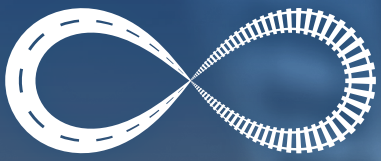

CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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OPERATING SPEED ON URBAN ROAD NETWORK – CASE STUDY IN RIJEKA, CROATIA

Aleksandra Deluka-Tibljaš, Sanja Šurdonja, Dario Malatestinić, Luka Strineka
University of Rijeka, Faculty of Civil Engineering, Croatia

Abstract

Speed is an important factor for road capacity and road safety level. It is the main reason for almost all types of traffic accidents on road network outside but also inside urban areas. Traffic speed is affected by different parameters such as traffic regulation and traffic signs, road geometry and road environment in general. Different researchers show that operational speed, measured on the road network, is different than design speed or posted speed limit. As in urban areas, there are many roads (mainly primary roads) with heterogeneous traffic (pedestrians, personal vehicles, bicycles…) the problem of speed control and prediction becomes even more complex than on roads outside of urban areas. In this paper, an overview of parameters affecting speed on the urban road network is done. Also, preliminary analyses of measurements done on the primary road network in Rijeka city is presented. Speeds were measured on the main primary road network in order to compare it with allowed speeds and other road parameters. The measurements were done on different types of road sections and the correlation between allowed and operational speed was established.

Keywords: operational speed, urban network, model, speed limits

1 Introduction

The urban road network is traditionally divided in two types of roads regarding their main function: primary road network with the dominant function of assuring mobility and high level of capacity and secondary road network with the main function of assuring accessibility and safe traffic conditions for different kind of users. In reality, those functions are mixed and primary roads in cities, in Croatian context but also elsewhere, very often also have an important function in assuring accessibility. That usually means that there are non-homogenous traffic conditions present with lots of pedestrians (and cyclists) on the roads on which higher speed should be allowed and higher capacity assured. The result can be a lower level of traffic safety. In Croatia in 2016. 80 % of all traffic accidents happened inside urban areas. [1]. The reasons for the accidents were different but exceeded speed or speed which was not adjusted to the road conditions prevail in general as traffic accident causes.
Traffic regulation in Croatia posted 50 km/h as speed allowed in urban areas where there is no specific speed regulated, on the primary road allowed speed are up to 80 km/h [2]. Dutch programme for enhancement of traffic safety Advancing Sustainable Safety [3] suggested speed limits connected to types and possible consequences of traffic accidents. For example speed limit for roads with possible conflicts between cars and unprotected road users is 30 km/h and for intersections with possible transverse conflicts between cars 50 km/h.
The problem is how to calculate in advance operating speeds that can be expected at certain road sections in real traffic conditions. Many types of research were done in order to define speed prediction models for operating speed on urban roads. It is conventionally accepted

that operating speed is equal to the 85th percentile of the travel speed of the isolated vehicle (v_{85}). The difference between this and design speed should be minimized in order to be in harmony with driver expectation and achieved design consistency [4].
In this paper, a short overview of existing speed models for urban roads and parameters used in that models is presented. Also, data from speed field measurements in Rijeka City are analyzed. The speed observations were done on 24 sections on primary roads with heterogeneous traffic. The measured data were used to establish if there is a significant difference between posted and operating speed at primary road network. In the second step, the results were analyzed in order to establish a correlation between chosen variables and measured (v_{85}) speed. Posted speed limit resulted as the most important variable in the model.

2 Operating speed models for urban roads

Many speed models were developed in order to establish main influencing factors and help to predict operating speeds for urban roads. Models are usually based on field measurements and developed using regression techniques. Even all of this models can generally help in analyzing operating speed the limitation that they were developed in specific conditions (road design elements, traffic rules, traffic culture etc.) has to be taken into account and therefore every model should be used where it has been calibrated [5].
Field operating speed observations are usually done in two ways: or by recording traffic at road sections [4] or by using laser gun [6, 7]. In any case, the suggestion is to conduct measurements in the way that the impact of the equipment on the traffic flow is minimal so that reliable data can be obtained for further analyses.
Analyses of researches done in order to establish operating speed models for urban roads show that models are developed for different types of urban roads: arterials, collectors [4], highways [6, 8] but also for residential or other low-speed urban streets [7, 9]. As operating speed in all of the mentioned researches, the V_{85} is accepted.
Different parameters are analyzed in order to define speed models. Variables go from those connected with area in which road section is situated (urban, suburban), traffic conditions (traffic volume, traffic structure ect.), road design elements (such as number of lanes and lane-width, horizontal curve, vertical grade), road surface conditions, road environment (presence of pedestrian crossings, nearby ...), vehicles types and others. According to [7] when urban road section is in a horizontal curve most influencing variables are horizontal radii and the degree of curve. At straight sections posted speed limit happens to be the most important variable in developed models. Different authors developed speed model based on PSL as the main variable, here are the examples of such a model and it's accuracy presented with R^2.
Fitzpatrick et al. model [6], developed on the basis of 36 straight road sections:

$$v_{85} = 29{,}18 + 0{,}701 * PSL; \quad R^2 = 0{,}53 \tag{1}$$

3 Operating speed model for primary road with heterogeneous traffic

Field measurements were conducted on chosen roads in the City of Rijeka. All selected cross sections were on the streets that form primary road network (main city roads) on which heterogeneous traffic is present. The speed up to which 85 % of all passing vehicles drive, is accepted as operating speed (v_{85}).

3.1 Field measurement methodology

Field measurements were done with traffic counters Datacollect SDR Traffic without interruption of traffic-free flow conditions in order to assure the quality of database for analyses. Transversal speed profile was recorded for every passing vehicle. At all measurement spots, traffic and speed were recorded for at least 4 hours in continuation during daylight in stable weather conditions. Measurements were done on 24 cross sections on urban roads outside intersection area. All cross sections were on the straight part of analyzed urban roads and on grade from -3.5 to +3.5 %.

Figure 1 Selected primary roads for field measurements – Rijeka City

The sample consisted of:

- 13 cross-sections on which posted speed limit (PSL) is 50 km/h, 6 with PSL of 40 km/h, 4 with PSL 70 km/h and one with PSL 20 km/h
- Analysed cross sections were both in one and two-way streets.
- Cross section A (1-6) are were situated in Janka Polić-Kamova Street, B (1-9) in 13. Divizije Street, C (1-2) in Franje Čandeka Street, D (1-4) in Opatijska and Istarska Street and E (1-2) in Zvonimirova Street (Figure 1). All of this streets are classified as primary roads and they are positioned in transit but in the same time built-up city areas.

3.2 Preliminary findings

Observed traffic conditions and measured data are presented in table 1 as follows: hourly traffic (HT); percentile of personal vehicles in total traffic (%PV); posted speed limit (PSL) and measured operating speed (V_{85}). Recorded traffic volumes per traffic lane were very different among observed cross sections, between 150 and 710 veh/h but still smaller than theoretical capacity for observed road categories [10].
Data show that at all observed cross sections operating speeds were higher than posted speed limits. In next step correlation between operating speed, posted speed level and other possible variables were examined in order to define correlation among this variables.

Table 1 Cross-section characteristics

Cross section	TR	HT [veh/hour]	% PV	PSL [km/h]	Operating speed v_{85} [km/h]
A-1	One-way	410	94	50	63
A-2	One-way	550	94	50	72
A-3	One-way	325	80	50	72
A-4	One-way	325	80	50	64
A-5	One-way	400	93	50	63
A-6	One-way	400	93	50	64
B-1	One-way	250	92	40	60
B-2	One-way	250	92	40	60
B-3	One-way	400	95	40	50
B-4	One-way	450	95	40	64
B-5	One-way	450	95	50	70
B-6	One-way	370	96	50	61
B-7	One-way	370	96	20	52
B-8	One-way	300	82	40	58
B-9	One-way	390	92	40	56
C-1	Two-way	250	95	50	67
C-2	Two-way	250	95	50	64
D-1	Two-way	155	97	70	85
D-2	Two-way	150	97	70	82
D-3	Two-way	500	94	70	75
D-4	Two-way	500	94	70	79
E-1	Two-way	540	80	50	68
E-2	Two-way	710	80	50	76
E-3	Two-way	460	80	50	72

Results of measured operating speed (v_{85} and average speed), only for sections A3-A6 and B1-B7, are shown in Figure 2. It can be seen that at all spots more than 58 % of vehicles go beyond posted speed limits (PSL) and on most of the spots that percentile is around 90 %. Also, average speeds on all cross-sections (longitudinal profile) are higher than PSL.

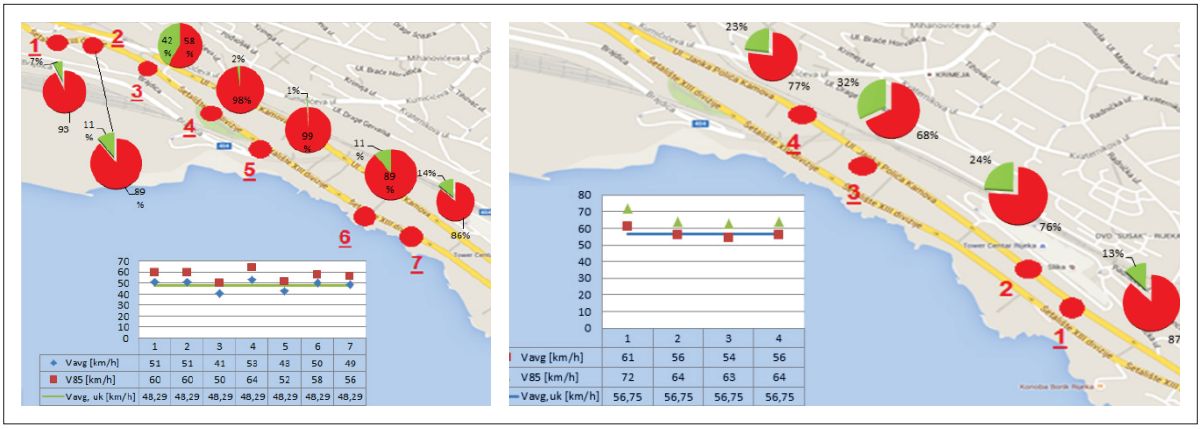

Figure 2 Comparison of measured and posted speeds observed at cross sections B1 – B7(left) and A3-A6 (right) [11]

3.3 Variable testing and model development

As a first step of the analyses the correlations between chosen variables: traffic volume, the percentile of personal cars and posted speed limits with measured operating speed were tested. The results are presented in Table 2. It can be noticed that there is, as proved in other researches [7], the strong positive correlation between operating speed and posted speed limit.

Table 2 Correlation among chosen variables and measured operating speed

	HT [veh/hour]	% PV	PSL [km/h]	Operating speed v_{85}
HT [veh/hour]	1			
% PV	-0.31143	1		
PSL [km/h]	-0.04674	0.122092	1	
Operating speed V^{85}	0.04417	-0.00697	0.864328	1

In the same time, there is no significant correlation between operating speed and traffic volume. Also, the analyses show that percentile of personal cars in traffic load structure does not have an impact on the operating speed. The reason can be that all measurements were done in free-flow conditions at which the amount of traffic has no influence on the operating speed. After establishing the correlation between operating speed and posted speed limit the simple regression model was developed to describe the correlation (Table 3).

Table 3 Regression statistics

Observations	24
Multiple R	0.85794924
R Square	0.736076899
Standard Error	4.693088811

The posted speed limit is variable which can explain 73,6 % of the operating speed variation and that can be acceptable. Finally, analytical model for operating speed (V^{85}) as a function of posted speed limit (v_{PSL}) can be defined as follows:

$$V_{85} = 33{,}78196501 + 0{,}660699865 * V_{PSL} \tag{2}$$

Graphically the data on which the model is based are presented in Figure 3.

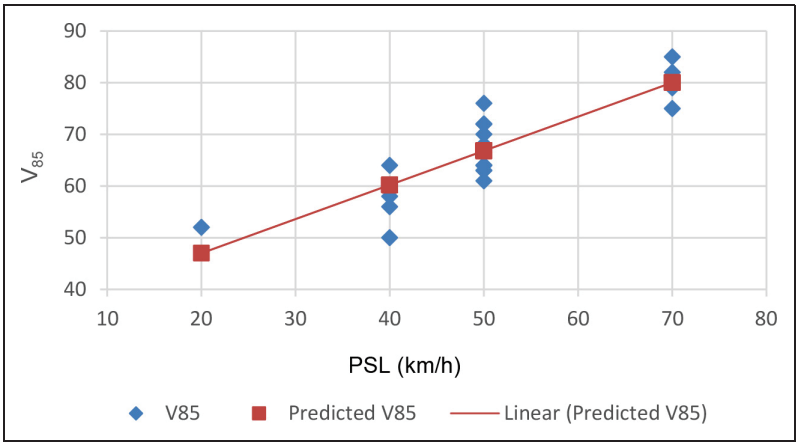

Figure 3 Correlation between variables of model

3.4 Possible application of model for operating speed

In Croatian technical regulation, it is common to introduce design speed for roads sections outside urban areas and posted speed limits inside urban areas as a relevant element for traffic safety analyses. Operating speed is not implemented. In Table 4 values for stopping sights distance from Croatian Rulebook for Road Design [12] for different speeds: PSL and v_{85} (calculated with developed model) are compared.

Table 4 Stopping site distance using PSL and calculated V_{85} speed

PSD / v_{85} [km/h]	40 / 60	50 / 67	60 / 73	70 / 80
SSD [m]	35 / 70	50 / 85	70 / 95	90 / 120

Values calculated on the basis of v_{85} are in all cases much higher than those calculated on the basis of PSL. It can be a great problem on roads where heterogeneous traffic is expected, meaning motor vehicles and pedestrians.

4 Conclusions

Operating speed is an important element in the process of urban road design especially for assuring traffic safety. In this paper, a simple model for operating speed on the urban road with heterogeneous traffic is developed. In this case, operating speed happened to have the highest correlation with the posted speed limit. Application of the model in the calculation of stopping sight distance proved that there is a need to analyze how to implement operating speed, instead of design or posted speed limit, in Croatian technical regulation. Future development of this research will aim at including geometrical characteristics of observed roads into analyses and to establish a possible correlation with operating speed.

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