of BiH No. 6/06, 75/06, 44/07, 84/09, 48/10, 18/13 and 8/17) the competent authorities that are managing roads shall, in accordance with the applicable regulations, analyze and undertake measures to remedy certain deficiencies on roads at locations where traffic accidents occur frequently. This law defines an intersection as follows: "an intersection is an area on which two or more roads intersect or merge, as well as a wider traffic area created as a result of intersecting or merging of roads".

Rulebook on the Method of Connecting to Public Road (Official Gazette of the Republic of Srpska No. 98/15) defines the minimum conditions for designing and construction of connections to a public road, conditions regarding the location for constructing connections, necessary technical documentation, engineering conditions and conditions for construction work as well as the manner of maintaining the built connections. This Rulebook defines a connection as follows: "a connection is the part of a road by which a public road, an uncategorized road or access to a building, is connected to that road". A connection can be constructed in the locations where sufficient visibility is provided.

Rulebook on Audit and Inspection, Conditions and Manner of Licensing (Official Gazette of the Republic of Srpska No. 72/12 and 94/18), road manager is obliged to periodically inspect the conditions of the road under operation, from the aspect of the safe flow of traffic, in the aim of reducing the risk of traffic accidents.

Rulebook on the Basic Conditions That Public Roads, Elements Thereof and Facilities on Them Must Meet from the Aspect of Traffic Safety ("Official Gazette of BiH" No. 12/07) defines the visibility at the intersection as follows: "Visibility when entering into an intersection is the length that allows the driver on the road with the right of way to stop the vehicle before the intersection if the vehicle from the side direction is merging into the same traffic lane or if it crosses the intersection.

Guidelines for Designing, Construction, Maintenance and Supervision of Roads, defines stopping visibility (sight distance) - Pz for the roads that belong to the technical group C (local roads and streets in settlements) as the minimum distance at which the driver perceives an obstacle in order to completely stop the vehicle prior to reaching the obstacle under the conditions of the permitted value of the friction coefficient:

$$P_Z = L_Z + 7m$$

Where:
Lz - stopping distance
7 m is a safety distance

For example, for the speed of 50 km/h on local roads and streets, stopping visibility Pz equals a minimum of 49 m (Figure 1).

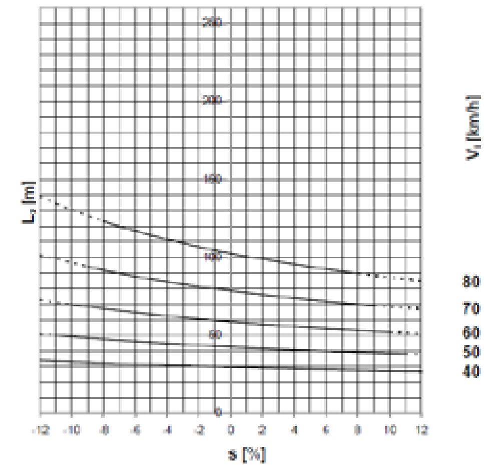

Figure 1. Stopping visibility for the roads of the technical group C

(Source: Rulebook on the Basic Conditions That Public Roads, Elements Thereof and Facilities on Them Must Meet from the Aspect of Traffic Safety)

ANALYSIS OF VISIBILITY AT INTERSECTIONS IN THE CITY OF BANJA LUKA

The following data was acquired by measuring the visibility at intersections with increased intensity of traffic in the city of Banja Luka. By the decision on the classification of public roads, the intersections taken into consideration had been classified as streets in a settlement and managed by the competent authority of the local self–government unit, in this case it is the City of Banja Luka, namely: Filipa Macure Street – Kozarska Street; Srpskih Vitezova Street – Kozarska Street; Mića Radakovića Street-Kozarska Street. These intersections are taken into account because based on the visual inspection from a vehicle, there is no necessary visibility on these intersections. The following tables and figures show the data of the intersections that were taken into consideration.

Table 1. Intersection Filipa Macure Street-Kozarska Street

Intersection	Filipa Macure Street-Kozarska Street
GPS coordinates	44.760653, 17.180304
Type of intersection	Minor road with mandatory stop - "STOP"
Intersection geometry	Three-way intersection at right angles
Stopping visibility (Guidelines)	49 m
Visibility length (Actual)	Right ~ 10 m, Left ~ 10 m
Intersection is marked by traffic signage	YES
Missing signs	NO
Speed limit on the main road	50 km/h
Note:	The tree-line and container on the left side reduce visibility while on the right side there is a concrete wall

Figure 2. Intersection Filip Macura Street-Kozarska Street (view to the right)

Figure 3. Intersection Filip Macura Street-Kozarska Street (view to the left)

Table 2. Intersection Srpskih vitezova Street-Kozarska Street

Intersection	**Srpskih vitezova Street-Kozarska Street**
GPS coordinates	44.759602, 17.179576
Type of intersection	Minor road with mandatory stop - "STOP"
Intersection geometry	Three-way intersection at right angles
Stopping visibility (Guidelines)	49 m
Visibility length (Actual)	Left ~ 15.0 m, Right ~ 25,0 m
Intersection is marked by traffic signage	YES
Missing signs	NO
Speed limit on the main road	50 km/h
Note:	Presence of large number of parked vehicles on the sidewalk

Figure 4. Intersection Srpskih vitezova Street-Kozarska Street (view to the left)

Figure 5. Intersection Srpskih vitezova Street-Kozarska Street (view to the right)

Table 3. Intersection Miće Radakovića Street-Kozarska Street

Intersection	**Miće Radakovića Street-Kozarska Street**
GPS coordinates	44.758384, 17.178845
Type of intersection	Minor road with mandatory stop - "STOP"
Intersection geometry	Three-way intersection at right angles
Stopping visibility (Guidelines)	49 m
Visibility length (Actual)	Left ~ 10.0 m, Right ~ 15,0 m
Intersection is marked by traffic signage	YES
Missing signs	NO
Speed limit on the main road	50 km/h
Note:	On the right side there is a large number of parked vehicles on the sidewalk while on the left side there is a fence that reduces visibility

Figure 6. Intersection Miće Radakovića Street-Kozarska Street (view to the right)

Figure 7. Intersection Miće Radakovića Street-Kozarska Street (view to the left)

Research results and recommendations for improving traffic safety

At all intersections subject to the research, it has been established that there was no visibility as prescribed on the basis of the Guidelines for Designing, Construction, Maintenance and Supervision of Roads, while in other aspects, each location was marked by the traffic signage as prescribed.

It was established by the analysis of the visibility of the observed intersections and connection points that the two most frequent reasons for reduced visibility were the following:

A) movable obstacles

At all controlled intersections, it was found that visibility was reduced due to the presence of movable obstacles (parked vehicles and containers on the sidewalk).

As a solution on these locations, we recommend the following:

1. Anti-parking bollards, planter-boxes, concrete cubes, etc.;
2. Moving containers to another location if possible or burying them in the ground (underground containers).

B) Immovable obstacles

At two intersections observed, namely Filipa Macure- Street – Kozarska Street and Miće Radakovića Street – Kozarska Street, visibility has been reduced by the installation of concrete and metal railings about 1.70 m high, which significantly reduce visibility when merging onto the main road.

As a solution on this location, we recommend the following:

1. Installing a traffic mirror;
2. It is necessary to limit the speed to 30 km/h on the priority road, at the approach to intersections.

In the previous period, the Republic of Srpska has adopted the Rulebook on Audit and Inspection, Conditions and Manner of Licensing (Official Gazette of the Republic of Srpska No. 72/12 and 94/18), and in this case, the road manager - City of Banja Luka, is obliged to periodically inspect the conditions of the road under operation, from the aspect of the safe flow of traffic, in the aim of reducing the risk of traffic accidents.

CONCLUSION

Visibility is key to safety at intersections, because it enables drivers to make the right decisions in critical situations. Due to improper parking of vehicles in the vicinity of intersections, visibility can be significantly reduced, which increases the risk of occurrence of accidents. Trees, shrubs, or other greenery may also restrict visibility which is why it must be regularly maintained. Installing traffic mirrors can help drivers to see vehicles or pedestrians. Also, traffic signage and lighting are key factors that affect visibility at intersections and therefore these must be regularly maintained. It is important to pay attention to the proper placement of traffic signs in intersections, so that drivers are able to see the warnings clearly and on time. In intersections with high-intensity traffic, the placement of roundabouts or traffic lights can help reduce occurrence of traffic accidents and improve visibility.

The deficiencies found at the observed intersections are not characteristic exclusively for these locations, yet to a lesser or greater extent, these deficiencies are present in the entire road network in the Republic of Srpska. Therefore, the approach to solving this problem must be systemic and must consist of amendments to legal solutions that treat this field. This would, principally, imply the following:

- In locations where the measures undertaken (currently existing) failed to yield results, it is necessary to limit the speed to 30 km/h and install traffic mirrors.
- Considering that these are the streets in the settlement, and that the road manager is the City of Banja Luka, it is necessary to perform a targeted traffic safety inspection (TSI) with an accent on visibility in the zone of intersections and connection points.
- Review the provisions of the Rulebook on the Basic Conditions That Public Roads, Elements Thereof and Facilities on Them Must Meet from the Aspect of Traffic Safety - in the part related to determining the necessary visibility at intersections.

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ORIGINAL SCIENTIFIC PAPER

Selection of an Electric Forklift for the Operational Planning Needs of the Warehouse System of GTC Doboj

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Abstract: The selection of handling equipment represents an important aspect of operational planning in logistics centers and affects the potential increase in work efficiency. Therefore, it is necessary to consider various factors when making decisions regarding the selection of handling equipment. This paper presents the selection of an electric forklift for the needs of loading and handling activities in a closed warehouse of the GTC (Goods Transport Center) Doboj. An MCDM model, consisting of FUCOM (Full Consistency Method) and MARCOS (Measurement of Alternatives and Ranking According to the COmpromise solution) was applied to evaluate electric forklifts. The FUCOM method was used to determine the values of criteria, and the MARCOS method was used to evaluate electric forklifts. After obtaining the results, sensitivity analysis and comparative analysis were performed.

Keywords: electric forklift, warehouse, GTC, FUCOM, MARCOS, MCDM

INTRODUCTION

The region of Doboj has an exceptionally favorable position in relation to main railway and road transportation routes. The city of Doboj is intersected by several main and regional railway and road routes with significant goods flows, making it predisposed to the formation and development of a goods transport center with comprehensive transportation and logistics services. Accordingly, it can be said that the need for its establishment has been evident for more than three decades, but circumstances have not allowed this project to come to life. Considering that the new European transport policy calls for a transition from road to rail transport, the development of a network of goods transport centers in Bosnia and Herzegovina has been a challenging issue for decades. In line with this, there are projects for the construction of the Goods Transport Center (GTC) Doboj, which relies partly on existing infrastructure. The GTC Doboj is located right next to the Doboj railway station and, with all its sub-systems, represents a compact entity. As part of the GTC Doboj, a closed warehouse with a length of 82 meters and a width of 46 meters, i.e. with a total area of 3772 m², is planned.

In order to adequately manage operational activities in the closed warehouse of GTC Doboj, it is necessary to determine potential flows of various goods gravitating around the center, the timing of certain operations, and suitable loading and handling equipment. This paper considers the introduction of an electric forklift for the purpose of performing the aforementioned activities in a closed warehouse. The aim is to select an appropriate electric forklift based on group decision-making involving the participation of a large number of decision-makers and the application of FUCOM and MARCOS methods and the Bonferroni operator.

After the introductory section, the paper is structured through the following sections. Section 2 presents the steps of the MCDM method, both for determining the weights of criteria and for evaluating forklifts. Section 3 outlines the formation of the MCDM model, along with displays of the obtained results, while Section 4 includes sensitivity analysis and the application of other MCDM methods through comparative analysis. Finally, Section 5 summarizes the results, presenting limitations and future research directions.

METHODS

FUCOM method

The FUCOM [1,2] method was developed by Pamučar et al. [3] for determining the weights of criteria:

Step 1. The first step is to rank the criteria from a predefined set of evaluation criteria $C = \{C_1, C_2, ..., C_n\}$.

$$C_{j_{(1)}} > C_{j_{(2)}} > \cdots > C_{j_{(k)}} \tag{1}$$

where k represents the rank of the observed criterion.

Step 2. In the second step, a mutual comparison of ranked criteria is made and comparative significance ($\varphi_{k/(k+1)}$), $= 1,2,\ldots,n$ is determined, where k represents the ranking of the evaluation criteria.

$$\Phi = (\varphi_{1/2}, \varphi_{2/3}, \ldots, \varphi_{k/(k+1)}) \tag{2}$$

Step 3. In the third step, the final values of the weighting coefficients of the evaluation criteria $(w_1, w_2, \ldots, w_n)^T$ are calculated. The final values of the weighting coefficients should satisfy two conditions: (1) The ratio of the weighting coefficients is equal to the comparative significance among the observed criteria ($\varphi_{k/(k+1)}$), which is defined in Step 2, i.e. that the following condition is fulfilled:

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)} \tag{3}$$

(2) In addition, the final values of the weighting coefficients should satisfy the condition of mathematical transitivity, i.e. that $\varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} = \varphi_{k/(k+2)}$. Since $\varphi_{k/(k+1)} = \frac{w_k}{w_{k+1}}$ and $\varphi_{(k+1)/(k+2)} = \frac{w_{k+1}}{w_{k+2}}$, we obtain that $\frac{w_k}{w_{k+1}} \otimes \frac{w_{k+1}}{w_{k+2}} = \frac{w_k}{w_{k+2}}$. Thus, we gain a second condition that should be satisfied by the final values of the weighting coefficients of the evaluation criteria:

$$\frac{w_k}{w_{k+2}} = \varphi_{\frac{k}{k+1}} \otimes \varphi_{\frac{k+1}{k+2}} \tag{4}$$

Based on the established settings, we can define a final model for determining the final values of the weighting coefficients of the evaluation criteria

$$\begin{aligned}
&\min \chi \\
&s.t. \\
&\left| \frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \right| = \chi, \ \forall j \\
&\left| \frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \right| = \chi, \ \forall j \\
&\sum_{j=1}^{n} w_j = 1, \\
&w_j \geq 0, \ \forall j
\end{aligned} \tag{5}$$

1.2. MARCOS method

In this section of the paper, the algorithm of the MARCOS method is presented [4,5]:

Step 1: Forming an initial decision matrix.

Step 2: Forming an extended initial matrix. In this step, the initial matrix is extended by defining an ideal (AI) and anti-ideal (AAI) solution.

$$X = \begin{matrix} \\ AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ AI \end{matrix} \begin{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix} \end{matrix} \tag{6}$$

The anti-ideal solution (AAI) represents the worst alternative while the ideal solution (AI) represents an alternative with the best characteristics. Depending on the nature of the criteria, AAI and AI are defined:

$$AAI = \min x_{ij} \ \ if\ j \in B \ and\ \ max\, x_{ij} \ \ if\ j \in C \tag{7}$$

$$AI = \max x_{ij} \ \ if\ j \in B \ and\ \ min\, x_{ij} \ \ if\ j \in C \tag{8}$$

where B represents a benefit group of criteria, while C represents a non-benefit group of criteria.

Step 3: Normalization of the extended initial matrix (X). The elements of the normalized matrix $N = [n_{ij}]_{m \times n}$ are obtained:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \quad if\ j \in C \tag{9}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \quad if\ j \in B \tag{10}$$

where the elements x_{ij} and x_{ai} represent the elements of the matrix X.

Step 4: Determining the weighted matrix $V = \left[v_{ij}\right]_{mxn}$. The weighted matrix V is obtained by multiplying the normalized matrix N by the weighting coefficients of the criterion w_j.

$$v_{ij} = n_{ij} \times w_j \quad (11)$$

Step 5: Calculation of the utility degree of the alternative K_i. By applying Equations (12) and (13), the utility degrees of the alternative in relation to an anti-ideal and ideal solution are calculated.

$$K_i^- = \frac{S_i}{S_{aai}} \quad (12)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (13)$$

where S_i (i=1,2,..,m) represents the sum of the elements of the weighted matrix V.

$$S_i = \sum_{i=1}^{n} v_{ij} \quad (14)$$

Step 6: Determining the utility function of alternatives $f(Ki)$. The utility function represents a compromise of the observed alternative in relation to an ideal and anti-ideal solution.

$$f(K_i) = \frac{K_i^+ + K_i^-}{\frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \quad (15)$$

where $f(K_i^-)$ represents the utility function in relation to an anti-ideal solution, while $f(K_i^+)$ represents the utility function in relation to an ideal solution.

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (16)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (17)$$

Step 7: Ranking the alternatives.

1.3. Bonferroni aggregator

For averaging weights in group decision-making process, the Bonferroni aggregator was used [6,7].

$$a_j = \left(\frac{1}{e(e-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{e} a_i^p \otimes a_j^q \right)^{\frac{1}{p+q}} \quad (18)$$

In this research, e represents the number of decision-makers for determining criteria weights, while $p, q \geq 0$ are a set of non-negative numbers.

EVALUATION AND SELECTION OF AN ELECTRIC FORKLIFT

Problem description and formation of an MCDM model

From a logistical standpoint, a warehouse is a place in a logistics network where goods are received, stored and forwarded to another direction within the network. It is a closed or semi-open space for storing and handling certain types of goods. The envisaged space for storing palletized units in the GTC Doboj is 78 meters long and 44 meters wide, with a total area of 3432 m². The space for storing bulk goods is 30 meters long and 20 meters wide, with a total surface area of 600 m². Transport corridors are 3 meters wide, while the railway track is 2.6 meters wide. The canopy facility, which serves for loading road transport vehicles and can also be used for temporary storage of palletized goods, is 46 meters long and 8 meters wide, with a total surface area of 368 m².

The loading area for pallet picking is 5 meters wide and is integrated with the storage facility allowing the merging of goods receiving and dispatch functions. Palletized goods transported by railway wagons and road vehicles will be stored in a selective racking warehouse in height, in four rows, with a pallet height of 1.3 meters, and a vertical aisle space of 1.5 meters between rows. The racks are made of metal construction which are attached to concrete load-bearing structures under the roof at the top parts. The layout of the selective racking warehouse provides direct access for forklifts to any pallet at any time. The average weight of a pallet is 1.2 [t], as they are Euro pallets with dimensions of 800 x 1200 mm. The height of the closed warehouse is 10 meters, so if necessary, palletized units can be expanded vertically, with a change in equipment.

For the formation of the MCDM model, nine criteria and five alternatives have been considered, which are explained in more detail below.

Criterion 1 – **Forklift Price expressed in BAM** represents a very important criterion that significantly influences the decision when selecting a forklift. Price is closely related to quality.

Criterion 2 – **Forklift Lifting Height expressed in mm** plays an important role in the operational characteristics of forklifts, determining the height of load stacking. It affects the work technology and warehouse capacity.

Criterion 3 - **Battery Capacity expressed in KWh** refers to the energy stored in the battery and is expressed in Ah (ampere-hours) or in Wh (watt-hours). The motor operating time represents the quotient of battery capacity in Wh (i.e. in kWh) and the motor power.

Criterion 4 – **Electric Motor Power expressed in KW** is based on the maximum power for continuous loading of forklifts. Electric forklifts are powered by a direct current motor that uses batteries of a certain capacity ranging from 10 to 75 KWh. Depending on the load, the motor draws the necessary current from the batteries.

Criterion 5 - **The Operating Time of the Forklift under Load** refers to the capacity of the current in the battery and the amount of current the battery possesses until discharge. The battery will discharge over time depending on operating mode of the forklift.

Criterion 6 - **Battery Charging Time** depends on the type of charger and the type of battery. For instance, lithium-ion batteries used in new electric forklifts can be rapidly charged and do not require cooling periods like lead-acid batteries.

Criterion 7 - **Forklift Load Capacity (*t*)** determines the modes of loading and at what heights individual forklifts can operate without the risk of overturning the load.

Criterion 8 - **The Lifting Speed of a Loaded Forklift (V**do) affects the time taken to lift the load:

$$\frac{H_0}{v_{do}} + t_g \tag{19}$$

Criterion 9 – **Forklift Service and Maintenance** is a continuous process. The need for forklift maintenance arises from its susceptibility to failure during operation. The aim of maintenance is to execute work according to plan, minimize forklift downtime, and apply modern technologies and equipment to maintenance tasks in order to ensure quality.

Alternative solutions are as follows: A1 - Toyota 8FBMT18, A2 - Linde H25D-04, A3 - Hyundai 22B-9, A4 - Still RX RX20-16, A5 - Jungheinrich EFG 320.

Table 1 illustrates the structure of the MCDM model with all characteristics.

Determining the values of criteria using the FUCOM method

In the group decision-making, nine decision-makers participated in the mutual evaluation of criteria. Initially, as the first step, they ranked the criteria according to importance, and the ratings are shown in Table 2.

DM1: C1>C2>C5>C7>C6>C3>C4>C8>C9
DM2: C1>C2>C7>C5>C6>C3>C4>C8>C9
DM3: C1>C5>C2>C3>C6>C4>C7>C9>C8
DM4: C1>C6>C2>C7>C5>C3>C4>C9>C8
DM5: C1>C7>C2>C6>C5>C3>C4>C9>C8
DM6: C1>C2>C5>C7>C3>C6>C4>C8>C9
DM7: C1>C5>C3>C6>C2>C7>C9>C4>C8
DM8: C1>C2>C3>C5>C6>C9>C7>C4>C8
DM9: C1>C5>C2>C4>C3>C6>C9>C8>C7

Table 2. Evaluation of criteria in group decision-making

DM1	1.11	1.67	2.00	1.16	1.43	1.19	2.78	3.85
DM2	1.14	1.56	1.85	1.22	1.32	1.16	2.63	3.57
DM3	1.20	1.23	1.50	1.02	1.26	1.60	2.00	1.92
DM4	1.09	1.38	2.14	1.34	1.02	1.21	2.94	2.61
DM5	1.22	1.32	1.39	1.28	1.25	1.09	1.67	1.61
DM6	1.07	1.23	1.69	1.11	1.32	1.20	1.75	2.23
DM7	1.19	1.09	1.47	1.02	1.11	1.25	1.61	1.39
DM8	1.04	1.06	1.43	1.09	1.16	1.32	1.52	1.28
DM9	1.09	1.14	1.12	1.07	1.17	1.45	1.26	1.20

After applying all the steps of the FUCOM method for each DM, the results presented in nine models were obtained (Table 3).

Table 3. Results of applying the FUCOM method and criterion weights for each DM

	C1	C2	C3	C4	C5	C6	C7	C8	C9
DM1	0.166	0.150	0.099	0.083	0.143	0.116	0.140	0.060	0.043
DM2	0.162	0.142	0.104	0.088	0.133	0.123	0.140	0.062	0.045
DM3	0.149	0.124	0.121	0.099	0.146	0.118	0.093	0.074	0.077
DM4	0.157	0.144	0.113	0.073	0.117	0.154	0.129	0.053	0.060
DM5	0.143	0.117	0.108	0.103	0.111	0.114	0.131	0.085	0.089
DM6	0.146	0.136	0.119	0.086	0.131	0.111	0.122	0.083	0.065
DM7	0.134	0.113	0.123	0.091	0.131	0.121	0.107	0.083	0.096
DM8	0.132	0.127	0.124	0.092	0.121	0.114	0.100	0.087	0.103
DM9	0.128	0.118	0.113	0.115	0.120	0.110	0.088	0.102	0.107

To obtain the final weights that are further implemented in the model, the Bonferroni operator for averaging was applied, resulting in the final weights of the criteria as follows: w1=0.145, w2=0.129, w3=0.114, w4=0.092, w5=0.128, w6=0.119, w7=0.115, w8=0.077, w9=0.076.

Table 1. Data required for the formation of an electric forklift evaluation and selection model

	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	69,900	6500	34.56	10	8h 18 m	3h 19m	1.8	0.60	**Sarajevo, B&H**
A2	89,500	4700	36.8	13	6h 30m	2h 35m	2.5	0.58	**Banja Luka, B&H**
A3	88,600	4300	31.68	12	6h 34m	2h 37m	2.2	0.54	**Laktaši, B&H**
A4	71,000	3742	30	11	6h 16m	2h 30m	1.6	0.53	**Sarajevo, B&H**
A5	76,500	4500	28.8	8	7h 32m	3h 01m	2	0.46	**Novi Banovci, Serbia**

Selection of an electric forklift using the MARCOS method

The initial decision matrix is shown in Table 4, and is obtained based on specifications for each alternative and the evaluation of qualitative criteria such as the ninth criterion.

Table 4. Initial decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
Antiideal	89500	3742	28.80	8.00	6.27	3.32	1.60	0.46	2.00
A1	69900	6500	34.56	10	8.3	3.32	1.8	0.6	7
A2	89500	4700	36.8	13	6.5	2.58	2.5	0.58	5
A3	88600	4300	31.68	12	6.57	2.62	2.2	0.54	9
A4	71000	3742	30	11	6.27	2.5	1.6	0.53	3
A5	76500	4500	28.8	8	7.53	3.02	2	0.46	2
Ideal	69900	6500	36.80	13.00	8.30	2.50	2.50	0.60	9.00

Applying the MARCOS method, the alternative solutions (Table 5) are ranked according to the following results.

Table 5. Results of integrated FUCOM-MARCOS model

Alternatives	Si	Ki-	Ki+	fK-	fK+	fKi	Rank
AAI	0.669	1.000					
A1	0.888	1.328	0.893	0.402	0.598	0.703	1
A2	0.860	1.285	0.864	0.402	0.598	0.680	2
A3	0.844	1.262	0.848	0.402	0.598	0.668	3
A4	0.770	1.151	0.774	0.402	0.598	0.610	4
A5	0.750	1.121	0.754	0.402	0.598	0.593	5
AI	0.995		1.000				

After conducting the FUCOM-MARCOS model procedure, the ranking of potential solutions is as follows: A1>A2>A3>A4>A5.

SENSITIVITY ANALYSIS AND COMPARATIVE ANALYSIS

The most common verification systems for initially obtained results in such models are sensitivity analysis and comparative analysis [8-10]. Primarily, the impact of changing the values of nine criteria was determined. A total of 90 new scenarios, altering the values of each criterion, have been formed (Figure 1).

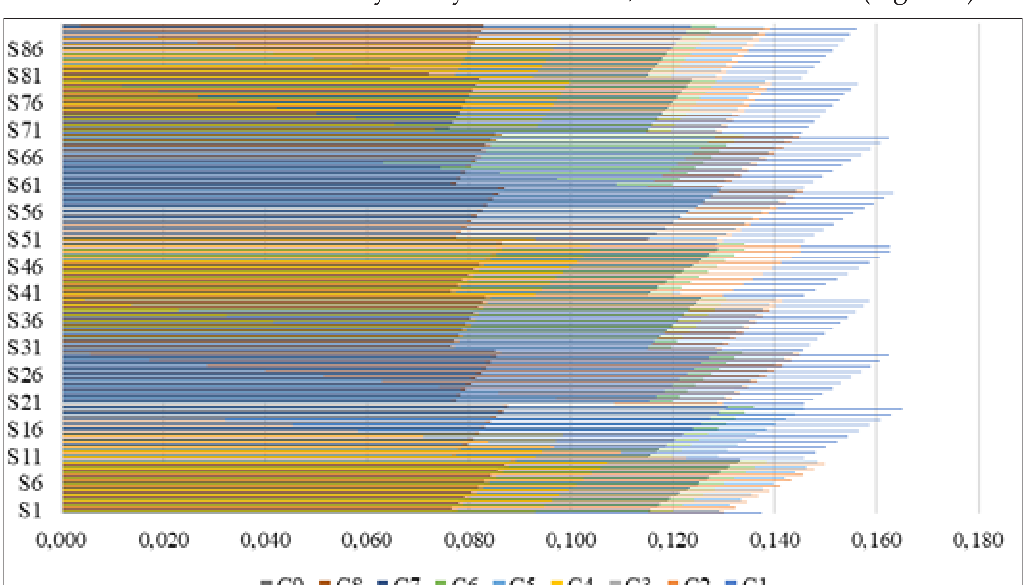

Figure 1. Simulated values of criterion weights in sensitivity analysis

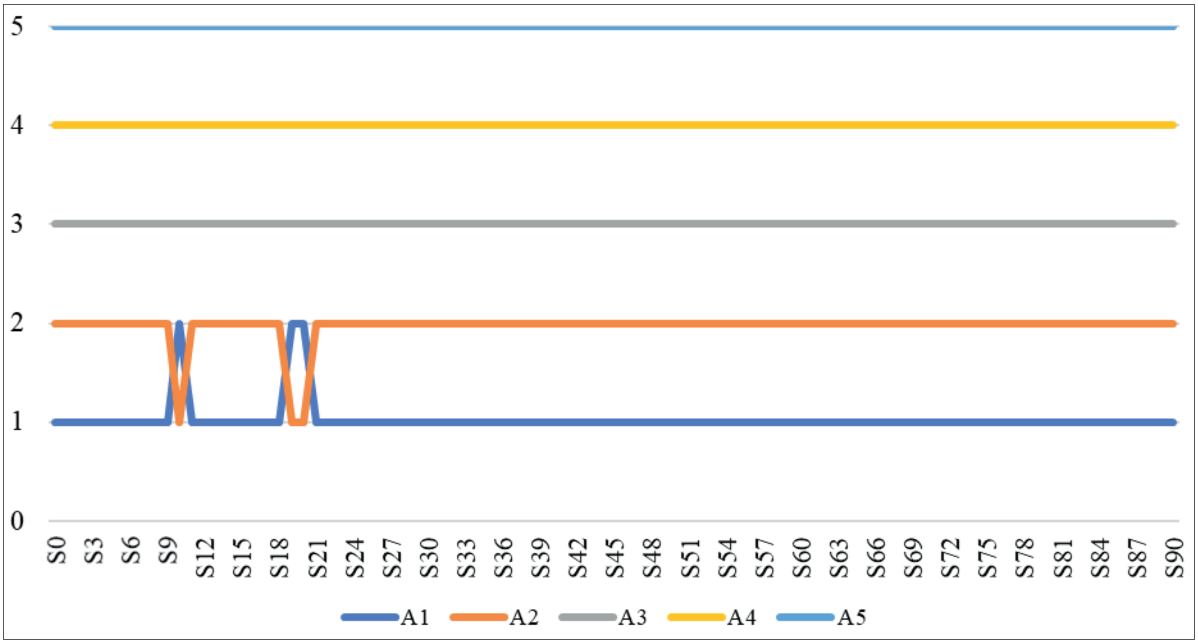

Figure 2. Results of sensitivity analysis

The criterion values are simulated in a way that the values of the criteria are reduced to a negligible value in certain scenarios, while other criteria become more significant. After defining 90 scenarios, an analysis that included 90 new models was conducted, which is given in Figure 2.

The sensitivity analysis results indicate that the first two criteria have a significant impact on the ranking of solution alternatives, because when the values of C1 and C2 are reduced in scenarios (in S10 for the first criterion and S19, S20 for the second criterion), two best alternatives change. This occurs only when the value of the first or second criterion is reduced to a negligible value, i.e. when it tends to zero.

Figure 3 shows the results of the comparative analysis. Six other MCDM methods were applied: SAW [11], WASPAS [12], AROMAN [13], EDAS [14], MABAC [15] and CRADIS [16].

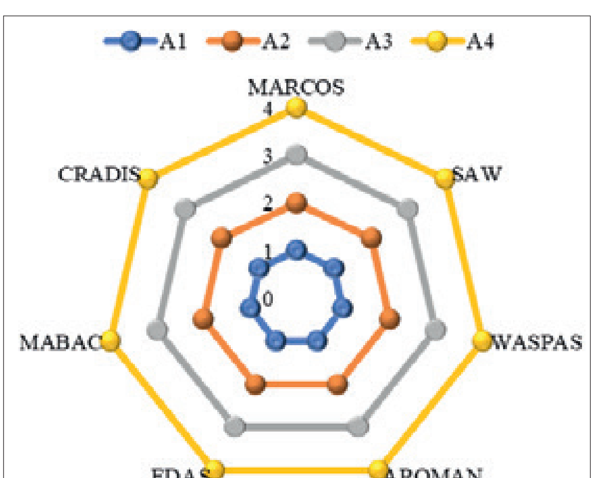

Figure 3. Results of comparative analysis

The results of the comparative analysis show the stability of the initial results as there are no changes in the rankings of alternatives.

CONCLUSION

Operational planning of technological processes at the GTC Doboj should create a sketch of the near future that should anticipate all possible handling activities in a closed warehouse which impacts warehouse operations. The aim is to make a projection of future activities with forklifts and select a forklift that will properly respond to the technological handling processes. The methodology for determining the required forklift at the Goods Transport Center Doboj requires an approach based on the technical characteristics of forklifts, the technical characteristics of the closed warehouse, the work technology in the closed warehouse and contemporary decision-making methods. Through the applied MCDM model, which consists of FUCOM and MARCOS methods, the selection of an electric forklift based on the preferences of nine decision-makers regarding the significance of evaluation parameters, i.e. criteria, was proposed. Future research should include an analysis of the operation of the selected forklift with a focus on its efficiency.

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ORIGINAL SCIENTIFIC PAPER

The influence of the corona virus pandemic on the characteristics of vehicle flow on the e-661 highway

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Abstract: In this work, the characteristics of the traffic flow on the section of the Gradiška - Banja Luka highway, which is part of the European road route E-661, were analyzed in the period from 2019 to 2022. Data on the size of flow requests were taken from the database of the toll station "Jakupovci" on the Gradiška - Banja Luka highway. When defining the size of the flow request, the structure of the traffic flow was also taken into account, in accordance with the categories according to which the toll is collected. The period in which the analysis of flow characteristics was performed also includes the period in which the coronavirus pandemic reigned, when certain travel rules and prohibitions were in force. In accordance with that, the work will specifically analyze the impact of the COVID 19 pandemic on the characteristics of the traffic flow on the Gradiška - Banja Luka highway section. Given that the „Jakupovci" toll station is the busiest toll station on the Gradiška - Banja Luka highway, the results of the analysis can be applied to other sections of highways in the Republic of Srpska.

Keywords: Traffic flow characteristics, vehicle flow, COVID 19 pandemic, Gradiška - Banja Luka highway

INTRODUCTION

Traffic is affected by numerous factors, such as traffic accidents, works, weather conditions, natural disasters, etc. Given that, predicting the flow of traffic is an extremely complex and complex job. The accuracy of predictions depends on the credibility and precision of the data we use in research. When we collect and process data, it is very important to organize them into one common set, so that we can more easily predict the traffic flow based on them.

Determining the characteristics of the traffic flow on the national road network and monitoring trends is an integral part of the road manager's activities in order to manage the development and management of the road network and to determine the real needs for improving the existing network or its individual parts in the dynamics of time.

Changes in the flow request sizes are influenced by various factors, changes in the degree of motorization, land use, i.e. the construction of new attractions and travel generators, weather events...

Until 2021, the world did not face an occurrence similar to the Corona virus pandemic and the way of organizing the way of life that also affected the change in the characteristics of the traffic flow. The subject of this paper is the analysis of the impact of the Corona virus pandemic on the characteristics of vehicle flow on the E-661 Highway. The analysis includes the flow of vehicles at the "Jakupovci" toll station, through which the largest number of vehicles pass during the year. The goal of the analysis is to determine whether the Corona virus pandemic, and to what extent, had an impact on the characteristics of the flow of vehicles on the observed section of the highway.

MATERIAL AND METHODS

Bearing in mind that the goal of the work is to determine and compare the flow of vehicles before and after the Corona pandemic, the first task was to choose the location from which the data will be collected. In this regard, the toll station "Jakupovci" (Figure 1) was selected, which is the busiest station on the E-661 highway (Figure 2).

This station is located north-east of Banja Luka, at the entrance to Highway E-661, going from the direction of Banja Luka towards Gradiška. The station was conceived as one of the stations in the closed toll collection system on the highways of the Republic of Srpska. It has six traffic toll lanes, of which one on the far right in each direction is intended exclusively for electronic tolling, the two middle lanes are exclusively used for manual tolling, while the remaining two are combined, and can be used for both electronic and manual payment. The two central lanes are reversible, and can be used for tolling in both directions if necessary, while the remaining lanes, two in each direction, are intended exclusively for vehicle movement and tolling in one direction.

Figure 1: *"Jakupovci" toll station, direction Banja Luka-Gradiška (True, 2018)*

Figure 2: *Highway E-661 (Freelance artist, 2013)*

The conducted research included the counting of traffic during four years, after the transition to a closed charging system on the entire network of highways in the Republic of Srpska. The research was conducted in the period from the beginning of November 2019 to the end of December 2022. The data were collected from the Public Company " Republic of Srpska Motorways", from the Center where all traffic data on highways managed by the mentioned company are stored. After data collection, a database was created in the "Microsoft Office Excel" program, in which data analysis was performed. General data analysis was performed for each month individually, as well as for each year separately.

RESEARCH RESULTS

Data for the subject research were obtained from the System for management and supervision of toll collection of the Public Company " Republic of Srpska Motorways", made by the "Mihajlo Pupin" Institute.

Table 1: The flow request sizes during 2019

Year			
2019			
Month			
	Input	Output	Total:
January			0
February			0
March			0
April			0
Maj			0
June			0
July			0
August			0
September			0
October			0
November	105827	104484	210311
December			0
In total:	105827	104484	210311

Table 2: The flow request sizes during 2021

Year			
2020			
Month			
	Input	Output	Total:
January	19847	16680	36527
February	59403	61983	121386
March	67295	69997	137292
April	33680	35391	69071
Maj	61097	66572	127669
June	104392	111530	215922
July	102893	113553	216446
August	115228	120610	235838
September	105938	111693	217631
October	111854	118822	230676
November	96824	100758	197582
December	119599	131732	251331
In total:	998050	1059321	2057371

Table 3: The flow request sizes during 2021

Year			
2021			
Month			
	Input	Output	Total:
January	111619	111341	222960
February	119057	124986	244043
March	121906	129672	251578
April	110373	117987	228360
Maj	136113	142276	278389
June	140413	149261	289674
July	158334	179889	338223
August	191143	191427	382570
September	147031	152310	299341
October	149964	160392	310356
November	137120	138483	275603
December	142631	162865	305496
In total:	1665704	1760889	3426593

Table 4: The flow request sizes during 2022

Year			
2022			
Month			
	Input	Output	Total:
January	134179	126940	261119
February	123165	128350	251515
March	128807	137238	266045
April	144783	157261	302044
Maj	158573	161824	320397
June	153637	161762	315399
July	170814	188251	359065
August	201153	194767	395920
September	164377	165995	330372
October	194027	202894	396921
November	164824	161078	325902
December	161115	177160	338275
In total:	1899454	1963520	3862974

The research includes data on the total number of vehicles that pass through the Jakupovci toll station in both directions. On that occasion, November 2019 and all months in 2020, 2021 and 2022 were taken into account. During the research period, a total of 9557249 vehicles passed through this toll station. In November 2019, 210311 vehicles passed through the station, while during the whole of 2020, 2021 and 2022, 2057371, 3426593 and 3862974 passed through the station, respectively. A detailed presentation of the data is given in Tables 1, 2, 3 and 4.

The system categorizes vehicles into 5 categories. Category I consists of motorcycles, while category I, II, III and IV are determined based on the height of the vehicle above the front axle and the number of axles, so that category I consists of vehicles that have a height above the front axle less than or equal to 1.3m and less of 3 axles, category II vehicles that have a height above the front axle less than or equal to 1.3m and 3 or more axles, category III vehicles that have a height above the front axle greater than 1.3m and less than 4 axles and category IV vehicles that above the front axle have a height greater than 1.3m and 4 or more axles.

The counting of vehicles is done automatically when passing through the toll lanes of the Jakupovci station, in which there are counters in the form of electromagnetic loops, as well as "OCR" cameras, so that the possibility of error during counting is reduced to a minimum.

For the year 2019, there was data on the flow only for the month of November, and in order to assume the flows for the other months, as well as for the whole year, it was calculated what share the month of November has in the total annual flow. For this, the flows in November 2021 and 2022 were used, whereby it was obtained that November 2021 participates with 8.04%, while November 2022 with 8.44% in the total annual flow. In the further calculation for the year 2019, the mean value of the received participation in November was used, i.e. 8.24%.

After assuming that November 2019 participates with 8.24% in the total annual flow, it was calculated that in 2019 a total of 2552377 vehicles passed through the Jakupoveci toll station. The flows for the other months of 2019 were calculated according to the average value of the participation of individual months of 2021 and 2022 in the total annual flow. The obtained percentages were multiplied by the total annual flow in 2019 and the obtained results were presented in a table (Table 5).

Table 5: The flow request sizes by month and in total during the relevant four years of research

	2019.	2020.	2021.	2022.
January	169303	36527	222960	261119
February	173982	121386	244043	251515
March	181589	137292	251578	266045
April	184834	69071	228360	302044
Maj	209530	127669	278389	320397
June	212082	215922	289674	315399
July	244589	216446	338223	359065
August	273281	235838	382570	395920
September	220629	217631	299341	330372
October	246716	230676	310356	396921
November	210311	197582	275603	325902
December	225532	251331	305496	338275
In total:	2552377	2057371	3426593	3862974

DISCUSSIONS

The analysis of the obtained results was performed according to the total flow of vehicles (input + output) per month and according to the total annual flow of vehicles.

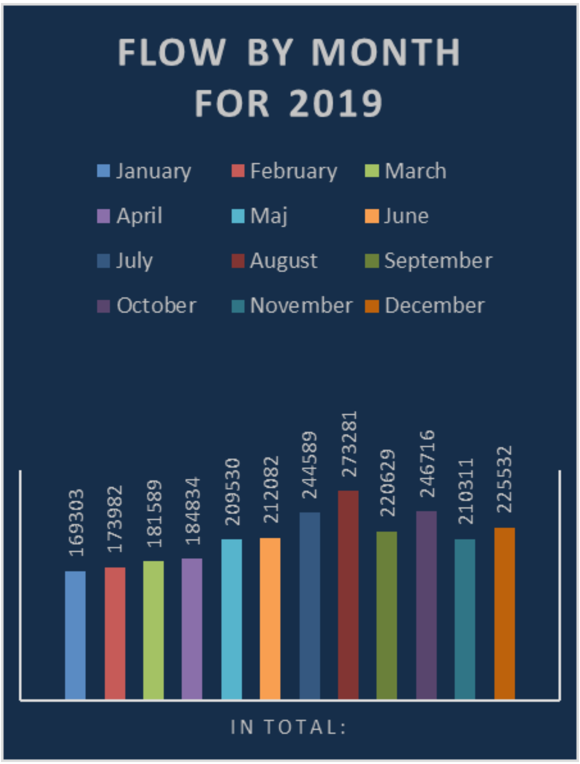

Figure 3: Chart of flow request sizes during 2019

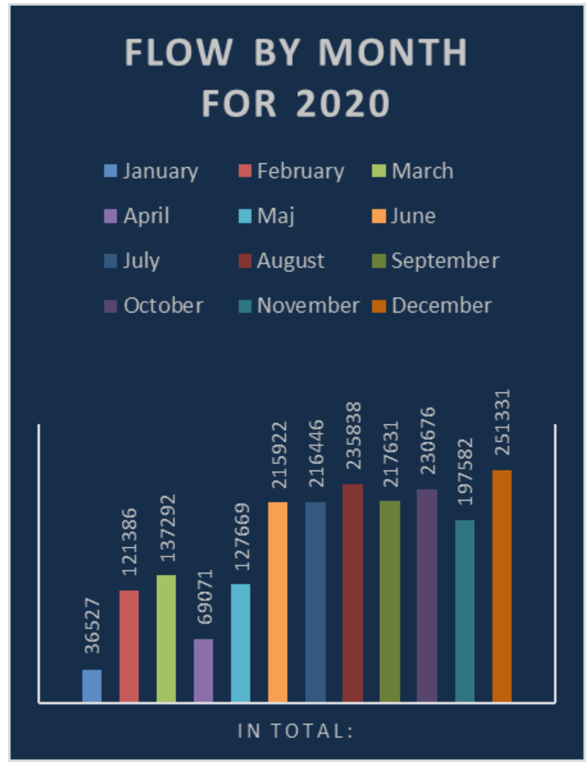

Figure 4: Chart of flow request sizes during 2020

Figure 5: Chart of flow request sizes during 2021

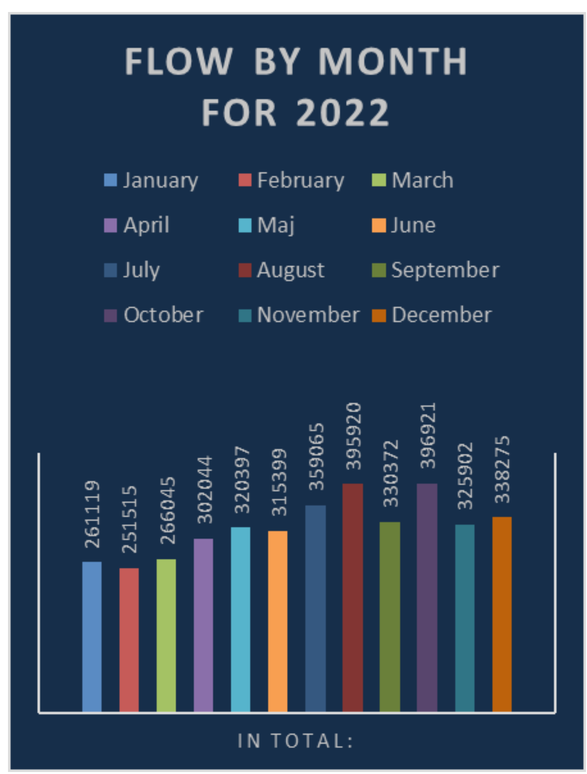

Figure 6: Chart of flow request sizes during 2022

Display of flow request sizes in 2019

Figure 3 shows the assumed flow per month for 2019 in the form of a diagram. The highest flow was recorded during August, which is expected, considering the annual holidays and increased traffic on all roads during that period. The month of January had the lowest flow.

Display of flow request sizes in 2020

The flow by month for 2020 is shown in Figure 4. Unlike 2019, when the highest flow was in August, the highest flow in 2020 was recorded in December. The reason for this is that the Corona virus pandemic reached its peak during April and May of that year, as well as numerous movement restrictions in European and surrounding countries, so it is assumed that a smaller number of people could travel on vacation during the summer.

Display of flow request sizes in 2021

What characterizes the flow by month for the year 2021 is that August is again the month with the highest flow during the year, which we can see in Figure 5. The reason for this is the liberalization of movement after the weakening of the Corona virus pandemic, so that people are provided with a greater opportunity for movement during vacations. The month of January is again the month with the lowest flow, as it was during 2019.

Display of flow request sizes in 2022

When we look at the year 2022, it can be noticed that the flow experienced its maximum during the month of October, which is shown to us in Figure 6.

In addition, we can see that August still retained the status of one of the months with the highest flow during the year, while this year February had the lowest flow.

Growth trends in the flow request sizes during the four years of the study in question

If we look at the total flow of vehicles during the relevant four years of the study, it can be concluded that the corona virus pandemic had a significant impact on the flow of traffic. This can be seen from Table 6, which represents the total flow of vehicles through the toll station "Jakupovci" during the observed four years.

Table 6: The flow request sizes by month and in total during the relevant four years of research

	2019.	2020.	2021.	2022.
January	169303	36527	222960	261119
February	173982	121386	244043	251515
March	181589	137292	251578	266045
April	184834	69071	228360	302044
Maj	209530	127669	278389	320397
June	212082	215922	289674	315399
July	244589	216446	338223	359065
August	273281	235838	382570	395920
September	220629	217631	299341	330372
October	246716	230676	310356	396921
November	210311	197582	275603	325902
December	225532	251331	305496	338275
In total:	2552377	2057371	3426593	3862974

In 2020, the total flow dropped from 2552377 to 2077371 vehicles, and in 2021 and 2022 it reached the value of 3426593 and 3862974 vehicles.

A graphic representation of this is presented in Figure 7, i.e. a diagram of flow request sizes during the relevant four years of research.

From this diagram, it can be concluded that the flow of vehicles in 2022 was 436381 higher than in 2021. When the flow from 2022 is compared with the flow from 2019, it can be seen that its value is higher by 1310597. From all this, it can be seen that the flow has an average annual increase of about 438000 vehicles, so we can conclude that the flow of vehicles during 2021 and 2022 reached the expected value, and that the flow in 2022 maintained the expected growth trend compared to 2021.

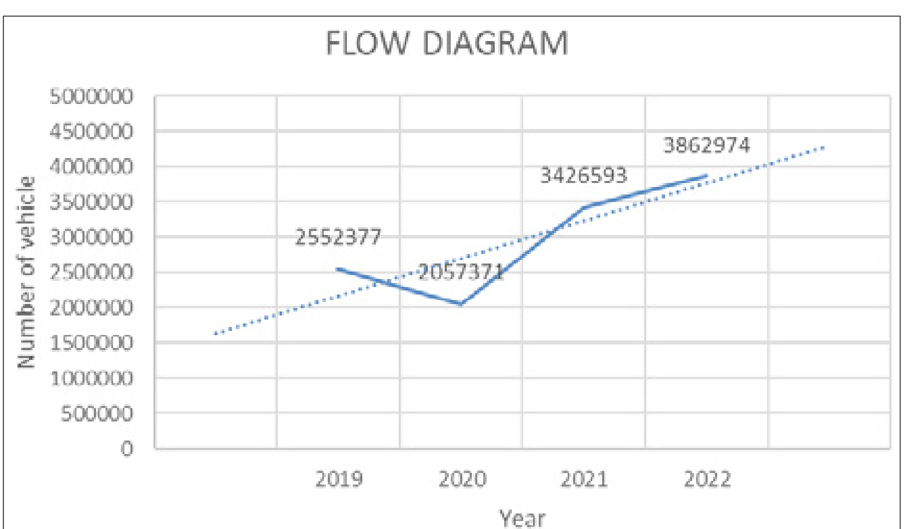

Figure 7: Diagram of flow request sizes during the relevant four years of research

CONCLUSION

As part of this work, an analysis of the flow of vehicles at the "Jakupovci" toll station, which is the busiest toll station on the E-661 highway, was performed. The flows during the last four years (2019, 2020, 2021 and 2022) were analyzed, with special reference to the year 2020, in which the Corona virus pandemic reached its peak.

It was observed that the flow of vehicles during 2020 experienced a significant decrease compared to 2019, which was undoubtedly influenced by the aforementioned pandemic. With the weakening of the pandemic, the flow of vehicles began to increase, so it already reached its expected value in 2021. The flow of vehicles in 2022 maintained the expected growth trend compared to the previous year.

From all this, it can be concluded that the Corona virus pandemic, during its duration, had an extremely significant impact on the characteristics of the flow of vehicles at the "Jakupovci" toll station, but that it did not leave a significant mark on the flow of traffic at this toll station after its completion.

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ORIGINAL SCIENTIFIC PAPER

Use of video surveillance systems for detecting seat belt usage, mobile device usage, or vehicle registration - penalty or prevention

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Abstract: The concept of smart traffic or smart cities involves the use of a large amount of data collected in real-time and processed using available tools. Data is collected from various sources. One common source for traffic control is video or imagery. In many countries, camera systems are installed to monitor traffic, track speed, or oversee intersections. Data is collected and processed in operational centers, allowing for insights into vehicle registration, vehicle speed, and passengers. At the same time, significant risks in traffic arise from the use of mobile phones or smart devices while driving. Furthermore, research indicates that wearing seat belts significantly reduces the risks of traffic accidents. A common occurrence in traffic is that vehicles are unregistered and uninsured. At the same time, the use of video surveillance systems is associated with the protection of privacy and personal data, necessitating the need to find an optimal balance between the right to privacy and the right to a secure environment, including safe participation in public traffic. The aim of this study is to explore the possibility and analyze the use of video surveillance to analyze the use of video surveillance in detecting mobile phone usage and seat belt compliance while driving. The systems for detecting mobile phone usage or seat belt usage during driving can instantly provide information on a prominently displayed screen near the roadside for preventive action. The paper analyzes the use of such systems for prevention purposes, along with an analysis of the potential application of penalties to reduce identified risks in traffic.

Keywords: Artificial Intelligence, Deep Learning, Machine learning, Smart Systems, Violations, Preventive Action

INTRODUCTION

The use of traffic video surveillance systems has significantly increased in recent years with the development of digital and video technologies. In the Republic of Srpska, systems have been installed to monitor traffic, particularly since this possibility has been legally defined for speed measurement.[1] Vehicle speed measurement systems are developed and widely used. As stated, the law in Bosnia and Herzegovina has defined the possibility of speed measurement, and a complete system for deploying radar or video systems that measure speed has been developed. Furthermore, enforcement systems have been developed to enable the identification, processing, and issuance of traffic violation notices, as well as monitoring of fine payments. An integrated system for issuing traffic violation notices and enforcing violations has been implemented, linking with vehicle registration systems and other citizen rights.

However, the development of high-resolution cameras equipped with integrated machine learning systems, along with the advancement of telecommunications systems for data transmission and data processing centers, has enabled the collection of large amounts of data about vehicles in traffic. It is now possible to read and automatically process vehicle registration data, as well as driver behavior data within the vehicle itself. Furthermore, systems for monitoring vehicles' compliance with traffic signals have been established.

The surveillance system for seat belt and mobile phone usage during driving, upon detection of an incident, instantly sends a notification to the display near the roadside for preventive action. The vehicle registration detection system identifies violations and sends a traffic violation notice to the vehicle owner. The paper describes these systems and analyzes their impact on law-

[1] Article 45, Law on Basics of Traffic Safety on the Roads in BiH (Official Gazette of BiH,6/06, 75/06, 44/07, 84/09, 48/10, 18/13, 8/17, 89/17, 9/18, 46/23, 88/23)

ful driver participation in traffic.

The paper presents in the chapter II "Artificial intelligence and machine learning in traffic surveillance systems" the possibilities of using artificial intelligence and machine learning in traffic surveillance systems. Furthermore, in chapter III "Detecting seat belt usage, mobile device usage and ANPR" a specific case in the Republic of Srpska is presented where a traffic surveillance system is used for detecting seat belt usage and mobile phone usage. The legal framework is discussed, particularly focusing on privacy protection aspects. Finally, in chapter IV "Data analisys", statistical indicators collected from internal records of the Ministry of Interior of the Republic of Srpska are presented.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN TRAFFIC SURVEILLANCE SYSTEMS

Artificial Intelligence, AI refers to the branch of science and engineering that produces intelligent machines, especially intelligent computer programs. In the security industry as well as in traffic systems, AI used is to create environmental analysis equipment. Deep learning technology, or improving intelligence by analyzing and learning from large datasets, has brought about a significant change in the field of AI [10]. The utilization of traffic surveillance systems gathers vast amounts of data, including information about the vehicles themselves, vehicle license plates, vehicle behavior in traffic, as well as the behavior of passengers inside the vehicle.

Systems of collecting and storing large amounts of data enable the development of machine learning systems. Machine learning is a subfield of AI that focuses on the development of algorithms and statistical models that enable computers to learn from and make predictions or decisions based on data, without being explicitly programmed to do so.

Subset of machine learning is deep learning. Deep learning, also known as deep neural learning, is a subset of machine learning that focuses on learning data representations using complex models inspired by the human brain, known as deep neural networks. These models are termed "deep" due to their ability to learn to represent data in hierarchical layers of abstraction. Deep learning often requires large amounts of data and computational resources to train complex models. It has become extremely popular due to impressive results in various fields, including image recognition, natural language processing, medical diagnostics, and many others.

In the surveillance industry, primary target objects of deep learning algorithms are people and vehicles. Key applications of deep learning, which are important for traffic surveillance systems, are metadata and ANPR (Automatic Number Plate Recognition) systems. [10]

Metadata is feature attribute information extracted from a target object which can be used for data retrieval. Currently, there are three main kinds of metadata in the traffic surveillance system industry: human face, human body, and vehicle metadata. Facial information includes sex, age, glasses, masks, expressions, beards. Human body information includes tops, pants, clothing color, hair, backpacks, seat belt or mobile device. Vehicle information includes license plate, color, brand, model, etc. [10]

ANPR (Automatic Number Plate Recognition) is a technology that uses optical character recognition on images to read license plates with high recognition accuracy. ANPR applications include toll collection, traffic monitoring and security, speed and journey time measurement, parking and access control. [10]

An important part of deep learning systems is false alarm detection. This is particularly important in traffic surveillance systems to accurately determine passenger behavior in vehicles.

All in all, traffic surveillance systems have enabled the collection of vast amounts of data about vehicles, drivers, and the behavior of drivers or vehicles in traffic. This data, through the use of metadata and ANPR systems, facilitates the identification of unlawful activities aimed at increasing traffic safety.

The following text will present traffic surveillance systems that identify seatbelt and mobile device usage in vehicles, as well as a system to check if the vehicle is lawfully registered. Further analysis will be conducted on the results regarding the prevention and punishment of detected occurrences.

DETECTING SEAT BELT USAGE, MOBILE DEVICE USAGE AND ANPR

By using smart cameras to recognize the use of mobile phones, not wearing a seat belt, and to review the average speed of the vehicle and display information to traffic participants on the LED display, the driver and other traffic participants are immediately warned on non-compliance with traffic rules that can greatly endanger the lives of all traffic participants. It is also possible to introduce certain meters that can indicate the number of minor offences that person committed up to that time for the recognized license plate.

Legal Framework

For public use of traffic surveillance systems, a legal basis is extremely important. In Republic of Srpska, the Ministry of Interior (MoI) is responsible for traffic control and has the authority to record[2] public areas including public transportation and roadways. In addition, the

[2] Law on Police and Internal Affairs (published in Official Gazzete no. 57/16,110/16,58/19, 82/19 and 55/23),video survilence including road traffic safety and traffic control and safety in other areas of traffic, Article 5, point 12).

Ministry of Interior is responsible for maintaining registries of citizens, vehicles, fines and driver's licenses, meaning it possesses data within its jurisdiction[3]. MoI has the capability to collect data from traffic surveillance video footage. Additionally, it possesses data about vehicles, drivers, and penalties.

Personal data protection

In Bosnia and Herzegovina, the Law on Personal Data Protection[4] is applied. This law guarantees privacy. The use of video surveillance systems, especially in the segment related to processing facial images, is strictly regulated and must be prescribed by law.

Overall, the relationship between video surveillance in traffic systems and personal data protection underscores the importance of striking a balance between security needs and privacy rights, ensuring that data is collected and processed lawfully, transparently, and responsibly.

Installation of the system

The installation of intelligent cameras should be carried out above the road at the minimum allowed height, in the middle of the monitored traffic lanes, for greater accuracy. Cameras should have built-in analytics described in the introductory chapter. They should perform license plate recognition, detection of seat belt non-usage, and mobile phone usage.

An industrial computer is mounted on the pole in an appropriate space and serves to display warnings on the screen. A communication link enables data transmission to the MoI server. The camera should have a built-in SD card. In case of a link failure, it stores data in internal memory and sends it later to the server.

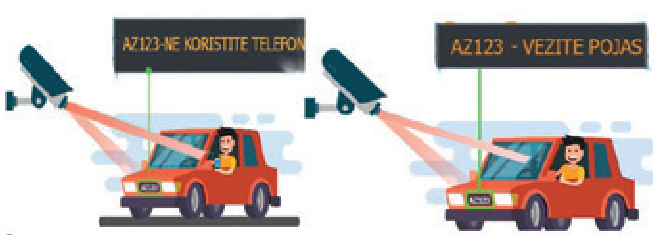


FIGURE 1: Recording of vehicles, detection, and notification[5]

Smart System for Detection and Notification Usage Safety Belt and Mobile Phone (AI-SS4DNUSBMP) improve traffic safety and traffic monitoring, where citizens receive information about the following events during the drive via LED displays:

1. Phone usage detection and warning on usage
2. Seat belt non-use detections and warning on non-use

The following image depicts the installation method of the system.

The camera contains a chip with embedded machine learning elements. Based on the specified functionality, the vehicle fulfilling the given parameters is identified, and an image of such a vehicle, along with certain metadata, is stored on an industrial computer. In real-time, the license plate data is read using ANPR functionality. Subsequently, the license plate data and information about the committed violation are projected onto the LED display.

FIGURE 2: Phone detection, example of picture[6]

In this way, it becomes visible to the driver and serves as a warning. Vehicles on which no violation is observed are not recorded. The following images provide an overview of real data that the machine learning system has detected as committing various types of violations.

[3] Law on Police and Internal Affairs (published in Official Gazzete no. 57/16,110/16,58/19, 82/19 and 55/23), Article 141 a

[4] Law on Protection of Personal Data („Official Gazette of Bosnia and Herzegovina" 49/06, 76/11 and 89/11)

[5] Source: Internal Project Documentation of the Ministry of the Interior of the Republic of Srpska

[6] Source: Real data from the traffic surveillance system of the Ministry of the Interior of the Republic of Srpska

FIGURE 3: Seat belt detection, example[7]

The previous image clearly shows the use of a mobile phone. Nighttime conditions are present, but the violation has been identified.

The installed system has the capability of detecting and reading license plates. As stated, these systems send data in real-time via web services to the database of registered vehicles. If an unregistered vehicle is detected in traffic, then a violation ticket is processed.

DATA ANALISYS

The traffic surveillance system was installed in the Republic of Srpska during the period of 2021 and 2022. During this time, traffic data was collected. Certain cameras detected seatbelt and mobile phone usage, providing information for preventive action. All ANPR cameras detected registered vehicles. Upon detection of driving an unregistered vehicle, violation processing was conducted.

Violations related to seatbelt usage and mobile phone use are identified by police stopping vehicles. There is no explicit legal provision that addresses the use of video surveillance systems for seatbelt and mobile device usage violations while driving.

Further in the text, data is presented alongside a description of the sample.

Detecting seat belt usage

Data on seatbelt usage and smart phone usage was collected from April 2021 to April 2024 on a camera in Banja Luka. The system collected data and informed drivers via a display without imposing penalties. The following table provides monthly data.

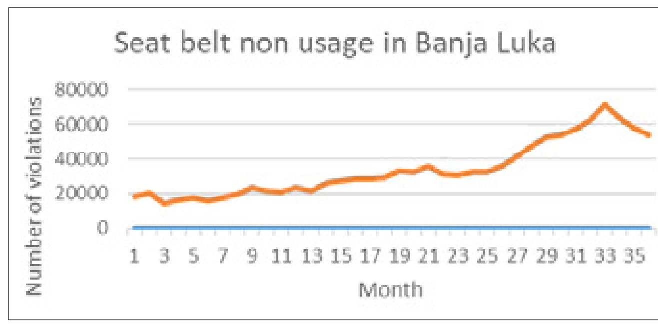


FIGURE 4: Number of detection seat belt usage in Banja Luka in one location per month

TABLE 1: Number of detection Seat Belt and Smart Phone Usage in Banja Luka in one Location per Month[8]

YEAR	MONTH	NUMBER OF SEAT BELT	NUMBER OF PHONE USAGE	YEAR	MONTH	NUMBER OF SEAT BELT	NUMBER OF PHONE USAGE
2021	4	18.651	3.009	2022	10	33.129	3.870
2021	5	20.563	2.880	2022	11	32.535	3.331
2021	6	14.545	2.019	2022	12	36.088	3.592
2021	7	16.341	2.192	2023	1	31.579	2.930
2021	8	17.485	2.338	2023	2	30.336	3.147
2021	9	15.484	2.117	2023	3	32.585	3.955
2021	10	17.799	2.183	2023	4	32.571	4.091
2021	11	19.539	2.054	2023	5	35.598	4.644
2021	12	23.459	2.355	2023	6	41.445	5.184
2022	1	21.746	1.920	2023	7	47.346	5.488
2022	2	20.878	2.137	2023	8	52.794	5.882
2022	3	23.218	2.876	2023	9	54.007	5.951
2022	4	21.664	2.972	2023	10	57.281	6.055
2022	5	25.956	3.473	2023	11	62.455	6.512
2022	6	27.139	3.474	2023	12	71.550	6.902
2022	7	28.860	3.514	2024	1	63.684	5.887
2022	8	28.627	3.738	2024	2	58.023	6.054
2022	9	29.215	3.874	2024	3	53.683	6.396

[7] Source: Real data from the traffic surveillance system of the Ministry of the Interior of the Republic of Srpska

[8] Source: Data from the records of the Ministry of the Interior of the Republic of Srpska

Before the system was put into operation, a campaign was conducted, and drivers were informed about the implementation of such a system through public communication channels.

Before the system was put into operation, a public awareness campaign about the system's functioning was organized. From the diagram, it is evident that there is a lower number of violations in the initial months. This is clearly a result of the campaign. Violation data is only displayed as notifications on the LED display. Violation tickets are not issued, nor is there any punishment. Data shows that the number of violations is increasing from month to month.

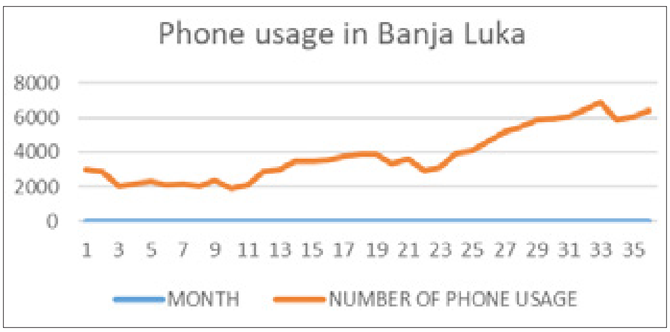


FIGURE 5: Number of detection phone usage in Banja Luka in one location per month

In Doboj, a system with cameras detecting seatbelt and phone usage was installed. The following table provides an overview of 12 months starting from November 2022.

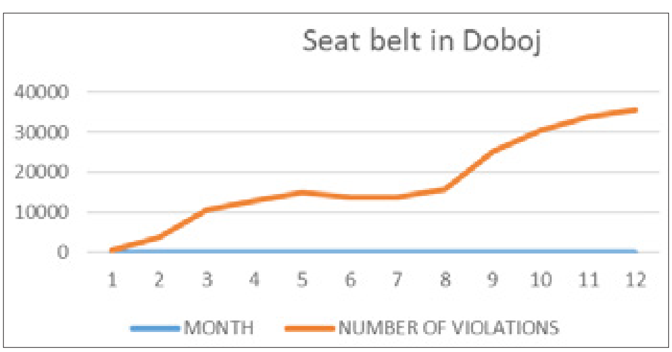


FIGURE 6: Number of detection seat belt usage in Doboj on one location per month

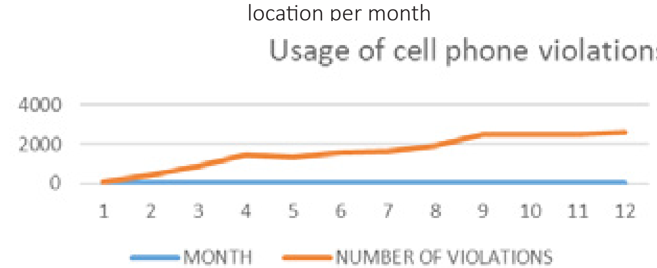
TABLE 2: Number of detection seat belt usage and phone usage in Doboj in one location per month[9]

YEAR	MONTH	NUMBER OF SEAT BELT	NUMBER OF PHONE USAGE
2022	9	458	56
2022	10	3.745	435
2022	11	10.558	862
2022	12	12.955	1.459
2023	1	14.895	1.365
2023	2	13.745	1.580
2023	3	13.632	1.633
2023	4	15.846	1.889
2023	5	25.287	2.513
2023	6	30.300	2.510
2023	7	34.006	2.518
2023	8	35.620	2.597

[9] Source: Data from the records of the Ministry of the Interior of the Republic of Srpska

In Doboj, situation is same like in Banja Luka. In the initial months of using the system, there are fewer violations. Since there are no penalties, the number of violations increases over time.

FIGURE 7: Number of detection phone usage in Doboj in one location per month



Detection of unregistered vehicles

In Republic of Srpska, a system of ANPR cameras has been installed. The purpose of ANPR cameras is described in earlier chapters. Regulations in Bosnia and Herzegovina stipulate that drivers and vehicle owners who enable the participation of unregistered vehicles in traffic will be penalized. [10]

As stated, the MoI of Republic of Srpska is responsible for maintaining records of registered vehicles and records of monetary fines. Accordingly, a system has been developed that detects the vehicle's license plate. The license plate number data is then transmitted via a web service to the vehicle registration system, where a check is performed to determine if the vehicle is registered.

If it is determined that the vehicle is not registered, the violation is processed. The owner of the vehicle is identified, and a violation notice is sent.

In the mentioned case, sanctions are imposed on the offender because there is a legal basis for it.

In cases of seatbelt and mobile phone usage, violations were not issued. Drivers were only informed about the violation through the display. Additionally, information about the operation of such cameras was disseminated through public communication channels. However, in the case of registered vehicles, violation notices were sent to the drivers.

[10] Article 234 and 234a, Law on Basics of Traffic Safety on the Roads in BiH (Official Gazette of BiH,6/06, 75/06, 44/07, 84/09, 48/10, 18/13, 8/17, 89/17, 9/18, 46/23, 88/23)

TABLE 3: Uregistered vehicles in Banja Luka and Bijeljina[11]

Year	Month	Banja Luka	Bijeljina	Year	Month	Banja Luka	Bijeljina
2020	10	3.638	1.163	2022	06	1.165	271
2020	11	1.653	1.077	2022	07	1.130	272
2020	12	1.370	488	2022	08	1.129	365
2021	01	912	214	2022	09	1.302	367
2021	02	795	291	2022	10	1.188	357
2021	03	961	346	2022	11	797	297
2021	04	866	268	2022	12	821	248
2021	05	1.132	372	2023	01	559	198
2021	06	1.515	412	2023	02	665	203
2021	07	1.311	428	2023	03	720	221
2021	08	1.284	452	2023	04	842	232
2021	09	1.264	396	2023	05	1.037	248
2021	10	1.321	431	2023	06	1.093	346
2021	11	1.082	282	2023	07	1.004	401
2021	12	980	296	2023	08	989	292
2022	01	680	214	2023	09	961	377
2022	02	859	221	2023	10	1.020	377
2022	03	1.036	263	2023	11	952	260
2022	04	1.146	205	2023	12	944	263
2022	05	1.248	333				

The previous table provides an overview by months, starting from October 2020 until the end of 2023.

FIGURE 8: Number of detected unregistered vehicles per month in Banja Luka

In the case of Banja Luka, it is evident that the number of unregistered vehicles participating in traffic has been decreasing since the installation of cameras and the commencement of issuing violation notices.

Similar like in the Banja Luka is in the Bijeljina. Number of unregistered vehicles participating in traffic has been decreasing since the installation of cameras and the commencement of issuing violation notices.

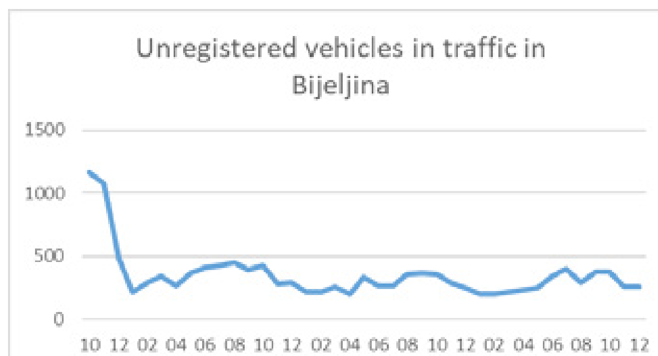


FIGURE 9: Number of detected unregistered vehicles per month in Bijeljina

In Bosnia and Herzegovina, the Law on Personal Data Protection[12] is applied. This law guarantees privacy. The use of video surveillance systems, especially in the segment related to processing facial images, is strictly regulated and must be prescribed by law.

Overall, the relationship between video surveillance in traffic systems and personal data protection underscores the importance of striking a balance between security needs and privacy rights, ensuring that data is collected and processed lawfully, transparently, and responsibly.

[11] Source: Data from the records of the Ministry of the Interior of the Republic of Srpska

12 Law on Protection of Personal Data („Official Gazette of Bosnia and Herzegovina“ 49/06, 76/11 and 89/11)

CONCLUSION

The use of traffic surveillance systems opens up possibilities for implementing mechanisms that can significantly increase traffic safety. However, the video surveillance system must be designed to ensure lawful and transparent use of data, especially from a privacy protection perspective. The study has shown that it is possible to establish mechanisms based on artificial intelligence methods, including machine learning and deep learning, that can detect various types of illegal behavior in traffic. The technical mechanisms for the use of such systems must be prescribed by law. It is also necessary to define the optimal relationship between penalty policy and preventive action in traffic.

The analysis shows that it is possible to detect violations related to mobile phone usage or failure to wear a seatbelt in the car. This information is immediately available to the driver at the moment the violation occurs in the form of a warning, aimed at prevention. However, the number of violations of this type is constantly increasing. This is indicated by the results of the analysis from two cities in Republic of Srpska over different time periods.

At the same time, the ANPR system enables reading the vehicle's license plate. Based on that data, it is determined whether the vehicle is registered. If it is found that the vehicle is not registered, a violation notice is issued. In this case, the number of violations for driving unregistered vehicles is trending downward.

The conclusion is that preventive activities alone are not sufficient in traffic management and that they need to be combined with penalty enforcement. However, even though violations for driving unregistered vehicles have been issued for years, it is evident that there is consistently a certain number of unregistered vehicles in traffic. Therefore, even penalty enforcement alone is not sufficient. It is necessary to seek an optimal balance between preventive measures and penalty enforcement, utilizing modern technologies including traffic surveillance combined with intelligent systems.

Finally, it is crucial that there is a legal basis and clear procedures for the use of surveillance systems, as well as for enforcement.

Further research should continue towards examining the impact of legislative changes and the introduction of penalties on the number of offenses. Additionally, research should continue in the domain of expanding the possibilities of using AI in traffic surveillance systems.

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ORIGINAL SCIENTIFIC PAPER

Measuring and assessment of road traffic air pollution assessment on the motorway e-661 at the locations near the mahovljani and gradiska interchange

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Abstract: The paper gives an overview of different air pollution models in projects and studies in the field of road traffic. A brief description is given for the presented models with key elements for their application. Special emphasis in the paper is given to the application of the current model in the Republic of Srpska. Literature analysis in the field of air pollution modeling has shown that there are a large number of air pollution models. The most comprehensive model in terms of applicability and available data is the COPERT IV model, which is widely used in the European Union.

Keywords: traffic, air pollution, models

INTRODUCTION

The emission of air pollutants can lead to various negative effects. The most relevant and probably best analyzed are the effects on health resulting from the air pollutants. However, other damages are also relevant, such as construction and material damages, loss of crops and biodiversity [7].

Air pollution can be defined as the presence of any substance or several substances in the atmosphere, which are undesirable or harmful to human health, either externally or internally, or the presence of which either directly or indirectly impairs human well-being [18].

Air pollution directly affects the deaths of about seven million people worldwide each year. Data from the World Health Organization show that 9 out of 10 people breathe the air that contains high levels of pollutants. Air pollution worldwide contributes to 7.6% of all deaths in 2016 [22].

In the European Union, air pollution continues to have a significant impact on the health of people, especially in urban areas. Major air pollutants in the European Union are: carbon monoxide (CO), nitrogen oxides (NO_X, NO and NO_2, sulfur dioxide (SO_2), suspended particles ($PM_{2,5}$ and PM_{10}) and ground-level ozone (O_3). Estimates of the impact on human health, which can be attributed to exposure to air pollution, indicate that in 2016, the concentration of $PM_{2.5}$ suspended particles is solely responsible for about 412,000 premature deaths, which resulted from a long-term exposure in Europe [9].

According to measurements performed by the Republic Hydrometeorological Institute in the territory of the Republic of Srpska in 2018, the air quality was classified into the following three categories [19]:

- Category I - clean or slightly polluted air was recorded in the agglomeration of Banja Luka and Trebinje;
- Category II - moderately polluted air was not recorded in any agglomeration;
- Category III - excessively polluted air was recorded in the agglomeration of Doboj (suspended particles PM_{10} and suspended particles $PM_{2.5}$), in agglomeration Prijedor (suspended particles PM_{10} and suspended particles $PM_{2.5}$) and in the agglomeration of Bijeljina (nitrogen dioxide NO_2) (Republic Hydrometeorological Institute, 2019).

In order to examine the key causes of air pollution, researchers around the world apply various methods and models for examining the impact of air pollution resulting from road transport. Some of the key models used in evaluating the impact of air pollution resulting from road traffic shall be presented further in this paper.

MODELLING OF AIR POLLUTION IN EUROPE

Pollutant emissions occur in the planetary boundary layer, which is the lowest part of the troposphere and is in direct contact with the Earth's surface [3]. Atmospheric pollution modeling is used to describe causal links between emissions, meteorological parameters, pollutant concentration, etc. Valuation of emission measurement results is a procedure where the measurement results are compared with the stipulated limit values.

The division of models describing air pollution can be performed in a number of ways. The researchers have classified the models for air pollution modeling into three categories, i.e. dispersion, statistical and physical models [1].

Dispersion models calculate the concentrations of pollutants from the emission inventory and the meteorological variables according to the solutions of various equations, which represent relevant physical processes. The most commonly used model is the Gaussian dispersion model [6]. According to WHO, the Gaussian model is particularly useful for describing the dispersion of pollutants at local level [21]. Gauss's equation is used to calculate the dispersion in conditions where the emission source is downwind, in advection conditions and with the defined direction of the wind. Characteristic picture related to Gaussian model of dispersion:

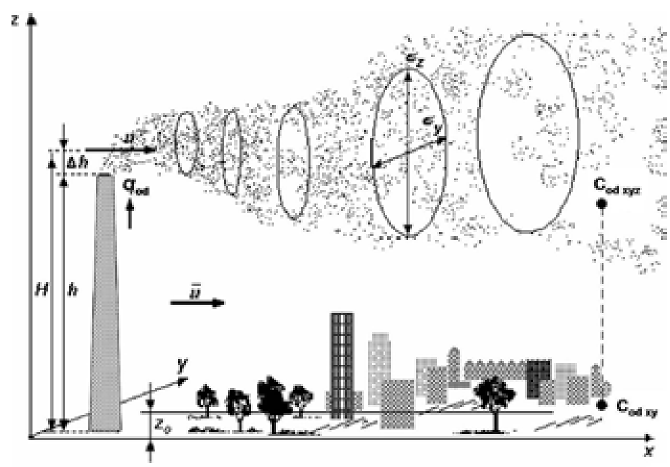

Figure 1. Gaussian spread model [15]

$$C_{od,xyz} = \frac{q_{od}}{2\pi\bar{u}\sigma_y\sigma_z} exp\left[-\frac{y^2}{2\sigma_y^2}\right]\left\{exp\left[-\frac{(Z-H)^2}{2\sigma_z^2}\right] + exp\left[-\frac{(Z+H)^2}{2\sigma_z^2}\right]\right\} \quad (1)$$

$$\sigma_y = Ax^a \qquad A = 0{,}08\left(6m^{-0,3} + 1 - ln\frac{H}{Z_0}\right) \qquad a = 0{,}367(2{,}5 - m) \quad (2)$$

$$\sigma_z = Bx^b \qquad B = 0{,}38m^{1,3}\left(8{,}7 - \ln\frac{H}{Z_0}\right) \qquad b = 1{,}55exp(-2{,}35m) \quad (3)$$

where: C - is concentration of pollutants, Q_1 - is the emission factor per unit of length, u - is average wind speed, θ - is the angle between the street and the direction of the wind x, y, z - are spatial coordinates, H - effective height of the source, p - half of the length from the source line, σ_z and σ_y - vertical and lateral dispersion parameters.

In contrast to deterministic modeling, statistical models calculate concentrations by statistical methods from meteorological and traffic parameters, after the corresponding statistical ratio from the measured concentrations has been empirically obtained. Key statistical modeling methods are regression, multiple regression techniques, time series, and artificial neural networks [1].

Some authors have analyzed and compared three classes of hierarchical models and they came to the conclusion that the model with a complex hierarchical structure is generally preferable to a model with complex space-time covariance[4]. Nevertheless, in the absence of adequate computational resources, one can choose a model that is simple in its structure and with a simple covariance function, as it shows good prediction characteristics at reasonable computational costs.

In a physical model, a physical experiment simulates a real process on a smaller scale in a laboratory, which models important characteristics of the original processes that are being studied [17]. Typical experimental devices, such as air tunnels, are being used, where atmospheric flows are simulated inside a tunnel. This type of physical modeling conducted in an air tunnel, where atmospheric flows are modeled by air as a liquid medium, is also referred to by various researchers as liquid modeling ([17]; [20]).

Contemporary software tools are based on these models. Additionally, air pollution models are the basis for the development of strategic, legal and regulative framework.

Contemporary tools in the analysis of air pollution

The application of software tools for the calculation of pollutant's emissions by road traffic enables the creation of high-quality, comparable and standardized databases, and faster and simpler analysis of a large number of data.

Mostly applied in the USA is the atmospheric dispersion modeling system AERMOD [5]. It is an integrated system that includes several models: model for dispersion in the atmosphere (AERMOD model), terrain processor AERMAP (which is used in the presence of complex terrain for estimating the height of the scale of each receptor), meteorological processor AERMET, (which is used for preparation of inputs for the simulations by dispersion model), AERSURFACE model (used for determining the geophysical parameters being entered into the AERMET). AERMOD can simultaneously simulate multiple sources of different shapes, ground-level or elevated, floating or non-floating, emitting one or multiple pollutants. AERMOD is capable of explaining the inhomogeneous vertical structure of the boundary layer (also by using the vertical profile of meteorological variables). Vertical mixing is limited in the case of stable conditions. This model enables modelling of the spatial spread of pollution.

In California, the software tool CALINE 4 is used [2]. The model uses emissions of polluting substances generated from road traffic, terrain geometry and meteorology to predict pollutant concentrations in the air in the vicinity of roads. Carbon monoxide, nitrogen dioxide and suspended particles can be predicted.

In the European Union, the software tool COPERT IV is used for determining the quantities of emitted gaseous polluting substances generated from road traffic [10]. This software tool uses AADT (Annual Average Daily Traffic), mileage crossed, speed and other data, such as e.g. the temperature of the environment, and it calculates the emission and the consumption of energy for a particular state or region. The software tool COPERT IV estimates the emission of the most significant pollutants (CO, NOX, NO2, SO2, PM2.5, PM10, O3, etc.) This model returns the amounts of emitted substances.

The German-Swiss model (HBEFA) was developed with the aim of determining the emission of all relevant categories of road vehicles in the two countries [12]. The emission factors in this model were not represented as a continuous function (for example of the average speed), but rather as a parametric discrete function that depended on the traffic flow. Traffic flow parameters are described based on manner in which the speed changes. The characteristics of the speed changes enable calculation of a wide range of kinematic parameters, which describe the traffic flow.

In addition to these solutions, numerous models and software tools are used in the world, but for the purposes of this paper, only the most significant ones according to the author's knowledge are specified.

Regulations of significance

The regulations for assessing air pollution generated from road transport includes agreements, conventions, standards, laws, rulebooks, ordinances, technical instructions and similar.

The most significant international agreement related to air pollution, which limits emission of pollutants, is the Kyoto Protocol [11]. It defines legal obligations to reduce greenhouse gas emissions (*greenhouse gas* - GHG).

Particular attention in the European Union, within the White Paper, is dedicated to environmental issues, i.e. GHG emissions [8]. A total of ten goals have been defined, the achievement of which will lead to structural changes in the traffic system of the EU by the year 2050. The defined goals are in line with the targets to reduce GHG emissions by 20% by 2030 and by 70% by 2050, compared to 2008 levels. In addition to this, several regulations and directives have been defined, in particular:

- Regulation (EU) No 1293/2013 of the European Parliament and of the Council of 11 December 2013 on the establishment of a Programme for the Environment and Climate Action (LIFE) and repealing Regulation (EC) No 614/2007;
- The revised Directive on limit values of national emissions (*National Emission Ceilings Directive* 2016/2284/EC), with more strict ceilings for national emissions of the six major pollutants (NO_x, VOC, SO_2, NH_3, $PM_{2.5}$ и CH_4), as well as measures to reduce soot;
- Directive on the quality of ambient air (*Ambient Air Quality Directive* (AAQD) 2008/50/EC);
- Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment;
- Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the strategic assessment of the effects of certain plans and programmes on the environment;
- Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing Infrastructure for Information on Spatial Planning (INSPIRE).

Legislation of the European Union is being transposed in the Republic of Srpska through the AQUIS. The assessment of air quality, i.e. emission of pollutants, is carried out on the basis of the following regulations and standards:

- Law on Environmental Protection ("Official Gazette of the Republic of Srpska", No. 71/12 and 79/15);
- Law on air protection ("Official Gazette of the Republic of Srpska", No. 124/11 and 46/17);
- Regulation on air quality values ("Official Gazette of the Republic of Srpska", No. 124/12);
- Regulation on conditions for air quality monitoring ("Official Gazette of the Republic of Srpska", No. 124/12);
- Regulation on designation of zone and agglomeration ("Official Gazette of the Republic of Srpska", No. 100/12);
- BAS ISO/IEC 17025:2055, IDT: General requirements for the completeness of test and calibration laboratories;
- BAS EN 14625:2005, IDT: Ambient air quality - Standard method for measuring ozone concentration by ultraviolet photometry;
- BAS EN 14211:2005, IDT: Ambient air quality -

Standard method for measuring concentration of nitrogen-dioxide and nitrogen-monoxide by chemiluminescence;

- BAS EN 14212:2005, IDT: Ambient air quality - Standard method for measuring concentration of sulfur-dioxide by ultraviolet fluorescence;
- BAS En 14626:2005, IDT: Ambient air quality - Standard method for measuring concentration of carbon-monoxide by non-dispersive infrared spectroscopy;
- BAS EN 12341:1998, IDT: Analyzing suspended particles, RM_{10} fractions.

Regulation on air quality values ("Official Gazette of the Republic of Srpska", No. 124/12) sets the air quality values for the purpose of air quality management on the territory of the Republic of Srpska. If no limit of tolerance is prescribed for some particular polluting substance, its limit value is taken as a tolerable value. Air quality categories are determined once a year for the previous calendar year.

EXAMPLE OF PRESENTATION OF THE RESULTS OF AIR QUALITY ANALYSIS IN THE REPUBLIC OF SRPSKA

For the purpose of environmental air quality assessment in the exploitation phase of the motorway E-661 (Banja Luka – Gradiška), the impact of air pollution on the environment was assessed at the following two locations on the Motorway E-661: the location "Mahovljanska petlja" [13] and "Gradiščanska petlja" [14].

At the location "Mahovljanska petlja" (Mahovljani Intersection) in Laktaši, air quality sampling was performed from 10:00 hrs on 15 October 2018 until 10:00 hrs on 22 October 2018. The location of the measuring point is next to the motorway – chainage km40+600.00, cross-section PR 80. While at the location "Gradiščanska petlja" (Gradiška Intersection) in the settlement of Čatrnja, Municipality of Gradiška, air quality sampling was performed from 09:00 hrs on 12 June 2018 until 09:00 hrs on 19 June 2018. The measurement was performed in the courtyard of an individual residential building immediately next to the highway, i.e. the measuring point is at the distance of about 75 m from the motorway. There were no physical obstacles between the air quality measurement station and the motorway. The examination was carried out according to the principle of 24-hour sampling for 7 days at the particular measurement site.

Monitoring of the concentration of SO_2 is performed on the SO_2 concentration measurement analyzer, Model T 100 (*UV Fluorescence* SO_2 *Analyzer*) and UV fluorescence method, measuring range 0-20 ppm. Monitoring concentration of NO_x is performed on the analyzer for measuring the concentration of NO_x, NO, NO_2, Model T 200 (*Chemiluminescence NO/NO_2/NO_x Analyzer)*. To determine the level of pollution for NO_x, NO, NO_2 the method of chemiluminescence, measuring range 0-2000 ppb, is used. For monitoring of suspended particles up to 10µg/m^3 the β-ray absorption method is used, the requirements of which are set out in the standard BAS EN 10473. PM_{10} and $PM_{2.5}$ are the fractions of suspended particles (PM - *particulate matter*) that passes through the filter for sampling and measuring PM_{10} and $PM_{2.5}$ fractions, with the efficiency of 50% of the catchment of particles of aerodynamic diameter of 10 µm, or 2.5 µm. The sampling and analysis is carried out by the VAM 1020 device (*Particulate Monitor*). Monitoring of ground ozone emission is carried out by the reference UV photometric method, measuring range 0-10 ppm, Model T 400 (*UV absorption O_3 analyzer*). For carbon monoxide (CO) monitoring, Model T 300 analyzer (MODEL T 300 *Gas Filter Correlation* CO *Analyzer*) and non-dispersive infrared spectrometric method (NDIR) of the measuring range of 0-1000 ppm.

The measuring site "Mahovljanska petlja" is located about 700 meters from the center of Laktaši towards the northwest, on the southwest part of the Lijevče field. It is part of a spacious alluvial terrace plane with an absolute height of 126 meters. The space is in direct contact with the foothill slopes located at the western part of Lijevče field.

Measuring location "Gradiščanska petlja" is located at about 6.5 km from the center of Gradiška towards the West, in the northwestern part of Lijevče field. It is part of a spacious alluvial terrace plane with an absolute height of 126 meters. The space is in direct contact with the foothill slopes located at the western part of Lijevče field.

Figure 2. Location of air quality measurement "Mahovljanska petlja" and "Gradiščanska petlja"

Several different factors are currently influencing the air quality in the measurement catchment area, the following:

- Intensity of traffic on the motorway E-661, intensity of traffic on the main road M-16 (Banja Luka-Gradiška) situated about 500 meters east from the measuring site ("Mahovljanska petlja"), intensity of traffic on the adjacent local roads especially on the local road Gradiška-Gornji Podgradci ("Gradiščanska petlja"), intensity of traffic on the adjacent roads, types of vehicles as well as the fuels used by the vehicles, quality of the roads,
- Furnaces in residential and commercial buildings in Laktaši and in surrounding rural settlements, which again depends on the season, weather conditions and the type of energy-generating product used in residential buildings for heating and other activities,
- Agricultural works on the surrounding agricultural lands,
- Hydro-meteorological circumstances.

When selecting micro-locations for fixed measurements, the following factors are taken into consideration: disturbance sources, safety, access, availability of electricity and telephone lines, visibility of the measuring spot in relation to the surroundings, safety of the public and of the technical staff, possibility of setting the site for taking samples of different polluting substances at the same location and requirements related to spatial planning.

The measuring station "Mahovljanska petlja" is set up within the courtyard of an individual residential building. The courtyard borders the motorway E-661 on the west side. In the process of expropriation, prior to the construction of the subject motorway, the house was purchased from the previous owners, and it is now used for the purposes of the PE "Autoputevi Republike Srpske", i.e. it is being rented to a family of three. In the vicinity of the measuring site, there is another individual residential building, located towards the center of Laktaši.

While the measuring station "Gradiščanska petlja" is set up within the courtyard of an individual residential building. The courtyard borders the motorway E-661 on the west side. In the vicinity of the measuring site, there is also a small steel-foundry, and several individual residential buildings that are situated more than 300 m from the measuring site. The site is extremely rural, with cultivated agricultural areas, livestock accommodation facilities - stables, and woodlots.

During measuring, sampling was carried out according to Article 9 of the Regulation on conditions for air quality monitoring ("Official Gazette of the Republic of Srpska", No. 124/12), i.e:

- suction pipe for taking air samples must be in the open so as to allow free air flow (in an arc of at least 2700) and without obstructions that could affect the air flow (most often this is the distance of several meters from buildings, balconies, trees and other objects or at least 0.5 m from the nearest building, in the case that the measuring site for sampling represents quality of the air in a building's surroundings),
- pipe height: 1.5-4m, 8m if the measuring site is representative for a large area,
- the suction pipe for sampling must not be mounted in the vicinity of an emission source,
- for the purpose of monitoring the effect of roads: no more than 25 m from the edge of an intersection, i.e. 10 m from the curb.

When selecting micro-locations for fixed measurements, the following factors are taken into consideration: disturbance sources, safety, access, availability of electricity and telephone lines, visibility of the measuring spot in relation to the surroundings, safety of the public and of the technical staff, possibility of setting the site for taking samples of different polluting substances at the same location and requirements related to spatial planning.

Air pollution calculations for characteristic road sections were carried out on the basis of a developed computer program, the basis of which is based on the settings of the German model defined in the guidelines for the calculation of air pollution on roads [16]. Calculations were performed on the basis of emission factors, i.e. the total amount of pollutant substances being emitted from the vehicles of a particular class, age, average fuel consumption and average speed of movement, taking into consideration the road section crossed (in km) and the AADT. The parameters of the components of the air pollutants in the form of the mean annual values and the values of the 95th percentile are determined on the basis of the deterministic law in the exponential form:

$$K_i(s) = K_{i^*} \times g(s) \times f_{vi} \times f_u \quad \left[\frac{mg}{m^3}\right] \tag{4}$$

where: K_{i^*} - is the reference concentration of the individual component *(i)* at the ground level at the edge of the carriageway, *g(s)* - is the function of dispersion of harmful substances, f_{vi} - is the function that takes into account specific traffic data, f_u - is the function by means of which the wind speed is taken into account.

The comparison of the average daily value of concentrations in the environment to the limit values taken from the Regulation on air quality values was carried out after collecting and processing of data from the field.

In the Table 1. and Table 2, basic statistical indicators are given: arithmetic mean, median, 98th percentile, measurement uncertainty, minimum value, maximum value, detection limit and quantification limit for the values measured at the location "Mahovljanska petlja" and "Gardiščanska petlja".

Table 1. Basic statistical indicators at the location "Mahovljanska petlja" (Mahovljani Intersection)

Pollutants	Arithmetic mean [µg/m³]	Median	98. precentil [µg/m³]	Measurement uncertainty	Minimal value [µg/m³]	Maximal value [µg/m³]	Detection limit [µg/m³]	Limit of quantification
SO_2	20.20	20.36	33.10	0.03	6.83	40.38	0.1	1
NO_2	25.80	25.72	38.06	0.03	11.08	39.26	0.1	1
ULP	41.82	36.61	83.24	0.03	18.20	106.55	10	100
O_3	30.24	28.44	73.43	0.03	4.06	79.26	1	4
CO	813.42	676.33	1808.95	0.03	256.52	2599.36	10	2
NO	31.07	25.07	79.41	0.03	10.08	192.92	0.1	1

Table 2. Basic statistical indicators at the location "Gradiščanska petlja" (Gradiška Intersection)

Pollutants	Arithmetic mean [µg/m³]	Median	98. precentil [µg/m³]	Measurement uncertainty	Minimal value [µg/m³]	Maximal value [µg/m³]	Detection limit [µg/m³]	Limit of quantification
SO_2	11.47	10.20	22.66	0.03	8.02	30.58	0.1	1
NO_2	70.48	68.29	86.14	0.03	61.63	93.74	0.1	1
ULP	25.84	20.10	100.71	0.03	5.49	117.80	10	100
O_3	714.40	678.60	119.99	0.03	26.34	125.22	1	4
CO	267.75	250.30	445.98	0.03	133.02	569.92	2	10
NO	134.60	12.20	36.66	0.03	6.71	54.60	0.1	1

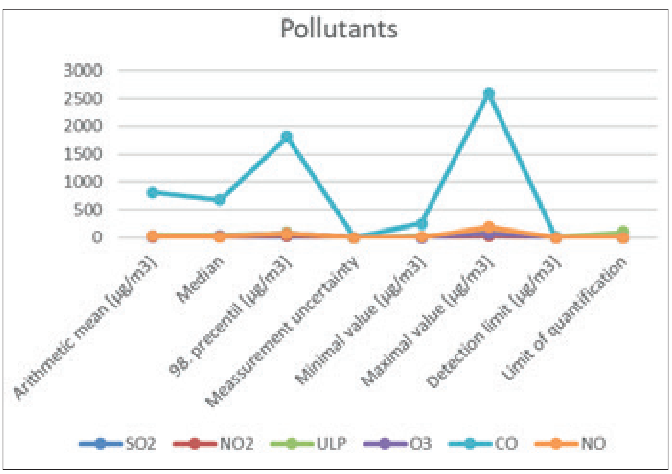

Figure 3. Basic statistical indicators at the location "Mahovljanska petlja" (Mahovljani Intersection)

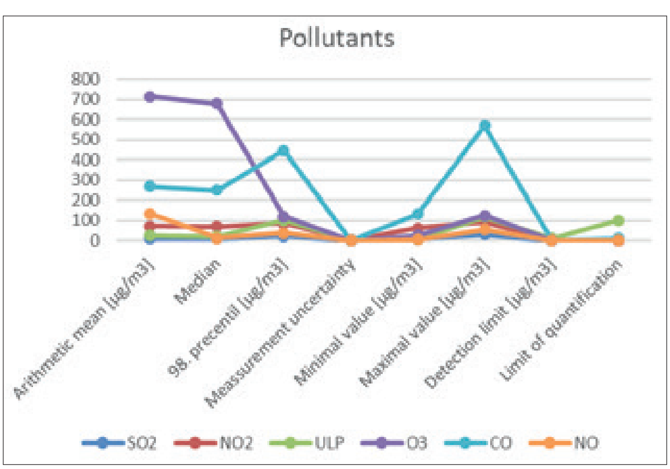

Figure 4. Basic statistical indicators at the location "Gradiščanska petlja" (Gradiška Intersection)

Based on the measurements carried out at the locations "Mahovljanska petlja" and "Gardiščanska petlja", it is notable that the average daily values of concentrations of SO_2, NO_2, ULP and CO in the environment, were below the air limit value and below the tolerable air value for protection of human health (sampling period 1 day).

Also, based on the measurements, it was determined that the average daily values of the concentration of O_3 in the environment was below the target air value for protection of human health (sampling period 8 hours).

The limit values of concentrations of NO in the air in the environment are not prescribed by the Regulation on air quality values.

CONCLUSION

Based on the models presented, it can be clearly concluded that there are different practices in the way of treating air pollution originating from road traffic in projects, studies and practices in the field of traffic.

On the analyzed example of the assessment of the environmental air quality in the exploitation phase of the motorway E-661 (Banja Luka – Gradiška) at two locations ("Mahovljanska petlja" and "Gardiščanska petlja"), 6 of the most frequent and most significant air pollutants in the Republic of Srpska were observed (SO_2, NO_2, ULP, CO, O_3 and NO). On this occasion, the following was established:

- Average daily values of sulphur-dioxide concentrations in the environment are below the limit value of air pollution and below the air pollution tolerance value for the protection of human health;

- Average daily values of nitrogen-dioxide concentrations in the environment are below the limit value of air pollution and below the air pollution tolerance value for the protection of human health;
- Average daily values of total floating/suspended particle concentrations in the environment are below the limit value of air pollution and below the air pollution tolerance value for the protection of human health;
- Average daily values of carbon-monoxide concentrations in the environment are below the limit value of air pollution and below the air pollution tolerance value for the protection of human health;
- Average daily values of ozone concentrations in the environment are below the target value of air pollution for the protection of human health;
- Average daily values of concentrations and maximum one-hour concentrations of nitrogen-monoxide have been measured, but this was not sufficient to draw conclusions about pollution at the locations where the measurement was carried out;
- Limit values of nitrogen-monoxide concentrations in the air in the environment are not prescribed by the Regulation on air quality values, and therefore had not been further analyzed, although this is necessary for the assessment of air quality, i.e. pollution assessment.

The methodology being applied in the Republic of Srpska, which is based on the German model, has to a large extent become obsolete. The disadvantages of this methodology are reflected in the fact that it relies only on the AADT and the road section traveled, while it does not take into consideration the effect of the very structure of a particular country's vehicle fleet and the extent of its use (average trip length). Therefore, there is a large space for improvement and for the application of newer tools.

Significant scope also exists in the improvement of the existing legislation, as is the practice in the surrounding countries, especially in the European Union. This primarily refers to amending current standards and regulations, in order to keep the pace with contemporary technological and technical solutions, which are used for treating air pollution in projects and studies in the field of traffic.

Bearing in mind that the COPERT IV model is recognized in the European Union, we are of the opinion that the introduction of this European model for evaluating the effect of air pollution when developing studies, would significantly contribute to the improvement of the existing practice in the Republic of Srpska.

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PROFESSIONAL PAPER

Classification of vehicle routing problem

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Abstract: The vehicle routing problem is a general name for a whole set of problems in which a group of vehicles located in a depot needs to visit all customers with the condition that only one vehicle visits each customer and that all vehicles return to the depot. Vehicle routing problems are a generalization of the traveling salesman problem. The purpose of present survey in the field of vehicle routing problem (VRP) is to classify different well known variants of VRP according to the type of objects with previously defined system performance was applied . These variants include a whole class of problems where a set of routes for a car fleet located in one or more depots should be determined for some geographically distant nodes or customers, at that, the purpose of routing is the optimization of the series of customers requests (number of vehicles, distance traveled, time spent in vehicles or user waiting time).

Keywords: Vehicle routing problems (VRP), vehicle routing, optimization

INTRODUCTION

Road transport is the most used form of transport in the world. Since it is the most flexible form of transport, today, in the era of globalization and the emergence of internet commerce, its importance is greater than ever before. Road traffic, due to its characteristics and due to the fact that the road infrastructure has the best geographical coverage, enables exactly that.

On the other hand, road transport is, after air transport, the second most expensive form of transport and therefore for suppliers, especially for those who have a large number of daily deliveries with a fleet, the process of optimizing transport routes is extremely important, in order to reduce their costs, but at the same time maintained the quality and speed of service to its customers.

Vehicle routing problem (VRP) is standard name that refers to combinatorial optimisation problems where a set of customers are to be serviced by available vehicles, the solution of which aims to reduce the total costs of transportation and storage. Some of the most common parameters that are optimized are:

- vehicle number,
- the distance traveled by the vehicle,
- vehicle time spent,
- customer waiting time.

Fewer vehicles reduce overall costs. Vehicles depreciate whether they are used or not, so if possible, it is better to do the same job with fewer vehicles. A smaller distance traveled reduces vehicle depreciation costs, fuel costs and the total number of vehicles required for transportation. Less time spent means less expenses on driver's wages, etc.

The term 'vehicle routing' was coined by Golden et al. [1]. Actually, the solution to the classical VRP consists in the construction of a Hamiltonian cycle for a connected weighted graph whose vertices are the customers, and the edges show the cost (time and distance) of the route. In the general case, the task is to determine the number and locations of service facilities in such a way as to minimize the sum of the operating costs of locations and routing costs.

In fact, routing problems are located at the intersection of two well-studied problems:

Travelling Salesman Problem (TSP) - if the carrying capacity C of each vehicle is infinite (or rather, sufficient C=i ∈di), then VRP falls into the category of the Multiple Travelling Salesman Problem;

Bin Packing Problem (BPP) - the solution to this problem resembles the solution of VRP, provided that all the boundary costs are assumed to be zero (thus, the effectiveness of all feasible solutions will be identical).

Routing issues are key issues in the fields of transportation, handling and logistics [2]. In many areas of the market delivery of goods adds a certain sum to its value, and this sum is comparable to the cost of the product itself. Nevertheless, the use of computer optimization techniques of delivery is often expressed in saving about 5-20% of its total value.

MOTIVATION AND SURVEY METHODOLOGY

One of the basic steps in any theory is the description and classification of the research subject according to the chosen criteria. In this paper, the classification of the location model according to the type of objects with previously defined system performance was applied. Specifically, it is a locational routing problem that allows us to make three important decisions: where to locate the plant, how to allocate consumers, and how to route vehicles.

VRP is one among the most widely studied topics in the field of operations research. The Vehicle Routing Problem is a general name for a whole set of problems in which it is necessary for a group of vehicles located in a depot to visit all customers with the condition that only one vehicle visits each customers and that all vehicles return to the depot.

Most works on VRP is available in the form of journal articles, conference proceedings, thesis, technical reports/books etc. Inspite of such a large amount of literature, not much effort seems to have been made on reviewing VRP. Gendreau and Potvin [3] discussed stochastic VRP and solution methodologies. Laporte and Osman [4] is the most cited contribution in the field of review of VRP. Review of VRP provided by Eksioglu et al. [5] revealed more than a thousand articles published on VRP till that date. However, most of the recent surveys/reviews of the available literature mainly focus on the specific variants of VRP and/or specific solution techniques. Pillac et al. [6] and Laporte [7] presented surveys on CVRP. Vidal et al. [8] focus on VRPTW and so on.

The purpose of present survey is to classify different well known variants of VRP. Keeping in view the exhaustive review of Eksioglu et al. [5], here, we have tried to review the works available on VRP and its variants from 2009 onwards[14] [15] [16].

In real problems there are numerous constraints, which actually define numerous variations of this problem, which are known to us under different names of VRP. In this paper, the researchers systematized and presented the classification of all relevant vehicle routing problems according to the used (adopted) optimization criteria (number of vehicles, distance traveled, time spent in vehicles or user waiting time).

VEHICLE ROUTING PROBLEM (VRP)

The vehicle routing problem is a general name for a whole set of problems in which a group of vehicles located in a depot needs to visit all customers with the condition that only one vehicle visits each customer and that all vehicles return to the depot. In doing so, the goal is to determine the routes along which the total costs will be minimal. Costs are primarily affected by the number of engaged vehicles, so minimization of the number of vehicles is the primary goal, while minimization of the total distance traveled or time spent is usually a secondary goal of optimization.

In case we have only one vehicle and if there are no additional restrictions, then VRP turns into the oldest and one of the most studied routing problems, the well-known Traveling Salesman Problem, when it is necessary to visit all points of the graph with a single vehicle at minimum cost (distance, time) (Figure 1).

This problem boils down to visiting the nodes by the shortest possible path. Let the nodes and their mutual distances be given. The goal of solving the traveling salesman problem is to visit all nodes starting from the first to the last and back, so that all cities except the starting one are visited exactly once and the total distance traveled is minimal. Solving every vehicle routing problem also requires solving the Traveling Salesman Problem as its subproblem.

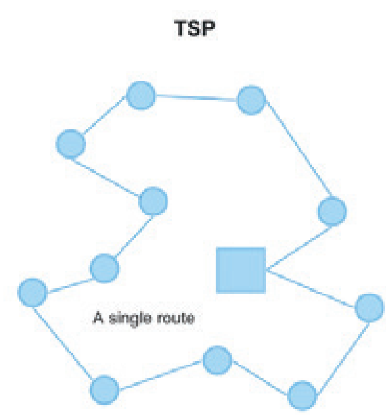

Figure 1. Illustration of the traveling salesman problem (TSP)

Vehicle routing problems are a generalization of the traveling salesman problem. If the limitation of the ca-

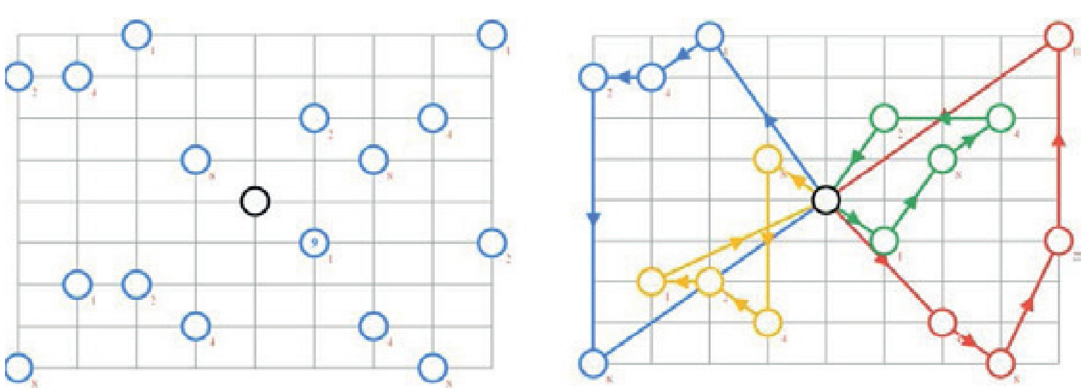

Figure 2. A typical input and one of the possible output for VRP

pacity, that is, the amount of goods he can carry, is added to the traveling salesman, it is clear that in some cases one traveling salesman is not enough to solve the problem. A similar problem arises if the commercial traveler has to arrive at each node in a predetermined time interval. Additional restrictions introduced in TSP may require the parallel engagement of several salesmen (vehicles), multiple depots (warehouses), interaction between salesmen (transshipment of goods from vehicle to vehicle) and the like (Figure 2).

Therefore, the TSP problem has as its primary task the determination of the route, and the VRP problem simultaneously contains the assignment problem (assigning an individual customer to a specific vehicle/route and the problem of determining the route of each individual vehicle).

VRP can be modelled as a directed weighted graph $G(V, E)$ where $V = \{v_0, v1, \ldots, vn\}$be the set of nodes i.e. customers to be visited from the central depot v_0. Also $E = [\{vi, vj\}, (i, j) = 0, 1, 2, \ldots, n, i \neq j)]$ is the set of arcs interlinking two locations i, j. Furthermore, a set of vehicle having homogeneous capacity is available to serve all the customers.

Mathematically, VRP can be represented as:

$$Min\ F = \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{K=1}^{V} c_{ij}\, x_{ij}^{v} \quad (1)$$

Subject to:

$$\sum_{v=1}^{V} \sum_{j=1}^{N} x_{ij}^{v} \leq V \text{ for } i = 0 \quad (2)$$

$$\sum_{v=1}^{V} x_{ij}^{v} = \sum_{j=1}^{N} x_{ji}^{v} \leq 1 \text{ for } i = 0 \text{ and } v \in \{1, \ldots, V\} \quad (3)$$

$$\sum_{v=1}^{V} \sum_{j=0}^{N} x_{ij}^{v} = 1 \text{ for } i \in \{1, \ldots, N\} \quad (4)$$

$$\sum_{v=1}^{V} \sum_{i=0}^{N} x_{ij}^{v} = 1 \text{ for } j \in \{1, \ldots, N\} \quad (5)$$

$$\sum_{i=0}^{N} c_i \sum_{j=0}^{N} x_{ij}^{v} \leq q_v \text{ for } v \in \{1, \ldots, V\} \quad (6)$$

$x_{ij} = 1$ if customer j is served after serving customer i and 0 otherwise ($i \neq j$; $i,j = 0, 1, \ldots, N$).

Here:
V is total fleet size
N number of locations/customers to be visited
c_i customer i ($i = 1, 2, \ldots, N$)
c_0 central depot
d_{ij} travelling distance between customer i and customer j
q_i total servings for customer i
q_v upper limit for capacity of vehicle.

Here the objective function given by (1) is to be optimised satisfying constraints (2) to (6).

Objective function (1) corresponds to minimisation of total travelled distance. The first constraint (2) ensures that all of the tour must be completed with at most V vehicles. Beginning and completion of tour at central depot is ensured by (3). Constraints (4) and (5) restrict the partial servings i.e. every location must be visited by exactly one vehicle. Constraint (6) ensures that the net demand on every route must be within vehicle's capacity.

In practice, the basic VRP can be associated with constraints, for instance, maximum allowed capacity of the vehicle, length of route, arrival/departure time at each location and service time, collection or delivery of goods.

Usually, when solving real optimization problems, a number of constraints arise, from which the most important variants arose:

- each vehicle has a limited capacity and load capacity (Capacitated VRP - CVRP);
- each customer must be serviced at a certain time (VRP with Time Windows - VRPTW);
- some car should pick up the goods from the customer after all clients are served (VRP with Backhauls - VRPB);
- the customer can return some of the goods at the depot (VRP with Pick-Ups and Deliveries -VRPPD);
- delivery can be made within a few days (Periodic VRP - PVRP);
- any member of the task can have random behavior (Stochastic VRP - SVRP);
- the customer can be served with a variety of vehicles (Split Delivery VRP - SDVRP);
- the company uses several transport vehicles from the depot to service customers (Multiple Depot VRP - MDVRP).

A schematic representation of the approach to the classification of vehicle routing problems is shown in the Figure 3.

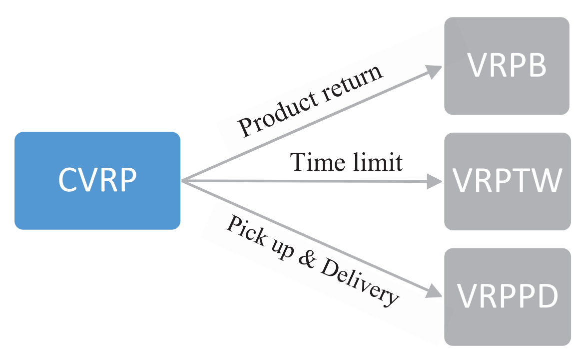

Figure 3. Scheme classification of VRP

CAPACITATED VRP (CVRP)

Capacitated Vehicle Routing Problem (CVRP) is a basic type of vehicle routing problem. In the CVRP, all the customers correspond to deliveries and the demands are deterministic, known in advance, and may not be split [17]. The vehicles are identical and based at a single central depot. Only the capacity restrictions for the vehicles are imposed. The objective is to minimize the total cost (length or travel time) to serve all the customers. Solving CVRP is the determination of routes (each route is connected to only one vehicle) where the total cost of the route should be minimal. The total cost is obtained as the sum of the costs of the arcs belonging to the route. The solution should satisfy these conditions:

- each route should start and end at the depot;
- each client vertex visited exactly once;
- the sum of the demands by customers who are served in one route must not exceed the capacity of the vehicle.

VRP WITH TIME WINDOWS (VRPTW)

The VRP with Time Windows is the extension of the CVRP in which capacity constraints are imposed and each customer is associated with a time interval called a time window. In addition to these times, the time when the vehicles leave the depot, the travel time that the vehicles spends on each of the arches and an additional service time for each customer is also specified [18].

The solution to the VRPTW problem consists in finding routes with minimum cost and satisfying the following conditions:

- each route should start and end at the depot;
- each client vertex visited exactly once;
- the sum of the demands by customers who are served in one route must not exceed the capacity of the vehicle;
- for each customer, the service starts within the time window and the vehicle stops for time instants.

VRP WITH BACKHAULS (VRPB)

The VRP with Backhauls is the extension of the CVRP in which the customer set is partitioned into two subsets. The first subset L contains n Linehaul customers each requiring a given quantity of product to be delivered. The second subset B contains m Backhaul customers, where a given quantity of inbound product must be picked up. In the VRPB problem, there is a restriction priority where all customers in set L must be served before customers in set B. When the cost matrix is asymmetric, the problem is called Asymmetric VRP with Backhauls (AVRPB).

The solution to the VRPB and AVRPB problem consists in finding routes with minimum cost and satisfying the following conditions:

- each route should start and end at the depot;
- each client vertex visited exactly once;
- the total demands of the linehaul and backhaul customers visited by a route do not exceed, separately, the vehicle capacity;
- in each route all the linehaul customers precede the backhaul customers, if any.

VRP WITH PICK-UP AND DELIVERY (VRPPD)

The pickup and delivery problem (VRPDP) deals with delivery as well as collection of items from the customers, aiming to minimise the total travelled distance. Each location is associated with the items either to be recollected or delivered or both. There is also a precedence associated with each of the location to be visited. Moreover, the pairing constraints bound the set of routes so that one vehicle has to do both the pickup and the delivery of the load of one transportation request [19].

The solution should satisfy these conditions:

- each route should start and end at the depot;
- each client vertex visited exactly once;
- the current load of the vehicle along the route must be nonnegative and may never exceed the vehicle capacity;
- for each customer *i*, the customer O_i, when different from the depot, must be served in the same route and before customer *i*;
- for each customer *i*, the customer D_i, when different from the depot, must be served in the same route and after customer *i*.

The case of VRPPD in which time windows are present has been studied in the literature and is called the VRP with Pickup and Deliveries and Time Windows (VRPPDTW).

OTHER VARIANTS VRP

Many other variants of VRP were considered, which represent a combination of some of the previously mentioned variants. These include multi-depot VRP, stohastic VRP, periodic VRP and split delivery VRP [20] [21].

Periodic VRP (PVRP)

With classic VRP, the planning period is usually one day. In the case of periodic VRP, classic VRP is used by extending the planning period to several days [9].

The goal is to minimize the vehicle fleet and the total travel time required to serve all customers. The restrictions are the same as for the classic VRP with the additional conditions that the vehicle cannot be returned to the depot on the same day it leaves, and that during a multi-day period, each customer must be visited at least once. Each customer's needs must be met in one visit to one vehicle. Periodic VRP can be viewed as the problem of generating a group of routes for each day such that the involved constraints are satisfied.

Stochastic VRP (SVRP)

In this version no exact information about customer's actual demands is available before starting the tour. Moreover, the travels times are also stochastic due to varying traffic, accidents etc. This is in a way stochastic VRP where routes need to be planned based on the assumed probability distribution of the demand of the customer. In such problems, a strategy needs to be specified as to what would happen when a vehicle fails to follow its committed route due to shortage of goods to be delivered.

The constraints for the task are connected with the fact that when some data are random, it is no longer possible to require that all constraints will be satisfied for all realizations of the random variables. So the decision maker may either require the satisfaction of some constraints with a given probability, or the incorporation into the model of corrective actions when a constraint is violated.

Some articles dealing with this variant are Marinakis et al. [10] and Juan et al. [11].

Split Delivery VRP (SDVRP)

Classic VRP expands, allowing one customer to be serviced with different types of vehicles, if it reduces overall costs. This case is typical of a situation where the size of the customer's order is equal to the capacity of the vehicle. As a rule, the optimal solution for the routing problem with different types of transport [12] is more difficult to achieve than for the classic VRP.

With this VRP, the goal is to minimize the vehicle fleet and the total travel time required to supply all customers.

Restrictiveness, unlike the classic VRP, consists in the absence of a requirement to serve the customer with only one vehicle. In addition, the fleet includes cars with different payloads.

VRP is modified into Spit Delivery VRP by splitting each customer order into several indivisible orders.

Multiple Depot VRP (MDVRP)

A company can have several depots with whose help it serves its customers. If the customers are clustered around depots, then the distribution problem can be modelled as a set of independent VRPs. However, if the customers and the depots are intermingled then a Multi-Depot Vehicle Routing Problem should be solved [13].

A MDVRP requires the assignment of customers to certain depots. A fleet of vehicles is based at each depot. Each vehicle leaves its depot, services the customers assigned to that depot, and then returns to the same depot.

The objective of the problem is to minimize the number of vehicles and the total travel time. The constraint for the task consists in the demand for each route to satisfy the standard VRP constraints and also to begin and end at the same depot.

CONCLUSION

Due to the practical importance of VRP in real life, the problem has attracted the attention of numerous researchers in the past. Most of the works are dedicated to classic goals, e.g. minimizing total distance traveled, fleet size or time. Some survey also has been done considering multiple objectives such as load balancing, distance/time balancing etc. The papers dealing with profit maximisation, penalty consideration, customer's satisfaction etc. usually tend to optimise multiple objectives simultaneously.

This paper provides a classification of VRP through certain of its most popular variants. In research, we provide a defined classification of the basic problems of the vehicle routing class. These problems, which received considerable attention in the scientific literature, were studied and classified in accordance with the optimization criteria used. Capacitated VRP is introduced first, which is the simplest and most studied member of the family, then we present time-windowed VRP, backhaul VRP, VRP with pick ups and Deliveries, then we present Stohastic VRP, Split Delivery VRP and finally Multiple Depot VRP.

Moreover, it was also noted that there are no benchmarks available for a more realistic classification of VRP versions. As a result, there is still room for further work in the field. Certain subvariants of the vehicle routing problem in the available literature may motivate some of the researchers in this field.

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PROFESSIONAL PAPER

Autonomous vehicles in road traffic

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Abstract: The tendencies in further technological development and across all branches of industry are well-known worldwide, with a focus on the advancement of robotics and artificial intelligence. Over the years, there has been significant progress in the development of robotics, coupled with increased human awareness of its potential applications. Consequently, we find ourselves in a period where the commercialization and widespread utilization of artificially intelligent machines in human environments have become a reality. Among the significant applications of robotics in human lives is the utilization of robotic vehicles, commonly referred to as autonomous vehicles, in traffic management.

The implementation of new technologies aims to address various challenges in transportation, including congestion reduction, cost optimization, safety enhancement, and mitigation of environmental impact. This endeavor involves the integration of telecommunications, electronics, and informatics with traffic engineering principles for effective planning, design, and management of traffic systems. Such integration leads to improved efficiency and safety within the traffic system, while also yielding positive environmental outcomes.

Keywords: information integration, artificial intelligence, autonomous vehicles, road traffic, robotic vehicles

INTRODUCTION

The concept of autonomous vehicles encompasses all vehicles that operate without the need for a driver, commonly referred to as automated vehicles, robotic vehicles, or self-driving vehicles. In real-time driving, all functions of these vehicles are managed by the Vehicle Automation System. The passenger's role is solely to select a destination without intervening in the driving process. Autonomous vehicles rely on a database containing real-time maps and roads, which require continuous updates. Utilizing this data, autonomous vehicles process information to determine the optimal route and permissible speed.

During self-management and interpretation of information while steering, autonomous vehicles utilize various sensors such as video cameras, radar sensors, and laser rangefinders, in conjunction with the database maps, to detect other vehicles in traffic. Continuous data collection from the vehicle's immediate environment includes monitoring its position relative to lane markings, while other sensor systems determine distances and travel speeds between detected vehicles on the road.

Advanced automated vehicles possess the capability to update maps based on sensor input, including radar, lidar, GPS, and machine vision, allowing them to navigate through environments not defined in maps. Autonomous vehicles offer several advantages and perspectives, including:

- Significantly reducing traffic accidents compared to human drivers due to the continuous exchange of data, minimizing human error.
- Increasing the capacity of road routes by maintaining controlled distances between vehicles.
- Managing traffic flow effectively, thereby reducing overall driving time.
- Enabling greater utilization of speeds beyond prescribed limits.
- Decreasing the demand for parking space.
- Streamlining traditional road and traffic signals by obtaining information electronically. (1)

PRACTICAL APPLICATION OF AUTONOMOUS VEHICLES IN ROAD TRAFFIC

The advent of this new technology is anticipated to significantly alter people's fundamental perspective on road accidents. V2V (vehicle-to-vehicle) technology represents a revolutionary advancement, albeit accompanied by concerns regarding potential conflicts in the wireless spectrum necessary for communication. Should vehicles share this spectrum and encounter signal jamming, the circuits designed to provide warnings may fail to receive alerts, potentially leading to collisions. Moreover, the public may raise privacy concerns, as such technology could enable tracking of drivers and their driving behaviors.

Over the past decade, the rapid development of road transport has necessitated the utilization of information systems, paving the way for the emergence of driverless vehicles, also known as autonomous vehicles.

The integration of traffic infrastructure aims to enhance safety by facilitating V2V and vehicle-to-road station communications via short-range communication (DSRC) technology.

Additionally, through the implementation of communication systems such as V2V and V2I (vehicle-to-infrastructure), vehicles can preemptively address sudden scenarios, such as the need for deceleration due to vehicles ahead slowing down. This system allows a vehicle entering a speed-limited zone to transmit information to the following vehicle, alerting it to the impending slowdown and enabling the onboard computer to adjust speed accordingly. Such communication proves crucial, particularly in areas like rural highways with high traffic volumes, including near schools, where vehicles often travel at faster speeds compared to urban areas. Furthermore, proper placement of vertical signage, such as signs indicating speed limits, is essential to facilitate timely vehicle deceleration and speed adjustment within designated areas. These signs provide the vehicle's control computer with crucial information regarding speed limit changes.

PROPOSAL OF SUBSYSTEM FOR AUTONOMOUS VEHICLES IN ROAD TRAFFIC

Existing speed limiting solutions primarily focus on warning systems. However, a novel approach involves integrating a dashboard display onto the road surface in areas with restricted vehicle movement, as illustrated in Figure 1: a software block diagram based on the vehicle speed regulation system.

Communication among sensors, the control computer, and the actuators—the action initiators—is facilitated through software. The camera, positioned on the front of the vehicle or within the middle rearview mirror, serves as a primary component. This camera utilizes sign recognition capabilities to provide essential information to the software. Subsequently, the software processes this information and transmits it to the control unit, which activates the appropriate actuators based on the received data.(2)

This new technology is expected to significantly reduce traffic accidents and alleviate congestion. An innovative suggestion involves implementing priority lanes equipped with electric vehicle charging technology beneath the road surface. These specialized "green" pavement lanes, fitted with induction coils, allow electric cars to recharge while in motion. Utilizing such lanes would continuously replenish the vehicle's battery via induction, eliminating the need for frequent stops to recharge—an issue commonly faced by electric vehicles.

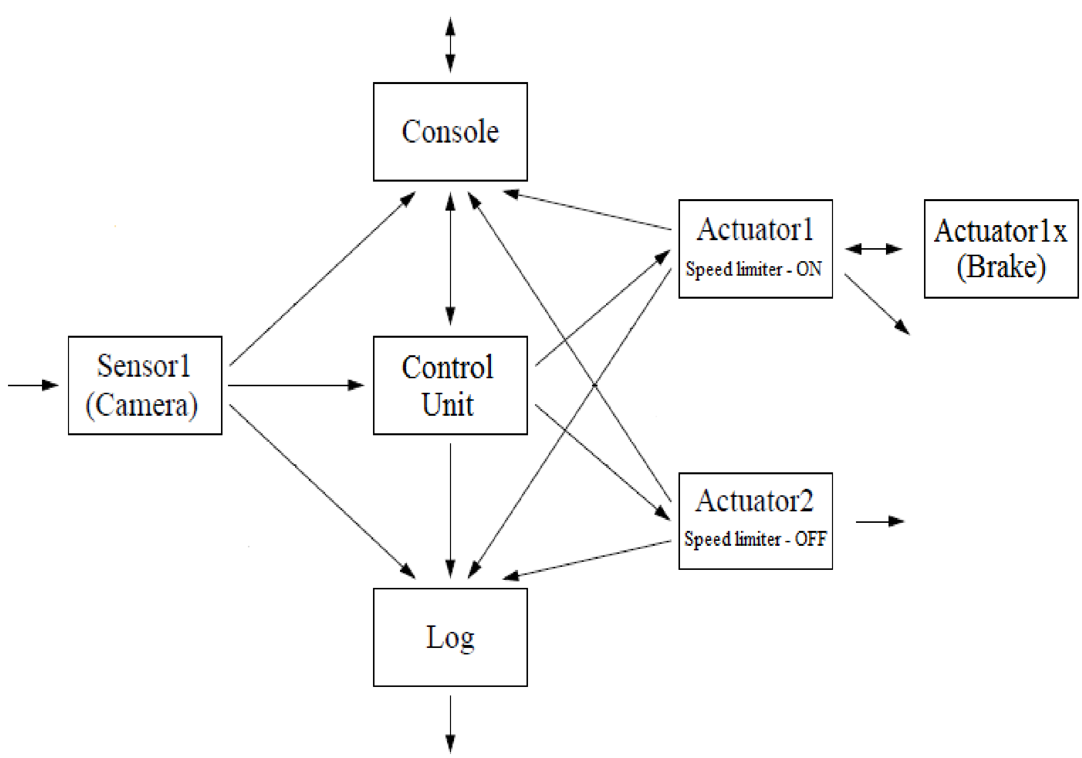

Figure 1: software block diagram based on the vehicle speed regulation system

Over the past decade, the development of road transport has witnessed significant advancements in capacity, technical features, safety measures, comfort, environmental standards, and transport economy. Improvements in autonomous vehicles contribute to traffic safety by enabling error-free driving through meticulous calculation of all relevant factors. Innovative technologies, such as roads illuminated in darkness, dynamic paint, interactive lighting, and priority inclusion lanes, aim to enhance road visibility while conveying crucial information directly onto the road surface.

Key elements of this system include GNSS and communication satellites, ground stations for data reception and processing, a ground system for road traffic monitoring, and information systems deployed within road transport units and central control units. The central control unit plays a pivotal role in receiving, processing, and disseminating information to all stakeholders within a unified road traffic system.

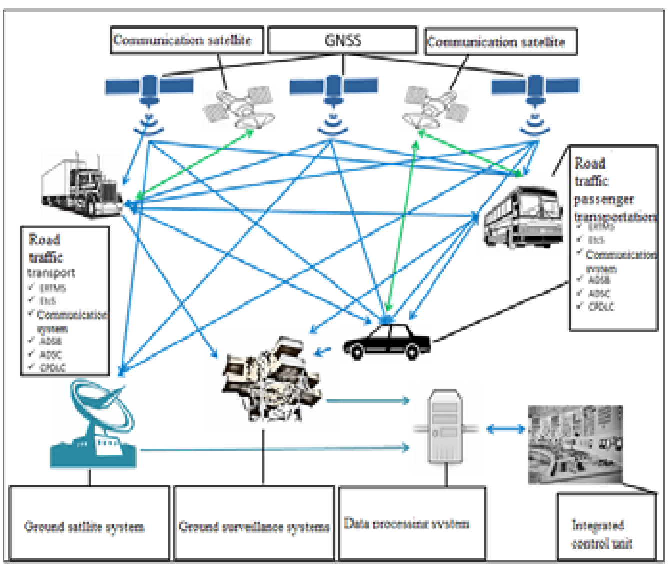

Figure 1: Integrated road traffic information system model

CONCLUSION

The fundamental task of traffic management is to utilize the capacitive capabilities of the traffic network in the most rational and efficient manner, aiming to provide quality service to the current traffic demand. This task becomes increasingly significant considering that the traffic network in the developed world has largely reached its "final" form (configuration and capacities).

This paper has presented the technology of utilizing autonomous vehicles. Alongside safety as an imperative, regularity and expediency are important. All these mentioned components are tied to economic efficiency and cost reduction, thus addressing the ecological aspect of gas reduction, environmental pollution, and ecology.

The new development of technologies will necessitate the standardization and automation of all functions-elements for safe, regular, and efficient traffic flow by continuously implementing supervisory components of the system and reducing risk factors through the use of autonomous vehicles.

Devices have been developed as elements to enhance safety in road traffic—autonomous vehicles. Their use is clearly defined by strictly prescribed technological applications. The need for using these devices is growing daily, as is their technological advancement in accordance with required new and planned safety factors that will enable increased capacity in road traffic.

The efficiency of traffic management is a strategic component of the overall system that will continue to evolve and keep pace with progress in the use of robotic vehicles or autonomous vehicles in traffic as one of the most important, of autonomous vehicles.

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PROFESSIONAL PAPER

Optimization of the toll collection system in the republic of srpska

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Abstract: Toll collection, as part of the source for financing the maintenance and reconstruction of existing and construction of new traffic infrastructure facilities, has an extremely significant place in the total costs of the mentioned processes. Therefore, it is extremely important to choose the optimal charging system and technology, which will satisfy the needs of users, as well as the needs of road managers and owners. The subject of this work are toll collection systems and technologies that are used in the world and in our country. The paper will analyze the open and closed tolling system, the zone or cordon system, the "HOV/HOT" system, and the network toll collection system, as well as the advantages and disadvantages of each of them. In addition, various toll collection technologies will be explored, including traditional, manual toll collection, electronic toll collection and vignettes, with a focus on more modern toll collection models and technologies. The main goal of the research is to compare the advantages and disadvantages of each of the toll collection systems and technologies in order to choose the optimal model of toll collection in the Republic of Srpska, which would satisfy all ecological, economic, traffic, security and sociological aspects.

Keywords: Toll, collection systems and technologies, collection optimization, toll collection in the Republic of Srpska

INTRODUCTION

The traditional way of paying tolls involves manual payment at toll booths. Although the payment of tolls can still be made in the traditional way, in cash, lately more and more people are switching to electronic toll collection systems. For this purpose, transponders are used, which are placed on the inside of the front windshield. Within the traditional method of toll payment, there are two basic systems for collection: open (the toll is collected only at one place on the highway, regardless of the section traveled) and closed (the user's presence is registered at the entrance to the system, and the collection is performed at the exit from the highway). In the open and closed toll collection system, with traditional, manual toll collection, all vehicles stop at the toll ramps to pay the toll.

In contrast, with electronic tolling, the toll is collected without stopping the vehicle.

In addition, there are also the zone or cordon system, the "HOV/HOT" system and the network billing system. Modern highways usually combine all types of toll collection systems.

Figure 1: Toll collection

Some countries have a sufficiently developed standard, and in addition, a high level of motorization and a huge number of vehicle kilometers, that is, a huge traffic of oil and oil derivatives, from which they finance their highway networks, and they are not forced to charge tolls on them. Unlike them, less developed countries, including Bosnia and Herzegovina, that is, Republika Srpska, are forced to charge tolls, so that the entire system of highways in them is sustainable.

RESEARCH METHODOLOGY

Several scientific methods were used within the thematic research, primarily methods of analysis and synthesis of materials from relevant domestic and foreign texts in the field of the toll collection system. By processing the previous materials and sources, an outline list of literature was given. The optimal toll collection system was defined by the deductive method, which influenced the final considerations, in terms of the realized advantages of the electronic toll collection system, as well as the advantages of the introduction and development of new toll collection technologies.

The causal method is useful for establishing cause-and-effect relationships between the advantages and disadvantages of the toll collection system. The systemic and comparative method was used for the overall evaluation of the function of the electronic toll collection system. When comparing the existing system and the introduction of new electronic toll collection technologies, a comparative method was used.

RESEARCH RESULTS

Modern toll collection systems, in addition to being economical in the business of companies - highway managers, have the purpose of increasing the flow of vehicles, reducing congestion and obtaining higher financial indicators. Modern technologies of one type of transport are less and less a special feature today, and more and more a feature of the common technology of all types of transport. The technology of free flow of vehicles is a new type of technology that allows vehicles to pass through toll booths without reducing their speed. Users no longer need to own a transponder, because the system scans their registration plate with the help of implemented optical character recognition technology.

Toll collection systems

Toll collection theory and practice know open systems, closed systems, zone or cordon systems, HOV/HOT systems and network toll collection systems. There are countries that do not collect tolls, that is, using the highway is free. These are economically developed countries, with a high degree of motorization, which finance their highway networks from registrations, oil and oil derivatives traffic, and other sources.

Open toll collection system

An open toll collection system can save money because there is no need to build more toll ramps, because the toll ramp is located only at one end of the road, but this type of system can cause traffic congestion and crowds at the toll point. It is also possible for cars to enter the highway and exit before the toll booth, thus allowing them to use certain sections of the highway for free. Therefore, roads with an open toll collection system have certain loops or ramps with controlled access, in order to prevent the possibility of bypassing the toll booths.

Closed toll collection system

With a closed toll collection system, toll ramps are located at both ends of a certain section of the highway (entrance/exit), and also, all bends on the highway have toll ramps, in order to prevent the possibility of free use of some sections. In the closed system of toll collection, drivers take the card at the entrance to the highway, on the ramps adapted for that purpose. Users present this card at the exit ramps, where the toll amount is calculated based on the length of the section covered. If the user loses the card, he is usually charged the amount of toll he would have paid if he had driven on the longest section of that highway. Within both systems, there may be a combined variant of electronic toll collection. Electronic toll collection - ETC - allows the user to quickly and efficiently collect tolls, without the mediation of cashiers and waiting at toll booths.

Zone or cordon toll collection system

This toll collection system is used mainly to manage traffic flows in more urban areas. First of all, it is applied in the central parts and zones of the city or in areas that require greater environmental awareness (protected areas, national parks, etc.). Examples of the application of this system are in metropolises such as: Milan, London, Singapore, Stockholm... Cordons do not always have to function on the basis of paying to pass through the zone, but can allow certain users to pass or access the zone without paying. An example of this is the tenants of certain zones or the owners of business premises in those zones. The price of the toll in the zonal system is most often a function of achieving the appropriate environmental goal. Most of these systems usually use some of the non-stop billing technologies, in order to prevent queues, congestion, and all their negative effects.

"HOV/HOT" toll collection system

The "HOT" system ("High Occupancy Toll lane") is a charging system developed on the basis of "HOV" traffic lanes ("High Occupancy Vehicle lanes"), which include lanes intended for vehicles with more passengers. This system is mostly used in the United States of America. In addition, it is also used in Israel, while its use in the rest of the world is negligible. The difference between the HOV and HOT lanes is that the HOV lane can only be used by vehicles with a higher number of passengers than prescribed for that lane, while the HOT lane can be used free of charge by vehicles with a higher number of passengers than prescribed for that lane, and vehicles with a lower number passengers pay a toll for using those lanes. These lanes are usually separated from the rest of the traffic.

Network toll collection system

The network toll collection system system allows for different pricing depending on the road rank or the congestion charging policy. It enables toll payment according to the volume and quality of the road network used by the driver. In Europe, there are several examples of its application, but it refers primarily to the network of highways and expressways. By applying this system, it is possible to introduce charging for entry into certain sections or charging for congestion on city roads. This type of system usage is still not sufficiently developed and has not yet been fully implemented anywhere.

Toll collection technologies

Toll collection is possible in cash, payment cards, and in lanes with electronic payment, payment is made cashless and without stopping using a TAG-device. In addition, there are modern toll payment technologies, such as toll machines, vignettes, “DSRC” with barriers, “MLFF” technology, “BAR-code” technology, “RFID” technology, “GNSS/CN” technology, “ANPR” “ technology, “Infrared” technology, “Tachograph” technology, “Smart card” technology, “Smartphones” technology... Traditional methods of toll payment were used massively until the end of the last century. However, with the development of new technologies, the possibility has opened up for the development of new toll collection systems.

Manual toll collection

Experience so far has shown that with the traditional, manual, method of toll collection, traffic flows slow down significantly, crowds and traffic congestion increase. Therefore, since 2006, the introduction of payment systems based on wireless technology, i.e. the Electronic Toll Collection system, has started.

The transition from the traditional, conventional method of collection to electronic toll collection is becoming more and more intensive both in the whole world and in our country. Along with the existing open and closed tolling systems, at least one or more separate traffic lanes for electronic toll collection are being built. If there is no physical possibility to build an additional traffic lane for electronic tolling, the existing manual tolling lanes are used as combined lanes, in which there is a possibility for both manual and electronic toll collection.

Electronic toll collection

Electronic Toll Collection (ETC) systems support the collection and processing of toll transactions without requiring the driver to stop and pay manually, increasing operational efficiency and convenience for highway travelers. ETC systems operate either as an integrated multi-state system, such as the E-Zpass system, or as a stand-alone state toll system, such as the Oklahoma Turnpike System. ETC can reduce fuel consumption and emissions at toll booths by reducing delays, queuing, and idling. The transit toll system can provide greater convenience to customers and generate significant savings for transportation agencies by increasing the efficiency of handling processes and improving administrative control. Public transport users can choose different products, such as magnetic strips (read only or write and read), smart cards with different levels of memory and processing power, or use credit cards to pay for transport. Toll machines can read and write to different types of media and products, and regional processing centers can consolidate financial information and simplify the management of toll transactions for higher-level agencies. Billing systems can be used in the coordination of human services transportation, linking the reservation system to a payment system that tracks the billing of various mobility programs depending on the client’s eligibility. (Drašković, 2017)

Electronic toll collection (ETC) is a collection method without the intervention of a cashier, and the toll collection process takes place using an ETC device located on the windshield of your vehicle and an antenna on the toll road. TAG-devices, with which the electronic toll collection service is used, can be downloaded by users at the “Jakupovci”, “Čatrnja”, “Prnjavor”, “Kladari” and “Kostajnica” toll stations. (Highways of RS, 2019)

Electronic toll collection (ETC) is a wireless system for collecting fees for the use of highways, tunnels, bridges, and other traffic facilities. This way of paying the toll is much faster than the traditional way, where the vehicle has to stop and the driver manually pays the toll with cash or a payment card.

Electronic toll collection is a collection system where vehicles pass through the entry/toll lane without stopping. It is a contactless payment system. Between the radio device, which can be battery-powered, and which is most often placed on the inside of the front windshield, an automatic transaction is performed with the short-range communication system, whose antenna is installed on the canopy above the entrance/toll lane.

In most electronic toll collection systems, vehicles are equipped with an automated radio device, a transponder. When a vehicle with a transponder passes by a vehicle reading device, a radio signal from the vehicle registration antenna excites the transponder, which returns a signal with vehicle data, as well as data on the vehicle’s movement path on the highway section in question, and based on that, the electronic system charges it the toll by removing the appropriate number of pulses from the transponder, which is proportional to the length of the road section traveled.

The main advantage of this method of toll payment is that there is no stopping of the vehicle, which reduces the loss of time and minimizes traffic delays, and in addition, it greatly contributes to the increase of traffic safety, because traffic congestion is reduced, and the possibility of traffic accidents is also reduced.

Electronic toll collection is cheaper than toll collection, because the use of electronic tolling reduces the transaction costs of road owners. This system requires users to top up their account with the desired amount of money in advance, so that the appropriate amount of toll is deducted from that account, every time the vehicle passes through the toll booth, and in accordance with the length of the highway section traveled.

Electronic toll collection is an increasingly popular way of collecting fees for the use of traffic infrastructure facilities, because it, among other things, reduces traffic bottlenecks caused by the slowing down and stopping of vehicles that pay the toll manually. There are also electronic payment systems that function on the principle of automatic recognition of vehicle license plates, and based on the data recorded at the entrance and exit of the highway, the amount of toll that the user needs to pay is calculated, and the bill arrives at his home address, or the bill can be can be paid online or by phone.

Combined toll collection technology

In addition to the previously mentioned technologies, there is also a combined method of toll collection, which involves a combination of the previously mentioned technologies, and which is very often used in practice.

Electronic toll collection can be combined with traditional, manual toll collection, so that drivers who do not have a transponder, or who have a transponder but do not have enough credit on it, can pay the toll (Figure 2).

Figure 2: Symbols of electronic and manual toll collection

DISCUSSIONS

So far, about 112 kilometers of highways have been built in the Republic of Srpska. First, the section from Banja Luka to Gradiška was built, with a length of 33.7 kilometers, which was put into traffic in 2011. The section from Prnjavor to Doboj, 36.91 kilometers long, was put into traffic at the beginning of 2017, so that the complete highway "9. Januar", as the highway connecting Banja Luka and Doboj is called, and whose length is 72 kilometers, and part of which is the section from Prnjavor to Doboj, opened for traffic at the end of 2018. The last to open to traffic was the section Johovac-Rudanka, with a length of about 8 km, which is part of the international corridor "5c".

In March 2015, the Public Company " Republic of Srpska Motorways" started collecting tolls on the section of the highway from Banja Luka to Gradiška. The system was conceived as open, with one front toll station in the town of Jakupovci (Laktaši municipality), within which there was also the possibility of electronic toll collection. The toll was charged in accordance with the Rulebook on toll collection, which provided for the division of all vehicles into four categories, depending on the number of axles and the height above the front axle of the vehicle. Along with the collection in Jakupovci, with the completion of the construction of the highway section "9. January", from Prnjavor to Doboj, in December 2016, tolling on the mentioned section began. The toll stations in Kladari (Doboj) and Prnjavor were organized as open system toll stations, with the possibility of electronic payment. This system was maintained until November 2018, i.e. until the completion of the section of the highway from Banja Luka to Prnjavor, which completed the complete highway "9. January", when it was switched to a combination of open and closed tolling system, on the highway network of Republika Srpska. The open system was maintained on the section from Banja Luka to Gradiška, while on highway "9. January" payment was made in a closed system.

Experience has shown that the open tolling system was not fully effective, because users could enter the highway in Čatrnja (Gradiška), use more than 20 kilometers of the highway, and bypass the Jakupovci toll station, by turning off the highway via the Mahovljanska loop, or via one of the previous two exits from the highway (Nova Topola and Aleksandrovac), then via Laktaš to return to the Banja Luka Gradiška highway, and to use the aforementioned sections of the highway for free.

In November 2019, the collection system was closed on all sections of the Republika Srpska Highways, which is still in effect today, and into which the collection of tolls on the section of the "5c" corridor, from Johovac to Rudanka, was integrated, after it was put into traffic. Payment is made per kilometer of the highway, according to the valid toll price list, adopted by the Government of the Republic of Srpska.

Toll collection in Republika Srpska is carried out by kilometers traveled, that is, it is based on the "distance-based (DB)" approach. The price of tolls in the Republic of Srpska is generally cheaper compared to the price of tolls in the countries of the region, and for the first toll category of vehicles, which includes passenger cars (PA), the toll price per kilometer is 0.10 KM.

Multi-criteria tariff model

The problem of choosing a toll collection system in the Republic of Srpska was treated as a task of multi-criteria ranking of four alternatives, considering six criteria, using the Analytical Hierarchy process. Each toll collection system is scored according to defined criteria, taking into consideration the importance of each of the different evaluation factors, in order to obtain a ranking of results that is the least sensitive in relation to the change in the weight of the criteria. As a result of the application of this method in the consideration of the possibility of introducing toll collection in the Republic of Srpska and the selection of the optimal collection system for the purpose of sustainable development of transport, by ranking the alternatives it is obtained that the vignette system represents the best solution when economic, traffic, technical, organizational and operational factors are taken into account eligibility criteria. The vignette as a toll collection system is a very simple model, which is why they have been introduced by almost all smaller European countries. They also have certain advantages over other billing systems, first of all due to the simplicity of collecting funds, which provides certain benefits for the budgets of each country through advance payments, then avoids possible crowds and delays due to billing, and achieves greater traffic safety. (Injac, Macura, & Bojović, 2014)

Figure 3: Vignettes

Vignettes (Figure 3) are applied in the countries of Central and Southeastern Europe, namely: Bulgaria, Hungary, Moldova, Romania, Slovakia, Slovenia, Austria, the Czech Republic and Switzerland. European directives provide for the abolition of vignettes and the transition to the single EETS electronic toll market. A vignette implies that occasional users have to stop, park their car, get out and buy a vignette, which is then stuck on the windshield, which takes a lot of time, and drivers are often forced to turn off the road to buy a vignette, which creates an additional road. Also, drivers are subject to stops during the journey to check the correctness and validity of the vignette. (Glavić, 2016)

Hybrid tariff model

The hybrid tariff model is a combination of payment based on time and mileage, adapted to specific groups of highway users. By introducing a defined hybrid tariff system, the so-called "win-win" situation both for the highway user, as well as for the driver and society as a whole. In other words, by applying the hybrid tariff model of toll collection, all interest groups would have certain benefits. Although the highway provides users with a higher level of service, greater safety and shorter travel time for the same distances, previous research indicates that a significant number of users prefer free, alternative routes, which are not their primary choice for the "additional costs" of toll collection. implementation of the trip. Avoiding the use of toll highways has a significant impact on users, road managers and society as a whole. The road manager aims to achieve as much revenue as possible from toll collection by increasing the number of highway users. Also, it is in the interest of the road manager that there are as few users as possible on the alternative secondary network, especially users of commercial vehicles, so that the damage to this infrastructure is as small as possible, and thus the costs of reflecting the road are lower. Accordingly, the main goal of the road manager is to retain existing users, with a constant effort to attract users who would naturally use the highway due to their requirements, but do not do so because of the toll collection. From the user's point of view, the economic dimension implies the costs incurred by users when using certain road infrastructure. In the case of using the highway, the user's costs are first of all reflected in the costs of the toll and the costs of travel time and the exploitation of motor vehicles. Users of the secondary alternative road network do not have toll costs, but due to the inferior technical exploitation characteristics of the road, the costs of travel time and exploitation of motor vehicles of these users are often higher, compared to the costs of highway users. In addition to the road manager and the users themselves, certain costs are borne by society as a whole. Namely, the use of an alternative secondary network, due to the worse technical exploitation characteristics of the road, entails higher costs of traffic accidents, emissions of pollutants, noise, etc. A hybrid tariff model would entail a combination of toll payments based on time/mileage and adapted to specific groups of highway users. From the user's point of view, toll collection on a monthly and annual basis at more favorable prices is an adequate solution for everyday users. In this way, this group of users is enabled to use toll roads, and thus avoid local roads of poor quality, which reduces the deterioration of local roads, reduces vehicle operating costs and pollutant emissions. On the other hand, the road manager will increase his income, which can be used to improve the level of service and traffic safety. Having this in mind, the road manager must take these findings into account and offer the group of users who avoid using the highway a specific compensation scheme through a hybrid model. Such a hybrid model would imply a combination of toll collection based on time and kilometers traveled as an optimal solution for both road managers and users. This hybrid model of tolling represents the potential for a successful compromise between road managers who aim to minimize the number of users who avoid using the toll highway and thereby maximize toll revenue, and users whose goal is to maximize the use of the highway at an acceptable cost. (University of Belgrade, 2022)

CONCLUSION

The choice of the toll collection system (which should be optimal at a given moment) is extremely important, in order to avoid possible economic, traffic, environmental, security and social problems. An appropriate balance must be found when choosing a tolling system, because the chosen system must adequately meet the needs of both road managers and road users.

In this paper, the advantages and disadvantages of individual toll collection systems are analyzed, with reference to newer technologies applied in this area, and some systems are proposed that would lead to the optimization of the toll collection system in the Republic of Srpska. With the introduction of electronic toll collection technology, all the disadvantages of traditional, manual collection have been largely reduced, if not completely eliminated. It can be said that the electronic toll collection system has as its primary goal the avoidance of vehicle waiting in toll queues, increasing the flow of vehicles, simplifying collection, reducing environmental pollution and reducing the number of traffic accidents. The introduction of the electronic toll collection system has in practice shown a reduced efficiency of the system in unfavorable weather conditions (fog, moisture). The paper also shows the advantages of introducing vignettes, which greatly improved toll collection compared to previously used systems, but even this system is not ideal, so European directives foresee the abolition of vignettes and the transition to a single market of electronic toll collection with the most modern technologies.

There is a tendency to introduce new, more modern technologies, which have much greater efficiency, and which would remove all the shortcomings of electronic tolling and vignettes and improve the entire toll collection system. An example is the technology of free flow of vehicles, but it has not yet taken root in wide application, both in the world and in our country.

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REVIEW

Fuel Cell Technologies in Automotive Applications

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Abstract: This paper provides an analysis of the latest fuel cell technology through a general description and characteristics of the six most important fuel cell technologies, indicating their use and future development in the automotive industry.

Keywords: Fuel Cell, Electric Vehicle

INTRODUCTION

Fuel cells are seen by many people as a key solutions for the 21st century, enabling clean efficient production of power and heat from a range of primary energy sources.

A fuel cell produces energy from an electrochemical reaction, very similar to a battery. Batteries store energy and when they are used up, the battery must be discarded or recharged using an external power supply, by starting an electrochemical reaction in the reverse direction.

Fuel cell uses an external energy supply and may operate indefinitely as long as it is equipped with a source of hydrogen and an oxygen (usually air) source. Hydrogen atoms react with oxygen atoms electrochemically during oxidation to create water; electrons are released within the process and flow as an electrical current through an external circuit [1].

The chemical energy in hydrogen is directly converted into electricity by fuel cells, the only by-products being pure water and potentially useful heat. Fuel cell systems can produce up to 60 percent efficiency of electricity and even higher with cogeneration [2].

A new phase in the development of motor vehicles has gone through several technological phases and today we are definitely in a new era that is primarily related to steering autonomy and vehicle propulsion systems [3].

PRINCIPAL FEATURES OF FUEL CELLS

A fuel cell is an electrochemical device which converts the chemical energy of a fuel and an oxidant directly into electrical energy. The basic physical structure of a single fuel cell consists of an anode, a cathode and an electrolyte sandwiched between the two electrodes. Bipolar plates are placed on either side of the cell and enable distribute gases and current to the external circuit.

In a fuel cell, hydrogen gas flows to the anode through channels, as depicted in Figure 1, where a catalyst allows the hydrogen molecules to separate into protons and electrons. The membrane is permeable for protons to pass through it. The protons are conducted to the other side of the cellthrough the membrane and the negatively charged stream of electrons is conducted through an external circuit to the cathode. This flow of electrons is electricity, which can be used to power an electric motor [2].

The electrochemical reactions in case of a fuel cell with an acid electrolyte are:

Anode reaction:

$H_2 \rightarrow 2H+ + 2e-$

Cathode reaction:

$½O_2 + 2H+ + 2e- \rightarrow H_2O$

Overall reaction:

$H_2 + ½ O_2 \rightarrow H_2O + heat$

Air flows to the cathode through channels on the other side of the cell. At the cathode, the electrons returning after doing work react with oxygen in the air and the protons, which have moved through the membrane inside the cell to form water. This union is an exothermic reaction, where heat iis generated that can be used outside the fuel cell.

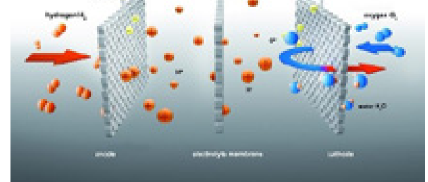

Figure 1. Fuel Cell Principle

The Advantages of Fuel Cells

Compared with traditional fossil fuel-powered electrical generators, the use of fuel cells has many advantages:

- Higher Efficiency: The higher volumetric and gravimetric efficiency of fuel cells is a result of the chemical production of electric energy directly from the fuel used, without combustion. On the other hand, in a Carnot thermic cycle the electric generation efficiency is restricted by its lower combustion efficiency.
- *Low Chemical, Acoustic, and Thermal Emissions:* Due to lower fuel oxidation temperatures, we have the case that fuel cells produce less greenhouse gases, carbon dioxide and nitrogen oxides for kilowatt of power generated. Also, in absence of any moving parts in fuel cells, noise and vibration are negligible.
- *Modularity and Flexibility:* A single fuel cell produces less than one volt of electrical potential. Fuel cells are stacked on top of each other and connected in series to produce higher voltages. Desired power output and individual cell performance dictates the number of cells in a stack, which ranges from a few hundreds of W to several hundred of kW up to some MW.
- *Low Maintenance:* It is relatively easy to identify and substitute a damaged or malfunctioning cell contained inside a stack due to high modularity of Fuel cell systems, which leads to lower maintenance costs.
- *Fuel Flexibility:* For fuel cells requiring low temperatures, hydrogen is most widely used as pure gas for operation. The fuel flexibility depends on the operative temperature range of the type of fuel cells used. In principle, higher the temperature, less pure the gas that the fuel cell can use to generate hydrogen.
- *No pollutants:* Fuel Cells produce only pure water & heat as by-product. No Carbon dioxide/ monoxide gases are produced.

The disadvantages are as follows

- Fuel cells costs are still too high and unsuitable for the substituting the technologies based on fossil fuels. To compete with current internal combustion engine technology for automotive applications a cost of €10 to €50 per kW and an operation life of 4000 hours is required.
- Hydrogen is one of the main fuels for fuel cell technologies. However, it is expensive and is lacking in a wide network for its production and distribution.
- The life cycle and the degradation time of fuel cells technologies is still insufficiently known, especially for high-temperature technologies that have proven to be the best for electric power generation.
- Hydrogen is a flammable and potentially explosive gas and is difficult to compress a suitable quantity of hydrogen in small fuel containers. This is precisely the reason why the use of low-temperature fuel cells in the automotive market is very limited [4].

TYPES OF FUEL CELLS AND APPLICATIONS

Actually there are many technologies of fuel cells available on the market, and each one of those is characterized by: the operative temperature range, the type of fuels which can be used, the type of catalyst used by the cell and the efficiency ratio of the energy conversion.

Today we can talk about several types of fuel cells technologies that exist on the market and where they are used. Therefore, we can define the following division of fuel cells into:

- Alkaline - AFC
- Polymer Electrolyte Membrane - PEMFC
- Direct Methanol - DMFC
- Phosphoric Acid - PAFC
- Molten Carbonate - MCFC
- Solid Oxide - SOFC

FUEL CELLS FOR AUTOMOTIVE APPLICATIONS

Fuel Cells based vehicle propulsion has zero emissions, much higher performance than ICE or battery vehicles and a higher degree of well-to-wheel efficiency than ICE or BEVs. The Fuel Cells EVs have a higher range and shorter refueling time compared to battery-EVs [7–13].

A series of PEMFC powered cars have been designed by Daimler-Benz since 1994 in collaboration with Ballard. In 1997 Daimler-Benz launched a 640 km range methanol-fueled car for the first of these vehicles.

Japanese automakers launched their Fuel Cells EVs. One Fuel Cells EV manufacturer has a 100 kW PEFC stack with a power density of 3 kW/liter, powered by two 700 bar H_2 tanks providing a range of 650 km. The hybrid system is equipped with a 1.6 kWh Ni-MH battery that is also used for regenerative braking.

The PEM fuel cell was an obvious choice in the late 90s due to its rapid start-up time. However, one of the main problems associated with hydrogens is its on-board storage in passenger vehicles. Hydrogen can be contained in metal hydrides or as compressed gases as cryogenic fluid. The compressed gas hydrogen tanks are bulky, even though hydrogen is compressed to 450 bar. It takes around 40–50 liters of volume for storing 1 kg of pure hydrogen. The fuel quantity that is stored onboard is dependent upon the fuel efficiency and the range needed.

Diesel engines for road vehicles achieve an efficiency of 48 percent (best engines, one stage with the most powerful loads). SOFC is the natural alternative in many heavy vehicle applications because of its ability to run on biogas, bio-ethanol, bio-methanol and syngas reformed hydrogen (Figure 2) [4].

There are no CO_2 emissions from a fuel cell operating on hydrogen except for water. The overall system's GHG emissions depend however on the hydrogen production's GHG emissions intensity. In the applications of Fuel Cells, strong environmental benefits are therefore expected.

Fuel Cells reduce noise emissions in vehicle applications, especially at low speed. Other benefits include the reduction of gear changes, improved possible reliability, compatibility with other electrical and electronic devices, and different safety design choices for cars.

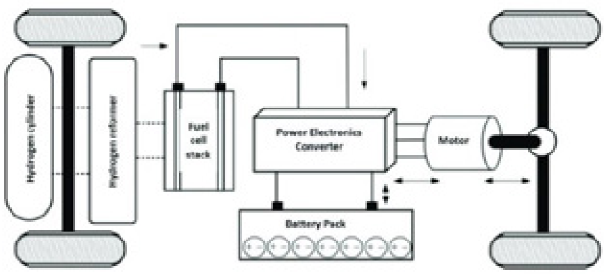

Figure 2. Fuel Cell System for Electric Vehicle (FCEV)

CONCLUSION

Fuel Cells provide the electric energy without polluting environment, due to which they are looked as potential source of energy for automobiles. As can be read from the above, many fuel cell technologies exist and each of these technologies has its own strengths and weaknesses. Each technology is well-suited for specific application environments and has many issues that actually prevent their full commercialization. There are certain Fuel Cells which require pure Hydrogen for reaction inside the Fuel Cell and other types require hydrocarbons/certain compounds which disintegrates into Hydrogen inside an Fuel Cells. On one hand, storage of compressed Hydrogen is a practical difficulty, while operating an Fuel Cells at low temperature poses another challenge in an automobile. Another challenge posed is excessive cost of technology for developing and manufacturing the Fuel Cells.

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Table 1. Fuel Cell Comparison [2, 5, 6]

	AFC	PEMFC	DMFC	PAFC	MCFC	SOFC
Operating temperature	<100°C	60-120°C	60-120°C	160-220°C	600-800°C	800-1000°C
Electrolyte	KOH	Perfluoro sulfonic acid	Perfluoro sulfonic acid	H_3PO_4 immobilized in SiC matrix	Li_2CO_3 –K_2CO_3 eutectic mixture immobilized in ϒ-LiAlO2	YSZ (Yttria stabilized zirconia)
Anode reaction	H_2+2OH– → $2H_2O$+2e–	H_2 → 2H^+ +2e–	CH3OH+H2O→ CO2+6 H^+ + 6 e–	H_2→2H++2e–	H2+CO3 $^{2-}$ → H2O+CO2+2e–	H_2+O_2– → H_2O +2e–
Cathode reaction	1/2O2+H2O+ 2e–→2OH–	1/2O_2+2H^+ +2e– → H_2O	3/2 O_2+6 H^++6e–→3 H_2O	1/2 O_2+2H^++2e– → H_2O	1/2O_2+CO_2+ 2e– →CO_2^{2-}	1/2O2+2e– →O_2–
Electrode materials	Anode: Ni Cathode: Ag	Anode: Pt, PtRu Cathode: Pt	Anode: Pt, PtRu Cathode: Pt	Anode: Pt, PtRu Cathode: Pt	Anode: Ni-5Cr Cathode: NiO(Li)	Anode: Ni-YSZ Cathode: LSM
Application	Transportation space, military energy storage systems			Combined heat and power for decentralized stat. power systems	Combined heat and power for stationary decentralized systems and for transportation (trains, boats,…)	
Realized power	Small plants 5-150 kW modular	Small plants 5-250 kW modular	Small plants <5 kW	Small medium sized plants 50 kW-11 MW	Small power plants 100kW-2 MW	Small power plants 100-250 kW
Electrical efficiency (LHV)	60%	60% direct H_2 40% reformed fuel	35%	40%	50%	60%
Life time	Not available	2,000-3,000 h	1,00 h	> 50,000 h	7,000-8,000 h	1,000 h

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REVIEW

The role of the BRT system in the function of sustainable public passenger transport

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Abstract: Bus rapid transit (BRT) is a system of public urban passenger transport (PUPT), based on the bus subsystem, designed to improve capacity and reliability compared to the classic bus system. Typically, a BRT system includes bus lanes and gives priority to buses at intersections where buses can interact with other traffic. Public transport is crucial to the future of a nation. Strengthens the economy, conserves energy and resources, reduces congestion, reduces global warming and improves air quality and health, critical emergency and disaster relief, increases real estate value and development, mobility in small urban and rural communities. As an instrument of transport policy, transport demand management measures generally do not require large material investments, which gives them additional attractiveness. The paper was conceived on the strategy of sustainable development of cities as a function of quality of life, and the basic characteristics of the BRT system and its role in urban mobility are presented in the work. Also, an insight into their potential is given based on past experiences of application in the world's developed cities.

Keywords: Bus rapid transit, sustainable transport, public passenger transport, mobility

INTRODUCTION

According to the definitions of sustainable transport, the basis of the implementation of the strategy of sustainable development in transport is the balanced development of economic, ecological and sociological goals. Negative transport impacts are numerous and varied and require continuous monitoring. Current trends point to the biggest environmental problems of transport in the past two decades: an increase in greenhouse gas emissions and energy consumption, with the sector's high dependence on fossil fuels; problems of exceeding the permissible concentration of air pollutants in many European cities are still present, despite the overall progress in reducing harmful emissions; over one hundred million urban and suburban population are exposed to the harmful effects of noise; the number of victims in traffic accidents in road transport is decreasing, but the desired safety levels have not yet been achieved; the effects of congestion in road transport are present to a greater or lesser extent in the entire European area and impair the overall European economic potential. (1)

Because the PUPT system is such an important part of any city, it should be accessible to everyone regardless of social group or physical ability. However, in many European cities this system is still inaccessible to some citizens and visitors. Meanwhile, other groups choose not to use the PUPT, as it does not meet their needs. Providing access to efficient public transit for all types of users requires striking a balance between installing enough stops to reduce walking distance and travel time (10). Using new solutions and technology, access to mobility can be made available to people who were previously unable to take full advantage of the PUPT system. In the meantime, the efficiency of the system can be increased. The problems that arise in PUPT are primarily those problems that affect mobility, i.e. free, fast and efficient movement, as well as accessibility to all users who want to use this system.

Today, the BRT concept is increasingly used by cities that are looking for economical transit solutions. As new experiments in BRT appear, the condition of engineering in BRT will undoubtedly continue to improve. Regardless, BRT user orientation is likely to remain its defining characteristic. Developers of high-quality BRT systems in cities such as Bogota, Brisbane, Curitiba, Ottawa, Guayaquil and Rouen noted that the ultimate goal was to move people quickly, efficiently and economically, not cars.

The starting point of this paper is that, based on the past experiences of implementing the BRT system, it is possible to gain insight into the potential of sustainable development strategies in the function of "quality of life" and mobility measures for sustainable urban public transport of passengers.

IMPROVEMENT OF BUS SERVICE

In addition to the bus line, there is another category of bus services that deserves special attention. In order for a system to be designated as a BRT system, there must be a separate road alignment. However, there are several systems that possess many of the other qualities of BRT, but they do not have a significant component. In some cases these systems may use bus lanes or even mixed traffic lanes. These types of systems are called "Enhanced Bus Services". Some authors call such systems "BRT Light". Most of these "Enhanced Bus Services" are located in developed countries, especially in Europe and North America. In cities with low urban public transport (UPT) use and low-density development, the difficulty of obtaining exclusive right-of-way for UPT vehicles can be significant. However, systems in Europe, North America, and other parts of the world have added similar improvements as in to BRT on classic bus lines and during the process they achieved significant improvements in travel time and safety.

Figure 1. Corridor of Los Angeles Metro Rapid service on Wilshire Boulevard

London's bus network handles 5.4 million journeys every day, far outstripping the city's underground tube system. London is one of the few cities in the world where bus travel has steadily increased over the past ten years. London's success is based on four broad service quality objectives:

1. frequency ("show up and go" service with a wait of 12 minutes or less);
2. reliability (forced bus lanes);
3. comprehensiveness and
4. simplicity.

Figure 2. London's use of camera-based bus lanes

To achieve these goals, London has implemented many of the features of BRT within a conventional bus service:

- accessible low-floor vehicles for quick entry and exit;
- ticket collection before boarding in central areas;
- information about departure times at stations;
- quality incentive contracts with concessionaires;
- improved driver training and
- measure priority lanes.

Bus lanes are quite different in design and efficiency. Although some well-defined and well-implemented bus lane systems in developed countries are successful (eg London), in general, bus lanes alone, especially those located on the curb, do not improve the efficiency of UPT. Bus lanes are streets that are primarily reserved for UPT vehicles permanently or at certain times. Bus lanes are not physically separated from other lanes. Although the lanes are sometimes colored, demarcated and marked with a sign, it is still feasible to change bus lanes. In some cases, bus lanes may be shared with high-occupancy vehicles, taxis and/or non-motorized vehicles. Bus lanes may also be open to private vehicle use near intersections. Bus lanes are physically separated lanes that are exclusively used by UPT vehicles. Entering the bus lane can only be done at certain points. The bus lane is separated from other traffic by a wall, curb, cone or other well-defined structural features. Non-transport vehicles generally do not have access to the road, although emergency vehicles can often use the lane. Bus lanes can be on the surface, elevated or underground, but if they are located on mixed traffic lanes, they are most often located in the middle of the roadway. BRT systems usually consist of bus lane (road) infrastructure.

MODERN BRT SYSTEMS

However, the complete BRT system was not realized until the "surface metro" system was developed in Curitiba (Brazil). Construction of the first 20 kilometers of the Curitiba system was planned in 1972, completed in 1973, and the system opened for use in 1974. Combined with Curitiba's other advancements with pedestrian zones, green space and innovative social programs, the city has become a well-known urban success story around the world. Ironically, Curitiba initially gravitated toward building a rail, based on metro system.

In most of Latin America, private sector operators dominated the public transport market. However, left unchecked and unregulated such operators have not met the needs of transport in terms of comfort, convenience or safety. Disadvantage of resources to develop a rail-based or city-based UPT system, Mayor Lerner's team created a low cost but high quality alternative using bus technology. Today's modern Curitiba subways and double-articulated 270 passenger buses serve as an example to the world. The BRT system now has five radial corridors starting from the city core. The construction of the sixth corridor is underway through financing provided by the International American Development Bank (IADB). Currently, the Curitiba system has 65 kilometers of exclusive bus lanes (roads) and 340 kilometers for loading vehicles. The system annually attracts hundreds of city officials from other municipalities, who want to study the organizational and design features that have shaped Curitiba's success.

Figure 3. The main road used only by BRT vehicles

The most significant news and changes in brt systems

The BRT system must be constantly monitored and requires frequent changes in terms of its improvement, so that such a large system can be used by people correctly, quickly and safely. The most significant novelties and changes in BRT systems are:

- *Focus on safety* – To better address the issue of safety, the pedestrian section has been renamed. Pedestrian access and safety now requires more safety features, such as safe and frequent pedestrian crossings in built up areas. In addition, new work deductions were added, including a deduction for excessive pedestrian waiting time and poor maintenance of pedestrian and bicycle facilities;
- *Increased focus on operations* – To encourage high quality system performance, new elements have been added to defend operations for the many issues that have arisen on BRT corridors that significantly degrade corridor quality, even on corridors with excellent design. They include the bus crowding deduction, allowing unsafe bicycle use, lack of traffic safety data and buses running parallel to the BRT corridor;
- *Separate Design Options and Full Score (Operational Design)* – A separate design score, indicating potential performance, is now allowed for evaluating the design elements of an operational BRT corridor. This can be assessed when the corridor is launched. The complete result combines design and operational deductions and can be assessed 6 months after commercial operations have begun, allowing utilization and operations to stabilize. This gives a complete indication of performance based on design and operations;
- *Improved right-of-way definition* – The dedicated right-of-way element has been modified to create a simpler and more efficient means of evaluating exclusive bus lanes. Greater emphasis is placed on physical separation, which reduces the need for execution;
- *New bus line alignments* – The bus line alignment element has been expanded to include 4 routes out of 8 for two types of routes that are increasingly common; both alignments are for roads on boulevard streets with two separate central and express carriageways and service roads (Figure 4);

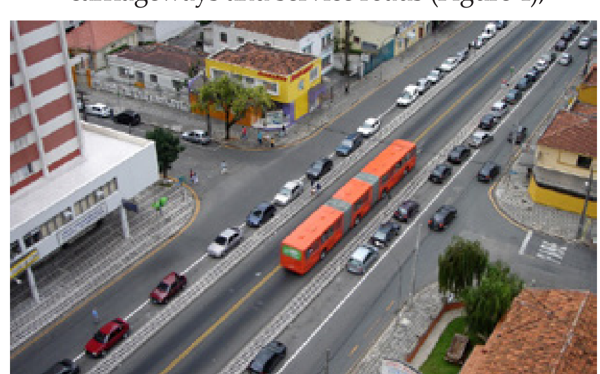

Figure 4. Middle traffic lane intended for BRT vehicles

- *Value check* – the BRT standard now assigns a certain number of points for the evaluation of tickets purchased outside the vehicle (Figure 5). This type of system is used in many cities in Europe and is also being implemented in corridors with lower demand in North America. It can provide significant time savings in conjunction with boarding.

Figure 5. Reading a ticket for using the BRT system

Infrastructure for the operation of the brt system

Good pavement quality ensures better service and operation over a longer period, reducing the need for maintenance. Roads with poor pavement must be closed more often for repairs. Buses will also have to slow down and drive carefully on the damaged roadway. Easy ride is key to creating a high-quality service that can attract and retain customers. Regardless of the type of road, a duration of 30 years is recommended. There are several options to achieve road construction for that time period, with advantages and disadvantages to each.

Figure 6. Appearance of the infrastructure after BRT implementation

There are three such examples:

1. Properly designed and constructed, asphalt pavement can last 30 years or more with surface replacement every 10 to 15 years. This can be done without interrupting traffic, which makes for a smooth ride. At stations and intersections, it is important to use rigid pavement pads to resist potential pavement damage from vehicle braking, a problem that is most common in warm climates. Each bus should be 1.5 times the total length of the buses using it at any given time;
2. Concrete Pavement Joints, this type of pavement design can have a service life of 30 years or more. In order to ensure durability, the roadway must have round bars for indentation at the transverse joints, tied with reinforcing steel strips of appropriate thickness;
3. Permanent reinforced concrete slab, Permanent reinforced concrete slab can add additional stiffness to the pavement and may be considered under certain design conditions.

Traffic lanes for the passage of brt vehicles

Pass lanes at stations are of crucial importance for enabling express and local services. They also allow the stations to accept a large number of buses at the same time, without jamming the buses waiting to enter. On corridors with low bus frequency, it is more difficult to politically justify a specific place on the street for passing lanes, if those lanes are not occupied most of the time. Lanes are usually a good investment in the medium term, providing multiple service options and significant travel time savings and allowing flexibility as the system grows.

Figure 7. Traffic lane intended for BRT vehicles only

On high-demand corridors that require frequent service, through-lanes at stations are particularly useful for providing sufficient corridor capacity to support higher speeds. Corridors with increasing demand may not initially have large capacities, but through lanes can allow for large growth without saturating the corridor. Through lanes also allow for a variety of service options, which can be useful even on corridors with lower demand. In some cases, many of the benefits of passing lanes can be provided by allowing BRT buses to pass in the approach dedicated bus lane. However, for safety reasons, this should only be done where there is good visibility and a relatively low frequency of buses. Similarly, BRT corridors can also allow buses to pass in mixed traffic lanes. But this is mostly useful in a location with low bus frequencies and limited mixed traffic congestion.

STRATEGY AND MEASURES OF SUSTAINABLE DEVELOPMENT

From the perspective of UPT, the strategy of sustainable development implies enabling the mobility of residents while controlling the use of vehicles. In the European

Union, the achievement of the goals of "sustainable development" in the function of "quality of life" in relation to the UPT system is achieved through the conduct of a policy that takes as a principle the mobility of the population with the limited use of passenger cars. The policies and measures of European countries in "sustainable development" are shown in table 1. (7,8)

Key trends in the field of UPT today are:

- The obligation and concern of local communities to ensure the mobility of residents with limited use of passenger cars in accordance with the strategy of "sustainable development" and "quality of life",
- Opening the service market for all carriers and all types of ownership,
- The development of intermodal transport (which implies the systematic use of two or more modes of transport with the aim of increasing the overall efficiency of the transport system),
- Full integration: of transport networks (physical integration), tariff integration and logical - informational integration,
- The need to increase production efficiency and reduce the operating costs of carriers,
- Citizens' pressure on local self-government bodies to realize a higher level of quality with an acceptable price for public transport services and a single ticket for all carriers and modes of transport.

In order to realize the strategic goals of "even development of city units" and "quality of life in the city", it is necessary to know the characteristics of modern cities, the possibility of identifying strategic problems and indicators that are important for the redesign of a modern or developed city. The strategy of sustainable development as a function of the quality of life in the city is based on an urban mobility platform in which the use of individual traffic by using one's own car is reduced to the minimum. In order to achieve such goals, there is a need to intensify the capacity of UPT in terms of its availability in time and space, in order to use the capacity more massively, so that individual traffic and the use of cars are used as little as possible. The strategy involves the realization of traffic, transport and other processes in the city in which daily trips are made using the means of UPT, as well as using the possibility of transport by means of urban micro mobility (walking, bicycle,...) as well as electro mobility (electric bicycle, electric scooter). (3)

The strategy of sustainable development in the city includes the following measures:

- Mobility management
- Increasing the participation of flexible (paratransit) in UPT
- Combined mobility i
- Smart mobility

Urbanization of settlements from public transport locations

Urbanization has been one of the dominant modern processes because an increasing proportion of the world's population lives in cities. Considering this trend, urban transport issues are of utmost importance for the passenger transport and freight mobility requirements of large urban areas. Traffic in urban areas is very complex due to the modes of transportation, the multitude of departures and destinations, the amount and variety of traffic. In general, the focus of urban transport was on passenger transport, as cities were seen as locations of the greatest human interactions with intriguing transport forms associated with commuting, commercial transactions and leisure/cultural activities. However, cities are also locations of production, consumption and distribution, activities related to the movement of goods. Theoretically, the urban transport system is closely related to the urban form and spatial structure. Urban transit is an important dimension of mobility, especially in high density areas.

The process of urbanization, or "urban transition", describes the change of the population from one that is

Table 1. The policy of European countries in the development of livable cities

Sustainable development of cities (mobility with controlled use of a passenger car)	
Resource management (car usage management)	- Pedestrian zones, - Zones protected from motor traffic, - Restriction of access for passenger cars to certain zones or at certain times, - Traffic calming (slowing down), - Management and charging of parking, - Traffic management.
Development and management of the public transport system (system building, development, integration and quality)	- Allocation and Priorities, - Operational system management, - Information systems for users, - Integration of different subsystems, tariffs and information, - Development of paratransit.
Planning and mechanisms of taxation (development management, restrictions on the use of passenger cars, financing of development)	- Land planning and use (reservation of locations for rail subsystems of public transport), - Taxes (sale of real estate, valuation of location and commercial value), - Center entrance control, - Collection of tolls (toll booths, collection according to the length of the journey, etc.).
Organization and financing	

Figure 8. The impact of urbanization on public passenger transport

distributed through small rural settlements where agriculture is the dominant economic activity to a population concentrated in larger, dense urban settlements characterized by industrial and service activities. (11)

Today's cities are growing twice as fast in terms of land as in population. Accordingly, projections show that future trends in urbanization could produce an almost three-fold increase in global urban land between 2000. and 2030., as hundreds of thousands of additional square kilometers are developed into urban density levels. Such urban expansion threatens to destroy habitats in key biodiversity hotspots and contributes to carbon emissions linked to tropical deforestation and land use.

Mobility management

Mobility Management (MM) implies the reform of the transport market whenever it is cost-effective, taking into account all costs and benefits, and applies the capacity expansion measure as the last. In the context of sustainable transport development policy, mobility management is an important instrument of transport policy that aims to facilitate mobility and at the same time influence the reduction of negative environmental, economic and sociological impacts of transport. The core of this concept is the management of mobility requirements - the most important feature of the concept is its orientation towards demand instead of supply, so in the USA and some other countries, it is known as the concept Transport Demand Management (TDM).

Transport demand management measures aimed at reforming the transport market can be divided into "soft" and "hard" transport policy measures. Hard transport policy measures, sometimes called coercive, represent the "old branch" of TDM and include physical infrastructure improvements, but also increasing the cost of using cars, for example, through congestion charges or road space management. Although these measures are sometimes necessary, they are difficult to implement due to public opposition and political ineptitude (4,6).

Soft measures of transport policy, which are sometimes called non-coercive measures (9), psychological and behavioral strategies (5), measures of smarter, i.e. smart choice or mobility management tools (2), are defined in such a way as to encourage individuals to voluntarily change their behavior related to transport, in order to choose sustainable modes of transport. This approach is, for example, known in Australia as mobility management in a way to achieve "voluntary change in passenger behavior when planning a trip". The most famous MM tools in Japan, Travel Feedback Programs (TFP), inform and educate users about ways and habits in travel (daily migrations). This leads to a reduction in the use of single-passenger cars and an increase in the use of less harmful and more efficient modes of transport, through the provision of detailed information on public transport, the provision of incentives, feedback on user behavior, as well as through marketing techniques aimed at individual behavior together with by choosing the mode of transportation. (2)

Smart mobility

Smart Mobility is a concept and tool that enables efficient, flexible and environmentally friendly travel by various modes of transport in space and time using smart transport systems, smart infrastructure and smart technologies (new methods that increase mobility in the UPT system).

Figure 9. Presentation of the functioning of the smart mobility system

"Smart Mobility" is a new revolutionary approach to the realization of the mobility of residents in urban areas and implies an integrated approach to the planning and design of transport systems, mutual cooperation and interconnection (networking) of all available modes of transport and infrastructure, rapid exchange of information and data and complete orientation towards the user (Figure 9). Smart mobility creates and shapes transport systems "customized by the user", i.e. creates the conditions for the realization of mobility through flexible packages of services that the user chooses according to his needs.

Figure 10. Mobility according to the user

CONCLUSION

BRT is a collective urban passenger transport service that operates at high levels of user performance, especially in terms of travel time and passenger capacity. Mass rapid transit can achieve reduced travel times by providing widely accessible networks, higher speed vehicles, exclusive right-of-way infrastructure, special limited or rapid transit services, efficient fare collection systems, and/or faster boarding and disembarking techniques.

Without UPT, other sustainable and innovative mobility services cannot offer an affordable alternative to car ownership. The problems that occur in cities in the region are traffic jams at peak times, and the biggest problem is the increase in the degree of motorization, which is related to the increase in the number of passenger cars, and therefore much greater congestion, taking up much more space, greater problems than the occurrence of accidents. , congestion and slow movement on important routes through the city, as well as the problem of increasing air pollution from vehicle exhaust systems. The strategy and measures for consolidating and improving the state of the UPT system stated in this paper, as a result of research by cities in the world, can realistically be applied in the cities of the Western Balkans, which will contribute to better passenger transport and increased traffic safety.

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