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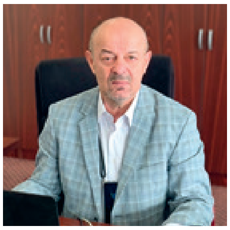

EDITOR'S WORD

Dear readers,

It is my pleasure to present to you the ninth, printed and electronic issue of the "Traffic and transport theory and practice – TTTP" magazine with its mission to promote traffic and transport engineering, a major driver of developments in economic, social and all processes in general in the world today. This issue of the Magazine, as the issues before, is particularly focused on researchers who have their interests in advanced traffic and transport technologies.

The publisher – the Faculty of Traffic of Apeiron Pan-European University wishes for the Traffic and transport theory and practice – TTTP magazine to be a place to gather new, first of all scientific ideas that would influence the development of traffic and transport engineering techniques. The Magazine has provided open access to older issues on its website (https://apeiron-uni.eu).

In regards to that, the Magazine has open access that provides wider population of researchers to publish and protect the copyright of their papers.

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

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ORIGINAL SCIENTIFIC PAPER

Influence of Geometric Elements of Roundabouts on Speed at the Approach

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Abstract: Research conducted in recent decades has shown that there are significant variations in speed at roundabouts depending on the geometric elements. Due to the characteristics of roundabouts and the way vehicles move, there is a reduction in speed, not only in the roundabout zone, but also at the approaches to the roundabout. This paper analyzes the influence of different types of roundabouts as one of the elements of the street system, on speed as one of the basic parameters of traffic flow that defines the functionality and quality of traffic conditions. The research of speeds was done on the approaches to the roundabout, as one of the characteristic segments of the roundabout.

Keywords: roundabout, speed, approach, geometric elements.

INTRODUCTION

Roundabouts are increasingly being part of the city's arteries, and their impact on traffic conditions is specific compared to other types of intersections. Compared to other types of intersections, roundabouts, due to their specific geometry, significantly affect the speed of traffic flow for all movements and maneuvers, on all approaches. Ever since the first scientific and professional papers, the functional connection between the geometric and constructive characteristics of the functional parts of the road and street network and the speed of traffic flow (HCM, 1950), and thus the conditions of traffic, has been established (Bogdanović, V., 2005).

Many papers have investigated the relationships between certain geometric characteristics of roundabouts and average speed, which they defined as the average value of input speed, speed at the roundabout and output speed (Chen, Y., Persaud, B., Lyon, C., 2011), (Akçelik, R., 2011), (Almoarawi M., D. E., 2018), (Bezina, Š., Dragičević, V., Stančerić I.,, 2019)

The connection between the geometric characteristics of roundabouts, speed and capacity, traffic flow parameters and traffic conditions has been confirmed in many studies (Davidović S., Bogdanović V., Garunović N., Papić Z., Pamučar D., 2021) (Vincenzo, G., Rosolino, V., Teresa, I., 2014), (Rodegerdts, L., Bansen, J., Tiesler, C., Knudsen, J., Myers, E., Johnson, M., & O'Brien, A., 2010). The combination of the influence of geometric elements, traffic flow parameters and driver behavior makes the conditions of traffic at roundabouts very complex with significant variations in speed and other traffic flow parameters.

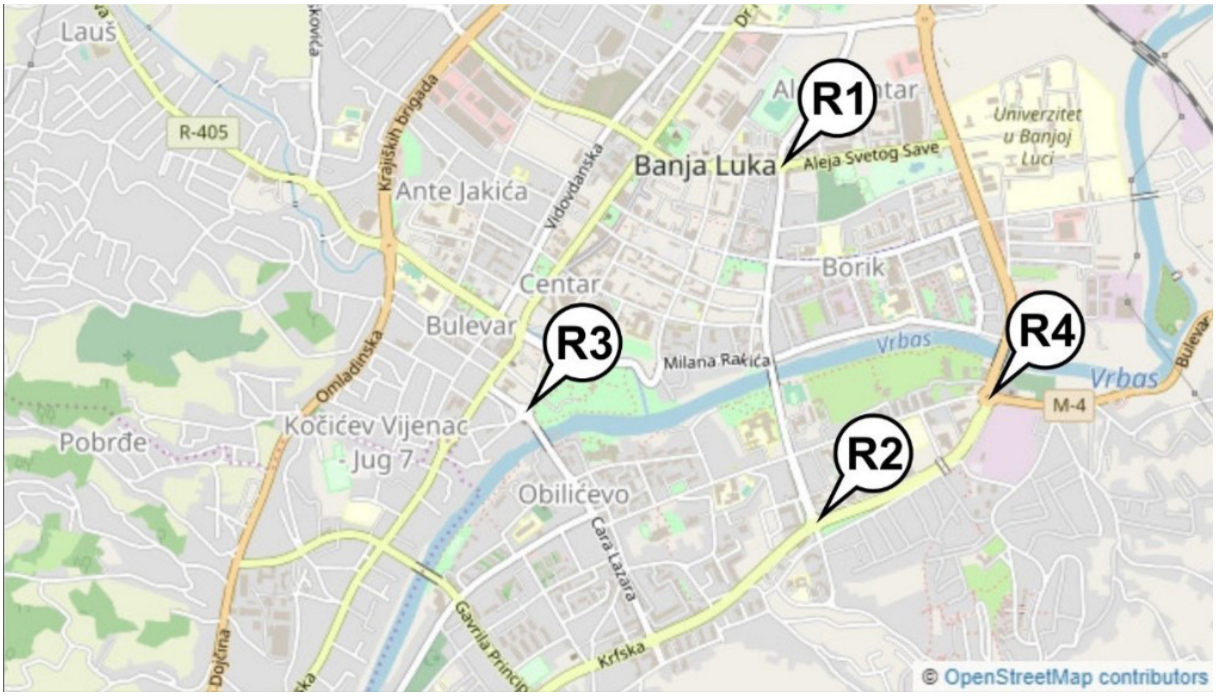
Speed is one of the basic parameters defined in simulation models in order to describe as much as possible the real conditions of traffic at roundabouts (Nikolic, G, Pringle, R., Bragg, K., 2010), (Gallelli, V., Vaiana, R., Iuele, T.,, 2014)

There is no methodology for calculating traffic flow parameters, capacity and service levels related to the part of the street network where the conditions of uninterrupted traffic flows prevail (Highway Capacity Manual, 2010) in which the influence of the geometric elements of the road is not included and valorized through various parameters.

The main goal of this research is to define and model the influence of geometric characteristics of roundabouts on the speed of vehicles at the approach to the roundabout.

In order to realize the goal, research was conducted in the real conditions of traffic, and the dependence between the geometric characteristics of roundabouts and the speed of traffic flow at the approaches to the roundabout was analyzed and defined.

Data collection was done by recording the real traffic flow at four roundabouts (picture 1) in the urban area of the city of Banja Luka (Republika Srpska - Bosnia and



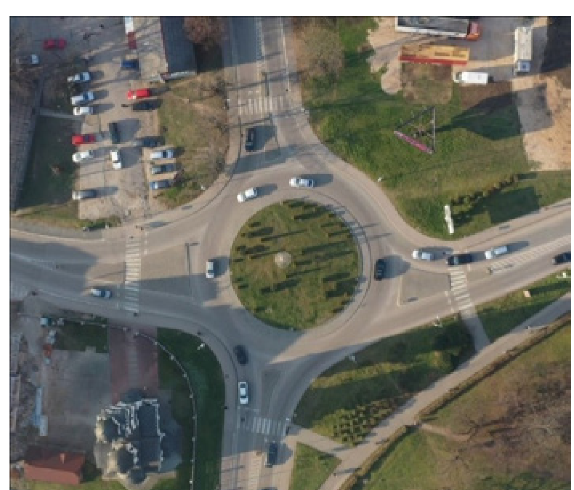
Picture 1. Positions of analyzed roundabouts on the street network of the city of Banja Luka

Herzegovina). The roundabouts where the research was done belong to the roundabouts of medium size and large city roundabouts.

4 roundabouts with different geometric characteristics were selected:R1 Aleja svetog Save – Gundulićeva (picture 2); R2 Majke Jugovića – Bulevar Desanke Maksimović (picture 3), R3 Patre – Isaije Mitrović (picture 4) i R4 Bulevar Stepe Stepanovića – Bulevar Petra Bojovića (picture 5). During the research, it was sunny weather with a temperature of 15-35 °C, without fog, rain, strong wind and other unfavorable climatic conditions, the road was dry and without damage, without situations that would affect the flow of traffic.

Picture 2. R1 Aleja svetog Save – Gundulićeva

Picture 3. R2 Majke Jugovića – Bulevar Desanke Maksimović



Pisture 4. R3 Patre – Isaije Mitrović

Pisture 5. R4 Bulevar Stepe Stepanovića – Bulevar Petra Bojovića

Table 1. data on GPS position of roundabouts

Position of roundabouts in WGS-84 coordinate system	R1	R2	R3	R4
Latitude	44.773963	44.762172	44.765897	44.766366
Longitude	17.199593	17.201245	17.187834	17.209049

Traffic recording was done by the "DJI Mavic 2 Pro" drone. The created video material has a frequency of 24 fps and is processed by the software "Data From Sky" which enables marking of reference lines, analysis of the movement of objects (vehicles) on the image and review of the image by sequences with an accuracy of approximately 0.042 seconds.

By viewing the videos, two categories of vehicles were formed: vehicles that were obstructed and those that were not obstructed. Obstructed vehicles are those that had to stop at the approach to the roundabout (significantly reduce speed, below 10 km / h) for the following reasons:

- In front of the pedestrian crossing due to pedestrians,
- Before the entrance due to the traffic situation in the circulation zone.

Vehicles were also considered obstructed if they stopped at the exit from the roundabout due to pedestrians or other reasons (for example due to another vehicle that stopped due to pedestrians).

Tables 2 and 3 show the approach speed characteristics (S_app), for unobstructed (CON) and obstructed vehicles (DIS).

Based on the results of previous research and field observations, fourteen geometric parameters have been identified that could potentially affect vehicle speed:

En_lane - Parameter that defines the movement of the vehicle on the approach, entrance to the circle, roundabout and exit;
N_lne - Number of traffic lanes on the approach;
W_lne - Width of the traffic lane at the approach (m);
W_en - Entrance width (m);
R_en - Radius of entrance (m);
D1 - External diameter of the roundabout (m);
D2 - Diameter of the central island (m);
N_cr - Number of traffic lanes in the roundabout;

Table 2. Characteristics of approach speed (S_app), unobstructed vehicles (CON)

INT	APP	N	Mean	SE Mean	StDev	Min	Q1	Med	Q3	Max
R1	1	-	-	-	-	-	-	-	-	-
	2	5	23,46	2,87	6,41	18,7	19,00	20,28	29,52	34,04
	3	8	25,23	0,87	2,46	22,07	23,44	24,64	27,14	29,74
	4	-	-	-	-	-	-	-	-	-
R2	2/1	26	32,08	0,96	4,91	19,42	28,95	31,97	35,25	41,46
	2/2	48	30,52	0,88	6,08	20,10	26,30	30,95	33,55	50,84
	4/1	22	34,48	1,18	5,54	24,68	29,51	34,91	38,74	42,99
	4/2	20	32,87	1,21	5,38	24,21	28,60	32,77	36,70	44,30
R3	1	14	28,71	1,28	4,77	19,28	24,72	29,81	32,20	35,36
	2	16	26,08	1,12	4,48	18,84	22,19	26,99	28,21	36,53
	3	26	22,44	0,56	2,88	18,07	20,38	21,72	24,19	30,14
	4	8	21,18	1,19	3,38	16,87	18,48	20,39	24,05	27,03
R4	1/1	21	34,22	0,71	3,25	28,22	31,49	34,58	36,98	40,77
	1/2	25	36,34	0,97	4,84	24,08	33,97	35,94	39,48	45,49
	2	23	26,71	0,75	3,62	22,01	24,39	26,52	28,25	38,34
	3/1	8	29,85	2,08	5,88	24,08	24,76	28,25	35,02	39,50
	3/2	18	30,87	1,33	5,63	21,79	27,23	3013	33,62	43,51
	4/1	15	28,49	1,21	4,67	21,84	23,02	29,27	32,72	35,34
	4/2	25	29,12	0,80	4,00	22,21	26,73	28,85	31,00	40,49

Table 3. Characteristics of approach speed (S_app), obstructed vehicles (DIS)

INT	APP	N	Mean	SE Mean	StDev	Min	Q1	Med	Q3	Max
R1	1	7	16,48	2,89	7,66	9,62	11,61	15,23	18,72	32,48
	2	33	14,20	0,63	3,60	7,79	11,45	14,74	16,16	21,29
	3	14	18,16	1,34	5,00	9,69	13,42	17,74	21,87	26,30
	4	16	11,87	0,76	3,04	7,29	8,96	12,19	14,08	17,29
R2	2/1	42	24,57	0,73	4,74	16,09	20,71	24,90	26,90	36,46
	2/2	43	23,92	0,98	6,83	10,79	19,37	24,00	29,20	34,98
	4/1	40	28,33	0,91	5,77	16,50	24,07	28,56	33,23	39,23
	4/2	39	27,70	0,89	5,58	14,86	24,33	28,00	30,60	41,67
R3	1	21	23,60	0,93	4,27	17,36	18,88	24,56	26,95	30,95
	2	24	21,34	1,29	6,31	9,44	17,97	20,98	25,54	32,95
	3	48	15,55	0,51	3,55	8,21	12,59	15,47	18,85	22,06
	4	23	17,37	0,46	2,21	13,06	15,85	17,37	19,36	21,43
R4	1/1	20	28,89	1,58	7,06	17,03	22,49	30,27	33,35	43,54
	1/2	27	24,13	1,11	5,79	14,66	19,75	21,48	29,41	39,47
	2	30	19,38	1,07	5,83	7,38	15,75	18,56	23,71	31,02
	3/1	11	26,08	1,14	3,77	15,99	24,67	27,65	28,16	29,29
	3/2	22	25,42	1,22	5,74	7,64	21,9	25,45	29,34	32,84
	4/1	13	22,67	1,42	5,11	8,95	20,76	22,62	26,58	29,42
	4/2	13	22,45	0,85	3,07	19,25	19,93	21,09	25,79	27,75

W_lnc - Width of the traffic lane in the roundabout (m);
W_cr - Road width in a circle (m);
N_lnx - Number of traffic lanes on the exit branch to which the observed vehicle flow exits;
W_lnx - Width of the traffic lane on the exit branch to which the observed vehicle flow exits (m);
W_ex - Width of the exit at which the observed flow of the vehicle exits (m);
R_ex - Exit radius at the exit branch where the observed vehicle flow exits (m);

In tables 4., 5., 6. i 7., the geometric elements of roundabouts are shown.

Table 4. Geometric parameters of the roundabout R1: Gundulićeva – Aleja svetog Save

R1 – Gundulićeva – Aleja svetog Save						
General geometric characteristics	External diameter of the roundabout (m)		33,6			
	Diameter of the central island (m)		22,0			
	Road width in a circle (m)		5,8			
	Number of traffic lanes in the roundabout		1			
	Width of the traffic lane in the roundabout (m)		5,8			
Geometric characteristics of the approach		Approach				
		1	2	3	4	
Number of traffic lanes on the approach		1	1	1	1	
Approach	Width of the approach (m)	3,6	3,6	5,0	3,6	
	Width of the traffic lane at the approach (m)	3,6	3,6	5,0	3,6	
Entrance	Entrance width (m)	5,0	5,2	5,3	5,0	
	Width of the traffic lane at the entrance (m)	5,0	5,2	5,3	5,0	
Radius of entrance (m)		14,0	21,2	15,0	20,0	
Entrance angle (°)		26,9	20,9	28,7	25,3	
Exit	Exit width (m)	5,3	4,6	5,5	5,0	
	Number of traffic lanes on the exit	1	1	1	1	
Width of the traffic lane at the exit (m)		4,0	3,6	4,5	3,6	
Radius of exit (m)		16,9	17,4	23,3	22,1	
Dividing island width (m)		1,8	2,9	3,0	2,6	

Table 5. Geometric parameters of the roundabout R2: Majke Jugovića – Bulevar Desanke Maksimović

R2 – Majke Jugovića – Bulevar Desanke Maksimović					
General geometric characteristics	External diameter of the roundabout (m)	33,0			
	Diameter of the central island (m)	16,0			
	Road width in a circle (m)	8,0			
	Number of traffic lanes in the roundabout	2			
	Width of the traffic lane in the roundabout (m)	4,0			
Geometric characteristics of the approach		Approach			
		1	2	3	4
Number of traffic lanes on the approach		2	3	2	2
Approach	Width of the approach (m)	7,0	9,8	6,4	7,5
	Width of the traffic lane at the approach (m)	3,5*	3,4+3,4+3	3,2*	3,75*
Entrance	Entrance width (m)	7,4	13,0	7,6	7,6
	Width of the traffic lane at the entrance (m)	3,7*	3,7+3,7+5,6	3,8*	3,8*
Radius of entrance (m)		12,6	15,8	15,9	12,3
Entrance angle (⁰)		23,8	21,8	50,7	42,2
Exit	Exit width (m)	7,6	8,2	9,2	7,2
	Number of traffic lanes on the exit	2	2	2	2
Width of the traffic lane at the exit (m)		3,5*	3,6*	3,2*	3,4*
Radius of exit (m)		12,0	14,2	14,0	18,2
Dividing island width (m)		1,2	3,1	1,1	4,6

** traffic lanes of the same width*

Table 6. Geometric parameters of the roundabout R3: Patre, Cara Lazara – Teodora Kolokotronisa, Isaije Mitrovića

R3 – Patre, Cara Lazara – Teodora Kolokotronisa, Isaije Mitrovića					
General geometric characteristics	External diameter of the roundabout (m)	43,0			
	Diameter of the central island (m)	31,0			
	Road width in a circle (m)	6,0			
	Number of traffic lanes in the roundabout	1			
	Width of the traffic lane in the roundabout (m)	6			
Geometric characteristics of the approach		Approach			
		1	2	3	4
Number of traffic lanes on the approach		1	1	1	1
Approach	Width of the approach (m)	4,6	4,6	4,1	4,3
	Width of the traffic lane at the approach (m)	4,6	4,6	4,1	4,3
Entrance	Entrance width (m)	5,1	4,7	5,9	5,1
	Width of the traffic lane at the entrance (m)	5,1	4,7	5,9	5,1
Radius of entrance (m)		15,4	13,4	21,6	15,2
Entrance angle (⁰)		35,3	25,8	31,0	33,8
Exit	Exit width (m)	5,4	4,7	5,5	4,7
	Number of traffic lanes on the exit	1	1	1	1
Width of the traffic lane at the exit (m)		4,3	4,5	4,1	4,3
Radius of exit (m)		18,4	22,5	15,0	62,2
Dividing island width (m)		3,4	11,5	3,9	8,4

Table 7. Geometric parameters of the roundabout R4: Bul. Desanke Maksimović – Bul. VojvodeStepe Stepanovića

R4 – Bul. Desanke Maksimović – Bul. Vojvode Stepe Stepanovića					
General geometric characteristics	External diameter of the roundabout (m)	57,2			
	Diameter of the central island (m)	34,8			
	Road width in a circle (m)	9,4			
	Number of traffic lanes in the roundabout	2			
	Width of the traffic lane in the roundabout (m)	4,7			
Geometric characteristics of the approach		**Approach**			
		1	**2**	**3**	**4**
Number of traffic lanes on the approach		2	1	2	2
Approach	Width of the approach (m)	7,2	4,3	7,4	7,6
	Width of the traffic lane at the approach (m)	3,6*	4,3	3,7*	3,8*
Entrance	Entrance width (m)	8	4,2	8,4	9,2
	Width of the traffic lane at the entrance (m)	*	4,2	4,2*	4,6*
Radius of entrance (m)		23	17,9	20	23,7
Entrance angle (°)		43,4	31,9	35,9	28,0
Exit	Exit width (m)	9,4	4,7	9,4	5,8
	Number of traffic lanes on the exit	2	1	2	1
Width of the traffic lane at the exit (m)		3,6	4	3,7*	3,8
Radius of exit (m)		26,9	20,2	26,2	20,2
Dividing island width (m)		2,6	6	3,6	4,1

**traffic lanes of the same width*

FORMATION OF THE MODEL OF THE AVERAGE FLOW SPEED AT THE APPROACH (S_APP)

In accordance with the analysis that was done, the model of speed S_app was formed:

$$S_{app} = -6{,}23 + 6{,}532\ P_{type} + 24{,}27\ N_{lne} + 4{,}62\ W_{lne} - 4{,}677\ W_{en} + 0{,}2343\ R_{en}$$

S_{app} Average flow speed at the approach (km/h);

P_{type} - Type of vehicle passage (1 - flows of unobstructed vehicles; 0 - flows of obstructed vehicles);

N_{lne} Number of traffic lanes on the approach;

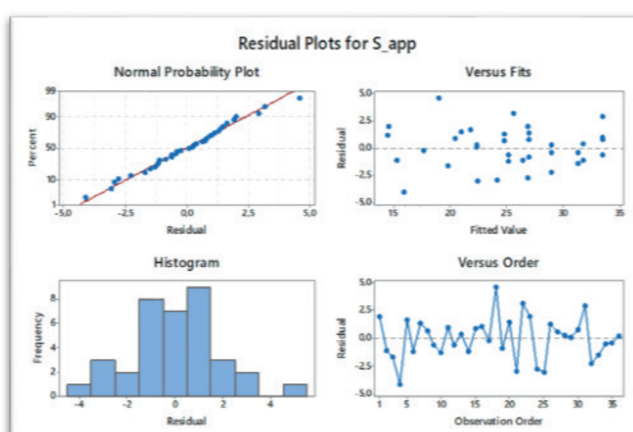
W_{lne} Width of the traffic lane at the approach (m);

W_{en} Entrance width (m);

R_{en} Radius of entrance (m);

The obtained regression has a derivation coefficient R2 = 90.19%. The corrected coefficient of determination R2 (adj) = 88.56%, while the predictive coefficient of determination is R2 (pre) = 85.95%. The standard regression error of the speed model S_app is S = 2.00 (km / h). Based on the summary parameters of the model, it can be concluded that the determined equation very well describes the dependence of the speed S_app and the selected predictors.

The analysis of the residues determined that they were randomly distributed around the line representing the regression curve. Residuals agree with the normal distribution (AD = 0.146; P-value = 0.965). The mean residual value is very close to zero and is 6.414622E-15. The following figure shows a graphical representation of the residuals of the velocity model S_app.



Picture 6. Residual from the speed model S_app

CONCLUSION

At the beginning, roundabouts were mainly used on the secondary street network, but due to the positive effects of use, they quickly began to be used on the main city arteries. For the needs of traffic planning and regulation, as well as in operational and planning analysis, the effects of roundabouts are analyzed using classical methods, without taking into account the specific traffic conditions generated by geometric elements of roundabouts. Many studies since the end of the last century have shown in an objective way that roundabouts affect the speed of traffic flow.

The research in this paper was focused on the analysis of the influence of roundabouts and its basic geometric elements on the change of speed at the approaches to the roundabout. The research was done in real traffic flow at four roundabouts with different geometric elements. The influence of the geometry of roundabout elements has been the subject of various studies, but in this paper, in addition to geometric elements, the influence of traffic flow, ie interaction with other vehicles at the roundabout, ie interference resulting from interaction. After the formation of the database of characteristic velocities, 14 geometric parameters of the roundabout were defined, which could potentially have an impact on the speed on the segments of the roundabout, as well as the mutual influence of speed.

With multiple regression analysis, a model was formed for calculating the average speed of traffic flow at the approach to the roundabout, which shows the type of arrival, number of traffic lanes at the approach, width of the traffic lane at the approach, entrance width and entrance radius. Further research on speeds at roundabout approaches should focus on a wider area of roundabout approaches than the one covered by the analysis in this paper.

REFERENCES

[1] Akçelik, R. (2011). Some common and differing aspects of alternative models for roundabout capacity and performance estimation. *International roundabout conference.* Carmel, Indiana, USA.: Transportation Research Board.

[2] Almoarawi M., D. E. (2018). Predicting Operating Speeds at Urban Multilane in Abu Dhabi, United Arab Emirates. *Journal of Advanced Transportation*.

[3] Bezina, Š., Dragičević, V., Stančerić I.,. (2019). Approach Alignment Impact on the Geometric Design of Urban Roundabouts. *AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS Roma 2019)* (str. 700-707). Roma, Italy: Transportation Research Procedia.

[4] Bogdanović, V. (2005). *Prilog proučavanju kapaciteta i nivoa usluge na trokrakim i kružnim prioritetnim raskrsnicama po novom konceptu.* Novi Sad: Fakultet tehničkih nauka Novi Sad.

[5] Chen, Y., Persaud, B., Lyon, C. (2011). Effect of speed on roundabout safety performance – implications for use of speed as a surrogate measure. *Transportation Research Board 90th Annual Meeting.* Washington DC, United States: Transportation Research Board.

[6] Davidović S., Bogdanović V., Garunović N., Papić Z., Pamučar D. (2021). Research on Speeds at Roundabouts for the Needs of Sustainable Traffic Management. *Sustainability*.

[7] Gallelli, V., Vaiana, R., Iuele, T.,. (2014). Comparison between simulated and experimental crossing speed profiles on roundabout with different geometric features. *Procedia – Social and Behavioral Sciences* , 117-126.

[8] Highway Capacity Manual. (2010). Washinton D.C.: Council, Transportation Research Board of The National Research.

[9] Nikolic, G, Pringle, R., Bragg, K. (2010). *Evaluation of analytical tools used for the operational analysis of roundabouts.* Halifax, New Scotia: Annual Conference of the Tranportation Association of Canada.

[10] Rodegerdts, L., Bansen, J., Tiesler, C., Knudsen, J., Myers, E., Johnson, M., & O'Brien, A. (2010). *National Cooperative Highway Research Program (NCHRP) Report 672 Roundabouts: An Informational Guide (2nd ed.).* Washington D.C.: Transportation Research Board of the National Academies.

[11] Vincenzo, G., Rosolino, V., Teresa, I. (2014). Comparison between simulated and experimental crossing speed profiles on roundabout with different geometric features. *EWGT2013 – 16th Meeting of the EURO Working Group on Transportation* (str. 117-126). Porto, Portugal: Procedia - Social and Behavioral Sciences 111 .

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ORIGINAL SCIENTIFIC PAPER

Increasing the Efficiency of the Bonus / Malus Determination Process When Contracting Auto Liability Insurance

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Abstract: Decrease in the price of the policy in the following text Bonus and increase in the price of the policy in the following text Malus is currently determined by searching the data in spreadsheets, hereinafter referred to as the Book of Incidents. The owner of the book of incidents is the Insurance Agency, which collects data from all active insurance companies. The insurance agency migrates all collected data into one file and distributes it by e-mail or CD to all active insurance companies. The book of incidents is a Microsoft Excel file from which the insurer can search for a vehicle or insured person who may have caused an incident in the past, damage to his vehicle as well as to the vehicle or a third party.

Keywords: Bonus, Malus, Insurance, Incident book, Vehicle insurance, Insurance company.

THE PROBLEM AND OMISSIONS OF THE EXISTING SYSTEM IN THE CALCULATION OF BONUSES AND MALUS

Insurers are currently using the Microsoft Excel spreedshet when searching. Based on any data found (incidents) about the vehicle and the insured, the bonus and malus are determined. This system does not take into account all the statutory provisions of the Insurance Supervision Agency. Current legal provisions are defined and can be found on the portals of the Insurance Agency in BiH - http://www.azobih.gov.ba/ and insurance agencies in RS –http://www.azors.rs.ba/azors/index.html.

The book of incidents is updated periodically, once a month, where each insurance company updates its own data related to damages and incidents. After collecting, migrating and updating the data, the insurance company sends the collected data by email or CD to the central insurance agency. Insurance agencies migrate all data into one file and send back updated data to each insurance company via email or CD.

After several years of using this system for determining malus and bonus, it turned out that there are a number of omissions and problems in this system such as:

- Fields in Microsoft Excel are not formatted, so data related to damage cannot be found and compared accurately and easily. For example, the date of occurrence of the damage is not the same format in all insurance companies. In some insurance companies date format is DD.MM.YYYY and in some MM.DD.YYYY or DD.MM.YY.
- Data in Microsoft Excel is not standardized. For example, the record related to repaid damages is defined differently in each insurance company. In some insurance companies, if the insured repays the damage, the damage record is deleted from the book of incidents, while in other insurance companies this record is left in the book of incidents with the comment that the damage has been redeemed.
- The possibility of an error in the data search as well as the untrainedness of the insurers who is performing the search. For example, driver information may appear in several places but entered differently. In some cases, the data is entered in format of first name and last name, and in other cases, in format of last name and first name.
- When searching for data, it is impossible to take into account and process all inquiries and checks prescribed by the Insurance Agency in legal provisions.
- There is no possibility of automatic data search or automatic determination of bonuses and malus from database. Therefore, it is impossible to determine the exact bonus and malus when buying a policy online as well as other automated systems.

LEGAL PROVISIONS OF THE INSURANCE SUPERVISION AGENCY

Legal provisions are defined in the conditions for ensuring the owner or user of motor vehicles against liability for damages caused to third parties.

Premium reduction terms and conditions (Bonus)

If the vehicle has been insured for at least one year and if at that time there was no reported damage for which the insurer paid compensation or at the time of extension of the insurance the damage was not in liquidation (hereinafter reported damage) the insured is entitled to a discount for that vehicle in the following insurance year in the amount of:

- -10% if no damage was reported in the previous insurance year
- -20% if no damage has been reported in the past two consecutive years of insurance
- -30% if no damage has been reported in the past three consecutive years of insurance
- -40% if no damage has been reported in the past four consecutive years of insurance
- -50% if no damage has been reported in the last five or more consecutive years of insurance

The provisions of these above percentages apply to policyholders who have up to five insured vehicles.

An insured person who has acquired the right to a discount of more than 50% under the previous premium system retains that right until the first claim in the sense of the previous paragraphs or until the loss of the right to a bonus on some other basis.

An insurance company who has concluded insurance with a duration of at least one year for six or more vehicles, where the ratio of claims paid to premiums paid in the past three calendar years is less than 68%, calculates a premium discount for the next insurance period of half (50%) of the difference between 68% of the percentage of the realized relationship. An insurance contractor who has not paid a claim in the past 3 calendar years is entitled to a 50% bonus.

Terms and legal provisions for premium increase (Malus)

a. An insurance company who has concluded insurance with a duration of at least one year for 5 vehicles, the premium for the next insurance year is increased, if in the previous insurance period two or more damages were reported based on his insurance.

Premium increase is:

- + 50% for two reported damages
- + 80% for three reported damages
- + 120% for four reported damages
- + 200% for five or more reported damages

And that for the vehicles that caused the damage, that is, for the vehicles that replaced them.

b. An insurance company who has concluded insurance with a duration of at least one year for 6 or more vehicles, where the ratio of paid damage to paid premium in the past 3 calendar years was more than 110%, calculates the premium (malus) on the premium in the percentage equal to half of the difference between the realized ratio and 110%, provided that the allowance may not exceed 85%.

Other provisions on bonus and malus

The following provisions also apply when contracting insurance premiums for insured persons who have insured vehicles:

a. If the insured had concluded insurance with a duration of less than one year, this insurance is not taken in the next year of insurance as a basis for granting a discount, regardless of the fact that no damage was reported.
b. If the insured had reported one damage in the previous period, then in the next insurance year he loses the right to the bonus in full.
c. viii. It is considered that the damage is not reported if it is liquidated within 3 years without compensation or is reimbursed in full on any basis, if the insured compensates the damage, if the damage is caused by a driver who drives a vehicle without authorization of the owner-insurer or is not families of the insured driver.
d. If the insurance was terminated, the insured is entitled after the insurance terminated for the same vehicle or the vehicle he replaced, the right to the same bonus if termination of insurance occurred before the end of the insurance year and if the termination did not last longer than two years. If there was a termination of insurance after the end of the insurance year in which no damage was reported, and the damage was not reported in the period of termination of insurance, the insured is entitled to a bonus as if the termination provided that the interruption did not last longer than two years. In all other cases, after the termination of the insurance, the insured loses the right to the bonus, ie the premium is calculated in terms of the relevant provisions on malus as if there was no termination.
e. In the case of stolen insured vehicle, the right to the bonus payment is not transferred to the new owner or new user of the vehicle, except when transferring ownership of the vehicle to a close family member, whether it is a transfer of own-

ership of the same vehicle or purchase of a new vehicle.

f. If the insured driver, after the vehicle demage, sale, etc., of the previously insured another vehicle, the realized right to the bonus, ie the obligation to pay the malus, passes to this other vehicle if it is a vehicle from the same premium group, the bonus is calculated from the insurance premium for the new vehicle.
g. Replacement of destroyed, sold, etc. vehicles must be completed within two years.
h. An insured person who has earned the appropriate bonus and purchased another vehicle from the same premium group does not have to sell the first vehicle in order to earn the same bonus with the newly purchased vehicle.
i. If an insured driver loses the bonus on one of the two vehicles because he caused damage to a third party, the insured retains the already recognized bonus for the vehicle with which he did not cause damage to a third party.
j. The insured is entitled to a bonus, i.e., the malus will be calculated on the basis of insight into the previous policy of another insurer, written statements of the insured on the previous duration of insurance and the number of consecutive years without damage and insight into the insurer's records of damages.

Determining the insurance premium for insured persons who have concluded insurance for six or more vehicles.

a. Bonus, ie malus on these bases is also calculated on vehicles purchased by the insured in the current insurance year.
b. In the event of termination of insurance and re-conclusion of the insurance contract, the insurance contractor with 6 or more vehicles is charged a bonus or malus based on the result of the last three calendar years of insurance. If the interruption lasted more than 2 years, a premium without bonuses and malus is calculated.
c. The joint stock company-insurer does not have data on damages and changes for at least 3 previous years of insurance because the policyholder was not previously insured for a sufficiently long period, then to determine the bonus and malus use available data for two years and one year insurance.
d. The paid claims, which is placed in relation to the collected premium, must be reduced by the amount of collected recourses on any basis before calculating this ratio.
e. In the case of an insured person with 6 or more insured vehicles, the calculation of the bonus or malus is performed on the basis of a single ratio of paid claims and collected premium for all his insured vehicles.
f. The provisions on determining the premium depending on the technical result shall apply only to policyholders who are 31.12. in the past calendar year had insured more than 5 vehicles.
g. The insurer and the policyholder have the right to request a recalculation of the bonus or malus if he subsequently determined that the calculation was based on claims that are unfounded. Automation of the process of calculating the bonus and malus

AUTOMATE THE BONUS AND MALUS CALCULATION PROCESS

The process of automating the calculation of bonuses and malus can be automated by the user (insurance company) entering certain data about the vehicle, the insured driver, the previous policy as well as other necessary information that will be used to view the insurer's records of damages.

Examples of data currently available to insurance companies

Sarajevo Insurance company

Tabela sa neophodnim elementima Knjige štetnika

Sarajevo osiguranje d.d. Podružnica Banja Luka

Red. br.	Broj štete	Datum prijave	Datum nastanka	Osiguranik imalac polise Prezime i ime /naziv firme	Tip vozila	Registarski broj	Oštećeni Prezime i ime /naziv firme	JMBG/JIB	Lice koje je upravljalo	Broj polise	Iznos štete	Napomena
1	2/10	25/02/10	17/02/10	STOJAKOVIĆ LJUBIŠA	PMV MERCEDES	172-T-989	ČEKO ZORAN	2801965116958	STOJAKOVIĆ LJUBI	1350722	2.960,00	
3	4/10	05/07/2010	05/07/2010	ZELJKOVIĆ STOJAN	PMV FIAT	521-T-734	MALIDŽA DRAGAN	1305981102095	ZELJKOVIĆ STOJAN	1351054	1.500,00	
4	3/10	06/11/2010	15/06/10	ĐURIČIĆ DUŠKO	PMV VW PASSAT	J04-T-166	TOPIĆ ZDRAVKO	1803962160017	ĐURIČIĆ DUŠKO	1360650	2.311,50	KRIVIČNA
5	5/10	14/06/10	14/06/10	TOMIĆ VLADIMIR	PMW FORD FIESTA	676-J-436	SPECIJALNO TUŽILAŠTVO RS	4402192270006	TOMIĆ VLADIMIR	1519678	350,00	
6	6/10	06/11/2010	06/08/2010	KOČIĆ NENAD	LADA 1118	216-M-176	JAKOVLJEVIĆ MLADEN	2005939101438	KOČIĆ BILJANA	1360296	49.132,00	
7	7/10	06/09/2010	31/05/10	POPOVIĆ SLAVIŠA	RENAULT 5	J54-A-692	KRALJ MILAN	2710953160018	POPOVIĆ MILENKO	1360580	550,00	
8	8/10	20/07/10	23/07/10	JOLDŽIĆ SINIŠA	PMV FORD DNW	A32-J-388	BOGOVAC ZORAN	101961100136	JOLDŽIĆ SINIŠA	1521022	750	
9	9/10	07/02/2010	07/01/2010	TODOROVIĆ SRĐAN	PMV PEUGEOT 206	725-M-981	STANKOVIĆ MILAN	1408962103205	STANKOVIĆ MILAN	1360811	860	
10	10/10	07/01/2010	29/06/10	VARMAZ SABAHUDIN	MOTOCIKL HONDA SC3	J41-A-345	TIKT MANUFAKTURA D.O.O	4401096170008	ĆUŠIĆ GORDAN	1519258	4.343,00	RENTA ALKOHOL
12	12/10	07/08/2010	07/03/2010	BLAGOJEVIĆ MILOMIR	PMV OPEL KADET	551-M-843	MILJUŠ MIRJANA	2309970885038	BLAGOJEVIĆ DALIB	1360544	3.500,00	
13	13/10	28/07/10	07/08/2010	SOFTIĆ HALID	PMW OPEL KADET	835-J-279	DALJEVIĆ DAVOR	210297916032	SOFTIĆ HALID	1351075	595,00	U OBRADI - RENTA

Jahorina Insurance company

Red. Br.	Broj štete	Datum prijave	Datum nastanka	OSIGURANIK - NOSILAC POLISE: Prezime i ime / Naziv firme	JMBG/JIB Osiguranika	Tip vozila	Registarski broj	OŠTEĆENI: Prezime i ime - Naziv firme	JMBG / JIB	Lice koje je upravljalo vozilom osiguranika	Broj polise osiguranika	Iznos štete KM	Napomena
	011-110/11	12/11	06.12.2011	STANIMIROVIĆ MILOVAN		0104	761-J-275				425363		
	011-111/11	12/11	02.12.2011	MIĆIĆ MILUTIN		0106	TA012326				401174		
	011-112/11	12/11	04.12.2011	VIDIĆ RADIVOJE		0104	378-M-330				412537		
	011-113/11	12/11	02.11.2010	DOO ŽELJA TRANSPORT		0209	891-J-811				333718		
	011-114/11	12/11	09.06.2011	DOO ALBATROS		0218	001-A-158				393507		
	011-115/11	12/11	17.10.2009	JOKIĆ SARA		0106	069-T-353				283807		
	002-13-01-001/12	03/01/2012	26/12/2011	ČISTOĆA AD	4400849160004	606	174-E-796	DIZDAR ZORAN	2308977100006	MIODRAGOVIĆ MILAN	486188		
	002-13-01-002/12	03/01/2012	18/11/2011	KLJAJIĆ DARIO	1801975104003	105	A95-O-083	MORAVAC MIRKO	1906973103531	SIMIĆ BOJAN	383093		
	002-13-01-003/12	03/01/2012	10/09/2011	VITAMINKA AD	4400925360009	203	863-T-454	STUDIO DESIGN DOO	nema	ČELIĆ SAŠA	382243		
	002-13-01-004/12	03/01/2012	18/06/2011	MEDIĆ TRANS DOO	4402936280006	210	070-E-293	ADRIATIC SLOVENICA	0609979501093	KAČAR NOVAK	392934		
	002-13-01-005/12	03/01/2012	20/12/2011	STOKANIĆ SAVO	2601345100010	104	K01-M-401	STOJANOVIĆ BOGDAN	0910959102745	STOKANIĆ ZLATKO	243580		
	002-13-01-006/12	04/01/2012	19/12/2011	BRAĆA RACA DOO	4402569980004	201	049-M-016	GLIGORIĆ DRAGOMIR	1307939103025	RACA RASTKO	428350		

As can be seen in the attached data, each insurance company uses a different date / time format as well as the data in the last column 'Napomena' where it is impossible to determine the status of the incident. The possibility of error in searching for data and information necessary for calculating bonuses and malus is high.

The second problem is calculating bonuses and malus. The accuracy of the calculated data is directly related to the ability and experience of the insurance company's staff.

Existing system - definition of columns in the spreadsheet

XCel columns	Description
XCel columns	Description
Incident number	Incident number in the Insurance Company
Damage number	Damage number in the Insurance Company
Damage date reported	Date of damage reported
Damage date	Date of damage
Insured-policyholder Name and surname / company name	Insured-policyholder Name and surname / company name
JMBG/JIB – policyholder	Policyholder JMBG/JIB
Vehicle type	Details of the vehicle involved in the incident
Vehicle registration	Vehicle registration number
Damages claim driver Name and surname / company name	Driver to claim damages Name and surname / company name
JMBG/JIB - Damages claim driver	Damages claim driver JMBG/JIB
Driver who drove the vehicle	The person who drove the vehicle
Insurance policy number	Insurance policy number in Insurace company
Vehicle chassis	Vehicle chassis number
Amount of damage	Amount of damage in KM
Comments	Incident comments

New system proposal

1. Designing a database (hereinafter DB) and defining DB objects.
2. Design a process to transfer data from Xcel spredsheet to DB.
3. Designing and defining parameters for entering the necessary information for the calculation of bonuses and malus.
4. Designing the process for calculating bonuses and malus based on the entered parameters (Input).
5. Design and method of displaying output parameters to the user (Output).
6. Database - Data base design

Database design

SQL Server 2012 Management studio will be used to design DB structure and other DB Objects.

DB name: INSURANCE DB schema name: AUTO

DB TABLES:

Table name	Description
InsuranceProvider	Insurer – Insurance Company
IncidentStageDetail	Progress and incident resolution
IncidentStage	Possible progress of the incident
IncidentOsiguranik	Insured details
IncidentClaimDriver	Details of damage claim driver
IncidentDriver	Incident driver
IncidentComment	Incident comments
IncidentVehicle	Vehicle details

InsuranceProvider

Column Name	Data Type	Allow Nulls
🔑 InsuranceProviderId	smallint	☐
Name	nvarchar(50)	☐
FullName	nvarchar(100)	☑
Address	nvarchar(50)	☑
ContactName	nvarchar(50)	☑
ContactNumber	nvarchar(50)	☑
Email	nvarchar(50)	☑
Town	nvarchar(150)	☑
TownPostCode	nvarchar(25)	☑

The InsuranceProvider table contains all registered and active insurance companies. A list of all insurance companies can be found in AZOBiH and AZORS. Insurance Agency in BiH - http://www.azobih.gov.ba/

RS Insurance Agency – http://www.azors.rs.ba/azors/index.html

IncidentVehicle

Column Name	Data Type	Allow Nulls
🔑 IncidentVehId	int	☐
VehicleType	nvarchar(100)	☑
RegistrationNo	nvarchar(25)	☑
ChasseNo	nvarchar(100)	☑
Active	bit	☐

IncidentVehicle table contains information about the vehicle that participated in the damage. The owner of these vehicles is a natural or legal person who is a participant in the incident and the damage.

IncidentInsuredDriver

Column Name	Data Type	Allow Nulls
🔑 IncidentOsigId	int	☐
OsigName	nvarchar(200)	☑
OsigJMBGJIB	nvarchar(50)	☑
PolicyNumber	nvarchar(50)	☑
Active	bit	☐

IncidentInsuredDriver table contains information about the natural person who drove the vehicle and was a participant in the incident and damage

IncidentClaimDriver

Column Name	Data Type	Allow Nulls
🔑 IncidentOstId	int	☐
OstName	nvarchar(200)	☑
OsigJMBGJIB	nvarchar(50)	☑
PolicyNumber	nvarchar(50)	☑
Active	bit	☐

IncidentOstecen table contains data on the natural person who was a participant in the incident (the so-called third party).

IncidentDriver

Column Name	Data Type	Allow Nulls
🔑 IncidentDriInd	int	☐
DriverName	nvarchar(200)	☑
PolicyNumber	nvarchar(50)	☑
Active	bit	☐

IncidentDriver table contains information about the individual who was driving the vehicle at the time of the incident and the damage done.

IncidentComment

Column Name	Data Type	Allow Nulls
🔑 IncidentComId	int	☐
Comment	nvarchar(200)	☑
Active	bit	☐

IncidentComment table contains notes and comments related to the incident and damage.

IncidentDetail

Column Name	Data Type	Allow Nulls
🔑 IncidentDetId	int	☐
InsuranceProviderId	smallint	☐
IncidentNumber	nvarchar(100)	☑
IncHappend	datetime	☑
IncRecorded	datetime	☑
DemagedCost	decimal(9, 2)	☑
IncidentOsigInd	int	☐
IncidentOstInd	int	☐
IncidentDriInd	int	☐
IncidentVehInd	int	☐
IncidentComInd	int	☐
LogDate	datetime	☐
LogUserId	int	☐
Active	bit	☐

IncidentDetail table ontains information about the incident and the damage.

IncidentStage

Column Name	Data Type	Allow Nulls
🔑 IncidentStaId	int	☐
Stage	nvarchar(50)	☐
Active	bit	☐

IncidentComment table contains static data on possible types of progress.

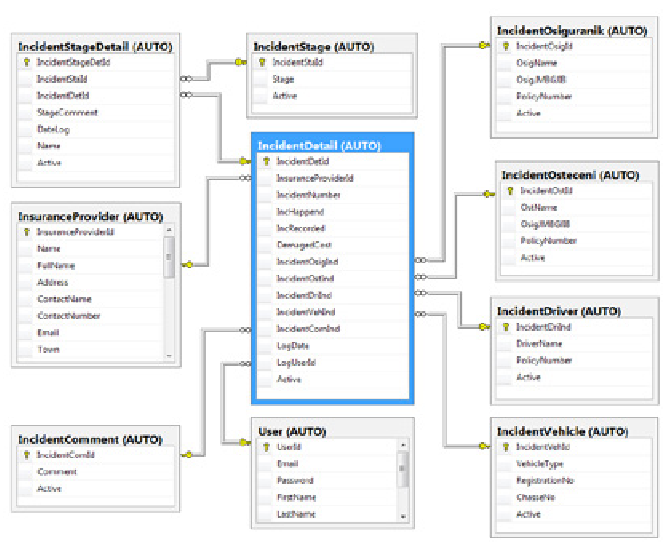
IncidentStageDetail

Column Name	Data Type	Allow Nulls
🔑 IncidentStageDetId	int	☐
IncidentStaId	int	☐
IncidentDetId	int	☑
StageComment	nvarchar(200)	☑
DateLog	datetime	☐
Name	nvarchar(50)	☐
Active	bit	☐

IncidentComment table sadrži podatke o progresu rješavanja incidenta.

IncidentComment table contains information on the progress of resolving the incident.

Database diagram and relationships between tables

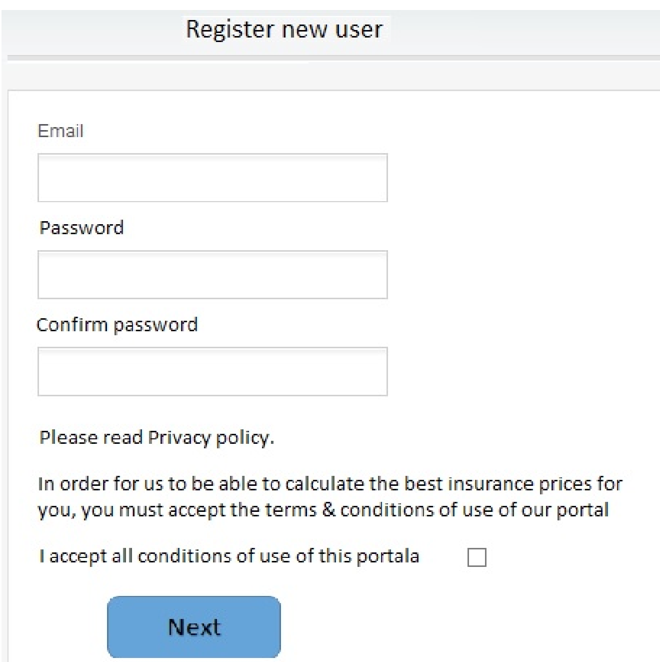


FRONT-END APPLICATION (APPLICATION DESIGN)

User Registration, Sign-In and Login

New user registration

Registration of a new user is a condition that the user of the application can access and use the application. When creating a 'username' and password, the user must have an active email address which will also be a 'username'. To register, the user should click on the 'Register' button:

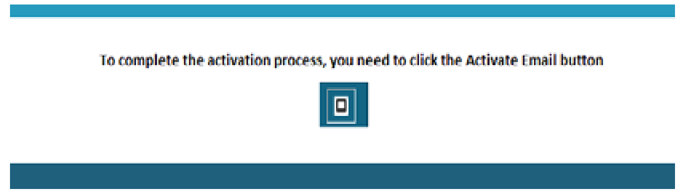


The registration of a new user requires the following mandatory fields:

a. Email
b. Password
c. Confirm new password
d. I accept the privacy policy and terms of use

Field	Field description	Fild type	Required field
Email	Email address must be active	Data field	YES
Password	The password must have at least one uppercase letter, one number and the rest of the letters.	Data field	YES
Confirm new password	It must be the same as Password	Data field	YES
I accept the privacy policy and terms of use	The user must click on the check box to accept the privacy policy and terms of use which can be read if the user clicks on the link below.	Check box	YES

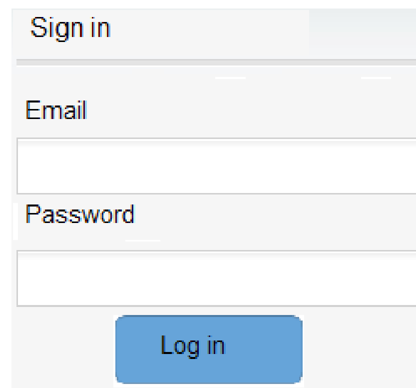
When the user clicks on 'Continue' the application will send an email to the user's address to activate the registration.



When the user clicks the middle button, the registration is complete and the user can use the application.

User login (log-in)

To log in, the user needs to feel requested fields and click on the 'Log in' button.

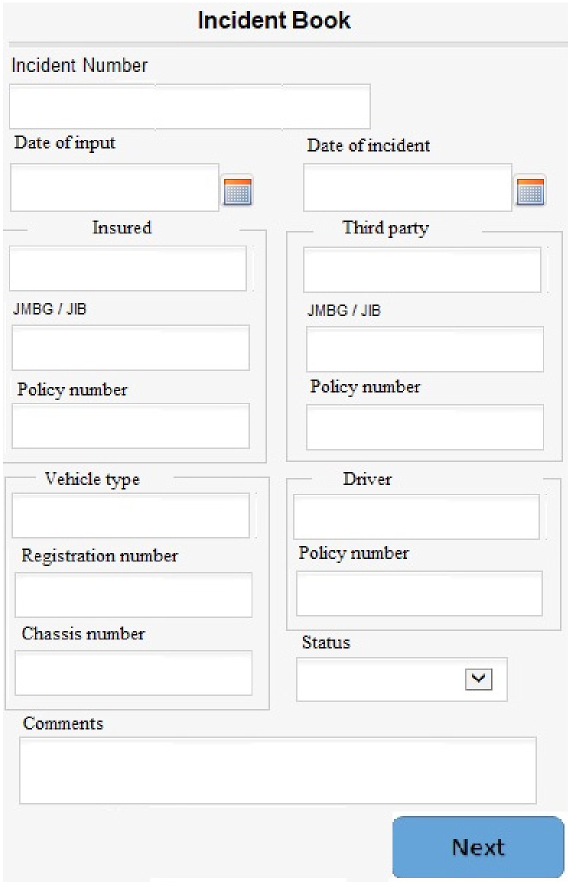


User registration fields:

Field	Field description	Fild type	Required field
Email	Email address	Data field	YES
Password	Password registered through activation app	Data field	YES

When the user logs in, the application will automatically recognize which insurance company the user belongs to and where the details of the incidents and damages will be related.

Cumulative Incident Book- Window for incident entry (damages)



All fields shown in the figure above for entering incident (damage) data must be the same as the fields in the database where each field must have the same data-type and length.

The status of the incident can be changed and each time a new status is saved in the table: IncidentStageDetail. JIMBG / JIB where the field-type numeric length is 13 digits long.

The Status could be:

- REGISTERED
- REJECTED
- REDEMPTED
- REGRESSED
- IN PROCESS

Processes when entering data in the Cumulation Incident Book:

1. The user of an insurance company may create, change and list all incidents, but only incidents related to his own insurance company.
2. When the user enters the data on the incident (damage) for the first time, the status will not be displayed on the window 'Cumulative incident book'. The system will automatically assign the status 'LOGIN'.
3. Change (update) incident data is possible only if the incident is in the status 'REPORTED'.
4. Only when the status of the incident is 'REPORTED' is it possible to change (update) all the data in the fields except the Status of the incident.
5. Search for the incident is possible through:
    a. Damage number
    b. Date of input (from date to date)
    c. Date of incident (from date to date)
    d. Name of the insured or JMBG / JIB
    e. Name of the third party or JMBG / JIB
    f. Insured policy number
    g. Vehicle / chassis registration number

When an incident is found, a new window will allow user to change the status of the incident.

6. Incident-related data cannot be changed if the status changes from status 'REPORTED'.
7. The new Incident Status is linked to the incident with the user's name and date of incident.
8. It is not possible to change the incident back to the status 'REPORTED'.
9. The system will automatically archive incidents and damages that are more than 5 years old from the date of the incident from the search date for incidents and damages in the Incident book.

REPORTS

Reports are usually made at the request of the user of the application with the principles to show the necessary results that are important for the further implementation of the process or presentation.

Damage report - IncidentReport_1

This report presents data on the damage found in the book of pests with the status 'REJECTED'.

Osiguravajuce_Drustvo	Broj_štete	Datum_prijave	Datum_prijave	Osiguranik	Osiguranik_JMBG_JIB	Osiguranik_Broj_polise	Oštećeni	Oštećeni_JMBG_JIB	Oštećeni_Broj_polise
Aura	MIP 5666666	2012-10-10	2012-10-15	Šegrt Simo	2202977104326	60010736	Lukic Duška	2202977104326	60010736

Registarski_broj	Broj_šasije	Vozac_vozilom	Vozac_Broj_polise	Iznos_štete	Napomena	Proces_incidenta
J69-A-258	VF7XS9HUC64221548	STANIŠIC CO D.O.O Bjeljina	17001285133	2900.00	Materijalna steta	REJECTED

Incident progress report (damage)– IncidentReport_2

This report presents data on the damage found in the Incident book including all incident statuses.

Osiguravajuce_Drustvo	Broj_štete	Datum_prijave	Datum_prijave	Osiguranik	Osiguranik_JMBG_JIB	Osiguranik_Broj_polise	Oštećeni
Aura	MIP 777766666	2011-01-29	2011-05-09	Obrenovic Mirjana	2510986158966	60010701	Peljto Muradif

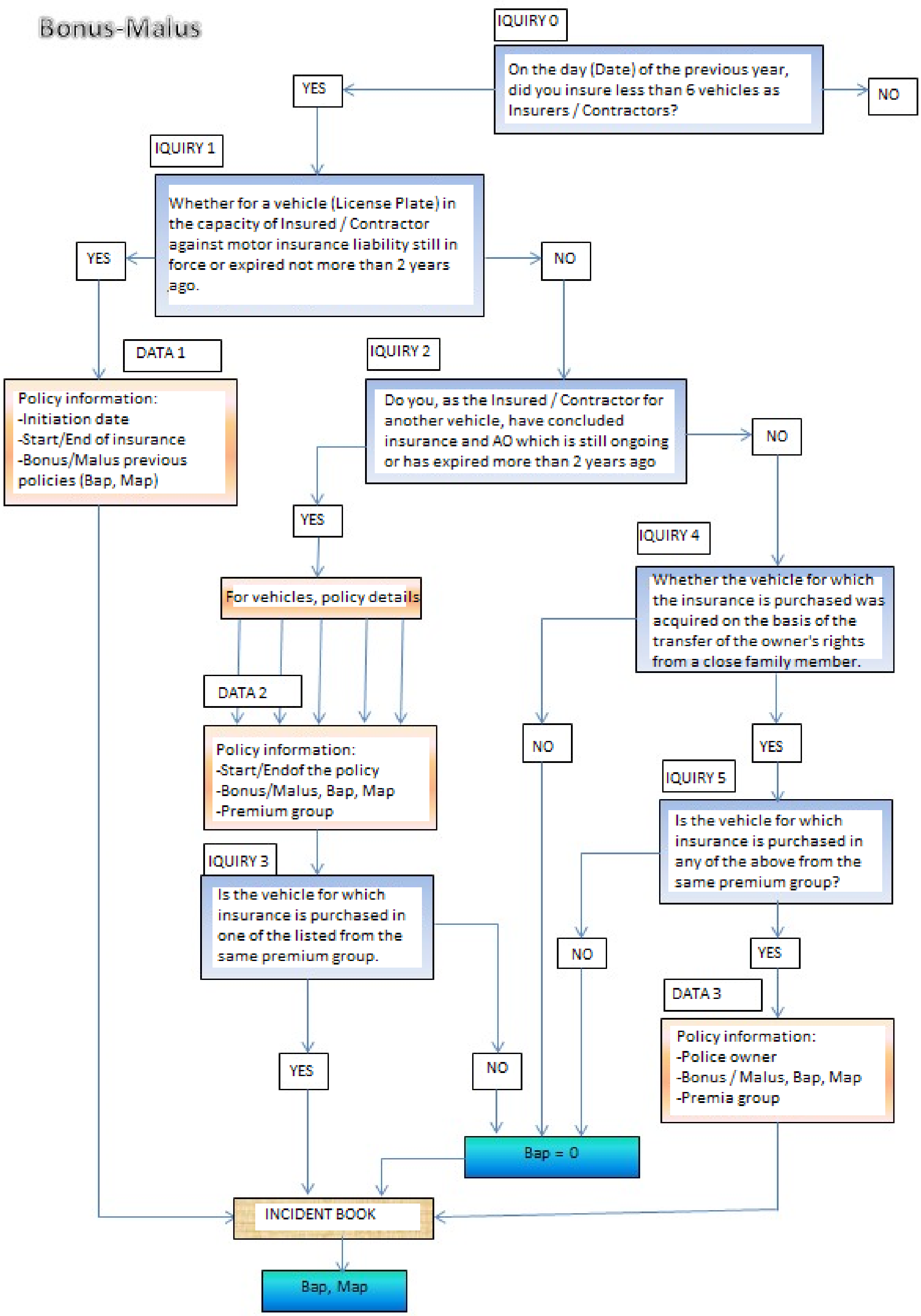
Oštećeni_JMBG_JIB	Oštećeni_Broj_polise	Registarski_broj	Broj_šasije	Vozac_vozilom	Vozac_Broj_polise	Iznos_štete	Napomena
2510986158966	60010701	A94-T-824	WKK32600001030968	Goran Maric	60010120	2900.00	Materijalna steta

Osiguravajuce_Drustvo	Broj_štete	Proces_incidenta	Log_datum	Log_ime
Aura	MIP 777766666	REGISTERED	2011-01-29 14:24:24.463	Rada Broz
Aura	MIP 777766666	IN PROCESS	2011-02-18 14:24:24.463	Ante Miric
Aura	MIP 777766666	REJECTED	2012-10-21 14:24:24.463	Mirsad Omeragic

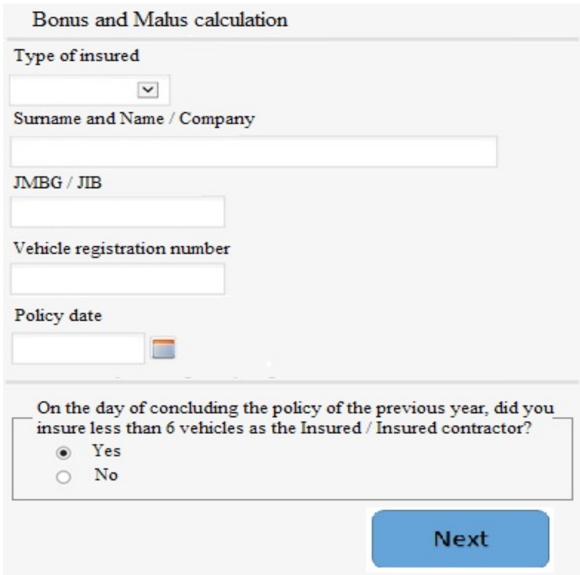
PROCESSES AND FLOW CHART (DIAGRAM) FOR CALCULATING MALUS AND BONUS

Process description and diagrams

Since AZOBiH and AZORS plan to exclude legal obligations for 6 or more vehicles, the process of calculating malus and bonus in this case will not be considered.



Bonus and Malus Calculation - Window for entering insured data and other necessary details for calculating malus and bonus



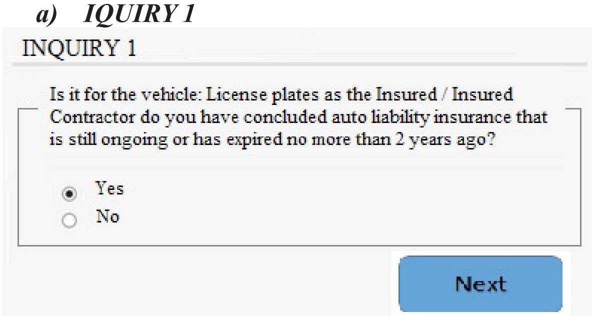
The type of insured person can be a person or a legal entity. If he is a person, then it is necessary to enter the JMBG number, otherwise the JIB number.

Collection of necessary data for bonus and malus calculation

The default will be the 'radio button' - Yes.

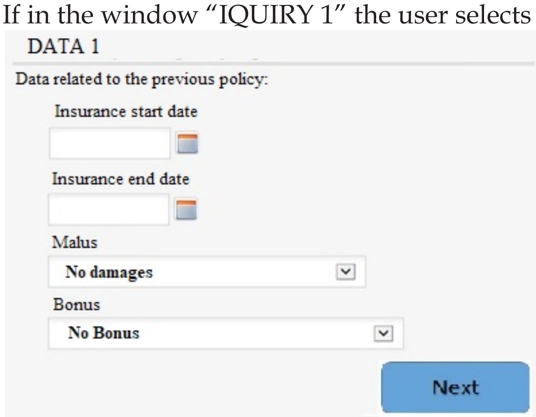
If the user clicks on the 'push-button' - Continue, the 'pop-up' window "IQUIRY 1" opens

a) IQUIRY 1



b) DATA 1

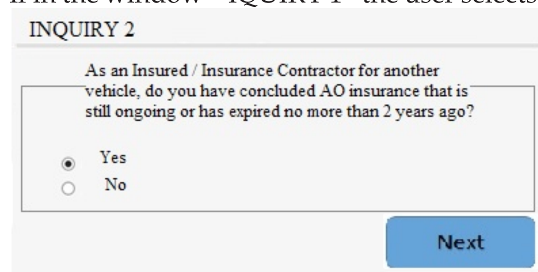
If in the window "IQUIRY 1" the user selects 'Yes'



After the window "DATA 1", the data in Incident book is searched and based on the found data, the calculation of the Bonus and Malus is performed.

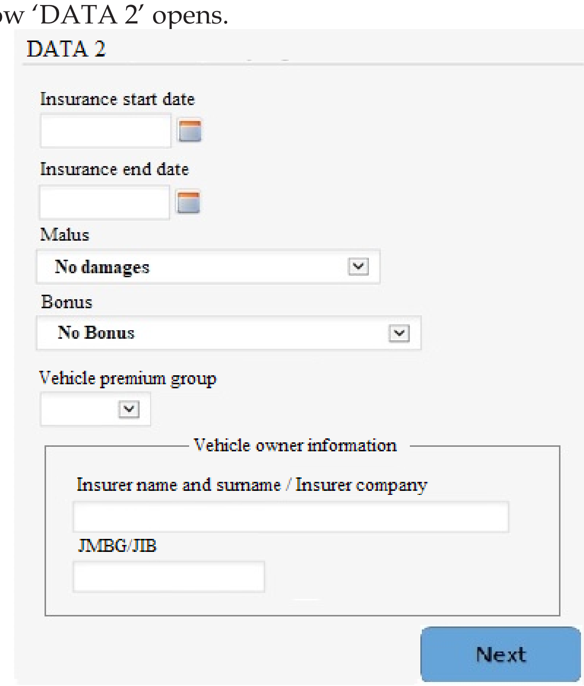
c) IQUIRY 2

If in the window " IQUIRY 1" the user selects "No".



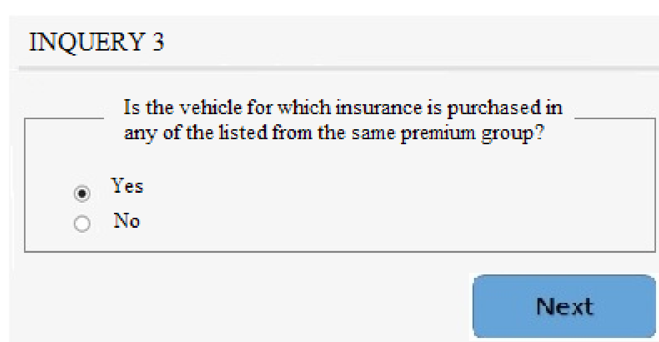
d) DATA 2

If the user has selected 'Yes' then the 'pop-up' window 'DATA 2' opens.



After the 'pop-up' window "DATA 2" the 'pop-up' window "IQUIRY 3" opens.

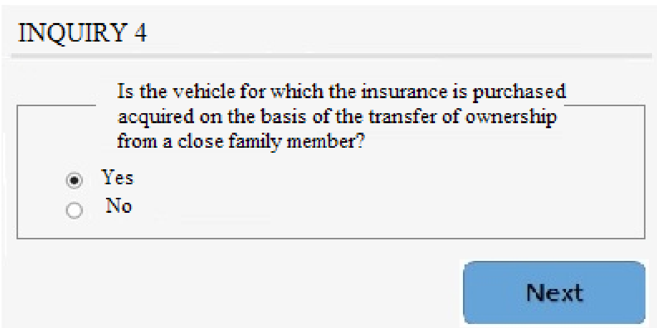
e) IQUIRY 3



If the answer is 'Yes', the data in the Incident book is searched and based on the found data, the calculation of Bonus and Malus is performed. If the answer is 'No', then the Bonus is zero (0) and the Insured is not entitled to the Bonus. In addition, the data in the incident book is searched and based on the found data, the calculation of Malus is performed.

f) IQUIRY 4

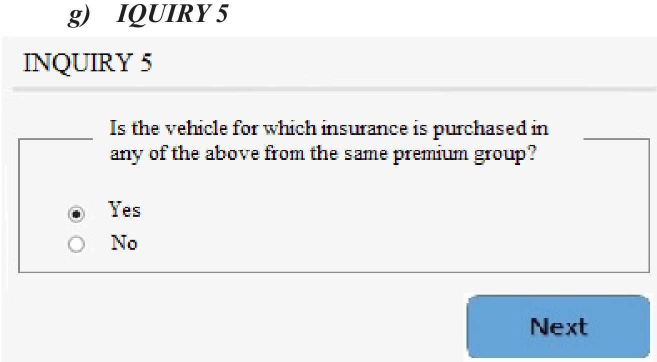
If the answer is 'No' in IQUIRY 2 then a new query 'IQUIRY 4' appears.



If the answer is 'No', then the Bonus is zero (0) and the Insured is not entitled to the Bonus. In addition, the data in the incident book is searched and based on the found data, the calculation of Malus is performed.

If the answer is 'Yes' then the 'pop-up' window "IQUIRY 5" opens.

g) IQUIRY 5



If the answer is 'No', then the Bonus is zero (0) and the Insured is not entitled to the Bonus. In addition, the data in the incident book is searched and based on the found data, the calculation of Malus is performed. If the user has selected 'Yes' then the 'DATA-2' pop-up window opens. After the window "DATA 2", the data in the incident book is searched and based on the found data, the calculation of Bonus and Malus is performed.

CONCLUSION

This scientific work (document) defines and summarizes the shortcomings in the existing system of manual search and determination of bonuses and malus in the records of insurers on damages (Incident book).

A new system model has been designed including:

1. Designing a database on Sql Server
2. Data update processes
3. Facilities for access to the system via the Internet
4. Data entry facilities necessary for the calculation of bonuses and malus

This new model is a system that uses a more modern approach in collecting, processing and accessing damage data. Thus, the new system eliminates existing shortcomings in the processing and inspection of insurer's claims records. Each insurance company has access to a central database via the Internet where it will enter and update insurer data on claims of its own organization. Every insurance company owns the same data. The insurance agency is the data administrator and thus provides a more effective way to monitor the data that insurance companies update. The update of the data is in real time, that is, the entry of new data is immediately after receiving the data on the damage. This eliminates the error in late entry of damage data and thus the accuracy of data in determining bonuses and malus.

Searching for data and determining bonuses and malus is enabled via the Internet, which allows insurance companies mobility and flexibility to use web services and access data remotely. The new system is completely flexible and through the Web service it is possible to use in other systems where parameters such as bonus and malus are required.

The database and processes for automatic bonus calculation are designed on Sql Server, which enables the purchase of insurance policies online.

In short, the new system provides the following:

1. Uniqueness and uniqueness of data for all insurance companies (data standard)
2. Centralization of data and the ability to access multiple users to the system at the same time
3. Accuracy of entered data and fast data search
4. Ability to monitor progress of incident resolution (Stage)
5. Ability to track who and when entered data on damages and incidents
6. Possibility of archiving damages and incidents that are not active in the process of determining bonuses and malus
7. Easier use of the system
8. Printing reports as well as printing evidence of bonus and malus
9. Access and search data via the Internet
10. Better data protection. Currently, the data is sent to the CD by mail or/and email.

LITERATURE AND WEB LINKS

[1] Information Technologies and Entrepreneurship of the University of Mostar, Dragan Mihic (Increasing the efficiency of the process of determining bonuses and malus in contracting auto liability insurance).

[2] Insurance Agency in BiH - http://www.azobih.gov.ba/

[3] Insurance Agency in RS – http://www.azors.rs.ba/azors/index.html

[4] Microsoft SQL Server Management Studio2012 - http://technet.microsoft.com/en-gb/

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UDC: 621.397-182.3:316.776

PRELIMINARY REPORT

Application of 5g Network to Autonomous Vehicle Mobility

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Abstract: General technological progress has improved all areas of human activity and especially effects are pronounced in the automotive industry. One of the new technologies, which promises a lot, is communication using the 5G network. Compared to its predecessors, 5G has many times greater capabilities and data transfer speeds. By applying the 5G network, vehicles will be connected to each other but also to the environment. With the help of 5G network and V2X communication, the vehicles will be enabled to communicate with other vehicles and exchange telemetry data, but also to "see" through the vehicle in front of it. The full application of these technologies will bring many advantages, but disadvantages are to be expected aswell.

Keywords: 5G network, V2X communication, autonomus vehicles.

INTRODUCTION

Today, we have a 5G network in use, which will further improve all management functions and enable a complete interaction between the vehicles themselves and their connection to the environment. Increased data transfer and processing capabilities will contribute to faster response of the vehicle system to disturbances and corrective actions. In such a way, the safety of the use of these systems and driving itself will increase, which at this time is still insufficiently protected from the influence of third parties or systems.

Appreciating the desired goals, there will be many benefits that these technologies bring, but they will not pass without unintended consequences. Given that the driver is the focus of research that will be conducted, it is important to try to assess the effects from the point of view of future safety, comfort and disturbances in the labor market.

5G NETWORK

5G is a fifth generation mobile network. It is the new global wireless standard after 1G, 2G, 3G and 4G networks.

5G refers to the fifth generation mobile communications network and is therefore a direct successor to LTE or Advanced LTE (4G) and UMTS (3G). The new standard aims at higher data rates, improved capacity and an intelligent network.

5G uses a system of cells that divides space into sectors and sends coded signals between access points using radio waves. Each cell must be connected to the main network, either wirelessly or via cables. [1]

The ITU Standardization Body has defined the specifications, that 5G must meet the IMT-2020 standard [2]:

- Maximum data transfer speed: 10 - 20 Gbit / s
- Peak spectral efficiency: 10 - 30 Gbit / s / Hz
- User data transfer speed: 50 - 100 Mbit / s
- Latency less than 1 ms
- Connection density: 1,000,000 devices per km^2
- Network availability 99.999%
- Almost 100% coverage
- Battery life of IoT devices up to 10 years.

The biggest advantage of 5G technology compared to its predecessors is the much higher data transfer speed. In the future, television broadcasts could be broadcast online without delay from multiple perspectives. Smart cars can share their telemetry data with each other and prevent accidents. Briefly: data speed is growing, the number of devices in the network is growing exponentially, and at the same time latency and load time are decreasing.

The beginning of the application of mobile communication technologies dates back to 1979 and the first, 1G network that enabled the development of analog telecommunications. With the 2G network, the commercial era of mobile communications technology began in 1991, enabling the transmission of speech and short text messages with limited data traffic. The next leap in the development of this technology occurred in 1998, when a more serious Internet access was achieved with the help of the 3G network, and since 2008 the 4G network has contributed to achieving even faster Internet access. This has enabled the transmission of content that requires better transmission network performance, such as e.g. videos.

5G is a new generation of mobile communications networks whose application is tied to 2019. The 5G network uses the resources of existing technology but also brings great improvements. The 5G network provides significantly faster Internet access and interconnection of a large number of connected devices (picture 1.). In addition, the 5G network allows very secure and efficient communication with low latency and allows the so-called "Network slicing", i.e. the allocation of transmission resources according to established priorities. This will be of great importance for future Internet of Things (IoT) or special services.

Picture 1. 5G network, illustration

However, the 5G network also has drawbacks. Due to the high frequencies used for transmission in the 5G network, the number of transmission poles must be significantly increased. Costs - both for network construction and for operation - are likely to be higher than costs for 4G networks due to higher pole density. Extensive network coverage tests, quality assurance and integration into existing infrastructure are also required for commissioning. Successful installation and commissioning of the national 5G network first of all requires time and money.

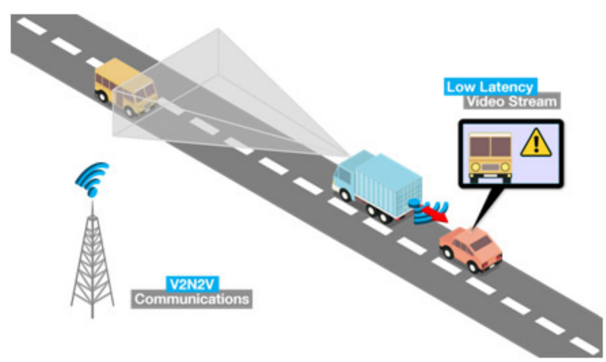
VEHICLE AND ENVIRONMENT CONNECTION IN ROAD TRAFFIC USING 5G NETWORK

Widespread use of autonomous driving is still not a reality and will require a reliable, robust and extended wireless network. Promising high data rates and very low latency, 5G is the future of autonomous vehicles. With the implementation planned as early as 2020, vehicle communication or V2X communication (Vehicle-to-Everything) will enable vehicles to interact in real time with their environment to increase road safety, traffic efficiency and energy savings (picture 2.).

Picture 2. V2X communication

Two main use cases illustrate the potential of 5G technology to improve vehicle connectivity via mobile networks: the self-explanatory "emergency vehicle approach warning" and the "transparent" use case, which allows drivers to see through the vehicle [3] (picture 3.).

The "Emergency Vehicle Approach Warning" aims to warn the driver that an ambulance is approaching even before it is visible because it is either too far or it is on an adjacent road. In order to do this, the connected ambulance sends its position to the server via its mobile router, which will show whether its emergency lights are activated or not. The server redistributes an ambulance position message to nearby vehicles, which then warn its drivers of its position if the emergency lights are activated.



Picture 3. Case of using 5G network

Another use case developed during the Towards5G partnership allows the driver of a vehicle to see "through" a vehicle in front of him that obstructs his view, which can help when overtaking, for example. To achieve this, a vehicle equipped with a high-definition camera connected to a mobile router can transmit a video stream when automatically requested by the mobile router of a vehicle that is behind. The video stream is then transmitted over part of the vehicle using a local interrupt, ensuring low latency.

The main limitation of the case of use in this form is the fact that is uses high bandwidth. However, the advantage is that it provides an incredibly visual display of vehicle performance at low latency while maintaining speed, compared to the mobile broadband limit, which is the first to be affected by any deterioration in radio and network performance.

"Lane connection" is used to assist an autonomously connected vehicle when connecting to a double carriageway or highway. This is made possible by the "traffic orchestrator", an application module located on the network and connected to a V2X server. It collects information on the positions and dynamic parameters of vehicles on the highway and suggests routes for vehicles to be connected as well as those within the connection zone in order to optimize the free flow of traffic and facilitate connection.

While connected vehicles permanently tell their position to the V2X server and are therefore taken into account by the orchestrator, unconnected vehicles detect smart cameras arranged around the junction zone and detect the positions of all vehicles. To do this, they use image processing techniques that rely on artificial intelligence. Data from these cameras is then sent to a V2X server, where the data fusion module compares them with data compiled by connected vehicles to avoid duplication.

APPLICATION OF 5G NETWORK TO AUTONOMOUS MOBILITY

Autonomous driving is considered a paradigm shift, but technically it is an evolutionary process. Prerequisite is the presence of sensors (radar, video, laser) and actuators (in engine control, steering wheel, brakes) in the vehicle. Autonomy is provided by computers in the car, which connect sensor data, form an image of the environment, automatically make driving decisions and pass them on to actuators. Machine learning is often used to handle large amounts of data, for example when recognizing traffic signs, before it is implemented in vehicles. Media theorists call for a broader social dialogue on the effects of autonomous driving, especially in situations of dilemma when the trip computer can no longer avoid damage, but must assess the damage - basically an ethical decision. [4]

Enabling even faster connectivity between transportation systems, the 5G network will offer new application options that enhance the development of autonomous cars. Not only will they be able to make decisions independently in the future, but they will also communicate and cooperate with each other. Automatic driving is a term used to describe scenarios in which, as a result of these possibilities, a fully interconnected and intelligent road transport system is created.

5G transmits huge amounts of data without interruption - as long as the network is firmly connected. Exactly these are the prerequisites for autonomous driving: fast, reliable communication networks and seamless data transmission. The car must be able to receive all safety information at all times. This is the only way to ensure safety while driving autonomously and avoid accidents. Only then can artificial intelligence (AI) take over the ride itself with the help of networked sensors and communicate completely reliably with other road users. Traffic jams would also be a thing of the past. The necessary technical standards are currently being fiercely debated and must be precisely defined.

Thanks to wireless technology and internet connection, connected cars with their digital and location-based services can greatly improve our driving comfort. The car relies on regular updates of navigation data, e.g. detailed roadmaps, plus updates in unexpected traffic situations such as congestion, rain or ice. Combined with driver and cloud applications, maintenance information or other status reports can be downloaded and sent. Thanks to mobile edge computing, these functions have already been implemented today, based on LTE at speeds of up to 300 megabits per second and latencies of less than 100 milliseconds, even in emergencies or remotely controlled driving at low speeds. 5G will offer even greater quality for many in-car digital services in the future.

Fifth-generation wireless technology will be a key trigger of more reliable communication for vehicles, which will play a key role in managing the safety challenges that come with vehicle automatization and autonomy. There are more, often complementary technologies that can be used for both direct and network-based communication - including 4G / LTE, satellites, DSRC and 802.11p.1 5G will significantly reduce latency and increase reliability compared to current technologies, enabling new use of cases such as route sharing, local real-time updates and coordinated driving. The application of these technologies will create conditions for additional progress in the development of intelligent transport systems.

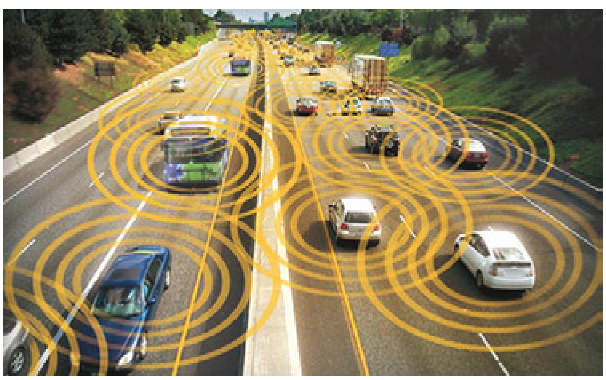
Automatic systems reach their limits when unexpected or unknown situations arise. In that case, the "autopilot" will decide to deactivate the system for security reasons, if in doubt. The autopilot would then return the task and responsibility of driving to the driver himself. However, if the driver does not take control of the vehicle, or not as fast as needed, then the car will pull to the edge of the road in safe driving mode.

With 5G, the car could, for example, be remotely controlled by an outside operator acting as a traffic controller. Remote control via operator, however, is definitely impossible without a 5G network, which offers key features such as very short response times and guaranteed network resources.

One huge advantage of 5G is what is known as network cutting. The wireless network is divided into virtual network levels. One level of the network is then used only for automatic driving, for example. This ensures that notifications related to the safety of self-driving cars do not end up in traffic jams on highway for data transfer and that they are given priority over other infotainment services used parallel.

Another advantage is the processing and storage of data in data centers that are close to transport routes. Such "edge" data centers ensure that data can be processed even faster on the network.

The sensors are used to implement car-to-car communication for automated driving. This includes, for example, intelligent camera and radar systems (picture 4.), which allow direct data exchange between cars. However, these systems have key physical deficiency. They can neither look around corners, nor over hills, nor through obstacles. That is why they limit the work of self-driving cars. This simple form of automatization is also inappropriate at higher speeds.



Picture 4. Communication between vehicles

Mobile technology expands the scope of autonomous mobility through direct and, above all, fast and broadband data communication with cars and properly equipped transport infrastructure, such as traffic lights. This can ensure improved traffic flows, for example by allowing cars to travel at higher speeds or reducing their speed at times when needed.

CONCLUSION

Automatic driving has already started with assisted driving. However, vehicle automatization is gradual. Fully automated driving, which can work reliably in a large number of driving situations, is only the final stage of a long process.

The functions of the autonomous car steering system are already partially performed by driver assistance systems, such as steering and lane keeping assistants. Nowadays self-parking cars are already available. Despite these assistants, it is the driver who remains responsible at all times. However, if the vehicle is fully automated, the responsibility is shifted from the driver to the means of transport, and thus to its manufacturer or operator. That is why, many automation functions will initially be limited to driving situations that can be sufficiently controlled, such as driving at low and medium speeds on motorways or parking in a demarcated parking space.

People use automated functions in their everyday lives mainly to save time, which can then be used in a more meaningful or convenient way. So in the future - as ordinary passengers in self-driving cars - using mobile networks, we will surely be able to read the latest news on our smartphones or tablets, participate in video conferences or work, use entertainment services or shop online while on the go. Or we could simply sleep while driving to arrive at our destination rested or come to a business meeting refreshed and relaxed.

In addition to all the benefits that these technologies bring, the risks that accompany complex systems and are related to the reliability and protection of the system should be faced.

Nevertheless, the development and application of advanced autonomous driving technologies will cause drastic changes in the labor market in the future. From the current situation, when there is a chronic shortage of professional drivers, it will happen that drivers will no longer be needed at all, so the driver will disappear from the list of occupations.

REFERENCES

[1] [1] Pisarov J.; 5G i samovozeći automobili, Inovacije u modernom obrazovanju, Zlatibor, 2020.;

[2] [2] Bruno Gransche e. a.: Wandel von Autonomie und Kontrolle durch neue Mensch-Technik-Interaktionen. Grundsatzfragen autonomieorientierter Mensch-Technik-Verhältnisse;

[3] [3] Ilić, Ž., Šišul, G., Janković, J.: Mobilne mreže – 4G, 2019.;

[4] [4] Bajić B., Talijan D., Nedić B.; Razvoj sistema za automatizovanu vožnju, 5. konferencija „Ka održivom transportu 2017, Zlatibor, 2017.;

[5] [5] URL: https://hellofuture.orange.com/en/5g-and-connected-vehicles-communication-and-cooperation/;

[6] [6]URL:https://www.etsi.org/deliver/etsi_en/302600_302699/302663/01.02.00_20/en_302663v010200a.pdf

[7] [7]URL:https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx

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UDC: 629.3:621.43

REVIEW

New Phase of Motor Vehicle Development

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Abstract: 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. Although electric vehicles have become an absolute priority in some countries, their global expansion is happening and it is to be expected that they will become a near future in these regions as well. Today, special attention is drawn to advances in the development of autonomous driving systems, which will cause many changes in design, regulations and the environment. For the coming wave of change, we need to be adequately prepared and take part in global processes. In addition, it should be noted that the futuristic versions of vehicles capable of moving in multiple environments, on land, on or in water and in the air, are being widely promoted, and the EU is introducing mandatory application of some active and passive safety systems.

Key words: vehicle development, electric vehicles, automated driving.

INTRODUCTION

Until the advent of the mobile phone, the car was the most commonly owned item. Today, it is estimated that there are about 1.5 billion vehicles in use on Earth, which means that every fifth inhabitant owns a vehicle. The development of cars was conditioned by development of technology, materials, energy, legislation, etc. The result of this is that almost every manufacturer has vehicles on the market in every segment. The period of the development cycle of the new type is decreasing and the number of manufactured vehicles is increasing. Although the vehicles look alike, out of 100 vehicles of the same type and model, only 5 completely identical vehicles will come off the production line. The new generation of luxury models has up to 70 different computers that control the operation of vehicles or serve for assistance purposes. This diversity indicates that many vehicle functions are related to modern information technology and computers. The role of the driver will become less and less important and driving comfort becomes greater. The autopilot has long shown its superiority over the professional driver. Already today in the serial offer we have vehicles with automated driving systems, so the question arises when the vehicle will definitely become self-driving in mass use. Models of vehicles that have the ability to move on the roads and in the air are exhibited at the fairs. What lies ahead in near future? Shall we, soon, only remember, with sadness, vehicles with conventional mode of operation and driving?

FROM THE FIRST CAR UNTIL TODAY

The first car is associated with Karl Benz and his construction of the first functional type of vehicle, which had all the basic construction systems as well as today's vehicles: body, drivetrain, engine, steering system, braking system and light signaling devices.

It is interesting to recall some important dates from the automotive industry and the dynamics of development of individual devices:

- 1828 Electric motor
- 1832 First electric car
- 1878 Gasoline internal combustion engine
- 1886 First car with gasoline engine
- 1897 Diesel internal combustion engine
- 1895 First tire
- 1918 Electric starter
- 1924 Integral body
- 1924 Hydraulic brake
- 1928 Synchronous transmission
- 1939 Automatic transmission
- 1947 Radial tire
- 1953 Disc brakes
- 1950-60 Fuel Cells
- 1974 Anti-lock- braking (ABS) system
- 1980 The reduction of exhaust emissions
- 1990 Start with application of computers in the automotive industry
- 1997 Hybrid vehicles

Time will tell in which direction the development of the vehicle is heading, in terms of propulsion energy, assistance system, automatic control and combination of modes of transport, and this paper will present some forecasts of the future development of vehicles and their systems.

DEVELOPMENT OF ENGINES

Exacerbated problems of environmental pollution, the greenhouse effect, uncertainty regarding oil reserves and the development of innovative technologies have contributed to the fact that today very intensive work is being done on improving existing engines and developing alternative motor vehicle propulsions.

Conventional propulsion

Internal combustion engines have experienced absolute dominance as a propulsion system for motor vehicles after resolving "children's diseases" and after the discovery of oil. Although the basics of internal combustion engine construction are based on solutions that are over a hundred years old, various innovations are still very successfully applied to them, which enable higher specific power, lower mass, better traction and speed characteristics, etc. The period of their domination lasted from the first vehicle until today, but alternative modes of propulsion are rapidly developing, which could soon suppress internal combustion engines, especially as the basic variant of motor vehicle propulsion.

Hybrid propulsion

Hybrid propulsion involves a combination of several types of propulsions. Until recently, such vehicles were produced only for military purposes, but today we have a wide range of very successful solutions of combined types of propulsion on the market. For now, the internal combustion engine and the liquefied petroleum gas are most often combined, and more recently the electric motor, in various variants and versions. The combination of internal combustion engines and electric motors utilizes the best characteristics of both drives, reduces pollution, reduces noise, and makes driving cheaper and so on.

Electric vehicles

It is interesting to mention that the electric vehicle was made about 20 years before the first vehicle powered by an internal combustion engine, but a number of circumstances have contributed to their actual affirmation in the last twenty years. Today, all major manufacturers have serious plans and are allocating large funds for the development of electric vehicles. We already have an enviable offer of electric vehicles whose motor is powered by its own battery. It is considered that fuel cell vehicles are the vehicles of the future, but much remains to be done to improve the design, although we already have fuel cell vehicles in serial production. How fast the development of electric vehicles is progressing can be seen in the behavior of some manufacturers, who have already stopped producing vehicles with conventional propulsion.

DEVELOPMENT OF VEHICLE STABILITY SYSTEMS

With the advancement of science and technology, manufacturers place on the market vehicles with very respectable speed performance, which poses a very delicate task for designers, how to tame a vehicle in some situations and adapt it to the average driver. Development of Anti-lock braking system (ABS) has created a ground basis for the construction and application of other systems that have become mutually complementary.

Electronic Stability Program

Electronic Stability Program ESP is tasked to neutralize the influence of the centrifugal force that causes inclination of the vehicle when driving in a curve. It is also called the dynamic stability program because with targeted action on individual brakes, and engine mode, it maintains the dynamic stability of the vehicle. ESP includes two main functions DSP (dynamic stability system) and ROP (rollover protection). DSP takes care mainly of the vehicle's stability at a lower coefficient of adhesion (e.g. rain, snow, ice). As a rule, it is activated only when there is a significant difference between the driver's desired direction of travel and the actual movement of the vehicle. Roll over Prevention (ROP) reduces the risk of rolling over with a high coefficient of adhesion on dry road.

Anti-slip regulation (ASR) system

This system should prevent the drive wheels from slipping in conditions of reduced or uneven grip, such as wet surfaces, ice, gravel, etc. The system is regulated by acting on the individual brakes and the engine operating mode.

Electronic brake force distribution system

The role of this system is to prevent the rear wheels from braking too hard before the anti-lock brake system is activated or when it is out of order.

Electronic differential lock system

The electronic differential lock allows driving on different surfaces, i.e. under different traction conditions, by activating the brakes on wheels which are slipping.

Engine Braking Control System (EBC)

This system prevents the driven wheels from locking due to engine braking when the accelerator pedal is released suddenly or when vehicle is braking with any gear engaged.

THE DEVELOPMENT OF THE ASSISTANCE SYSTEMS

The development of electronics has made driving as comfortable and safe as possible. We are assisted in this by various driver assistance systems, which warn, restrict and help him/her perform certain actions while driving. To illustrate, a few commonly used ones will be mentioned.

Panoramic view monitor

The panoramic view monitor, which shows the vehicle from a bird's eye view, has been enhanced with a view that "sees" through objects. At the touch of a button, the driver switches between a bird's eye view and a see-through view, which allows the driver to see the vehicle's surroundings as if the vehicle itself were transparent. Compared to the bird's eye view, the see-through view makes it easier to spot obstacles, as they are more clearly displayed on the monitor.

Active parking assist system

The parking assist system facilitates parallel and lateral parking of the vehicle. Whether activated or not, the system measures potential parking spaces as you pass them at low speeds (up to 35 km/h) at a maximum distance of 1.5 m from the row of parked cars. When a large enough space is found, the driver turns on the turn signal and the auxiliary parking device takes control of the vehicle, while the driver takes care of speed, brake and transmission. The system gives instructions on the control monitor and acoustic signals during parking. More advanced parking systems can do parking without driver assistance.

Parking support

When leaving the parking space by driving backwards, you get support for continuous monitoring of the road behind the vehicle via a sensors in the rear bumper. The support system provides visual and acoustic warnings when obstacles such as pedestrians, other vehicles or obstacles occur. In an emergency, automatic brake control prevents a collision.

Reversing cameras

Rear cameras allow the driver to see the area behind the car while maneuvering or parking with assistance of the control monitor. Reversing cameras also improve visibility when reversing at lower speeds. Vehicle guidance lines and color-coded obstacles, which appear on the control monitor, show the driver whether the selected parking space is long and wide enough for the vehicle and makes parking easier. Ultrasonic sensors constantly measure the distance between the car and the obstacle and the acoustic signal warns of possible dangers and thus reduces the chances of damage when parking.

Cameras for driving in conditions of reduced visibility

These cameras provide drivers with an overview of the situation on the road, outside the limits of normal visibility to the eye, at night, driving in fog and in other situations when visibility is reduced.

The adaptive cruise control

Adaptive cruise control (ACC) automatically regulates vehicle speed and distance from the vehicle in front. Automatic cruise control automatically brakes prematurely, if necessary, and maintains a safe distance between vehicles. This prevents sudden braking, which can cause another vehicle to crash from behind. Radar cruise control, in addition to maintaining the distance between vehicles, when the vehicle in front accelerates or moves away, reacts and car accelerates again to the desired speed. In cooperation with the Stop & Go function, it also helps in traffic jams or in conditions of slow traffic, automatic stopping and starting the vehicle.

Start-Stop (Go & Stop) system

The task of the start/stop system is to automatically switch off the engine when the vehicle is stationary. The engine is switched off as soon as the foot is removed from the accelerator pedal and switched on with a next pressure on the accelerator pedal. In this manner, fuel is saved and environmental pollution is reduced.

Lane Keeping System

This system warns of lane departure by detecting lane lines and alerts the driver to accidental lane changes when the vehicle reaches a certain speed, via an audio signal or steering wheel vibration. The system will not activate if the lane change is intentional, when the driver activates the turn signal.

Traffic Signs Recognition System

A camera housed in the interior mirror registers traffic signs with speed limits and overtaking restrictions and displays them on the instrument panel display. In this way, the driver is more focused on driving than on remembering signs because he/she knows at all times how fast he/she is allowed to drive and whether overtaking is allowed.

Blind spot detection system

This is a device that monitors side and rear of the vehicle and warns driver with a light or sound signal of the vehicle which is in a blind spot. The system is especially useful when changing lanes or on roads where several vehicles are moving in parallel.

Brake Assist System (BAS)

It is an additional system to ABS which helps reduce vehicle stopping distance while sudden braking. This system recognizes a situation where sudden braking is required. In this case, the system is currently developing its maximum power and may include ABS adjustment.

Emergency Brake Assist (EBA)

The Emergency Brake Assist system (EBA) makes vehicles even safer and reduces the risk of accidents. The system combines information from radar sensors and cameras in the front of the vehicle, which enables faster detection of dangerous situations and timely activation of emergency braking. On this occasion, in addition to the brake lights, the Emergency Stopping Signal (ESS) is activated, which warns road users with flashing lights with increased blinking frequency to a critical situation, thus reducing the risk of collisions.

Hill-Hold Control

Hill-Hold-Control allows vehicle to start going uphill without reversing the vehicle and without applying the parking brake. Also, when the brake pedal is released after stopping on an uphill, the uphill support will maintain pressure in the brake system for 1 to 2 seconds, long enough to continue relaxed driving without rolling the vehicle wheels backwards.

Pedestrian alert system

Pedestrian alert system, with soft braking function, reacts to pedestrians and operates at speeds between 10 and 60 km/h and emits a warning in the event of imminent danger. In the event of a danger, the system initiates braking and thus reduces the speed at which a collision can occur. The system works in steps - the warning symbol appears first, then the symbol starts flashing and a beep sounds, and finally a slight braking occurs.

Automatic adjustment of headlights and wipers

Adaptive headlights are very sophisticated. They work by monitoring the position of the steering wheel, vehicle speed and its inclination, and based on that headlights direct the light beam in the direction of the road, and not directly, like classic headlights. Additional, somewhat less demanding technological device that helps in better visibility is the rain sensor connected to the windshield wipers. If moisture is detected, the sensor turns on the wipers, and at the same time, depending on the amount of moisture, determines the speed of wiping.

High beam assist

High beams are automatically switched from high to low beams and vice versa, depending on the traffic situation. When the system is active, a camera installed on the inside of the mirror monitors the traffic situation and assesses the brightness, i.e. determines when the high beams should be switched on. When the vehicle is approaching from the opposite direction or when the exterior is sufficiently well-lit, the system automatically switches off the high beams.

Intelligent Shock Absorbers

Continuous Damping Control (CDC) calculates the required shock absorber power each time, depending on vehicle load and road characteristics, when braking or slipping during driving in curves or on hills. The control unit continuously regulates the solenoid valve which determines the flow rate of oil in the shock absorber. Height and pressure sensors provide data for the calculation and the system also has information on driving speed, deceleration and acceleration, lateral acceleration and wheel speed. The CDC adjusts normal attenuation to new circumstances measured in milliseconds. By continuously recording data on wheel position, bodywork and shock absorber stroke, this system can react extremely quickly to sudden traffic situations. Thus, the vehicle adapts to the requirements of the road section and its own driving style by stabilizing damper and brake parameters.

Driver fatigue detection system

During long journeys, reduced concentration and driver fatigue have a negative effect on the handling of the steering wheel and the time it takes for the driver to react. Precise motor skills are deteriorating, steering wheel handling is no longer so accurate, and the driver has to manage the steering wheel more often. The fatigue recognition system algorithm analyzes the driver's handling of the steering wheel at the beginning of the ride and thus recognizes the changes that result from further driving and driver fatigue. This function calculates the fatigue index based on the frequency of such typical steering wheel corrections, but also other parameters such as driving time, use of turn signals and time of day.

Tire pressure sensor

The tire pressure sensor provides information on whether or not the tire pressure is adequate, which can affect wheel grip and brake system performance.

Emergency call system (E-call)

E-Call or emergency call system is a novelty that appeared in the car market and will be mandatory for all cars made after April 1, 2018. E-Call will work on the same infrastructure throughout Europe. The system itself will call the call center, where it will report key information about the accident (location, direction, type of vehicle and number of passengers in the vehicle), and at the same time will establish a telephone connection between the center and the vehicle. The system is expected to shorten the emergency response time.

The system for navigation

Modern navigation system offers drivers the design in full 3D, in combination with the innovative concept of interface and numerous functions for navigation, office and multimedia. Navigation systems support the quick start function, fast calculation and route selection, individual counseling to reduce fuel consumption, selection of alternative tours, detection of obstacles on the road, etc.

MODERN PHASE OF MOTOR VEHICLE DEVELOPMENT

If we look back at the development of cars through the development of car systems, we could see that the design of the first car had 100 years of development and improvement of basic systems that functioned mainly on the principles of mechanics.

The first use of electronics in motor vehicles, when the seat belt was electronically supported in the United States, laid the foundation for electronic systems that were then used to develop systems that regulate fuel injection, control pollution from exhaust emissions and later on many other systems.

The development and application of computers progress has definitely enabled in the development of all systems on the vehicle, which has contributed to greater comfort, greater safety, better speed and traction characteristics, reduced fuel consumption, reduced pollution, etc. Modern vehicles of high class, can have about 70 computers that perform various functions, perform process optimization, manage the vehicle, provide support to the driver through assistance systems, etc.

Due to the specifics that automated driving systems will bring when showing on scene in the last phase of the development of fully automated driving, this phase of development could be called a special, modern phase of vehicle development.

The phases of development could be classified as follows:

Phase I: Perfecting the basic systems on the vehicle
Phase II: Application of electronics in vehicles
Phase III: Application of computers in vehicles
Phase IV: Autonomous vehicles

Appreciating the importance of the development Phase IV, the development of this phase will be explained separately, from the aspect of technical requirements and legal regulations.

Development of automated driving systems

Among all the technological innovations, automated driving system has drawn special and great attention. Although some elements of this system are already available to drivers, through some forms of assistance, it is expected that this system will bring major changes in all spheres, because its full implementation will require adjustment of traffic infrastructure and especially legal regulations both internationally and nationally.

For many years, the term "Advanced driver-assistance systems" (ADAS) has been in use, which in general, performs its function by collecting and processing information received from the vehicle sensor, regarding the characteristics of the vehicle relevant for its behavior (stability, handling), as well as monitoring and detection in the environment of the vehicle itself, and evaluation and processing of collected information. This also includes the option to collect and evaluate information from the transport infrastructure, if available. The systems have been developed to support drivers in performing their driving tasks and improve traffic safety.

Recently, there have been very intensive activities on creating premises for the development and wider application of automated driving systems, i.e. systems capable of performing some or all of the driver's dynamic tasks. Full implementation of these systems is planned to take place in five steps. Table 1 will present the distribution of responsibilities between the driver and the system depending on the category of the automated driving system.

Vehicles in which the driver performs all dynamic driving tasks are, from the aspect of driving automation, **conventional vehicles** - vehicles without automated driving system.

The first group of automated driving systems will be those in which the perception of objects and events in the environment, and the response to them, will be the responsibility of the driver. Within this group, two categories of systems have been singled out.

The Category 1 automated driving system (Driver assistance) takes over part of the driver's dynamic tasks, whether controlling longitudinal (acceleration/deceleration) or transverse (turning) vehicle movement, but not both at the same time.

The Category 2 automated driving system (Partially automated driving), when activated within the designed operational area, should perform the tasks of controlling longitudinal and transverse movement of the vehicle. Category 1 and 2 systems are expected to have

Table 1. Automated driving systems

System Category	System Name	Longitudinal and transverse movement	Environment observation	Reserve option
0	Not automated driving	Driver	Driver	Driver
1	Driver assistance	Driver + System	Driver	Driver
2	Partially automated driving	System	Driver	Driver
3	Conditionally automated driving	System	System	Driver
4	Highly automated driving	System	system	System
5	Fully automated driving	System	System	System

limited ability to detect objects and events in the environment and respond to them. Therefore, in the case of vehicles equipped with systems of these categories, there will be expectations for the driver-person to constantly perform all dynamic driving tasks not performed by the system, to assess when it is appropriate for the system to be (de)activated, to monitor the environment, to monitor the system (execution of the driving tasks) and immediately intervene when necessary due to environmental events or system requirements, and, when necessary, immediately take over the execution of all dynamic driving tasks.

The second group includes automated driving systems in which the detection of objects and events in the environment, and the response to them, will be the responsibility of the system. Automated driving systems from this group will perform all dynamic driving tasks. Within this group, three different categories of automated driving systems will be singled out.

The Category 3 automated driving system (conditionally automated driving) will continuously perform all dynamic driving tasks within the projected operational area. In the event of a failure of a system relevant for performing dynamic driving tasks, or in the event of an imminent exit from the projected operational area, the system will request from the driver to take action and continue to perform dynamic driving tasks or put the vehicle at least risk. The driver has the role of a backup option, and must maintain his ability at a level where he can timely, reliably and adequately respond to this type of stimulus by automated driving systems and vehicle in general, including determining whether and how (if necessary) to bring the vehicle in a state of least risk.

The Category 4 automated driving system (highly automated driving) will continuously perform all dynamic driving tasks within the projected operational area, including a reserve option (redundancy) to perform those tasks. The system of this category does not expect the driver (user) to respond positively to the request to take over the execution of dynamic driving tasks or to bring the vehicle to a state of least risk. While the system is active, the user will not need to supervise the operation of this category of system, nor maintain their state at a level where he/she is able to respond in a timely manner to the system's request to take over the execution of driving tasks. A driver is not necessary within the projected operating area of the system. The driver, while the system is active, will be allowed to perform a wide range of other activities.

Category 5 automated driving systems (fully automated driving) will continuously perform all dynamic driving tasks including the reserve option (redundancy) to perform those tasks. For the systems of this category, the existence of predefined boundaries of the operational area is not envisaged. A system of this category will not expect the user to respond positively to a request to take over the execution of dynamic driving tasks. Therefore, the system will "drive" the vehicle in all traffic conditions in which it can objectively be controlled by the driver - without projected geographical restrictions, restrictions related to the type of road, speed regime, part of the day, weather conditions etc. A driver is not required during the entire ride. Therefore, the person sitting in the driver's seat does not have to perform driving tasks, i.e. is not in the role of a backup option of the system, he/she does not have to think whether or how to bring the vehicle in state of the least risk, etc.

Of course, the introduction of automated driving system must be accompanied by very intensive development of regulations at the international and national level, in order to: (i) establish the minimum technical requirements that must be met by newly developed systems (devices, equipment), and gradually and systematically (ii) remove the restrictions imposed by the existing regulations regarding the approval of equipping vehicles with such "novelties" and their use in traffic.

VEHICLES OF THE FUTURE

It is known that the European Commission has already adopted a package of measures that require the application of 11 systems on all new vehicles intended for the EU market from 2021. The said systems are as follows:

1. Autonomous braking system in critical situations,
2. Driver's alcohol detection,
3. Drowsiness detector and low driver concentration,
4. "Black box" of the vehicle
5. Stop light for critical situations,
6. Improved seat belt systems and passenger front protection system
7. Head protection zone for pedestrians and cyclists and safety glazing in the event of a collision
8. Intelligent assistance to the driver in terms of speed of movement
9. Assistance in Lane Keeping
10. Lateral protection of passengers
11. Reversing cameras or an adequate detection system.

If we add to this, that ABS, electronic stability controls and isofix connections are already mandatory in the EU, it is to be expected that in the foreseeable future the EU will be closer to achieving the *EU Vision Zero* goal. This means that a significant improvement in the field of safety is expected, without severely injured and killed traffic participants.

It is difficult to answer what the vehicles will look like in the future on the basis of current development trends, because the development of vehicles, systems and devices is happening both vertically and horizontally. Vertically, it is to be expected that new forms of vehicles will appear, which, according to their construction characteristics, will not fit into the existing definitions. Such vehicles could have multiple mobility options; by land, in or on water and in the air.

Horizontal development, in this context, means upgrading or developing new systems and devices that will further improve vehicle performance, increase safety, facilitate or take over driving, or make propulsion more environmentally friendly and cheaper.

CONCLUSION

A new phase in the development of motor vehicles can be considered the time since the conceptual notion of construction has changed, including new concepts outside the standard terminology and automotive dictionaries. Appreciating the legal regulations, technical and technological achievements, the readiness of the regulators and the expectations of the public, it is to be expected that major and rapid changes will occur in the construction and production of cars that will contribute to greater comfort and greater traffic safety.

Mandatory systems will be the "basic package" of vehicle equipment, while more demanding customers will be able to enjoy the support of a large number of driving assistance systems. Technologies that were once developed for the needs of the aviation industry have long been used in the automotive industry and today are representing basic technologies, and one could say mandatory equipment on vehicles. A similar thing will happen soon with technological achievements that are the privilege of space programs and underwater systems, and fuel cells can be quoted as an example.

Special attention is drawn to the development of autonomous driving systems, which will cause numerous changes in legislation and the environment. With their full application, we are approaching the "zero vision" when there will be lost lives in traffic accidents. The technological and normative revolution will enable the realization of the idea of autonomous vehicles even sooner than we expect it, although, for the time being, it seems foggy and distant.

Appreciating the scope and expansion of the changes brought by modern technologies, it is to be expected that major changes will take place in the construction and exploitation of vehicles. Maybe the near future is already here, with vehicles not being pollutants, the driver being replaced by automatic pilot, the movement of vehicles being enabled by combining driving and flying, vehicles becoming completely safe, and so on.

REFERENCES

[1] Consolidated Resolution on the Construction of Vehicles (R.E.3), ECE/TRANS/WP.29/78/Rev.6. http://www.unece.org/, 2017.

[2] A proposal for the Definitions of Automated Driving under WP.29 and the General Principles for developing a UN Regulation. http://www.unece.org/, 2017.

[3] Edwards M., Seidl M., Tress M., Pressley A., Mohan S. Study on the assessment and certification of automated vehicles – Final Report. http://www.unece.org/, 2016.

[4] Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. SAE International, http://www.unece.org/, 2016.

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REVIEW

The Impact of Freight Vehicle Load on the Condition of Roads in Bosnia and Herzegovina

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Abstract: The number of registered commercial freight vehicles in Bosnia and Herzegovina has been increasing over the years, which affects the traffic load and the condition of roads, especially in Bosnia and Herzegovina. Vehicle overloading is considered to be one of the biggest causes of damage to part of the road surface, especially with regard to the load-bearing road substructure. The focus of the research is the vehicle overloading on the roads of Bosnia and Herzegovina, with special emphasis on determining the type and degree of overloaded vehicles and determining the equivalence factor (EF). In the research phase, data from weighing control stations were used, taking into account the total weight of vehicles, the distribution of total weight on vehicle axles and the equivalent standard axle load for a particular vehicle type over a period of two years. A high degree of overloading was found, especially 5-axle vehicles (58.7%). The level of overloading in the range of 10-20% in relation to the maximum allowed weight is especially apparent. The calculated EF is 3.64 and is higher than the standard EF.

Key words: vehicle overloading, design road pavement, axle weight.

INTRODUCTION

Vehicle overloading is an axle weight that exceeds the legally permitted values for vehicles, which dramatically contributes to the accumulated damage to the road [1]. It has been found that an increase in the occurrence of vehicle overloading causes a noticeable increase in road damage [2],[3],[4],[15]. As the share of road transport of goods has increased compared to other modes of transport, it is expected that freight vehicles will remain a common sight on our roads in the foreseeable future. Therefore, special attention should be paid to optimizing the use of vehicles and damage to road infrastructure caused by them.

Freight vehicles moving from the starting point to the destination use the public road network. If the control of axle weight and total weight of freight vehicles is not carried out, high loads can cause significant damage to the road infrastructure. Consequently, certain legal load limits have been imposed. Three types of load weight data are of particular importance: total vehicle weight, distribution of total weight on vehicle axles and equivalent standard axle weight for a particular vehicle type. Dimensions, total weight and axle weight of vehicles on the roads are determined by the adopted bylaws (Official Gazette of BiH, No. 23/07 and 101/12). Repetition to the loading and overloading of heavy goods vehicles adversely affects the road, the design life of the road becomes shorter, although the same quality standard is used in design and construction [5],[6],[7],[8]. The research study stated that, allowing the axle weight to increase from 10 to 13 tons, the road will last only half of its projected life in relation to axle weight of 10 tons [11].

Research in the USA and South Africa has shown that damage to road pavement caused by overload has increased disproportionately, (axle weight twice the legal limit can cause 4 to 60 times more damage than the permissible axle weight, depending on the structure and type of road). High vehicle wheel loads, tire pressure, frequency and duration along with environmental factors are important for road performance. However, the most important parameter is the axle weight. The main factors responsible for damage to the road caused by the vehicle, such as dynamic axle weight, number and type of axles (e.g. single, tandem), tire properties (e.g. larger widths, double) and road properties (e.g. road type, thickness, temperature and roughness) are given in research studies [1],[9],[10],[12],[13],[18],[19].

The road network in Bosnia and Herzegovina covers about 22,733 km and is divided into four main categories (toll highways - 198 km, - 4,039 km, regional roads - 4,496 km, and local roads). Their lifespan is between 10 and 15 years, however, damage to the road structure is still present and occurs earlier than expected. One of the new issues related to road transport is the overload behavior that is usually caused by freight vehicles when they are out of control, and at the same time these roads cannot provide load-bearing capacity with a certain design lifespan.

It is worrying that the determined degree of overload is extremely high, where 5-axle freight vehicles particularly stand out with the share of 58.7%. The research [20] has shown that the most significant level of overload is in the range of 10-20% in relation to the maximum allowed mass.

Overloaded vehicles endanger the lives of road users. Overloaded vehicles are difficult to drive, they are less stable, and require a longer stopping distance; which makes them very dangerous, especially on sharp curves and steep slopes.

In addition, overloading can also cause several detrimental effects on the integrity of the road pavement structure, shorten the life of the pavement itself, and can cause serious damage that could lead to traffic accidents [14],[16],[17].

Due to these problems, overload is recognized as a problem that must be taken into account. Therefore, the main objectives of this study were to determine the types of overloaded vehicles, the percentage of overloaded vehicles and the average equivalence (EF) for all vehicles.

RESEARCH METHODS

The main goal of this research is to understand the significance of the problem, ie the extent to which there is a problem with the overload on our roads.

Measuring total mass and axle weight of vehicles on the roads in Bosnia and Herzegovina began with the introduction of static scales that perform measurements while the vehicle is at rest, or out of traffic, so that reliable measurement results are obtained. These measurements are used to determine the axle weight exceedance and the total mass of the vehicle. Data collection was performed at a total of 45 selected locations over a period of two years, throughout Bosnia and Herzegovina.

The overloaded vehicles considered in this study include freight vehicles (rigid and articulated vehicles with 2 axles, 3 axles, 4 axles, 5 axles, 6 axles and possibly 7 axles). The percentage of vehicle overload and the average equivalence factor (EF) for each vehicle type were analyzed as secondary data. The percentage of vehicle overloading was analyzed in terms of vehicle types of overloaded vehicles and overload percentage per vehicle. Of the statistical techniques for data processing, nonparametric techniques such as the Kruskal-Wallis test, the Man-Whitney U-test, c2 test, and the Fisher test were used.

RESEARCH RESULTS AND DISCUSSION

Number of overloaded vehicles

In the observed time period, a sample of 504 controlled fright vehicles was observed, by measuring axle weight and total mass, using static scales, at 45 selected locations. In 122 controlled cases, vehicle overload was determined, which represents the total percentage of 24.2% of violations, compared to the number of controlled ones (Table 1).

The application of the Mann-Whitney U-test (Figure 1) gave significant differences (U = 5653,000, z = -12,602, p = 0,000) in the total weight (tons) of freight vehicles overloading (N = 122, Md = 41.34) of the total weight or axle weight in relation to vehicles without overloading (N = 382, Md = 34.70).

The intensity and quality of these controls does not meet the real needs, so the number of violations in terms of overloading freight vehicles is much higher.

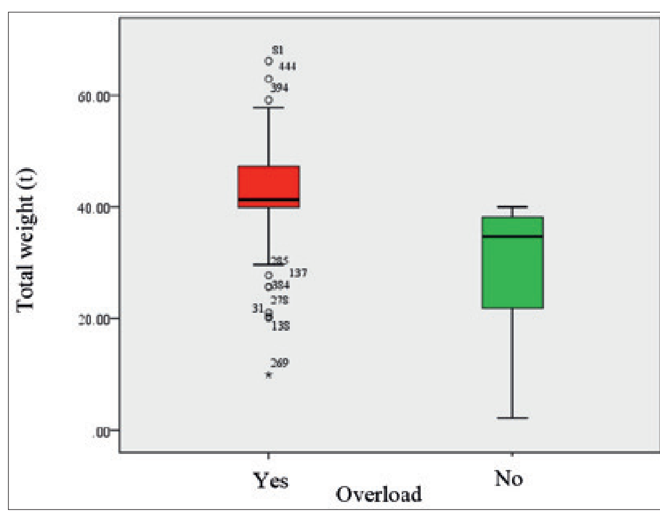

Figure 1: Ratio between overloading and total vehicle weight

***Table 1**: Total weight (t)*

Overloading	N	Minimum	Maximum	Range	Median	Mean	Std. Dev.
Yes	122	9.96	66.16	56.20	41.3400	42.5475	8.77453
No	382	2.20	40.00	37.80	34.7000	29.4702	10.53944
Total	504	2.20	66.16	63.96	36.6500	32.6357	11.58003

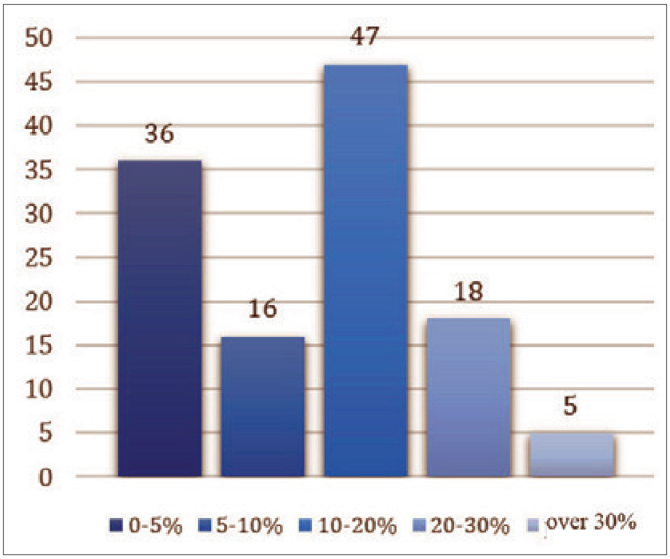

Figure 2: Overloading in percentage groups

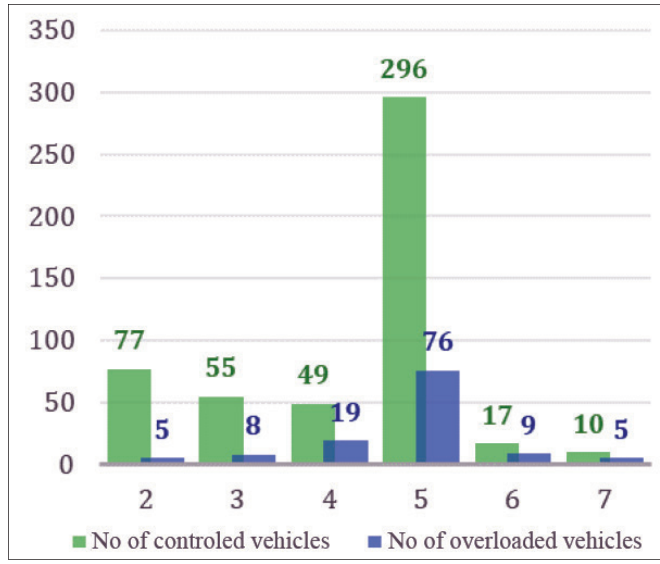

Figure 3: Overloading in relation to the number of axles

Although exceeding the total permissible vehicle weight can be considered quite high, even more worrying are the range of overloading values and the degree of overloading above the permissible limit for each category of commercial vehicles. The share of overloading in relation to overloading percentage groups was analyzed (Figure 2), as well as the share of overloaded vehicles in relation to axle groups of vehicles (Figure 3).

Table 2: Overruns

Number of axles	2	3	4	5	6	7	Total
YES	5 (6.5%)	8 (14.5%)	19 (38.8%)	76 (25.7%)	9 (52.9%)	5 (50.0%)	122 (24.2%)
NO	72 (93.5%)	47 (85.5%)	30 (61.2%)	220 (74.3%)	8 (47.1%)	5 (50.0%)	382 (75.8%)
Total	77 (15.3%)	55 (10.9%)	49 (9.7%)	296 (58.7%)	17 (3.4%)	10 (2.0%)	504 (100.0%)

The data on the performed axle weight measurements, according to the types and groups of axles, and in accordance with the legal regulations (Table 3, 4) were also analyzed, which is also presented graphically (Figure 4,5).

Table 3: Axle overloading

Axle	N	Minimum	Maximum	Range	Median	Mean	Std. Dev.
2	5	.36	6.40	6.04	1.3400	2.1720	2.40494
3	8	1.35	7.21	5.86	4.7150	4.2138	1.94870
4	18	.90	14.00	13.10	5.4050	5.6833	3.23061
5	56	.12	18.79	18.67	3.3400	3.9084	3.33334
6	9	2.10	15.72	13.62	5.6000	6.3678	4.69638
7	3	5.15	12.60	7.45	7.3400	8.3633	3.82897
Total	99	.12	18.79	18.67	3.8700	4.5267	3.48859

Table 4: Total axle overloading

Number of axles	N	Minimum	Maximum	Range	Median	Mean	Std. Dev.
2	5	.36	6.40	6.04	1.3400	2.1720	2.40494
3	8	1.35	7.21	5.86	4.7150	4.2138	1.94870
4	19	.90	14.00	13.10	4.9000	5.4100	2.91191
5	76	.02	17.86	17.84	3.4900	4.5241	4.57343
6	9	5.10	22.96	17.86	15.7200	14.3611	5.09210
7	5	.26	26.16	25.90	10.3600	11.2400	11.48072
Total	122	.02	26.16	26.14	4.8300	5.5462	5.39209

Overloading by vehicle types

In the structure of overloaded commercial vehicles by groups, the highest percentage of overruns was recorded in five-axle freight vehicles (58.7%). They are followed by two-axle freight vehicles (15.3%), three-axle freight vehicles (10.9%), and then four-axle freight vehicles (9.7%) in the observed sample (Table 2). The application of the χ^2 test gave a statistically significant difference ($\chi^2 = 33{,}260$, $p = 0{,}000$) for the presence of overruns in relation to the number of axles of the vehicle.

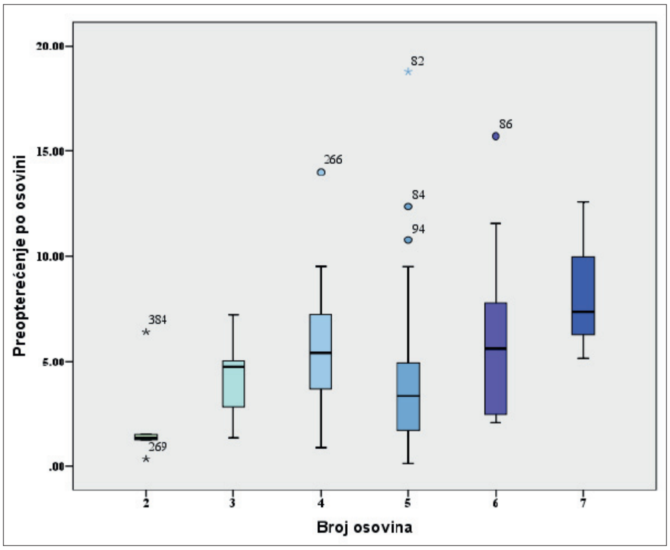

Figure 4: Axle overloading

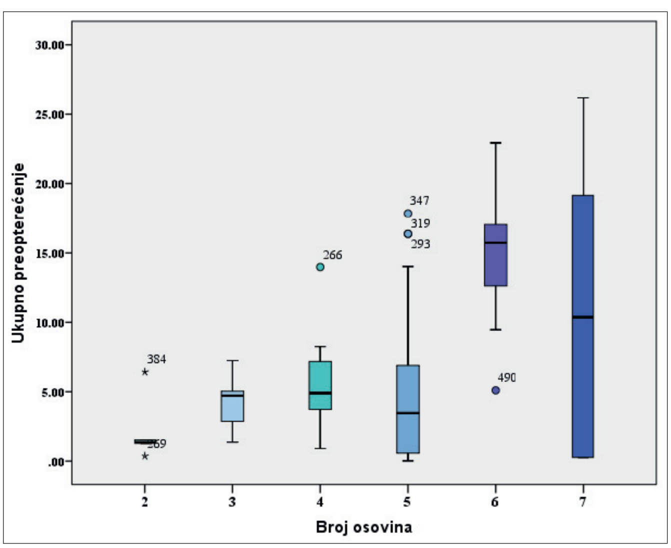

Figure 5: Total axle overloading

Axle overload testing (six groups: 2 to 7 axles) in the application of the Kruskal Wallis test, returned a statistically significant difference (c2=21.283, p=0.001) of the total overloading by axles. Additional analysis was then performed with the Mann-Whitney U-test (Table 5).

Additional tests using the Mann-Whitney U-test, give a statistically significant difference in total overload by axles (U=1,000, z=-2,867, p=0.004) of the tested vehicles with two axles (N=5, Md= 1.34) and six axles N=9, Md=5.60); three axles (N=8, Md=4,715) and six axles (U=1,000, z= -3,370, p=0.001); four axles (N=19, Md=5,405) and six axles (U= 2,000, z=-3,617, p=0,000); and five axles (N=76, Md=3.34) and six axles (U=59,000, z=-4,042, p=0,000). The statistically significant difference between the two and four axes is (U=17,000, z=-2,169, p= 0.030). In other cases, no statistically significant difference was detected.

Determination of equivalence factor (EF)

The impact of vehicle flow on the road is expressed by the number of equivalent traffic load for dimensioning asphalt pavement structures, according to the standard JUS U.C4.010 from 1981, which increases by the degree of four with increasing axle weight of vehicles (Figure 6), which means that overloads of 10% above the permissible weight, contribute to the damage of the road structure by 40%.

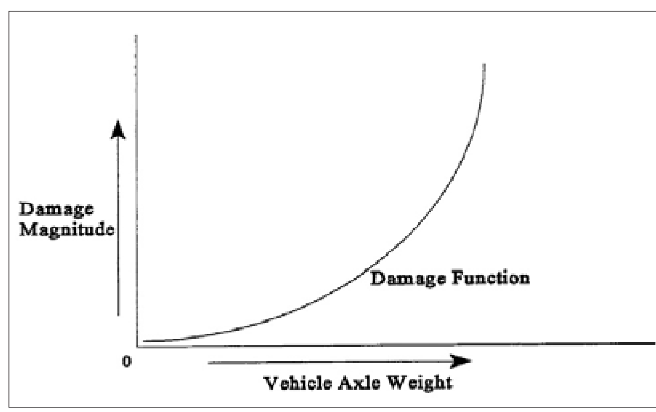

Figure 6: Ratio between vehicle overloading and road damage

Data from the place of control and weighing were analyzed by sorting data on vehicles according to the number of axles and the total weight of the vehicle. Dam-

Table 5: Significance of total overloading by axels

Number of axles	2 (5)	3 (8)	4 (19)	5 (76)	6 (9)	7 (5)
2 (5)		0.091	0.030*	0.468	0.004**	0.600
3 (8)	0.091		0.457	0.573	0.001**	0.557
4 (19)	0.030*	0.457		0.094	0.000**	0.545
5 (76)	0.468	0.573	0.094		0.000**	0.346
6 (9)	0.004**	0.001**	0.000**	0.000**		0.640
7 (5)	0.600	0.557	0.545	0.346	0.640	

Table 6: Equivalent factor (EF) for all vehicles

Freight vehicle type	Number of vehicles	Average equivalent factor (EF) per axle							Total average EF	Total EF	EF for all vehicles
		1	2	3	4	5	6	7			
2-axle	77	0.08	0.70						0,78	60.06	3.64
3-axle	55	0,59	0.94	0.96					2.49	136.95	
4-axle	49	0.75	0.72	1.80	1.81				5.08	248.92	
5-axle	296	0.36	2.06	0.68	0.65	0.62			4.37	1293.52	
6-axle	17	0.36	0.34	0.40	1.17	1.19	1.09		4.55	77.35	
7-axle	10	0.34	0.30	0.28	0.26	0.27	0.24	0.23	1.92	19.20	
TOTAL	504									1836.00	

age or equivalence factor (EF) for each weighted axis was calculated using equation (1). Table 6 shows the calculated EF for all vehicles. The result shows that the EF based on the current traffic volume is 3.64. Comparing the EF acquired in this research with the EF used in the design of road pavement structures for a standard load of 80kN per axle, which is 3.0, we see that the calculated EF has a higher value than the standard.

$$\text{Equivalent Factor (EF)} = (N/8.16)^{4.5} \tag{1}$$

where:
EF – is equivalent damage effect factor
N – is axle weight (tons)
4.5 – is exponent of load equivalence
8.16 – is Standard axle weight (tons)

The damage caused by the cumulative overloading on the pavement structure affects its lifespan, by shortening the time of the road operation in relation to the normative lifespan. The unplanned traffic load leads to endangering safe operation of traffic, or in the best case scenario it will lead to premature need to invest in renewal of the pavement in order to maintain the required level of quality and safety of traffic, causing increased costs for road infrastructure maintenance.

Overloading as a phenomenon in transport is often an indicator of economic growth, especially in developing countries such as ours. On the other hand, we cannot ignore the negative impact on road infrastructure (roads and bridges) and traffic safety when assessing the potential risks of overloaded vehicles.

CONCLUSION

Based on the results of the research, the following can be concluded:

- The results of the research showed the significance of the problem of overloaded commercial vehicles on the roads in Bosnia and Herzegovina. What is worrying is the degree of overloading, which is extremely high, especially for 5-axle vehicles (58.7%), followed by 2-axle and 3-axle vehicles. The most apparent degree of overloading ranges from 10-20% of the allowed total weight.
- Freight road traffic causes high costs in terms of maintenance and rehabilitation of the road pavement of the damaged road network, which occurs as a result of vehicle overloading. Also, the relative damage depends on the type and number of axles on each vehicle, as well as the type of pavement on which the vehicle is moving. Every vehicle moving on the road network currently causes significant deformation on the pavement construction of the road.

The total flow of vehicles has a cumulative effect that gradually leads to deformation of the pavement, followed by erosion. The effect of overloading is not felt in one day, but it is visible over a certain period of exploitation.

- The calculated EF for the current traffic volume was higher and was 3.64, compared to the standard EF which is 3.0. It can be concluded that the road network is not sufficiently well dimensioned because the current traffic load is significantly higher, and this is a result of overloaded freight vehicles moving on the road network of Bosnia and Herzegovina.

In order to prevent damage to the pavement due to the increased number of overloaded vehicles, the road network in Bosnia and Herzegovina must be controlled in terms of bearing capacity, establishing a good-quality control of total weight and axle weight of freight vehicles in order to withstand the current and the future traffic loads.

LITERATURE

[1] Mohammadi J. and Shah N. (1992). Statistical evaluation of truck overloads. *Journal of Transportation Engineering. Vol* 118(5): 651-665.

[2] AASHTO. (1993). AASHTO Guide for Design of Pavement Structure. American Association of State and Highway Transportation Officials, Washington, DC, 1993.

[3] Walton C. M. and Chien-Pei Yu. (1983). Truck Size and Weight Enforcement: A Case Study. *Transportation Research Record.* Vol (920): 26-33.

[4] Fekpe E. (1995). Evaluating Truck Weight Regulatory Policies. *Canadian Journal of Civil Engineering,* Vol 22: 1235-39.

[5] CSIR. (1997). The damaging effects of overloaded heavy vehicles on roads. *CSIR Roads and Transport Technology*, 4th Edition, ISBN: 1-86844-285-3.

[6] Chatti K. Lee H.S. and Mohtar S.E. (2004). Fatigue Life Predictions for Asphalt Concrete Subjected to Multiple Axle Loadings. *8th International Symposium on Heavy Vehicle Weights and Dimensions*, Gauteng province, South Africa, 2004.

[7] Abdullah M.E. Zamhari K.A. Buhari R. Nayan M.N. and Hainin M.R. (2014). Short term and long term aging effects of asphalt binder modified with montmorillonite. *Key Engineering Materials.* Vol 594-595: 996-1002.

[8] Mulyono A.T. Parikesit D. Antameng M. Rahim R. (2010). Analysis of Loss Cost of Road Pavement Distress due to Overloading Freight Transportation, *J. Eastern Asia Soc. For Transp. Stud.* Vol 8: 706-721.

[9] Karim R.M. Abdullah A.S. Yamanaka H. Abdullah A.S. Ramli R. (2013). Degree of Vehicle Overloading and its Implication on Road Safety in Developing Countries. *Civil and Environmental Research.* Vol 3(12): 20-31.

[10] Podborochynski D. Berthelot C. Anthony A. Marjerison B. Litzenberger R. Kealy T. (2011). Quantifying Incremental Pavement Damage Caused by Overweight Trucks, *Paper prepared for presentation at the Effects of Increased Loading on Pavement Session of the 2011 Annual Conference of the Transportation Association of Canada*, Edmonton, Alberta, 2011.

[11] Salem H.M.A. (2008). Effect of Excess Axle Weight on Pavement Life. *Emirates Journal for Engineering Research.* Vol 13(1): 21-28.

[12] Dodoo N.A. and Thorpe N. (2005). A new approach for allocating pavement damage between heavy goods vehicles for road-user charging. *Transport Policy.* Vol 12: 420-423.

[13] Idham M.K. Hainin M.R. Yaacob H. Warid M.N.M. and Abdullah M.E. (2013). Effect of Aging on Resilient Modulus of Hot Mix Asphalt Mixtures. *Advanced Materials Research.* Vol 723: 291-297.

[14] Oluwasola E.A. Hainin M.R. Aziz M.M.A. Yaacob H. and Warid M.N.M. (2014). Potentials of steel slag and copper mine tailings as construction materials. *Material Research Innovations.* Vol 18(S6): 250-254.

[15] Jacob B. La Beaumelle V.F. (2010). Improving truck safety: Potential of weigh-in-motion technology, *IATSS Research* 34: 9–15.

[16] Winkler C.B. (2000). Rollover of Heavy Commercial Vehicles. *UMTRI Research Review*. Vol. 31(4): 0739-7100.

[17] Saifizul A.A. Yamanaka H. Karim M.R. Okushima M. (2011b). Empirical analysis on the effect of gross vehicle weight and vehicle size on speed in car following situation. *Proc. of the Eastern Asia Society for Transportation Studies*. Vol 8: 305-317.

[18] Hanscom F. R. (1998). Developing Measures of Effectiveness for Truck Weight Enforcement Activities. *NCHRP Research Results Digest no. 229*.

[19] Straus S.H. and Semmens J. (2006). Estimating the Cost of Overweight Vehicle Travel on Arizona Highways. *Arizona Department of Transportation*. Final Report 528.

[20] Kulović M. Injac Z. Davidović S. Posavac I. (2017). Modeling Truck Weigh Stations' Locations Based on Truck Traffic Flow and Overweight Violation, A Case Study: Bosnia and Herzegovina. *PROMET-Traffic & Transportation, Vol.30, 2018,No.2, 163-171, Zagreb*.

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PROFESSIONAL PAPER

Flexible Transportation of Passengers and Combined Mobility

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Abstract: The paper describes the importance and the role of the subsystem of flexible transportation of passengers (paratransit) in the system of a public city transportation of passengers (PCTP). It is a system with several forms and can be defined by several parameters, but in large number of cities in the world it gains more importance in the PCTP system. This paper describes this system with its characteristics, i.e. its positive characteristics that lead to increased combined mobility of population in cities in the PCTP system, i.e. to decreased use of passenger cars.

Key words: Paratransit, public city transportation of passengers, combined mobility.

INTRODUCTION

Flexible transportation of passenger or paratransit – FTP, is a subsystem of the public city transportation of passengers and by its concept it is between the passenger car and the standard bus subsystem of passenger transportation in cities.

This subsystem is defined opposite to the institutional public city transportation of passengers (PCTP) and it based on the planned transport service. It is often classified as "informal" or even "illegal" transport, organised at the border of the institutional transportation system, sometimes taking the role of the main component of the passenger transport system [10].

In developed cities of the world today, the planning of city transportation system cannot be imagined without a balanced city transportation system and mutual cooperation between various forms of subsystems for transportation of passengers. In this way the passengers (users), can travel by combining several subsystems, but while each of the subsystems performs the role most suitable for it, both physically and operationally. This concept achieves overall convenience for the users while at the same time raising efficiency of the transportation system in an optimal way.

Regardless of the size of a city, the said concept is realised through a strategy of sustainable development and quality of life.

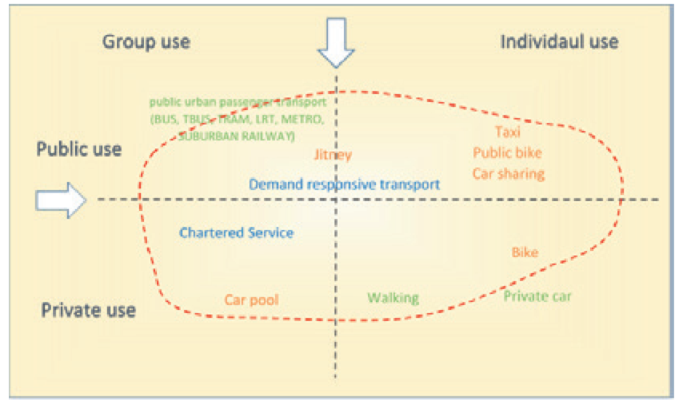
City's sustainable development strategy is an integral, economic, social and cultural development of a city (including its transportation system), harmonized with environmentally acceptable norms and standards, enabling present and future generation to meet their needs and improve their quality of life. A quality of life strategy is a subjective multi-dimensional concept that defines the level for emotional, physical, social, material and other prosperity.

In the European Union, achieving "sustainable development" and "quality of life" goals in terms of public transportation systems is achieved by running a policy that uses mobility of the population with limited use of passengers cars as its principle. The policy and measures of European countries in "sustainable development" are shown in table 1 [10].

Table 1. Policy of European countries in the development of cities suitable for living

SUSTAINABLE DEVELOPMENT OF CITIES (mobility with controlled use of passenger cars)	
Resource management (re-orientation of city functions Car usage management functions)	Pedestrian zones Zones protected from motor traffic Limited access to passenger cars to certain zones or at certain times Calming (slowing) the traffic Parking management and charge Traffic management

Development and management of Public Transport (building systems, development, integration and quality)	Reservation of land and priorities Operational system management Information systems for users Development of paratransit
Planning and taxation mechanisms (Development management, limitation in use of passenger cars, financing the development)	Planning and use of land (reserving sites for railway subsystems of public transport) Taxes (sale of real estate, valorising the site and commercial values) Payment zones Licencing of areas (controlling entry to the centre, circulating in the centre with tickets, etc.) Charging road tolls (toll stations, charging per length of the section, etc.)
Organisation and financing	



Picture 2. Schematic diagram of combined mobility

Global trends in the development of public transport systems that were based on the strategy concerned to satisfy essential needs of the largest "group of citizens" (providing accessibility in space and time, financial support and monitoring of the realisation of planned and contracted services) moved to the strategy of "concerns for satisfying specific needs of small groups of citizens" (decreasing congestions, protection of the environment, principle of competing for subsidies, satisfying said strategies of carriers depending on their capability to satisfy various needs of users of the public transport system, principle of coordination between transport companies).

In other words, the contemporary systematic approach to managing public transportation system is a concept where the public transportation is moving from a "system for itself" to becoming a "subsystem of the system of the city and surrounding residential areas".

In more narrow sense, this means that we are moving from the strategy of "a passenger that needs to be transported" to the strategy of "a user that needs to be served", i.e. from the strategy of "service quantity" to the strategy of "satisfying specific needs of all users of the system in a quality way".

Successful cities and cities suitable for life rely on an efficient PCTP system to realise the travel, which in synergy with the paratransit systems provides to the users of transport - passengers a combined transport service, so-called combined mobility service.

Picture 1. Combined mobility platform

Combined mobility is the result of work – synergy of the PCTP system and the paratransit system, and together with walking on foot they make the complete and coherent solution to realise transportation needs of citizens in urban areas. In the combined mobility concept various modal subsystems are coordinated in such a way that the users can conduct their travel by combining several modalities, but each modality performs a service that is most physically and operationally suitable for it. Combined mobility is a powerful tool in the process of creating a balanced PCTP system. By implementing and developing the concept of combined mobility we achieve overall convenience for users, and on the other side productive and economic efficiency of the transport system is raised to the optimum [11]. This concept today is becoming an important part of the sustainable transport strategy, with very significant influence and usefulness for the quality of life for citizens, the most important being:

- Changes the habits of users in realising their transportation needs and encourages redirection to sustainable modalities of city transport of passengers,
- Saves public place, because it decreases use of private cars,
- Influences modal distribution of motorised movement in a city, because it increases the number of users of the PCTP system.
- Encourages increased dynamics of the city's system for transportation of passengers, and contributes to creating a more efficient and effective subsystem – PCTP.
- Influences that the transport service provides a more flexible and comprehensive way,
- Decreases time of travel as one of the basic elements of all forms of quality according to users of the public city transportation of passengers,
- Decreases costs of travel compared to the use of private passenger cars,
- Contributes to sustainable development and quality of life in city agglomerations.

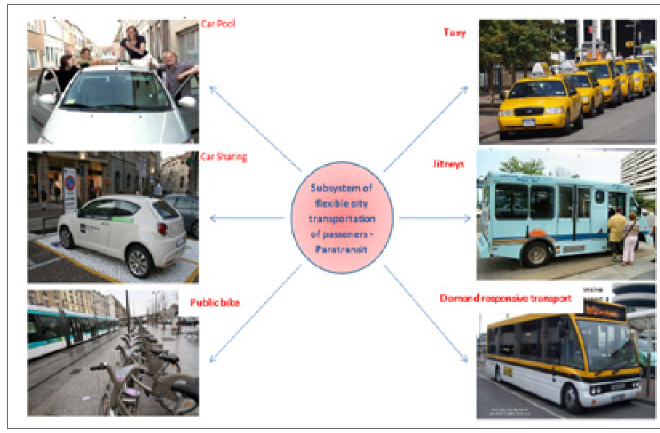
Periods of change, colloquially called a transition, envelop all segments of social and economic development of the countries in the region. The transition process in the structure of change in ownership relations, carries with it transfers of capital being invested in new technologies, sets new development strategies and reaches greater levels of competition in the market. The state acts as a regulator of economic development, in terms of creating a climate, most often by adopting regulations and creating equal market conditions. In order to ensure favourable and reliable investment climate in the area of services in the city public transportation system, it is necessary to create suitable climate, above all within process and substantive regulations defining conditions for operation and behaviour of businesses [17].

SYSTEMS OF FLEXIBLE TRANSPORTATION OF PASSENGERS

A division of flexible transportation of passengers can be made based on different characteristics that make this system different, but the usual division is according to the technical-technological characteristics criterion.

Based on this, the dominant forms of flexible transportation of passengers are (Picture 3.) [10]:

- taxi transport;
- modified use of personal vehicles - cars (so-called "carpool");
- semi-public transportation, i.e. transportation available only to a set of users (e.g.: residents of a zone, members of a business system or organisation), and which is realised by rented vehicles (buses, mini-buses,…);
- jitneys, i.e. taxi transportation over predetermined routes or corridors;
- group transport towards several individual calls (satisfies public transportation service in the "zone" between taxi transportation and public line transportation of passengers, with the route of the vehicle is formed according to concrete calls and needs);
- public bicycles;
- individual transportation on call (similar to taxi transportation, with the transportation performed by the people who do not do this full time).



Picture 3. Subsystems of flexible transportation of passengers

Joint use of private cars (carpool) is a subsystem of flexible city transportation of passengers, available to certain number of users in space and time. This joint use is achieved through various forms of car rentals or, more often, group transportation by private cars in movement lines, such as commuting to work [1].

Car sharing is a form of semi-public service in which the user individually optimises the realisation of the service in accordance with transportation needs. Use of such service is based on a community (membership in a group or a club).

Taxi system in most of cities is an important component of the total city transportation of passengers. It is a mode of public transport conducted in standard or specially adapted passenger cars (Picture 4.). It performs individual trips, i.e. "door-to-door" trips [2] [3].

Picture 4. Taxi vehicle

Jitneys are a form of flexible transportation of passengers that provides transportation services over a predefined (fixed) route, but without a timetable [5].

This service is provided in vehicles with relatively small capacity (up to the minibus size, Picture 5.). Along the route the entry or exit of passengers from the vehicles is conducted at predetermined locations or on user's request.

Picture 5. Minibus operating as paratransit

Demand responsive transport (call) is a type of semi-public and public transportation of passengers that provides service to individual users, over flexible routes, in flexible timeframes. In other words, demand for services and offering transportation service is constantly harmonised with the aim to be adjusted to individual requests, i.e. users.

In comparison to factors that more closely determine the character of the transportation service (such as the route, stops, time, reservations, etc.), there are different variants of this type of flexible transport:

- with **fixed characteristics of services over a corridor.** Static and dynamic elements are defined similar to line transportation, with possibility of deviations in accordance with changes in transportation requests and decisions of operators. The flexibility is most often reflected in that the departures are fixed on one part of the route, while on the other they are adjusted and extended according to needs. Issuing a request for transportation is conducted before or during the service itself (stopping the vehicle on the route).
- with **semi-fixed characteristics on a corridor**. According to this modality the base route, stops and timetable are defined. Departures of vehicles are conducted independently from issued transportation requests. If there are special requests, the vehicles can stop on other locations along the corridor (which is a problem for the operators, and the reason they ask for a request for transportation to be issued).
- with **flexible characteristics and defined stops over the service area.** This concept involves organising service realisation over a set service area (region and/or corridor) with defined stops where the service is performed (entry/exit of passengers) in accordance with issued requests and route optimisation by the operator according to different criteria (minimising the route length, minimising waiting times for users, minimising number of vehicles, etc.). A frequent modality is contracted transportation with certain subjects (businesses, institutions,…) according to which multiple starting points and one destination is defined, and vice versa, one starting point and multiple destinations.
- **''door-to-door".** This concept is organisationally most demanding, but the most flexible mode of transportation. It is suitable for users with limited capability to realise mobility needs. It is realised by grouping requests for transportation into one ride (so-called "group" taxi).

Public bicycles are a subsystem of flexible public city transportation of passengers available to users as a public service to realise transportation. The users realise or complement their transport needs by using public bicycles, optimising the transportation process by themselves.

The greatest positive characteristics of paratransit that it can be harmonised with other modes of public city transportation of passengers, in forms that are specific for each environment, but especially with line transportation of passengers.

DUALITY OF THE PUBLIC CITY TRANSPORTATION SYSTEM - FLEXIBLE TRANSPORT SYSTEM

In most of the cities in the world there are mostly two passenger transportation systems: institutional - PCTP and flexible. They work according to very different models and coexist in a complex relationship that varies from one to the other context. Institutional transport involves public passenger transportation services that are often referred to as planned or regular transportation services on line routes according to a predefined timetable. That means that public of private companies of a formal structure provide transportation services according to regulations defined by the competent body of that city (appointed by the city administration). These carriers develop their networks in accordance with quality standards of the transportation services defined (imposed) by their management body, with often low prices of transportation due to them being subsidised by the local authorities.

Flexible transportation of passengers often works on the "periphery" of institutional one, although sometimes in cities that do not have good and quality PCTP system (mostly smaller cities and towns) it takes over the main component of the PCTP system [6] [7]. In several documents that analyse public transportation of passengers in several cities, it is often described as poorly organised and inefficient sector in terms of transportation of passengers. Critics of flexible transportation also point out disloyal competition that severely punishes institutional transport. Experts that often believe that this subsystem is even harmful for the whole of city passenger transportation system still believe that the presence of flexible transportation is justified.

Flexible transportation meets those types of transportation requirements that generally only this transportation system can satisfy. As we said, in many cities this is the only available type of transportation. This system, in a pragmatic way is adjusting to the local context in cities where the institutional framework is inadequate or inefficient and where topography and geography become an obstacle for the development of bus lines. Along with that, unlike the PCTP subsystem which is under the authority of the city administration, services of flexible transportation have the ability to adjust to the expenditures of the city population. In order to study potential possibilities for coordination of flexible transportation and the PCTP it is necessary to understand basic business models of both types of services. Specifically, institutional PCTP is established by the city authorities (who are responsible for this system) who invest into the public transportation service. The authorities impose business conditions through subsidies and donations to the system, because it cannot cover on-going operational expenditures of carriers nor provide necessary funds for the development of this system. However, balancing quality and quantity (giving advantage to profitability) often results in: decreased road worthiness of the vehicles, poor organisation of the system, increased age of vehicles, causes disruptive competition amongst carriers, which is generally harmful for public transportation of passengers.

As far as the flexible transportation services are concerned, they are a result of private initiatives, i.e. carriers, which are developing spontaneously. The main goal of carriers is to survive at the transportation market and increase their profit. Due to the above, operation of the institutional PCTP system and the paratransit system can easily come into conflict [8] [9].

Recent research in large number of cities of the world shows that these two components of the public city transportation are in fact potentially complementary. These researches confirm a large share and importance of the flexible transportation subsystem in the total transportation system of each city.

Specifically, in a balanced city transportation system different modal systems are coordinated, so that users can easily travel by combining several subsystems, but while each of the subsystems is performing the role both physically and operationally most suitable for it.

On the other hand, many Case Studies in a wide spectrum of urban situations focused on the specific role that each type of service has in the city and on the operational relations achieved between the flexible and institutional transportation.

CONCLUSION

The strategy of UITP (International Association of Public Transport), in relation to the sector of the public city transportation of passengers aims at doubling of the market share of the PCTP system by the end of 2025.

Successful cities and cities suitable for life rely on efficient PCTP to realise their trips, which in synergy with the subsystem of flexible transportation of passengers provides users with a combined transportation service, i.e. provides the citizens of an urban area a so-called combined mobility service.

Combined mobility is the synergy of the system of public mass transportation of passengers and the system of flexible transportation of passengers (paratransit), and together with walking on foot they make the complete solution to realise transportation needs of citizens in urban areas.

However, balancing quality and quantity (giving advantage to profitability) often results in: decreased road worthiness of the vehicles, poor organisation of the system, increased age of vehicles, causes disruptive competition amongst carriers, which is generally harmful for public transportation of passengers [12].

One of the key characteristics of paratransit is that there are no direct subsidies by the local or national authorities (this excludes the use of urban infrastructure which is sometimes considered as indirect subsidies). The only source of income in this sector is the paying passengers. In general case, there are three financing options: through loans, through personal savings of carriers or through informal loans.

LITERATURE

[1] Ardila Gomez A., 2005: La olla a pression del transporte publico en Bogota. Revista de Ingenieria br. 21.

[2] Ardila Gomez A., 2007: How the past of public transportation is chasing its future in Bogota, Columbia. Transport Research Record 2038.

[3] Browning P., 2001: Wealth on wheels? Economic strengthening of minibus-taxis and new Cervero R., 2013: Connecting city transportation and use of land in developing countries. Transport and use of land magazine vol.6, issue 1, pg. 7-24.

[4] Cervero R., 2000: Informal transportation in the developing world. UN Habitat. New York, United States

[5] Lammoglia A., Faie R.M. & Josselin D., 2012: Return of taxi vehicles to Dakar: Is transportation necessary for transportation (TAD)? Confer-

ence CODATU KSV. Addis Ababa, Ethiopia

[6] Passengers transportation policy. Conference SATC 20. Pretoria, South Africa.

[7] Salazar Ferro P. and Behrens R., 2013: Paratransit and formal operative complementarity of public transportation: imperatives, alternatives and dilemmas. Conference VCTR. July. Rio de Janeiro, Brazil.

[8] Salazar Ferro P., Behrens R. and Golub A., 2012: Planned and paratransit integration service through trunk and feeder arrangements: International review. Conference SATC. July. Pretoria, South Africa.

[9] 1996: Physical characteristics of paratransit in developing countries of Asia. Advanced transportation magazine vol.30, issue 2, pg. 5-24. Conference Thredbo 10. Hamilton Island, Australia.

[10] Tica S. (2016), Passenger transport systems, Faculty of Traffic, Belgrade

[11] Tica S. (2021), Technology of passenger transport, Faculty of Traffic, Belgrade

[12] P.Gladović, V.Popović, M.Stanković, J.Mišić, Importance and role of paratransit in the system of public city transportation of passengers, 24. INTERNATIONAL CONFERENCE "NEW TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT OF TRAFFIC, ECOLOGY, LOGISTICS AND POLYTECHNICS", 27 AND 28. may 2022, BOSNIA AND HERZEGOVINA

[13] D. Drašković, 2021: Contemporary models of organizing public city transport of passengers, Pan-European University Banja Luk.

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The **Introduction** should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of disciplines.

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EXAMPLES OF ACM PUBLICATION REFERENCES

Journal article [1]

[1] Zahavi Y. and Ryan, M. James. Stability of Travel Components Over Time. *Transportation Research Record*, 750 (1980), 70-75.

Book [2]

[2] Shinar, D. *Psychology on the Road: The Human Factor in Traffic Safety*. John Wiley & Sons, Inc., New York, 1978.

Article in a Periodical [3]

[3] Jolliffe, J.K. and Hutchinson, T.P. A Behavioural Explanation of the Association Between Bus and Passenger Arrivals at a Bus Stop. *Transportation Science*, 9, 3 (August 1, 1975), 248-282.

Government Report [4]

[4] Dempsey, J. Barry. *Climatic Effects of Airport Pavement Systems: State of the Art.* Report DOT2DRD-75-196. FHWA, U.S. Department of Transportation, 1976.

Web Page [5]

[5] Stevens, R.C. Testimony Before United States Senate Special Committee on the Year 2000 Technology Problem. Sept. 10, 1998. http://www.senate.gov/~y2k/statements/091098stevens.html. Accessed Oct. 5, 1998.

CD-ROM [6]

[6] Martinelli, D.R. A Systematic Review of Busways. *Journal of Transportation Engineering* (CD-ROM), Vol. 122, No. 3, May–June 1996.

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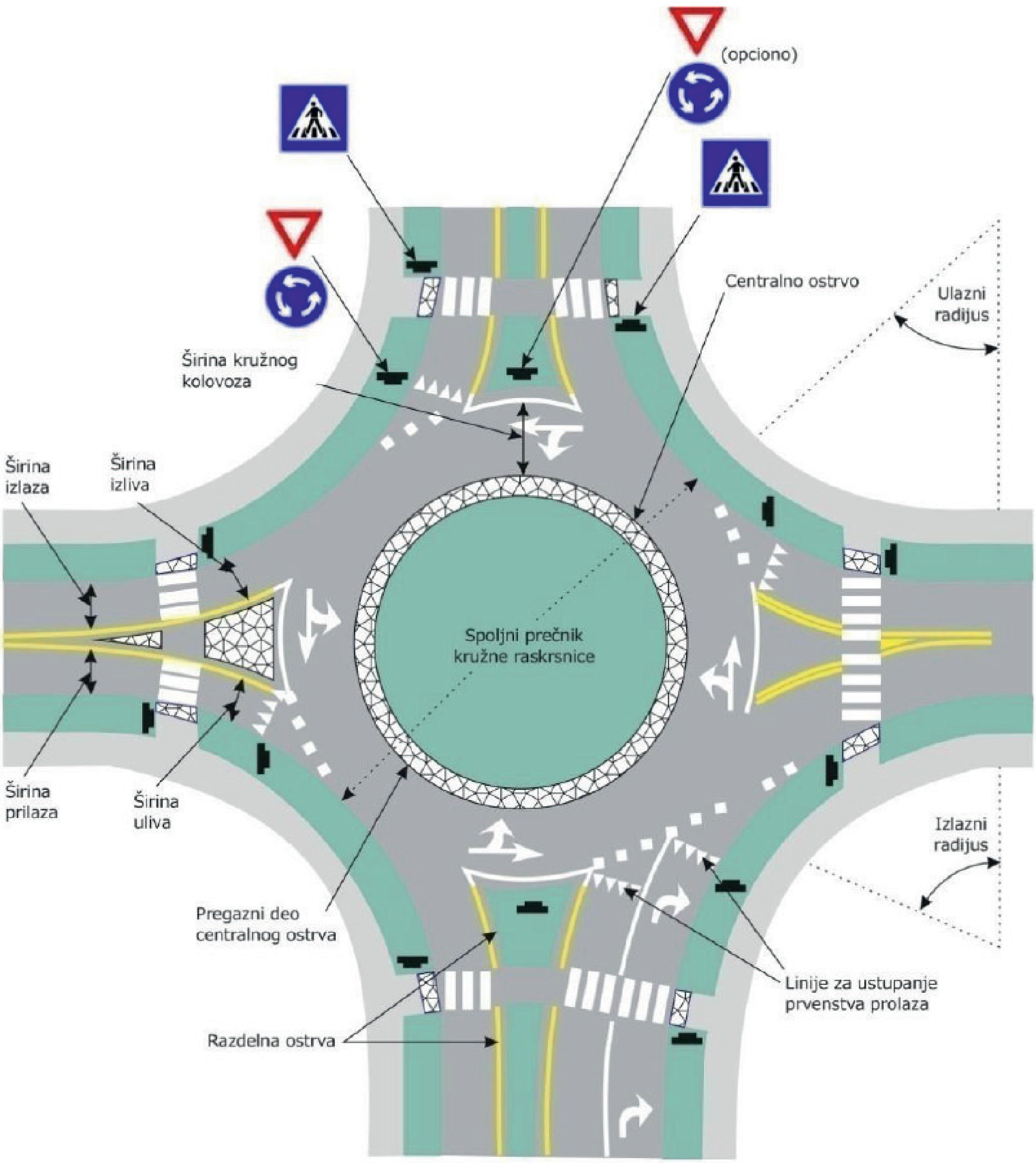

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