DRAŽEN CVITANIĆ, Ph.D.
E-mail: drazen.cvitanic@gradst.hr
DEANA BREŠKI, Ph.D.
E-mail: deana.breski@gradst.hr
University of Split,
Faculty of Civil Engineering, Architecture and Geodesy
Matice hrvatske 15, 21000 Split, Croatia
IVAN LOVRIĆ, Ph.D.
E-mail: ivan.lovric4@tel.net.ba
University of Mostar, Faculty of Civil Engineering
Matice hrvatske bb, 88000 Mostar,
Bosnia and Herzegovina

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POSSIBILITY OF MICROSIMULATION MODELS CALIBRATION – CASE STUDY IN THE CITY OF SPLIT

ABSTRACT

The paper presents a comparison of the possibility and complexity of the calibration process of two microsimulation models. The first model CORSIM is simple for use while the second named S-Paramics is more complex software. For research purposes, a model of street network with defined geometry (number, width and purpose of lanes) has been made. The volume and distribution of traffic as well as the data about traffic signals were input in the models. Numerous simulations were performed, first with the default parameters of models, and then with the calibrated parameters. Both programs have resulted in very good prediction of the intersection capacity and discharge volumes. However, for the calibration of speed more time and effort have been made in S-Paramics in which the average speed may be higher than the defined free-flow speed. This can present a problem in determining the level of service and comparing the S-Paramics results with other simulation models and analytical method results. On the other hand S-Paramics has greater capabilities than CORSIM (roundabouts modelling, dynamic traffic assignment, opportunity to interact with traffic signals...). Thus, for each specific task, one should carefully choose an appropriate program which would result in necessary and reliable output data with minimum effort and time consumed.

KEY WORDS

microsimulation, CORSIM, S-Paramics, calibration

1. INTRODUCTION

In the city road network, the intersections are the elements that define the capacity and thus the quality of traffic flow in the network.

Analytical models for capacity and level of service estimation based on theoretical methods (such as HCM – United States, HBS - Germany, SIDRA - Australia) are more reliable than simulation models when applied to the analysis of isolated intersections or homogeneous segments of road network.

However, during the last ten years, microsimulation models have been increasingly used not only for the analysis of street networks, where they have significant advantages over analytical models, but also for the analysis of individual intersections, homogeneous segments, etc. One reason is the increasing availability and development of simulation models and the possibility of monitoring the output in the form of animation which facilitates presentation of traffic flow quality.

Theoretical methods are more reliable and easier to use than simulation models when analyzing the isolated intersections because of their need to define only a few parameters such as the critical gap and follow-up time at non-signalized intersections or saturation headway and the start-up delay at signalized intersections.

In many countries, surveys of numerous isolated intersections were carried out and the average values of these parameters for different combinations of the intersections geometry and traffic volume distribution were determined. A small number of parameters that are calibrated or can be easily calibrated for local conditions make the analytical models simple and reliable to use for isolated intersections analysis. Besides, for that purpose they have been developed and tested.

However, when analyzing street network, where vehicles interact from the neighboring intersections, parking and other traffic areas, analytical models show considerable shortcomings. Most analytical models cannot give a clear picture of the propagation of the queue from the critical intersection to the upstream intersections (and the corresponding consequences in the street network). For example, Highway capacity manual (HCM) [1] methodology does not model the length of additional lanes at signalized intersections. It models it like a lane of infinite length. Therefore, this method can not describe the reduction of capacity and congestion of through passing lanes due to insufficient capacity of the additional lanes (left or right).

Ten years ago, a common engineering practice was such that isolated elements of the road network were analyzed by analytical models while simulation models were used for modelling the street network, including intersections and other traffic areas.

In the early stages of simulation models development, modellers were not concerned with the detailed description of the impact of intersection geometry on driver behaviour and the operating of the intersection. Only in the last few years the simulation models have reached an enviable level of describing traffic flows at intersections and other complex elements of the road network.

However, the problem with the use of microsimulation models is calibration because they have many parameters which can get a broad range of different values. When applying a model, it is necessary to calibrate the parameters to local conditions and to determine which parameters have a significant impact on the required outputs (average speed, travel time, fuel consumption, delay, etc.). It is an expensive and tedious job, so in conducting traffic analyses, only the basic parameters of drivers and vehicles behaviour, such as saturation headway are frequently calibrated.

Unfortunately, many analysts just use default values of parameters without taking into account how credible these parameters are in reflecting the local traffic conditions and what the reliability of the output is (the consequences of proposed solutions on the traffic flow quality). This was a motive for conducting the analysis of capabilities, complexity and reliability of calibration of two simulation softwares for most common types of analysis that are carried out in these areas of Europe.

This paper deals with the comparison of the possibility of calibration of two microsimulation models, i.e. CORSIM [2] and S-Paramics [3] on local conditions of signalized urban street network in Split, Croatia.

During the last ten years a few papers have dealt with the calibration of these softwares. Some of these papers concentrate on the calibration of driving behaviour parameters only, as in [4] and [5], while others incorporate this into a broader problem, wherein a route choice model and/or an origin-destination matrix were calibrated as well. The latter is not subject of interest of this paper.

Kim and Rillet in [4] presented the methodology based on the simplex algorithm which uses Intelligent Transport System (ITS) data to calibrate CORSIM and Transim simulation models on a 23km long Interstate section. They have compared the volume and the mean travel time data. It was found that the simplex algorithm had better results than manual calibration for saturated conditions.

Ma and Abdulhai in [5] used Genosim, a genetic traffic microsimulation parameter optimization tool that uses genetic algorithms and searches for an optimal set of values that minimize the discrepancy between simulation (Paramics) output and field data. They have compared vehicle counts, and they obtained promising results.

The paper [6] presents a detailed review of papers dealing with the calibration of microsimulation models and used methods (genetic algorithm, simplex and complex optimization algorithms and other methods). Among the calibration methodologies presented in papers there is substantial variation in the number of parameters being calibrated. According to [6] "*the advantage in focusing on a smaller number of parameters is that it enables paying more attention to each parameter when its value is modified; in some cases this is done through a manual procedure. Bigger parameter subsets are normally calibrated using automated algorithms, and hence get more efficiently closer to an optimal solution, but also make it harder to follow changes in the value of each parameter*".

In this paper the intention was to deal with a number of parameters which is big enough to cover various behavioural elements in the model analyzed, but small enough to enable paying individual attention to the value of each parameter, and thus the possibility of calibration is presented (done) through a manual procedure. Hence, only a few parameters were calibrated (saturation headway, gaps, free-flow speed) and the resulting capacity and speed were compared with the field data. The calibration was conducted in two stages; the capacity and discharge volumes on the intersection were calibrated first, and then the average travel speed. This calibration sequence is important because if the speed is calibrated first (capacity and discharge volumes are not yet calibrated), subsequent calibration of capacity and discharge volumes (e.g. increasing the number of vehicles that can pass during the green light) will result in the change in average travel speed.

Unlike some papers that are based on finding the best algorithm to estimate parameters which will yield results similar to measured ones (hence it is harder to follow a logic in changing the value of parameters) the basic aim of this paper was to present the openness of a particular software to change the values of parameters taking into account their theoretical foundation and the logical nature of range of the possible (measured) values.

2. ANALYZED SOFTWARES FOR MICROSIMULATION MODELLING

The ways of modelling interactions between individual components of the transport system have led to the development of different microsimulation models among which the most popular are: Aimsun (Spain), CORSIM (USA), Paramics and S-Paramics (United Kingdom), SimTraffic (USA) and VISSIM (Germany). Differences in capabilities of these models are reflected in the size of the network that can be modelled, possibility of defining the origin-destination (O-D) matrix or dynamic assignment of traffic on the network, opportunities to interact with traffic signals, visualization in 2D or 3D format, and other specific conditions that can be modelled (pedestrians, roundabouts, etc.).

The greatest difference between the models is the possibility of programming within the module and the ability of the software to connect and interact with traffic signals on the intersections, wherein these softwares, on the basis of traffic data, simulate traffic and optimize the distribution of time per cycle stages and send back those data to the traffic signals.

This paper deals with the comparison of one simple and easy-to-use program, CORSIM [2] (which has no possibility of connecting with traffic signals and where the animation of traffic is displayed in 2D) and a more complex software, S-Paramics [3] with greater modelling capabilities (O-D matrix, dynamic traffic assignment, interaction with traffic signals, 3D view, a detailed vehicle behaviour on roundabouts, etc.).

CORSIM (Corridor Simulation) is a microsimulation component of TSIS (Traffic Software Integrated System) integrated model for simulating traffic flows on the network of roads, urban and suburban streets. The CORSIM is software developed by the University of Florida for the Federal Highway Administration (FHWA), which is part of the Department of Transportation specializing in road transport. It was developed at the University of Florida on the basis of comprehensive scientific research commissioned and done for the needs of FHWA. Thus, the values of model parameters (over a hundred) were calibrated on the basis of these studies. The consequences of national (FHWA) development are low price for good quality (calibrated parameters on the basis of scientific research), but also simple 2D graphic and the lack of opportunities available in more complex commercial softwares such as dynamic traffic assignment, modelling of roundabouts, the time step less than 1 second and the ability to interact with traffic signals. CORSIM was selected for the analysis because it represents programs that have no possibility of modelling the phenomena that are not thoroughly investigated through various research projects.

S-Paramics was selected as a representative of more powerful softwares. It was developed by the Transportation planning consultants and modellers of over thirty years standing in collaboration with other research and business partners. SIAS created Paramics in 1986. Subsequently it was developed with the assistance of the University of Edinburgh high performance computer department (EPCC) in 1992. In 1996 several members of the University staff departed to set up Quadstone Ltd., a software marketing company. Quadstone and SIAS jointly formed "Paramics Traffic Simulation Limited" to develop and promote microsimulation software. This joint venture was dissolved in 1998. Today Paramics developed by Sias is labelled as S-Paramics to different from Quadstone Paramics.

S-Paramics is a commercial powerful software that has many possibilities, among them the opportunity to interact with traffic signals, and it can serve as an aid to traffic management in Urban Traffic Control (UTC) systems such as Signal Coordination and Timing System (SCATS) and Split, Cycle, and Offset Optimization (SCOOT) system. SCATS and SCOOT system controllers monitor traffic flow in real time and optimize signals by adjusting stage splits, cycle times and offsets, in order to minimize stops and delays. These systems control several junctions simultaneously, and measure every lane occupancy using vehicle detectors on all signalized intersection approaches. Besides, S-Paramics has the capabilities for dynamic traffic assignment with the possibility of defining the degree of perturbation i.e. applying variance to the "cost" of undertaken trip when there is a choice of routes as well as the possibility of modelling all types and forms of roundabouts, etc.

3. MODELLED NETWORK

For purposes of research of software capabilities and possibilities of calibration on local condition (Split, Croatia), a model of street network developed for the needs of *Traffic impact study of facility Small Mall during construction* [7] was used (*Figure 1*).

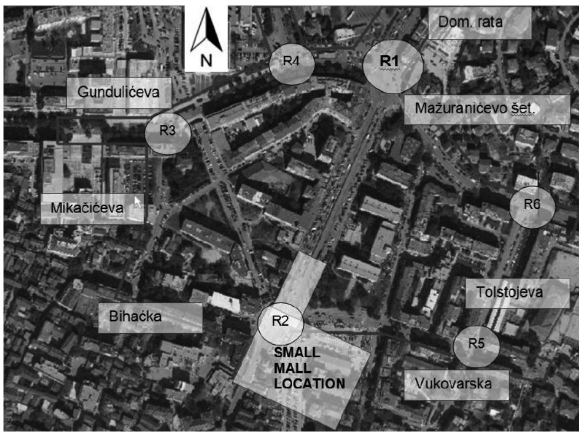


Figure 1 - The modelled part of the street network in the City of Split, Croatia

The modelled street network area includes: 2 signalized intersections (*R1* and *R2*) and 4 unsignalized intersection (*R3*, *R4*, *R5* and *R6*). The modelled network also includes the access to off-street parking spaces as well as routes and timetables of public transport.

During the construction of the "Small Mall" facility, the intersection R2 will be closed so that the entire traffic will be diverted through the surrounding street network to the intersection R1. This can be done in several ways. The aim of the study was to compare the impact of variants (way of using a street network during the construction of a facility) on the quality of traffic. The greatest impact on the traffic flow quality is exerted by the functioning of intersection R1. Thus, in the analyzed models special attention has been paid to the capacity and discharge volumes calibration on intersection R1 as well as the calibration of the average travel speed in the network. In order to make the model results reliable for the future conditions, a detailed model calibration of the current state of traffic has been done.

4. INPUT DATA FOR MODELS

The traffic flow quality, for a given population of drivers and vehicles, mostly depends on the geometric characteristics of a street network, volume, composition and distribution of the traffic flow and the intersection control type. The same input data were used in both software types, and were collected from relevant institutions or by means of field research.

4.1 Traffic data

For the purpose of the model development the all-day traffic counts of vehicles at all intersections and parking areas within the network area were made. The information on routes, stops and frequency of vehicle trips made by public transportation vehicles were obtained by the Promet company and tested by means of field research (number of buses, arrival time and loading time at the stations).

The traffic volume and distribution is given in *Figure 2*.

4.2 The geometry of the street network

Geometry of the streets (grade, number, purpose and width of lanes) as well as data on the road markings, signs and signals were collected in the field and by using the orthophoto plans. An important parameter which was defined for each link is the free-flow speed. The value of the street segment speed limit (posted speed) is set as a free-flow speed for the corresponding link.

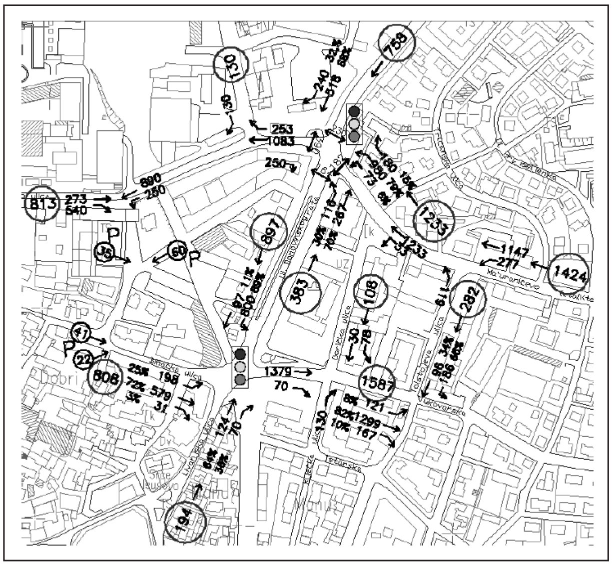


Figure 2 - Traffic volume and distribution in the afternoon peak hour

4.3 Type of intersection traffic control

Signal plans of intersections were obtained from the City of Split, and were made by "PEEK Traffic Ltd" company. They were also checked by inspecting the field.

The street network model made by CORSIM is presented in *Figure 3* while *Figure 4* shows the network model made by S-Paramics. In these models, the geometry of road segments and the intersections, traffic volume and distribution, signal plans as well as data on the public transport were defined according to the collected data.

5. MODEL CALIBRATION

The impact of the closure part of the street network on intersection R1 capacity and network travel time (speed) was investigated. A calibration of the model for the current state of roads and traffic should be made so that the output results replicate precisely the measured data.

Calibration of models was based on:

1. the comparison of approach capacities and discharge volumes of the modelled R1 intersection with the real intersection approach capacities and volumes, and
2. the comparison of the average travel speed on the modelled street segments with measured speeds.

5.1 Initial parameters of the calibration

The parameters for which the model gives different results (for a given geometry of the street network

Figure 3 - Network model developed by CORSIM

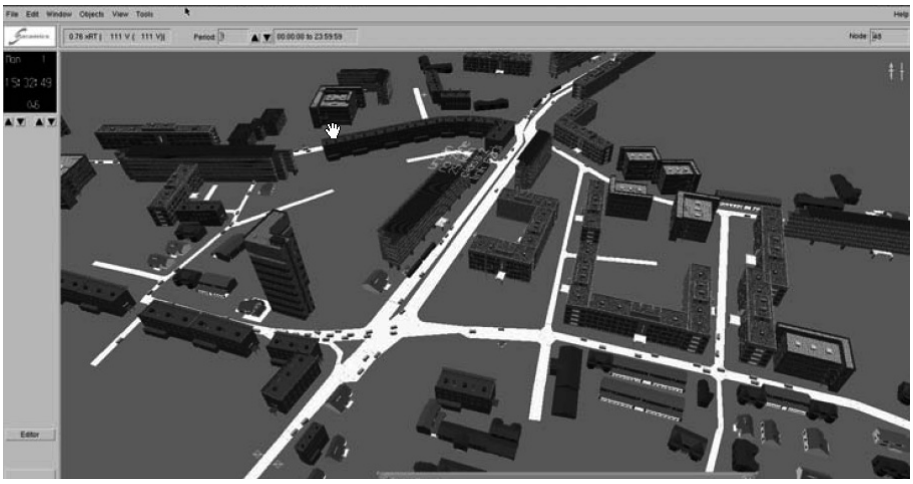


Figure 4 - Network model developed by S-Paramics

and operation of the signal) are those describing the behaviour of drivers.

5.1.1 CORSIM

CORSIM defines 10 different types of drivers (ranging from calm to aggressive) with different behaviour and reactions (desired speed, acceptable acceleration and deceleration resulting in e.g. pass or stop at an amber interval at signal, the choice of a critical gap for left turn, etc). The parameters which have the greatest impact on outputs (control delay at the intersection, speed...) in street network of signalized intersections are the saturation headway and free-flow speed as shown in the paper [8].

As each vehicle in a queue moves up to the stop line, it is assigned a delay until discharge, reflecting queue discharge headways. The distribution of values of discharge headway for a particular type of driver in relation to the value of average headway in CORSIM can be defined for each link as shown in *Table 1*.

Saturation headway represents an average discharge headway that can be achieved by a saturated, stable moving queue of vehicles passing through the signal.

Previous research [9] at several intersections in Split has shown that the value of saturation headway on urban intersection with intensive flows is 2.0 seconds i.e. the capacity is 1,800 vehicles per lane per hour of green light which is slightly less than the default settings in CORSIM and the recommended value in HCM. Based on this research the value of 2.0 seconds is entered at all intersections approaches.

Table 1 - Distribution of discharge headways

Driver characteristic	1	2	3	4	5	6	7	8	9	10
Distribution code	170	120	120	110	100	100	90	70	70	50

Source: TSIS help

These values as well as values of free-flow speed can be defined for each link. In each link the posted speed was input as a value of free-flow speed.

When the demand of left turn vehicles on permissive green approaches capacity then gap acceptance parameters for these vehicles have great impact on output results. A vehicle at a stop line facing a sign on minor road or vehicles on signalized major approach waiting for permissive left turn cannot discharge until an acceptable gap is available in the cross-street traffic. The acceptable gap depends on the type of sign, driver characteristic code and the total number of lanes to be crossed. In CORSIM the set of fields is used to specify a decile distribution of acceptable gaps in the oncoming traffic for all driver types. Values of critical gap and follow-up time on the modelled unsignalized intersections were taken from the research conducted in local conditions [10].

In CORSIM, which includes more than a hundred default parameters, in the initial model only the data on the discharge headway and gaps have been altered (based on research carried out in Croatia), besides values of free-flow speed.

5.1.2 S-Paramics

For modelling the behaviour of drivers in S-Paramics one can only change a few parameters: *Mean headway* that represents time in seconds between successive vehicles (default value 1 s) and the *min gap* i.e. gap between vehicles below crawl speed (default value 2m). Also one can change the distribution of driver aggressiveness. Recommendation of S-Paramics support team is that even these few parameters should not be changed without extensive research because they are calibrated based on research carried out on the roads in the UK. In addition, these parameters are general for all network elements and S-Paramics has no parameters describing specific driver behaviour on intersections. Instead, S-Paramics suppose that the vehicle dynamics and driver aggressiveness together with these two parameters would pretty well describe driver-vehicle behaviour on every specific element of the road network. It makes it difficult to calibrate S-Paramics for a detailed description of flow on specific road elements, especially on network of signalized streets. Because of the above, no adjustment of these values has been made in S-Paramics model.

5.2 Calibration of the intersection capacity, discharge volumes and lane utilization

The two most important indicators about the functioning of the street network are capacity and travel time.

Capacity of signalized intersection is defined with saturation headway *h*. It is convenient, namely, to model the driver behaviour at a signalized intersection by assuming that every vehicle in a lane consumes an average of *h* seconds of green time to enter the intersection. If every vehicle consumes *h* seconds and if the signals were always green then s vehicles per hour could enter the intersection and saturation flow rate s is defined as

$$s = \frac{3600}{h} \tag{1}$$

The saturation flow rate represents the capacity of approach lane if the signal is always green.

The portion of real time that is effective green (g) is defined with a green ratio (g/C), the ratio of effective green time to the cycle length of the signal. The capacity of an approach lane may then be computed as:

$$c_i = s_i\left(\frac{g_i}{C}\right) \tag{2}$$

where:

c_i = capacity of lane i, veh/h

s_i = saturation flow rate of lane i, veh/hg

g_i = effective green time for lane i

C = cycle length, s

Effective green g is related to actual green G as follows:

$$g_i = G_i + Y_i - t_{Li} \tag{3}$$

where:

g_i = effective green time for movement i, s

G_i = actual green time, s

Y_i = $y_i + ar_i$

y_i = yellow interval for movement i, s

ar_i = all-red interval for all movements, s

t_{Li} = total lost time for movements, s (includes start-up lost time of first four vehicles and clearance lost time at the end of green signal).

Often effective green time coincides with actual green time.

The calibration of capacity and discharge volumes as well as lanes utilization at the eastern intersection R1 approach were performed. This approach has two lanes. The left lane is intended for through and left movements and the right lane is intended for moving through and right. Most approach traffic goes through (80%), there are about 6% left turns and about 14% right turns. Given the distribution of traffic, it is expected that left and right lanes are equally used. However, about 200m downstream from the intersection R1, the left (approach) lane is converted into an additional lane for the left turn at R3 (there are about 25% of turns), while most traffic goes through using right lane. Therefore, at intersection R1 eastern approach, the right lane is much more often used than the left lane.

Testing and calibration of models were carried out as follows: On the basis of video recording in peak periods the number of passing vehicles per cycle was recorded (cycle time 80 sec.; 39 sec. green light for the subject approach, 3 seconds yellow time and 2 seconds of all red time).

Unsaturated as well as saturated cycles have been noted, in which the queue on the subject approach was greater than the number of vehicles that passed through the intersection during the green phase. The capacity was estimated according to HCM procedure i.e. headways between successive personal vehicles entering intersection starting with the fifth vehicle were measured in cycles when there was more than 7 vehicles in the initial queue. It resulted in an average saturation headway value and prevailing saturation flow rate. The capacity of the signalized intersection approach is then the saturation flow multiplied by the portion of effective green time in the signal cycle according to equation (2).

In addition to the number of passes, the number of vehicles using the left or right lane was recorded, too. The recorded values were compared with the model results. In the models, the volume and distribution of traffic movements as well as the duration of cycle stages were entered. Then ten simulations were performed which resulted in the following:

1. the number of vehicles that had used a specific lane as well as a total discharge volume in every cycle,
2. maximum number of vehicles per lane and max. total discharge volume during one cycle.

The results obtained after model calibrations are shown in section 5.2.3, *Table 2*.

5.2.1 CORSIM

In the link which defines the eastern intersection approach, a value of 2 seconds was entered for the saturation headway according to the previous research [9] and field data from subject intersection. The uneven distribution of traffic per lanes can be modelled in CORSIM by two parameters. The first is *Driver familiarity* which can be defined as percentage of vehicles that know one or two turns in advance i.e. all vehicles entering a link know either 1 or 2 non-through turn movements. The second parameter is *Distance over which drivers will perform a lane change*. This entry specifies the mean longitudinal distance over which the drivers decide to perform one lane change. To ensure that the vehicle will be in the proper lane to perform its next turning movement, CORSIM will scan up to 12 links ahead to determine the best lane for the vehicle to be positioned when it discharges each link. Based on the distance to attempt a lane change, the logic can determine how far back the vehicle should begin to seek a lane change and what lane should be its goal on each upstream link. As this value increases, the drivers are more likely to seek lane-changing opportunities further upstream and less likely to have to slow down to a stop to enter the lane required for their turn movement. The value of this parameter is changed from default 100m to 450m, thus achieving a more realistic distribution of vehicles per lane. Without calibration, the distribution of vehicles per lane per cycle was about 50/50%.

5.2.2 S-Paramics

In S-Paramics each vehicle knows two turns in advance and according to them chooses the optimal lane for an intended manoeuvre. The beginning of the manoeuvre is defined by parameter *Hazard distance* which has a value of 250m for the urban street and 750m for rural roads. S-Paramics can remember only one hazard distance, so for the case of two intersections at a distance of 100m, when a vehicle wants to turn left at the second intersection, the lane choice is made at only 100m before the subject intersection.

5.2.3 Comparison of model results

The subject intersection is continuously video recorded 24 hours per day. So, beside field inspection the data from video taping have been used for measurements of headways and number of vehicles entering the intersection during the effective green light.

The resulting average saturation headway between vehicles was 2 seconds. According to equation (2), for g=G=39sec the approach capacity is 1,753 vehicles/hour.

In order to obtain the simulated approach capacity in S-Paramics and CORSIM the input volumes were set greater than field counts in order to obtain a permanent saturated queue on the eastern approach. Then, ten sets of simulations were performed. The resulting discharge volume presents the approach capacity. Both models resulted in similar discharge volumes (CORSIM with 1,658veh/hour, S-Paramics with 1,619 veh/hour). The difference between field capacity and the modelled capacity for both models was less than 8%, which is a fairly good result.

More interesting is the comparison of vehicle counts with the model results which showed that both models resulted in very good estimates of discharge volume distribution over the cycles. *Table 2* shows the model results and part of the field measurement data.

Actually, in the 15-minute peak period the maximum of 36 vehicles passed in one cycle. S-Paramics resulted in a maximum value of 35 vehicles, while CORSIM resulted in 34 vehicles. The results show that both softwares are very good in predicting the maximum number of vehicles in the cycle, and that they are on the safety side because they result in slightly lower rates than the actual observed ones (CORSIM by 6%, S-Paramics by 3%). If one considers the aver-

Table 2 - Number of vehicles per lane in the models and the recorded number of vehicles

	Number of vehicles in each cycle								
	PARAMICS			CORSIM			REAL (VIDEO TAPING)		
Time	Left lane	Right lane	Total	Left lane	Right lane	Total	Left lane	Right lane	Total
16h 3’ 20”	15	18	33	13	13	26	14	13	27
16h 4’ 40”	13	15	28	13	17	30	13	18	31
16h 6’ 00”	16	17	33	17	17	34	15	17	32
16h 7’ 20”	11	16	27	12	17	29	9	17	26
16h 8’ 40”	13	10	23	15	14	29	13	17	30
16h 10’ 00”	16	19	35	13	19	32	13	14	27
16h 11’ 20”	13	16	29	13	13	26	8	18	26
16h 12’ 40”	14	14	28	14	13	27	16	20	36
16h 14’ 40”	13	18	31	15	18	33	10	16	26
Average	13.8	15.9	29.7	13.9	15.7	29.6	12.3	16.7	29.0
Max.	16	19	35	16	19	34	16	20	36

age number of vehicles per cycle, it can be seen that both programs resulted in a slightly larger number of passes (29.7 and 29.6) compared to an average of 29 passing manoeuvres measured in the field.

This means that both softwares assigned a slightly higher number of arrivals in the peak interval than in reality. The maximum number of vehicle passes per lane in CORSIM and S-Paramics in saturated conditions was 19, which corresponds to the saturation headway of 2 seconds. The maximum number of recorded vehicles per lane was 20, but the survey found that the passage of the 20th vehicle across the stop line always occurred during the red light.

In the modelling of the unequal use of lanes both softwares resulted in nearly equal values. Both models resulted in a more uniform distribution of vehicles per lane (13.8:15.9 S-Paramics, 13.9:15.7 CORSIM) than in reality (12.3:16.7). It must be noted that CORSIM results were obtained after changes of *the lane changes driver behaviour parameters*. Prior to change, the distribution was 15.8:15.3. In S-Paramics the above results were obtained without changing the parameters values.

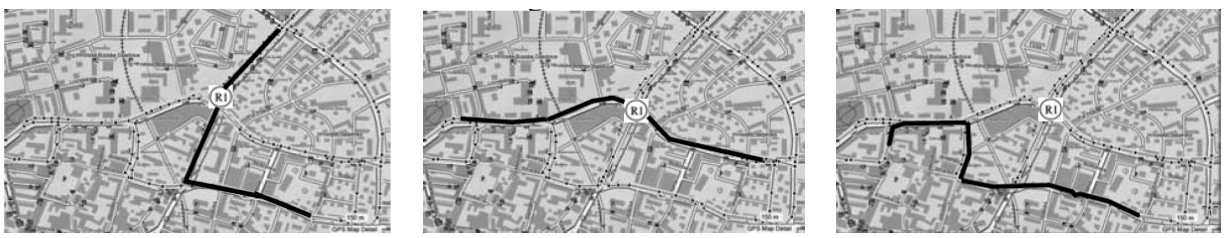
It can be concluded that both programs were very good in predicting volume distribution over cycles as well as saturation headway i.e. the capacity of the analyzed intersection approach, without making significant calibration efforts. It is important to emphasize that for different traffic conditions CORSIM can be easily adapted because there are many parameters describing the particular road element prevailing conditions, while S-Paramics is a more closed system in terms of describing driver-vehicle behaviour on specific element of road network because it deals only with two general parameters, as noted before.

5.3 Speed measurements on road sections and calibration of models

5.3.1 Speed measurement

The average travel time is one of the most important indicators of quality of a traffic flow on the street network. The average travel time can be expressed through the average travel speed, including all the slowdowns and stops at intersections. For the purposes of models calibration, speed measurements with GPS device were carried out on three street segments with the highest traffic volume. The analyzed segments are shown in *Figure 5*.

The GPS device registers when a vehicle is in motion and automatically records the point on the road it passes. In the case of vehicles stopping at signals, the



a) Segment 1 (L=916m) b) Segment 2 (L=938m) c) Segment 3 (L=976m)

Figure 5 - Measuring the speed on the network segments (GARMIN eTrex Vista HCx, software MapSource ver. 6.15.11)

Table 3 - Speeds including delays at intersection

Date	Measure-ment no.	SEGMENT 1		SEGMENT 2		SEGMENT 3	
		Length (m)	916	Length (m)	938	Length (m)	976
		Time (s)	Travel speed (km/h)	Time (s)	Travel speed (km/h)	Time (s)	Travel speed (km/h)
06. 05. 2010.	1st	185	18	126	27	173	20
	2nd	158	21	105	32	177	20
	3rd	182	18	106	32	217	18
10. 05. 2010.	1st	180	18	132	26	185	19
	2nd	127	26	93	36	174	20
	3rd	136	24	88	38	178	20
	4th			132	26	180	20
	5th			136	25		
Average		161.3	20.8	114.8	30.3	183.4	19.6

device does not record a point until the vehicle is in motion again. The parameters of every recorded point are the time of passage and position of the car, based on which the speed between points was calculated. Thus, for each road segment one can get the following data: total travel time and the average speed of travel. As S-Paramics deals with the average travel speed including delays at intersections, in this paper the speeds including delays were compared. The total of all time between the points where the speed was lower than 15km/h was accounted for as stop time. In the afternoon peak hour, 3 to 6 measurements were carried out for each segment. *Table 3* shows the average travel speed for each segment (including the waiting times at intersections). The difference in speed with and without delays is the greatest (13km /h) at section 3, where there are most (3) traffic signals.

5.3.2 Calibration of speed in S-Paramics and CORSIM

For the values of links free-flow speed the following values of posted speed were set in the model: Gundulićeva street (40km/h), Mikačićeva street (30km/h); while on other streets the posted speed is 50km/h.

5.3.2.1 CORSIM

For the current state (of traffic and roads) 10 simulations were performed and the average travel speeds on the analyzed segments were noted. The posted speeds were entered as input values of free-flow speed on the links. The results are shown in *Table 4*.

From *Table 4* one can see that the CORSIM (without additional calibration) resulted in average travel speeds that vary up to max. 12% of the actual measured speed, which is a very good result considering the complexity of the modelled network (bus stops, public transport vehicles, parking manoeuvres).

Table 4 - The average travel speeds in the model and the measured average travel speeds

	Average travel speed (km/h)		
	Segment 1	Segment 2	Segment 3
Measured	20.8	30.3	19.6
Corsim	21.9	29.5	22
Difference (%)	5	-3	12

5.3.2.2 S-Paramics

Table 5 shows the values of travel speed prior to model calibration as well as the travel speeds measured in the field.

Table 5 - Average travel speeds of the initial S-Paramics simulation and measured average travel speeds

	Average travel speed (km/h)		
	Segment 1	Segment 2	Segment 3
Measured	20.8	30.3	19.6
S-Paramics	27.6	39.3	31
Difference (%)	33	30	58

The results show that the travel speeds of vehicles in the model are considerably higher (up to 58%) from those measured. The only way to reduce speed while not disturbing the calibrated capacity and discharge volumes on the intersection is to reduce the free-flow speed on links. The calibration of the model began with a gradual decrease of the free-flow speed on the links. The speeds are (compared to the initial set) reduced by 5km/h, in each of the following simulations. After each reduction, a comparison between the calculated and the measured speed was performed. Several sets of simulations have been done and after each set, the free-flow speeds were corrected until the average speed in the model differed less than 20% compared to the average measured speed. Calibration results are shown in *Table 6*. *Table 6* shows the differences between the average speeds of the calibrated model and the measured average speeds.

Table 6 - The average travel speed in S-Paramics and the average measured speed after calibration

	Average travel segment speed (km/h)		
	Segment 1	Segment 2	Segment 3
Measured	20.8	30.3	19.6
S-Paramics	24.4	30.5	22.6
Difference (%)	17	0	15

The initial free-flow speed on some sections had to be significantly reduced (up to 15km/h) to achieve a relatively satisfactory speed in the model. Paramics is the only software in which the average speed can be higher than the modelled free-flow speed [11], which can be a shortcoming in some kind of traffic analysis (e.g. intersection analysis). Since S-Paramics computes the delay as the difference between the output speed and the input free-flow speed, it is not possible to calibrate the free-flow speed output by S-Paramics without also affecting the computed delay for the facility. If the analyst codes a lower free-flow speed to trick S-Paramics into outputting a lower speed, the lower input value becomes the new basis for computing delay, not the output speed. The technical support for S-Paramics suggested that it would be undesirable to adjust the driver's aggressiveness to force a lower free-flow speed, because it would affect other behaviour as well.

6. CONCLUSION

In this paper the possibility and the complexity of the calibration of two microsimulation programs, i.e. CORSIM and S-Paramics were analyzed. The intersection capacity, discharge volumes, unequal lane use and average travel speed were calibrated. In the models, the data on the geometry of the street network, the volume, the composition and the distribution of traffic flow and information about signal plans were defined.

For the initial set of simulations in CORSIM only the values of discharge headway and critical gaps according to research [9] and [10] were changed. In S-Paramics, the initial simulations were performed with the default parameters. The simulations showed that both softwares resulted in very good estimation of discharge volumes per cycle and the approach capacity (saturation headway), but slightly worse in describing the distribution of vehicles on a particular lane. Using both softwares it has been shown that CORSIM is a more open system because the user can change many parameters and in that way can describe the vehicle behaviour for a wide range of different conditions of intersection geometry and driver behaviour.

For example, in CORSIM the user can define (for each link) the average start-up delay, mean discharge headway, street parking manoeuvres (frequency and average duration), short and long interruptions of traffic in each lane. At the level of the entire street network the user can modify the values of the critical gaps at unsignalized and signalized intersections, the number of jumpers and laggers in relation to the number of opposing lanes, the driver reaction time, the percentage of drivers who cooperate with other drivers when changing lanes, and many others.

S-Paramics is a more closed system in which most of the properties of the drivers and vehicles cannot be changed or defined for a specific road element. The only parameters liable to change are the minimum gap, mean headway and the aggressiveness of the drivers. These parameters are general and S-Paramics has no parameters describing specific driver behaviour on intersections or other specific elements of road network. Instead, S-Paramics supposes that the vehicle dynamics and the driver's aggressiveness together with these two parameters would pretty well describe the driver-vehicle behaviour on every specific element of the road network. It makes this software not so adaptable to specific traffic conditions prevailing in other countries, or for description of specific types of intersections and other elements of the street network.

The posted speed is set as input data for the free-flow speed in the models. After completed simulations, CORSIM showed very good results for the modelled complex network (vehicles, pedestrians, parking, public transportation). The average speed in the model was different by max. 12% compared to the measured speeds. The initial simulations in S-Paramics resulted in speeds of over 50% higher than actually measured in the field. After reduction of the free-flow speeds up to 15km/h below the posted speed on the individual links, the model resulted in speeds differing up to 17% of the measured speeds. However, reducing the free-flow speeds (in the analysis of the intersection level of the service) results in lower values of the control delay. Since S-Paramics computes the delay as the difference between the output speed and the input free-flow speed, it is not possible to calibrate the free-flow speed output by S-Paramics without also affecting the computed delay for the facility. If the analyst codes a lower free-flow speed to trick S-Paramics into outputting a lower speed, the lower input value becomes the new basis for computing delay, not the output speed. In this way S-Paramics results in lower control delay and overestimated level of service of intersection compared to other analytical and simulation methods. This can be a flaw in the intersections analysis.

It can be concluded that for each type of analysis one should choose appropriate software with capabilities for modelling conditions required by the project objectives. Thus, e.g. if one wants to model the allocation of traffic to the street network, model detail behaviour on roundabouts or wants to use simulation models to interact with traffic signals at UTC projects or use other sophisticated ITS measures, they will use sophisticated programs such as e.g. S-Paramics. If one wants to model traffic on the street network of unsignalized and signalized intersections, including public transport, pedestrians, the impact of parking manoeuvres, blocking lanes, etc. one will use simpler software like CORSIM because it is easier to use and calibrate and yields very good results with less effort.

Dr. sc. **DRAŽEN CVITANIĆ**
E-mail: drazen.cvitanic@gradst.hr
Dr. sc. **DEANA BREŠKI**
E-mail: deana.breski@gradst.hr
Sveučilište u Splitu,
Fakultet građevinarstva, arhitekture i geodezije
Matice hrvatske 15, 21000 Split, Hrvatska
Dr. sc. **IVAN LOVRIĆ**
E-mail: ivan.lovric4@tel.net.ba
Sveučilište u Mostaru, Građevinski fakultet
Matice hrvatske bb, 88000 Mostar,
Bosna i Hercegovina

SAŽETAK

Izvršena je usporedba mogućnosti i zahtjevnosti kalibracije dva mikrosimulacijska modela, jednog jednostavnog za rad (CORSIM) i jednog zahtjevnijeg s većim mogućnostima modeliranja (S-Paramics). Za potrebe istraživanja izrađen je model ulične mreže u kojem su definirani geometrija dionica i raskrižja (broj, širina i namjena trakova). Uneseni su podaci o radu semaforskih uređaja te o veličini i razdiobi prometa. Izvršeno je niz simulacija, prvo s osnovnim vrijednostima parametara modela, a zatim s kalibriranim vrijednostima. Kalibracija se izvršila usporedbom stvarnog kapaciteta raskrižja i broja prolazaka vozila s rezultatima modela te usporedbom rezultirajućih brzina u modelu sa snimljenim brzinama. Oba su programa rezultirala vrlo dobrom procjenom kapaciteta raskrižja. Međutim, kod kalibracije brzina više se truda i vremena moralo uložiti u S-Paramics u kojem prosječne brzine putovanja mogu biti veće od definirane brzine slobodnog toka što može predstavljati problem kod utvrđivanja razine usluge raskrižja prilikom usporedbe rezultata s drugim simulacijskim modelima i analitičkim metodama. S druge strane, S-Paramics ima dosta veće mogućnosti od programa CORSIM (modeliranje kružnih raskrižja, dinamičko dodjeljivanje prometa, mogućnost interakcije sa semaforskim uređajima...). Stoga za svaki pojedini zadatak treba pažljivo odabrati odgovarajući program koji će uz manje uloženog truda i vremena rezultirati potrebnim i pouzdanim izlaznim podacima.

KLJUČNE RIJEČI

mikrosimulacija, CORSIM, S-Paramics, kalibracija

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