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CAPACITY AND LEVEL OF SERVICE ON THE ZAGREB BYPASS

ABSTRACT

As the capital of the Republic of Croatia, Zagreb is certainly the biggest motorway interchange, as well as the origin and destination of a large number of trips. Apart from obvious advantages, road traffic with its sudden development has caused certain undesired consequences as well, out of which the focus is on the traffic network congestion, including reduction of safety level, mainly because of the greater number of traffic accidents most pronounced in the summer months. The morning and afternoon hours see the highest traffic peaks at junctions, first of all at Buzin where long queues of vehicles are formed. In order to solve the problem the capacity and level of service need to be analysed and the attention should be drawn to the possible requirement of implementing measures in order to increase the capacity and the level of service in the corridor of the Zagreb Bypass.

KEY WORDS

Zagreb Bypass, motorway, capacity, level of service

1. INTRODUCTION

The construction of the motorway network in Croatia has brought to significant increase in traffic on the motorway network. The origin and destination of every transport are primarily big cities, and Zagreb, as the capital of the Republic of Croatia is certainly the biggest motorway interchange, as well as origin and destination of numerous trips.

The set of motorway sections from the Zaprešić interchange all the way to Popovec interchange which consists of the motorway sections A2 Macelj - Zagreb (Jankomir), A3 Bregana - Zagreb - Lipovac and A4 Goričan - Zagreb (I. Reka), which together form the Zagreb Bypass, present one of the busiest traffic routes of the Zagreb County, hence also of the entire Republic of Croatia. This is where the following motorway routes interweave: A1 Zagreb (Lučko) – Bosiljevo - Split - Dubrovnik, A6 Bosiljevo - Rijeka (Orehovica), (European route E 65) which is the connection between the City of Zagreb and Rijeka – the biggest Croatian port and the primary connection with the network of international motorways of Western and Central Europe, A3 Bregana - Zagreb - Lipovac, A2 Macelj - Zagreb (Jankomir), A4 Goričan - Zagreb (I. Reka), and A11 Zagreb – Sisak. The majority of these motorways have been constructed or are being constructed and all of them connect to the Zagreb Bypass which connects them and distributes the traffic per individual routes both of transit and source-target traffic.

All this indicates the traffic significance of the Zagreb Bypass both in international and in national road traffic, i.e. it accommodates the transit vehicle traffic from the City of Zagreb area, and it is also of high significance for the tourist traffic, mainly during the summer months. Apart from the obvious advantages, with its sudden development, road traffic has caused also certain undesired consequences out of which the most prominent one is the traffic network congestion, including thus lower level of safety, mainly due to the larger number of traffic accidents which is most stressed in the summer months. Especially in the morning and afternoon hours the traffic junctions are loaded, first of all the traffic interchange Buzin, with the formation of long queues of vehicles.

In order to solve the problem, the capacity and the level of service of the Zagreb Bypass need to be analysed, and the time requirement for the upgrade of the four-lane motorway into a six-lane one should be determined or some other measure regarding the increase of the capacity and raising of the level of

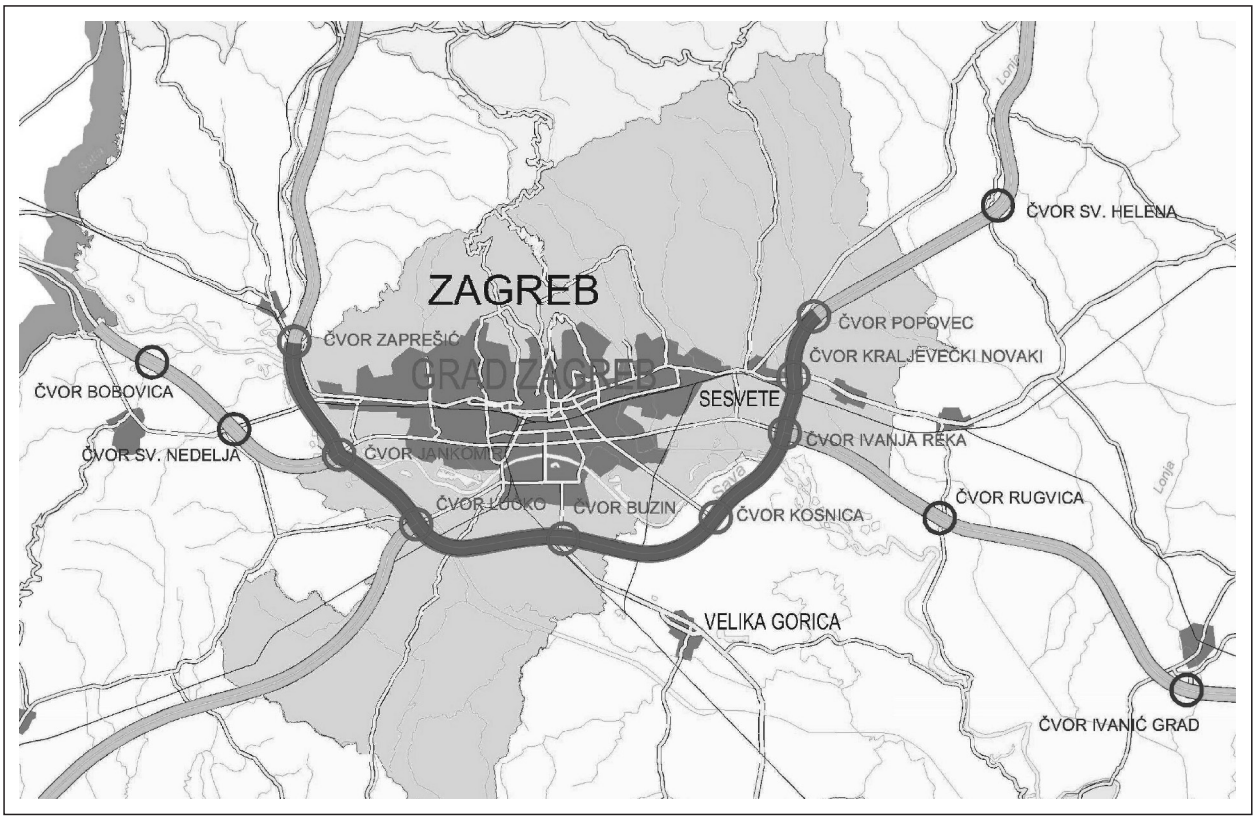

Figure 1 – Position of Zagreb Bypass and connections of the Bypass to the motorway network

service on the Zagreb road network needs to be predicted. In this context the Zagreb Bypass is increasingly acquiring the characteristics of a fast urban traffic route regarding the purpose of trips in which transit traffic is represented at the level of 10-15%.

2. CAPACITY ANALYSIS

The capacity of the section, Cd, in this analysis means maximal daily flow through the considered section under conditions which refer to physical properties of the traffic route, satisfactory level of service, time distribution of the traffic demand during the day and the capacity of the section.

The calculation of the section capacity starts from the capacity of the section (or cross-section) C (PCU/h – passenger car unit/h) that according to the definition by HCM represents the maximal number of vehicles which at reasonable expectation can pass in the unit of time (1h) through the section or traffic route cross-section under prevailing conditions of the road and traffic on it.

For the capacity analysis the software package HCS+ [1] was used which strictly follows the algorithms described in HCM.

Within the capacity calculation on the sections of the Zagreb Bypass between the Jankomir interchange and the Popovec interchange, as reference value the

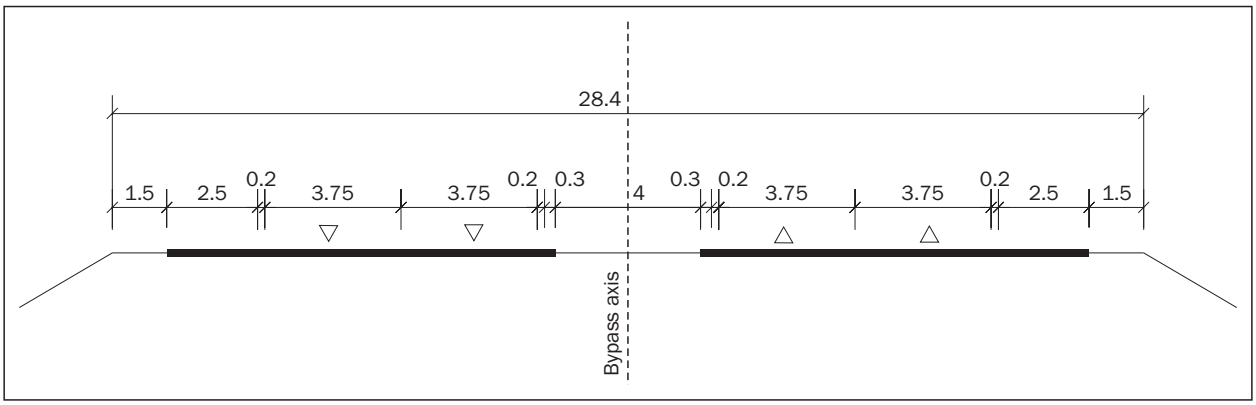

Figure 2 – Typical cross section of the Zagreb Bypass section

analysis has been carried out for the 30th hour of annual hourly distribution of traffic since the traffic on the Bypass proceeds in the conditions of significant urban influence.

Since the volume of traffic shows significant changes in different hours of the day and even greater annual fluctuations, the selection of hourly volume of traffic that will be used in the road design is closely connected to these fluctuations, so that it is necessary to know the peak loads and their distribution (the paper uses the criterion of the 30th hour as the percentage of AADT).

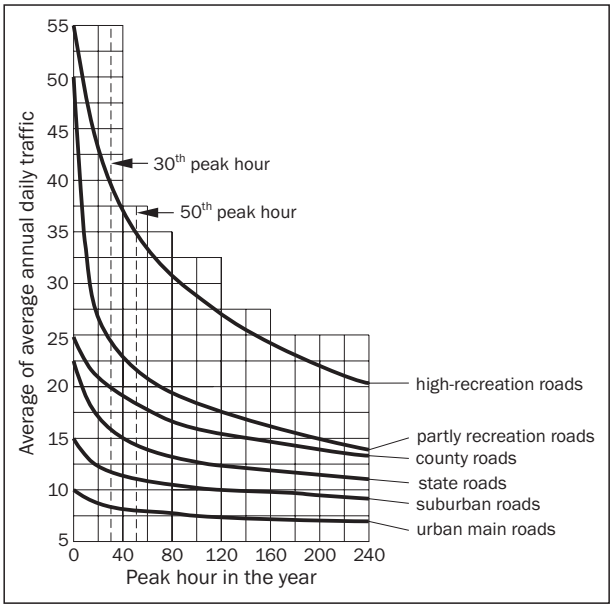

Figure 3 - Relation between peak-hour volumes of traffic and AADT on different types of roads

The curve that represents the fluctuation of hourly volumes of traffic during the year is extraordinary guide in the decision-making about the volume of traffic which best satisfies the design requirements. The studies of the characteristics of traffic load have developed the relation between the hourly traffic volumes and AADT. *Figure 3* shows the qualitative curves of the relation of peak hourly loads and AADT for roads with different purposes [2].

The studies have shown that around the 30th hour the curve gradient suddenly changes, and this is the point where the cost-benefit ratio approaches the maximum. Generally, this break on the curves occurs between the 20th and 50th peak hour.

Although in foreign practice the 30th peak hour is mainly implemented as the element for the design and determining of the road capacity, this cannot be accepted as a strict rule, since the determination of the relevant peak hour, apart from the type of road is also affected by a number of factors, with the economic potential of the state or region ranking first.

2.1 Analysis of traffic load on the Bypass

The basic method of collecting data about the traffic flows is the traffic count and it represents the most important activity in following the growth dynamics and the movement of traffic flows. All other basic studies of traffic flows – for instance source-target, the purpose of trip, type of goods, etc. rely on the count data which can be used to form the basic set in the concrete research.

The traffic analysis has been oriented from the beginning to the count data in accordance with the

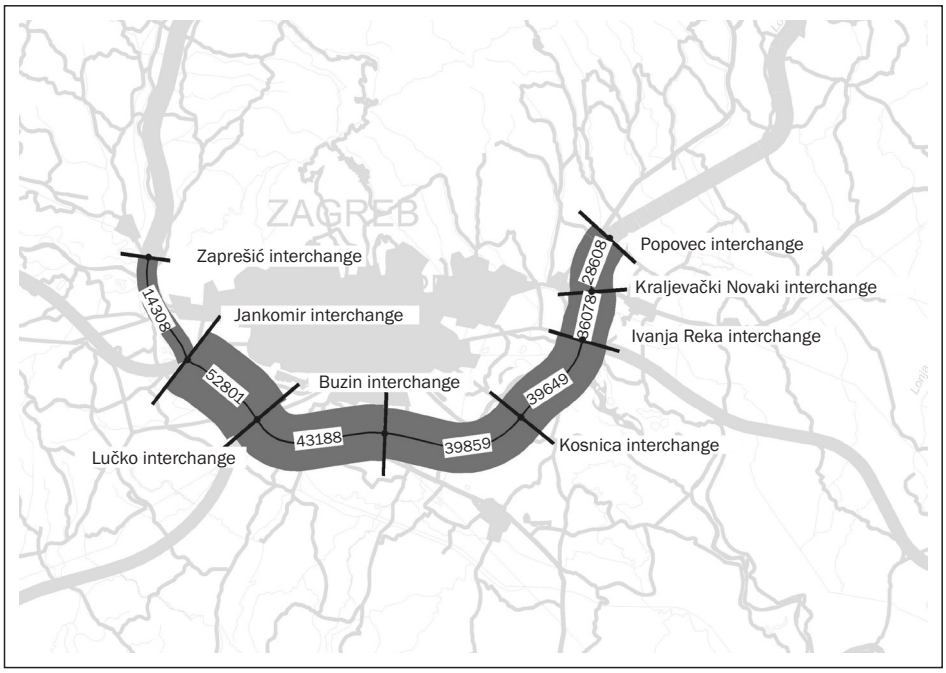

Figure 4 - AADT on the Zagreb Bypass in 2010

Table 1 – Basic characteristics of the traffic flow – morning peak hour

Cross-section	Initial time	Total (veh/h)	Entry into interchange			Exit from interchange		
			veh/h	veh/15'	PHF	veh/h	veh/15'	PHF
Popovec-North Popovec-South	...							
Sesvetski Kraljevec-North Sesvetski Kraljevec-South	7:30 7:30	1,666 2,234	596 1,400	165 408	0.90 0.86	1,070 834	312 236	0.86 0.88
Ivanja Reka-North Ivanja Reka-South	7:15 7:00	2,793 2,381	906 1,014	250 273	0.91 0.93	1,887 1,367	585 419	0.81 0.82
Buzin-East Buzin-West	7:00 7:30	2,589 2,540	936 1,032	288 266	0.81 0.97	1,653 1,508	492 477	0.84 0.79
Lučko-East Lučko-West	7:00 7:00	2,044 3,576	1,100 2,258	317 634	0.87 0.89	944 1,318	245 352	0.96 0.94
Jankomir-South Jankomir-North	7:15 7:45	3,067 1,795	1,474 667	406 191	0.91 0.87	1,593 1,128	464 366	0.86 0.77

Table 2 – Basic characteristics of the traffic flow – afternoon peak hour

Cross-section	Initial time	Total (veh/h)	Entry into interchange			Exit from interchange		
			veh/h	veh/15'	PHF	veh/h	veh/15'	PHF
Popovec-North Popovec-South	15:30 15:45	1,784 2,160	981 1,308	268 346	0.92 0.95	803 852	222 235	0.90 0.91
Sesvetski Kraljevec-North Sesvetski Kraljevec-South	16:45 16:45	1,658 2,380	869 1,125	243 310	0.89 0.91	789 1,255	211 361	0.93 0.87
Ivanja Reka-North Ivanja Reka-South	15:15 15:15	2,687 2,445	1,533 1,274	436 326	0.88 0.98	1,154 1,171	317 320	0.91 0.91
Buzin-East Buzin-West	15:45 17:00	2,607 2,691	1,298 1,443	343 391	0.95 0.92	1,309 1,248	344 357	0.95 0.87
Lučko-East Lučko-West	15:15 15:15	2,390 3,290	1,123 1,552	351 423	0.80 0.92	1,267 1,738	359 520	0.88 0.84
Jankomir-South Jankomir-North	16:00 16:30	3,283 2,190	1,026 1,421	285 369	0.90 0.96	2,257 769	592 210	0.95 0.92

purpose and level of research. Considered was the available base of data on traffic flows and certain additional studies which allows adequate level of accuracy in accordance with the profession requirements.

The analysis of data obtained by the traffic counts over a number of years indicates long-term tendency of road traffic growth. This long-term trend was temporarily disturbed during the Croatian War of Independence. Road traffic continues to have increasing share, especially in passenger transport. The basic value of observation is the AADT (average annual daily traffic, vehicles/day), which is defined as a statistical measure: total number of vehicles that pass along a section during the year in both directions divided by the number of days in a year. Regarding the available count methods AADT refers to the cross-section at a certain point of the section, but is assigned to the entire section.

In special cases of analysing certain locations the AADT values are not available, and then the ADT (average daily traffic, vehicles/day) values are considered, and these refer to the characteristically defined period. In accordance to the definition of AADT, ADT can also be defined as: total traffic through n 24-hour successive intervals divided by this number (n) of intervals.

The traffic analysis has been taken over from the study "Zagreb motorway interchange – traffic study, IGH, Zagreb 2007". *Figure 4* shows the traffic volumes (AADT) on the Zagreb Bypass in 2010, and the characteristic peak loads in Tables 1 and 2.

2.2 Capacity calculation

The steps of the procedure of calculating the capacity of the Zagreb motorway interchange on the section from the Jankomir interchange to Popovec interchange are the following:

1. The maximal hourly flow of vehicles on the section needs to be determined. According to HCM, the maximal flow of vehicles (C_{max}) for the motorway with two physically separated carriageways and two unidirectional traffic lanes per carriageway, amounts to 9,600 PCU/h.

Table 3 - Equivalent factors of the influence of trucks, buses and camping vehicles on the traffic flow in relation to passenger cars

	flatland	downhill	climb
ET (trucks and BUS)	1.5	2.5	4.5
ER (camping veh.)	1.2	2.0	4.0

Table 4 - Equivalent factors of influence of the trucks, buses and camping vehicles on the traffic flow in relation to passenger cars, as well as the percentage share of trucks, buses, and camping vehicles in the traffic flow

	PT	PR	ET	ER
AADT	13-23%	0.2-0.8%	1.5	1.2

2. From the annual hourly distribution of traffic flow for the observed section the share of 30 busiest hours is read (p_{30}) during the year as the percentage of AADT in the total traffic flow. The busiest 30 hours of the Zagreb motorway interchange on the section from the Jankomir interchange to Popovec interchange accounts for 10% of AADT [3].
3. The calibration factor of the share of heavy vehicles (f_{HV}) in the total traffic flow is calculated according to the expression:

$$f_{HV} = \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_{R-1})} \quad (1)$$

where:

f_{HV} – calibration factor of the share of heavy cargo vehicles in the traffic flow,

E_T, E_R – equivalent factors of influence of trucks, buses and camping vehicles on the traffic flow in relation to passenger cars,

P_T, P_R – average share of trucks, buses and camping vehicles in the traffic flow.

The results obtained by the performed procedure at AADT amount to:

f_{HV} = 0.9218 –Zaprešić – Jankomir section,

f_{HV} = 0.9181 –Jankomir – Lučko section,

f_{HV} = 0.8969 –Lučko – Buzin section,

f_{HV} = 0.8959 –Buzin – Ivanja Reka section,

f_{HV} = 0.9380 –Ivanja Reka – Kralj. Novaki section,

f_{HV} = 0.9159 –Kralj. Novaki – Popovec section.

The capacity is calculated according to the following expression:

$$C_d = \frac{C_{max} \cdot 100}{p_{30}} \cdot f_{HV} \quad (2)$$

where:

C_d – capacity of Zagreb motorway interchange on a certain section (veh/day),

C_{max} – maximal hourly flow of vehicles of the Zagreb motorway interchange (9,600 veh/h),

P_{30} – share of 30 busiest hours as average share in AADT (%),

f_{HV} – calibration factor of share of heavy cargo vehicles in traffic flow.

Having carried out the mentioned procedure the following values of the Zagreb Bypass capacity have been obtained:

C_d = 88,495 veh/day – Zaprešić – Jankomir section,

C_d = 88,136 veh/day – Jankomir – Lučko section,

C_d = 86,104 veh/day – Lučko – Buzin section,

C_d = 86,004 veh/day – Buzin – Ivanja Reka section,

C_d = 90,044 veh/day – Ivanja Reka – Kralj. Novaki section,

C_d = 87,929 veh/day – Kralj. Novaki – Popovec section.

2.3 Analysis of the level of service

The quality of the traffic flows means the freedom of movement, speed and time of travel, traffic interruptions, comfort and safety of driving and the price, and it is expressed by the term the level of service. Six levels of service have been defined denoted by symbols from A to F, where the level of service A is the best (free flow) and F is the worst (forced flow with possible complete gridlock).

For multi-lane roads with separated carriageways the level of service is defined by the density, and indirectly described also by the average speed and the travel time. According to HCM the level of service has been defined according to the following criteria:

Table 5 – HCM level of service criteria

Level of service	Maximal density (PCU/km/lane)
A	≤ 7
B	≤ 11
C	≤ 16
D	≤ 22
E	≤ 28
F	> 28

The traffic conditions have been recorded in the peak hour for the day 10 May 2006 and based on this peak hour according to the HCM methodology the level of service was calculated.

Table 6 – Calculations of level of service on Zagreb Bypass

Section	Level of service (2+2) current condition	Level of service (3+3)
Zaprešić - Jankomir	A	A
Jankomir - Lučko	C	B
Lučko - Buzin	B	A
Buzin – Kosnica	B	A
Kosnica – Iv. Reka	B	A
Iv. Reka – Kralj. Novaki	B	A
Kralj. Novaki - Popovec	A	A

The analysis of the level of service has been carried out using the software package "HCS+". As inputs for the analysis the following data had to be processed and entered:

V – volume or traffic load in peak hour veh/h,

FFS – free flow speed km/h (120km/h – main flow, 60/80 km/h - ramps),

E_T, E_R – equivalent factors of influence of trucks, buses and camp vehicles on the traffic flow in relation to passenger vehicles,

Terrain –type of longitudinal gradient (in ascent, at level, in descent) and gradient (%),

L – distance of the nearest ramp from the observed cross-section in the interchange (m).

f_P – driver population factor – in urban conditions it is 1 since the majority of drivers know road routes that they use (m).

PHF – peak hour factor based on 15-minute load,

$$PHF = \frac{V_{max1h}}{4 \cdot V_{max15min}} \quad (3)$$

where:

V_{max1h} – volume of peak hour in the observed period (veh/h),

$V_{max15min}$ – volume of peak 15 minutes in the peak hour of the observed period (veh/h)

The analysis was carried out on all seven sub-sections. According to the results of manual counts on the approaches to interchanges between which the analysed section is located the peak load was determined for each of the four carriageways. The highest load was accepted as the reference load for the calculation of the level of service on an individual section. The results of the level of service analysis have been presented both for the current situation of the carriageway design with two traffic lanes, and for the case it were expanded to three traffic lanes in *Table 6*.

Table 6 shows that the level of service on the sections ranges from A to C for the current version of the Zagreb Bypass profile. In expansion of the transversal profile to 3+3 traffic lanes the level of service is raised by one level, except on the Kraljevečki Novaki – Popovec and Zaprešić – Jankomir sections, where in the base and alternative case the level of service ranks the highest. The lowest level of service in the present version occurs on the Jankomir – Lučko (C) section where there is also high relation V/Cd = 60%.

3. CONCLUSION

At the level of service C (HCM 2000) it is necessary to consider the increase of the traffic route capacity, i.e. at this level it would be necessary to realise an alternative version which would enable better traffic flow and reduction of costs that are incurred for the society due to the longer travelling times, increase in the risk of traffic incidents and accidents and because of the increase in the vehicle operative costs. According to the results of analysis, LOS C is recorded for one section, LOS B is recorded for four sections and LOS A is recorded for two sections. Such analysis can serve as the basis for obtaining the picture about the projection of the increase in the traffic flows and approximate estimate of the need to upgrade the construction of the respective motorway to 3+3 traffic lanes from the aspect of traffic demand. These results of analysis can be the basis for further research into the level of customer service at the Zagreb Bypass, especially in terms of their opinions through constant recording and analyzing the variation of traffic through software packages such as HCM. At present, special attention should be paid also to environmental protection due to the increase of exhaust emissions that are generated and that concentrate in the areas of traffic congestions. Such analysis provides important inputs for the development of environmental studies.

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SAŽETAK

PROPUSNA MOĆ I RAZINA USLUŽNOSTI NA ZAGREBAČKOJ OBILAZNICI

Zagreb kao glavni grad Republike Hrvatske, svakako je najveće autocestovno čvorište u širem smislu, ali i ishodište i odredište velikog broja putovanja. Pored evidentnih prednosti, cestovni promet je svojim naglim razvojem uzrokovao i određene neželjene posljedice od kojih se ističe zagušenje prometne mreže, a samim tim i smanjenje razine sigurnosti, poglavito poradi većeg broja prometnih nesreća što je najviše izraženo u ljetnim mjesecima. Tijekom jutarnjih i u popodnevnih sati bilježe se najveća prometna opterećenja na čvorištima, prije svega na Buzinu gdje se formiraju dugačke kolone vozila. U cilju rješavanja problema potrebno je izraditi analizu propusne moći i razine uslužnosti te ukazati na eventualnu potrebu za provođenjem mjera u smislu povećanja propusne moći i razine uslužnosti u koridoru zagrebačke obilaznice.

KLJUČNE RIJEČI

zagrebačka obilaznica, autocesta, kapacitet, razina uslužnosti

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