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APPLICATION OF TRAFFIC SIMULATION MODELS FOR URBAN ROAD NETWORK ANALYSES – CASE STUDIES FROM RIJEKA CITY

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Abstract

The process of road network planning and designing in urban areas can be significantly improved by using microsimulation of traffic models. Traffic microsimulations are used for analyses and estimation of new proposals as well as for the reconstruction of existing infrastructure in order to reach optimum solution for defined problem. In this paper, applications of different analyses approaches are analyzed in two case studies. Both case studies are located in the city of Rijeka but in different parts of the city, in different traffic conditions and in circumstances where different changes in traffic network are planned. In both cases new solutions were tested through VISSIM traffic model and by application of SIDRA Intersection methodology. VISSIM is a stochastic, discrete, micro-simulation model designed for traffic analyses while SIDRA Intersection is a lane-based micro-analytical model. The results proved the suitability as well as advantages and disadvantages of both approaches. The paper contains suggestions for optimal application of selected models regarding different traffic problems.

Keywords: road traffic microsimulation, urban traffic, SIDRA Intersection, VISSIM traffic model

1 Introduction

Models used to analyze the capacity of a transport network or a section of it are generally divided into deterministic models where output is fully determined by the parameter values and the initial conditions, and stochastic models which possess some inherent randomness so the same set of parameter values and initial conditions can lead to different outputs. The application of microsimulation traffic models has been intensified in recent decades as it enables quality analysis and presentation of interventions in the transport network. Particularly interesting is the application of traffic simulations in complex urban conditions. Traffic microsimulations are used in the intersection optimization process at a specific location for traffic analysis of a section of the traffic network where changes occur as a result of planning of new contents, when planning changes in the traffic flow regime [1, 2, 3]. Recent studies related to the use of traffic microsimulation are aimed at the analysis of traffic safety [4] and simulation of traffic conditions in cases when in traffic, together with the standard vehicles, there is also a certain number of autonomous vehicles [5]. The quality of microsimulation results depends on how much detailed and precise are the input data) and on the extent to which they are calibrated to the local traffic conditions in a

particular area (country, city). Calibration is defined as the process of comparing and minimizing the differences between modeling results and the real data obtained by counting and measuring in a local network [6].
In this paper, the aim is to analyze the application of deterministic and stochastic models of traffic flow on the example of two planned changes in the traffic network of the city of Rijeka. In both cases, the scope of changes in the traffic system is to create more favorable conditions for non-motorized modes of traffic which consequently affect the quality of traffic flow of motor traffic. In both cases, new solutions were tested through the VISSIM model and by the application of the SIDRA Intersection traffic model. VISSIM is a stochastic, discrete, micro-simulation model designed for traffic analysis while SIDRA Intersection is a lane-based micro-analytical model. Microsimulation tools are explained in section 2 and two case studies in section 3. The results implemented the suitability as well as the advantages and disadvantages of both approaches. The suggestions for optimal application of selected models regarding different traffic problems are given in the section Conclusions and recommendations.

2 Microsimulation tools

In this paper two approaches were analyzed– deterministic approach by application of SIDRA Intersection software and stochastic approach by application of VISIM traffic microsimulation model in order to compare results and select a suitable approach.
Sidra Intersection is a program package designed to analyze standard and roundabouts capacity. In addition to traffic and geometry, the program takes into account vehicle characteristics and driver behavior, and in addition allows entering of the pedestrian volume. After selecting the intersection type and entering the geometry data, the program generates a layout of the intersection. The data on vehicle speeds, vehicle lengths and distances maintained by drivers in relation to the vehicle in front, as well as the data about pedestrians on each approach are entered. The output data include the level of service expressed in delay as well as some other parameters (e.g. regarding CO emission etc.).
Vissim microscopic simulation model is one of the program tools in the field of microsimulation of traffic and is used in many countries of the world. In Vissim it is possible to simulate and analyze all traffic forms and modes. The results of Vissim can be displayed in 3D animations, which is a great manner of presenting planned infrastructure measures to the public [7]. Vissim is stochastic, it uses a random seed generator to generate different vehicle encounter scenarios, and uses distributions to simulate the set values of some input parameters (for example, the default speed of each vehicle category is the median of normal speed distribution). On the other hand, the precondition for valid scientific and expert experiment is reproducibility, and accordingly, for a specific value of the random number generator, the VISSIM model gives the same (reproducible) simulation result. In order to reconcile two opposing requirements – modelling of the stochastic nature of the real system and the reproducibility of the experiment, the model is quasi-stochastic in nature. The quasi-stochastic nature of the model enables comparability of results when analyzing variant solutions, because when setting the same initial generator value, of the same step and number of scenarios for each variant solution, we know that we analyzed and compared the same traffic scenarios of vehicle encounters. [3]

3 Case studies – the city of Rijeka

The city of Rijeka has 112.000 inhabitants and it is the most densely populated city in Croatia with average density of around 2600 inh/km^2. Population density as well as built-up density makes every intervention in space or traffic organization very complex. In this paper, two of

the possible interventions in traffic organization that can improve traffic system by giving more space to non-motorized traffic are presented and analyzed. Analyzed case studies are:
- Case study 1: Improvement of overall traffic conditions in the city area Pećine – Rijeka
- Case study 2: Implementation of new pedestrian street - Ciottina street in the city center.

3.1 Traffic model for city area Pećine

The residential area of Pećine is located in the eastern part of the city of Rijeka, with an area of 45.6 ha and a population of around 3700 inhabitants. The backbone of this residential area consists of two two-lane one-way roads approximately 2 km long, which are categorized as major city roads and are also state roads (D8): Šetalište 13. divizije Street, extending from west to east (southern corridor) and J.P. Kamova Street (northern corridor) along which the traffic goes in opposite direction. Along both streets there are buildings specific to residential areas - residential houses, schools and kindergartens, as well as approaches to the city's swimming area, which make the pedestrian traffic particularly intensive during the summer. The basic characteristics of the aforementioned streets are shown in Table 1.

Table 1 Basic characteristics of streets in the analyzed area of Pećine

Street	Corridor traffic	Traffic lane [m]	Sidewalk [m]	ADT [veh/day]
Šetalište 13. divizije	Southern One-way	2x3,5 m	1,85-2,00m	5000
J. Polić Kamova	Northern Two-way	2x3,25	0-2,0 m	5000-8000*

* depending on the cross section at which it was measured

In both streets, the problem of lack of parking spaces is evident, and on the southern corridor (Šetalište 13. divizije) part of the vehicles are parked improperly along or on the pavement. There are two main intersections in the zone, standard three-legged intersections, one of which is signalized (Vulkan). At both intersections, there is a satisfactory level of service and somewhat impaired traffic safety conditions. Pedestrian traffic is most intense in the intersection zones.

Based on a detailed analysis of traffic and construction elements and traffic indicators of the zone [8], a proposal for improvement of traffic conditions in the zone was given. The proposed traffic solution for improvement of the conditions in the zone and the conditions for non-motorized traffic modes includes: a reconstruction of both intersections into roundabouts (carried out analysis of suitability according to technical standards), reconstruction of both main streets of the zone into one-lane one-way streets with bicycle lane and longitudinal parking where conditions allow, regulation of the most frequent pedestrian crossings by narrowing the road , organizing additional off-street parking lots. The solutions are shown in Figure 1. The VISSIM traffic model was used to analyze the traffic in the zone, which modelled and verified the entire zone (two road corridors, all local connections and two main intersections - Figure 1) for the existing condition to determine the reliability of the model, and then it was used to verify newly proposed traffic solutions. The data used to develop the model and calculate the capacity were collected in the field, with automatic traffic counts and measurements.

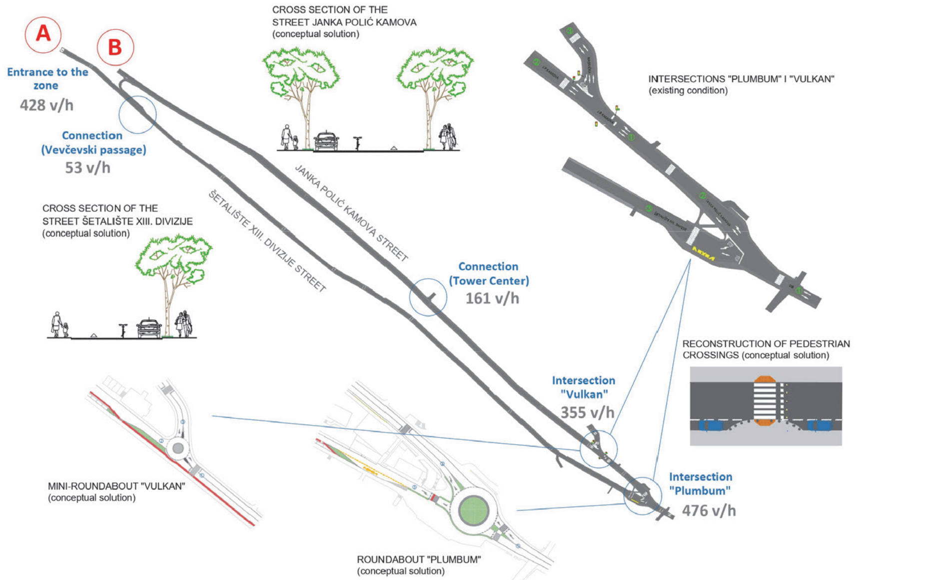

Figure 1 Input data for the VISIM model, with details of the existing and new solutions of the intersections and streets in the zone

Since Vissim is a stochastic model and uses random variables, three iterations were carried out for each solution, and in order to determine the validity of the model, the measured time of passage through the entire zone was calculated (from point A to point B in Fig. 1, total length approx. 3.5 km). The calculated and measured results of the passage are given in Table 2.

Table 2 Travel time for existing and new solution (Vissim) and field measurements

	Present solution			New solution			Field measurement		
Iiteration	1	2	3	1	2	3	1	2	3
Travel time [min]	4:59	5:18	5:23	5:13	4:59	5:07	5:11	4:54	5:30

Below are the traffic density results for the one and two lane variants (existing and new traffic solution) for both corridors.

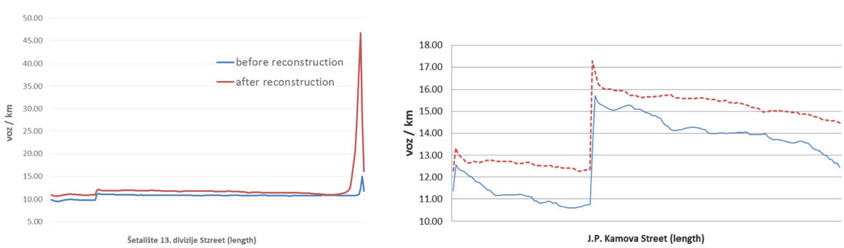

Figure 2 Results - traffic density (veh / km) before and after reconstruction (left-Šetalište 13 divizije, right - J.P. Kamova)

SIDRA Intersection software was used for intersection capacity calculation to analyze the level of service before and after the intersection reconstruction. Table 3 shows a comparison of the service level results obtained by the VISSIM traffic model and the mentioned SIDRA Intersection software, expressed in delay time s. For Visim, the average waiting time is shown according to three iterations, and for SIDRA according to the range that is used in the program for a certain level of service (A to F, or associated time losses). A very high level of compatibility can be observed between the results obtained by the mentioned two models.

Table 3 Delays in traffic flow calculated with SIDRA and VISSIM

	Intersection Plumbum delay (s)				Intersection Vulkan delay (s)			
Approach	**SIDRA (pres/new)**		**VISSIM (pres/new)**		**SIDRA (pres/new)**		**VISSIM (pres/new)**	
3-1	0-10	0-10	17,67	10,31	15-25	10-15	16,15	14,16
3-2	15-25	0-10	15,11	10,34	15-25	10-15	16,21	13,31
1-2	0-10	0-10	A*	7,1	0-10	0-10	10,38	6,68
2-1	0-10	0-10	A*	3,10	-	-	-	-
1-3	-	-	-	-	0-10	0-10	A*	6,82
*main direction – free traffic flow								

3.2 Traffic model for Ciottina Street Area in the center of the city of Rijeka

Ciottina Street is located in the very center of the city of Rijeka, in an area of exceptional built-up density and all-day heavy traffic. Due to the proximity of the Korzo pedestrian zone, interesting catering and shopping facilities in the street, and the proximity of schools, colleges and businesses, Ciottina Street has a very intensive pedestrian traffic and at the same time a very modest pedestrian infrastructure. The traffic lane is 3.5m wide and the pavement width varies from 70 cm to 1.5 m. In order to improve pedestrian conditions and widen the main pedestrian zone of Korzo, it is planned to reconstruct Ciottina Street into a pedestrian street, which would divert the motor traffic to the surrounding streets. The direct route through Ciottina Street from its entrance (point A) to its exit (point B) amounts to 330 m in total, while the bypass route that would take over the traffic load by closing Ciottina Street amounts to 650 m in total and includes driving through the streets of Ivana Pavla II and Erazma Barčića. (Figure 2). A section of Ciottina Street intended for closing of motor traffic is currently a single-lane, one-way street with ADT 4500 veh/day. As during a certain period, in the occasion of the Sustainable Transport Week (September 2018), Ciottina Street was closed for motor traffic, it was possible to collect real traffic load data for the case of an indirect route being activated. A VISSIM microsimulation traffic model was developed to determine the real impact of the additional traffic volumes on the surrounding intersections and the travel time through the zone, based on the data collected by field measurements. The level of service for existing intersections in changed traffic conditions, with increased traffic load, was also verified by SIDRA Intersection software. Figure 2 shows the direct and indirect route area and schematic level of service for key intersections taken from SIDRa Intersection.

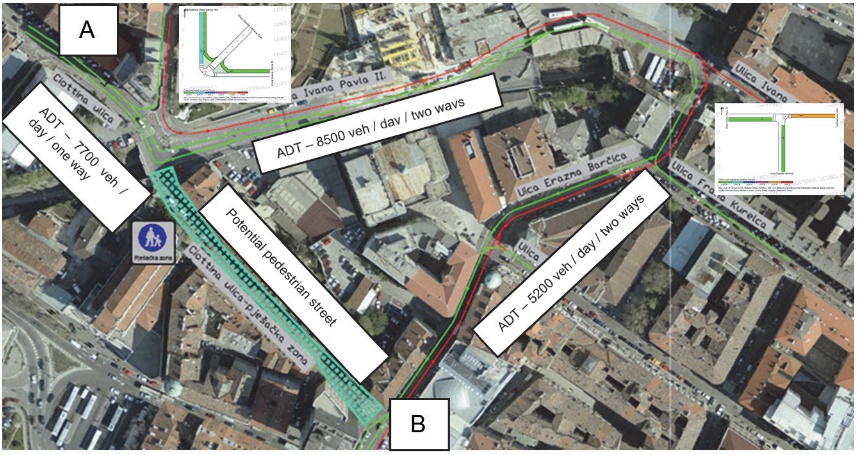

Figure 3 Ciottina Street Area - layout and main traffic inputs and results

The level of service analysis (SIDRA) or time losses (VISSIM) analysis was carried out for main intersections in the area and the results are well matched, in all cases the losses are up to 10 s (both before and after changes in traffic flows), which correspond to the level of service A according to SIDRA [9].

The VISSIM traffic microsimulation model for Ciottina Street and the surrounding area was first based on the VISSIM traffic microsimulation program settings and then calibrated to local conditions using a neural network method [3]. It was shown that the calibrated parameters for traffic conditions in Rijeka - average standstill distance, additive part of desired safety distance and multiplicative part of desired safety distance are significantly different from those in VISSIM settings. Table 4 shows the results of the travel time obtained for the direct and indirect route using the VISSIM model for the default and calibrated parameters as well as those obtained by direct measurement on the road network. The results clearly show that the precondition of the real values of the traffic indicators obtained by modeling is the calibration of the model to local traffic conditions.

Table 4 Travel time for direct and indirect route, model results and field measurements [3]

	Direct route – travel time (s)			Indirect route – travel time (s)		
	measured	VISSIM default	VISSIM after calibration	measured	VISSIM default	VISSIM after calibration
Travel time [s]	72,4	81,95	74,33	100	113,21	100,5

4 Conclusions and recommendation

In this paper the application of deterministic method for traffic flow analyses – SIDRA Intersection and of stochastic traffic model - VISSIM traffic microsimulation model is analysed in two case studies in the city of Rijeka, Croatia. Based on the two presented examples of the application of different methodologies of traffic flow analysis, it can be concluded that the deterministic approach (in this case SIDRA Intersection) sufficiently well describes a simpler traffic situation where, regardless of length, there are no many changes (interruptions) in traffic flows. For complex traffic situations where there is a series of intersections within less than 1 km and intensive pedestrian traffic that interrupts motor traffic flows in many places, a higher quality analysis is obtained by using the stochastic microsimulation models (in this case VISSIM). Both approaches provide the ability to calculate time losses, however using Vissim also allows verifying the travel time in a chosen section. In both cases, the quality of analysis is contributed by the fact that the actually measured input data were used (traffic volume) and in the second case (Ciottina Street) it was possible to test and calibrate them based on the existing and planned situation. The advantage of VISSIM is also the possibility of animated display of what is going on in the network.

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