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OBSERVING THE IMPACT OF VARIABLE SPEED LIMIT SIGNS ON THE TRAFFIC FLOW[1]

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Abstract

Variable speed limit signs are traffic control devices that consists of dynamic message signs (DMSs) that are deployed along a roadway and connected via a communication system to a traffic management centre. This article investigates how the observance of variable speed limit signs affects the main parameters of traffic flow: speed, density and volume. An analysis was done using a microscopic, time step and behaviour-based simulation model PVT VISSIM on a theoretical section of motorway through nine scenarios related to input volume and speed limit observance. The results showed that the observance of speed limits with variable speed limit signs would, besides increase of traffic safety, result in traffic flow harmonization.

Keywords – variable speed limit signs; traffic flow; traffic speed; traffic volume

INTRODUCTION

Traffic flow theory evaluates the operational quality of the traffic stream with the given set of prevailing conditions [1]. It is engaged in exploration and definition of basic indicators, relevant for the description of the traffic flow, research of its characteristics in ideal and real conditions and research the interdependence of the basic traffic flow parameters.

Research and description of traffic flow is based on the analysis of a number of factors that affect the way the vehicles move in the traffic stream. The most important factors are traffic volume, flow characteristics, psychological and physical characteristics and motivation of the driver, characteristics of the system for traffic management and environmental

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conditions (visibility, road conditions, climate, etc.) [2]. Simultaneous interaction of the above factors affect the complexity of description the principles of vehicle movement in the traffic stream, and is further intensified by the fact that the main influencing factors have spatiotemporal patterns. A spatiotemporal traffic pattern, as defined in [3], is a distribution of traffic flow variables in space and time.

A variable speed limit sign (VSLS), as one of the important ITS devices, provide real-time traffic information of road network to drivers in order to improve route choice and relieve the traffic congestion [4].

Although VSLS systems are used throughout the world, there is currently very limited documentation that describes quantitative safety and operational impacts [5].

Lee et al. in [6, 7] analysed the impact of VSLSs responses to real time measures of crash potential using microscopic simulation. The results showed that in highly congested locations, VSLSs provided a reduction of crash potential by 25% but increased overall travel time. Similar study conducted in [8]showed opposite results. VSLSsin this study provided a large reduction in crash potential in low congested conditions but had little impact for peak period conditions. In addition, it was found that consistent decrease in travel time during low congested conditions using VSLSs was present, although the relative change in travel time from the non-VSLS case to the VSLS case was very small.

Research in [9] focused on the impact of advisory VSLSs and proposed a statistical methodology for the comparison of traffic conditions before and after their implementation using the prevailing flow-density relationships. The results indicated that the advisory VSLS had no significant impact on traffic conditions, both immediately after the implementation and several months later.

This article investigates how the observance of variable speed limit signs affects the main parameters of traffic flow: speed, density and volume (traffic flow) in ideal weather conditions. An analysis was done using a microscopic, time step and behaviour-based simulation model PVT VISSIM. The thesis of the article was that the observance of speed limits using variable speed limit signs placed on the hypothetic motorway section will, besides increase of traffic safety, result in traffic flow harmonization.

DESIGN OF MICROSIMULATION MODEL USING SIMULATION PROGRAM PVT VISSIM

PTV VISSIM is a microscopic, time step and behaviour-based simulation model developed to model urban traffic and public transport operations and flows of pedestrians. For the purpose of the analysis microsimulation model was created containing theoretical section of motorway with length of 6200 m and width of 3.75 m per lane. The observed section is straight with no interchanges and ramps and with the maximum input volume of 4700 veh/h.

When defining classes of vehicles that will use the motorway except cars, heavy vehicles and buses, class *violators* was defined. The specified class of vehicles will not respect the speed limitations on the traffic signs. The percentage of heavy vehicles was limited to 5%.

Speed limitations were defined every 1000m and every 2000m speed was gradually decreased by 20km/h(100 km/hto 60km/h). To each vehicle after passing a fictitious speed limit traffic sign an appropriate distribution of desired speeds is assigned, depending on the class of vehicle. The desired speed is the speed, which the vehicle would achieve in terms of free traffic flow.

Figure 1shows thecumulative distributiongraph of desired speeds. On the x-axisspeed rangefrom minimum to maximumvalue is shown, andon they-axis is the cumulative percentagefrom 0 to 100. Curveis usuallyshapedas an S-curvepositioned aroundthe median.

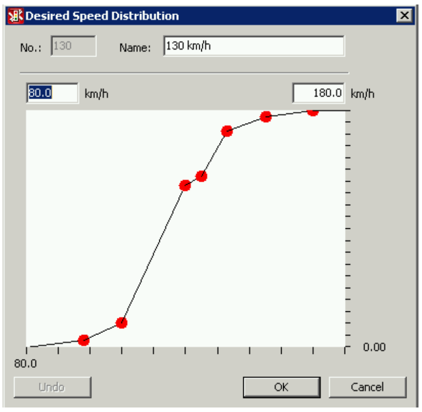

Fig.1. Distribution of desired speeds

The simulation model was conducted in the period of 3600 s with additional network “heating” of 900 s. Evaluation of the model was made using aggregated data from sections with length of 1000 m. The collected data is related to the density of traffic flow, space mean speed and traffic volume.

The simulation was carried through nine scenarios as shown in Table 1. Scenarioswere grouped according to the input volume into three groups: low input volume (20% of capacity), intermediate input volume (50% of capacity) and high input volume (90% of capacity). The observance of the speed limitations regulated by variable speed limit sings were also divided into three groups: low (40% of the input volume respects the speed limit), medium (70% of the input volume respects the speed limit) and high (90% of the input volume respects the speed limit).

Table 1. Simulation scenarios

Input volume (%volume)	**Observance of the speed limitations**			
	Low (40%)	Intermediate (70%)	High (90%)	Input volume (veh/h)
Low (20%)	S1	S2	S3	940
Intermediate (50%)	S4	S5	S6	2350
High (90%)	S7	S8	S9	4230

SIMULATION RESULTS EVALUATION

Evaluation of the simulation results was done by grouping simulation scenarios in such a way that the three scenarios of speed limitations observance are grouped with one input volume (for example, scenarios S1, S2 and S3 are grouped with low input volume).

In this section, results of each group of scenarios are presented.

ANALYSIS OFSCENARIOSS1, S2AND S3

Scenario S1 is characterized by low input volume, 20% of the capacity, or 940 veh/h and low observance of speed limitations (40% of the input volume to observe the limitations).Scenario S2, is also characterized by low input, 20% of the capacity (940 veh/h) and intermediate observance of speed limitations (70% of the input volume observe the limitations).Scenario S3, like the previous two scenarios, is characterized by low input and high observance of speed limitations (90% of the input volume observe the limitations).

In the Table 2average simulation results of scenarios S1, S2 and S3are shown.

Table 2. Averages of the simulation results for scenarios S1, S2 and S3

Parameters	**Scenario**		
	S1	S2	S3
Speed (km/h)	98.51	89.00	84.52
Density (veh/km)	5.06	5.72	6.03
Volume (veh/h)	468.39	468.03	468.52

Comparing the results of scenarios S1, S2 and S3 it can be concludedthat with the increaseof the observation percentage average speeds reduces (from

98.51 km/h in scenario S1 to 84.52 km/h in scenario S3), and thus density of traffic flow increases (from 5.06 veh/km in scenario S1 to 6.03 veh/km in scenario S3). Although speed is decreasing, traffic volume in all three cases remains almost the same (about 468 veh/h) with the highest level in scenario S3,i.e. when the observation percentage is high (90%).

ANALYSIS OF SCENARIOS S4, S5 AND S6

Scenarios S4, S5 and S6are characterized by intermediate volume, 50% of the capacity, or 2350 veh/h and low (40% of the input volume), intermediate (70% of the input volume) and high(90% of the input volume) observance of speed limitations.

Simulation results of scenarios S4, S5 and S6 are shown in the Table 3.

Table 3. Averages of the simulation results for scenarios S4, S5 and S6

Parameters	**Scenario**		
	S4	S5	S6
Speed (km/h)	83.96	80.62	79.87
Density (veh/km)	15.02	15.80	15.95
Volume (veh/h)	1,184,12	1,185,01	1,185,86

Table 3. showscomparison of scenarios S4, S5 and S6, and similar to previous results, it can be seen that with the increase of the observation percentage, average speed reduces (from 83.96 veh/km in S4 to 79.87 veh/km in S6) and thus density of traffic flow increases (from 15.02 veh/km in S4 to 15.95 veh/km in S6). Traffic volume in all three scenarios remains almost constant (1,185,00veh/h) with the highest level in scenario S6, i.e. when the observation percentage is high (90%).

ANALYSIS OF SCENARIOS S7, S8 AND S9

Scenarios S7, S8 and S9 are characterized by high volume, 90% of the capacity, or 4230 veh/h and low (40% of the input volume), intermediate (70% of the input volume) and high (90% of the input volume) observance of speed limitations.

Table 4. Averages of the simulation results for scenarios S7, S8 and S9

Parameters	**Scenario**		
	S7	S8	S9
Speed (km/h)	75.11	74.35	74.46
Density (veh/km)	29.76	30.27	30.36
Volume (veh/h)	2,129,25	2,129,02	2,130,08

Analysis of last three scenarios (table 4.) shows similar result pattern like the previous two scenarios: as the speeds reduce (from 75.11 km/h in S7 to 74.46 km/h in S9), density of traffic flow increases (from 29.76 veh/km in S7 to 30.36 veh/km in S9) and the traffic volume in all three scenarios remains almost the same (2,129,00veh/h) with the highest level in scenario S9, ie when the observation percentage is high (90%).

COMPARISON OF THE SIMULATION RESULTS

From the comparative analysis of all scenarios it can be concluded that the average speed of vehicles is reducing through all the scenarios (which is logical given the speed constraints) except the last (S9) when the speed is slightly increased compared to the previous case, as shown in the Figure 2. Speed increase in the latest scenarios is negligible and it can be said that the speed is continuously reducing.

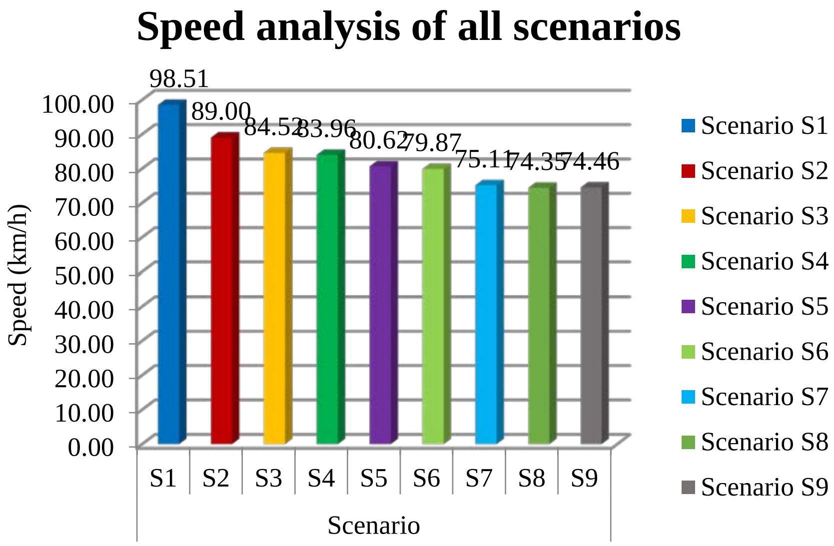

Fig.2. Speed comparison for all simulated scenarios

Densities of traffic flow are grouped depending on the input volume: S1-S2-S3; S4-S5-S6; S7-S8-S9; and each group is analysed separately as shown in Figure 3. From the figure it can be seen that with the increase of observation percentage of speed limits,density increased which was expected due to the speed reduction.

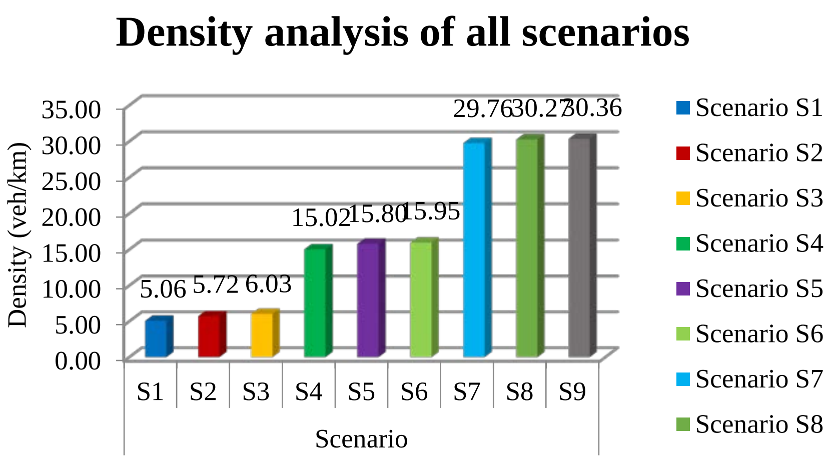

Fig.3. Density comparison for all simulated scenarios

Comparative analysis of the traffic flow volume by each group of scenarios represents the most significant analysis and based on it articles thesis can be confirmed. Volume's for the each scenario group are almost equal with a slightincrease in the scenarios with the highest observation percentage of speed limits in particular groups (S3, S6 and S9) as shown in Figure 4.

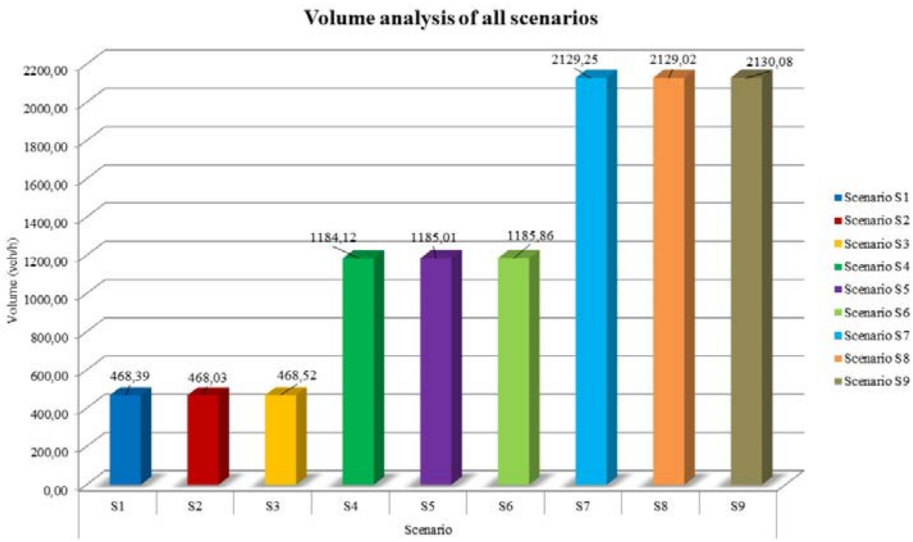

Fig. 4. Volumen comparison for all simulated scenarios

The simulation results show that the observance of the speed limitations using variable speed limit sings will increase traffic safety (through the reduction of speed) and traffic flow density while maintaining the same level of traffic flow which will result with its harmonization.

CONCLUSION

In order to analyse the impact of observance of variable speed limit signs on traffic flow, a theoretical section of motorway with length of 6200 m and width 3.75 m per lanewas constructed using microsimulation tool PTV VISSIM. The observed section was straight with no interchanges and ramps and with the maximum input volume of 4700 veh/h.

The simulation model was conducted in the period of 3600 s with additional network “heating” of 900 s. Evaluation of the model was made using aggregated data, related to the density of traffic flow, space mean speed and traffic volume, from sections with length of 1000 m.

The simulation was carried through nine cases grouped according to the input volume into three groups: low input volume (20% of capacity), intermediate input volume (50% of capacity) and high input volume (90% of capacity). The observance of the speed limitations regulated by variable speed limit sings are also divided into three groups: low (40% of the input volume respects the speed limit), medium (70% of the input volume respects the speed limit) and high (90% of the input volume respects the speed limit).

Based on the collected data and the analysis it can be concluded that the speed in all three scenario groups reduced thus causing the increase of the traffic flow density. Furthermore, although there is a higher density and speed decreases, the traffic flow volume does not oscillate and on contrary, in the scenarios with a higher observation percentage of speed limits, volume is growing.

From all above it can be concluded that the paper thesis is confirmed and that the speed limit besides increasing traffic safety can increase traffic volume and thus harmonize the traffic flow. With the harmonization of traffic flow, i.e. avoidance of sudden acceleration and deceleration that can occur in traffic flows with lower densities due to the speed reduction, reduction of gas emissions and noise levels emitted by the traffic flow can be reduced.

In further research it is recommended to conduct similar studies to get more information on how variable speed limit signs affect traffic flow harmonization. Additionally, it is recommended to study the gas emissions and noise levels in a correlation with the traffic flow harmonization.

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