# Analysis of the influence of car-following input parameters on the modelled travelling time

**Ištoka Otković, Irena; Tollazzi, Tomaž; Šraml, Matjaž**

ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
UDC/UDK 656.1.021:625.739

# ANALYSIS OF THE INFLUENCE OF CAR-FOLLOWING INPUT PARAMETERS ON THE MODELLED TRAVELLING TIME

*Irena Ištoka Otković, Tomaž Tollazzi, Matjaž Šraml*

Preliminary notes
The calibration process is a basic condition of traffic model application in local conditions. The choice of input parameters, which are used in calibration process, influences the success of the calibration process itself; therefore, the goal is to choose parameters with a larger influence on the modelling process. This paper offers a detailed analysis of car-following input parameters and their influence on the modelled travelling time. The experimental basis was a one-lane roundabout, and the tool used for traffic simulation was the VISSIM microsimulation traffic model. The results show that the car-following input parameters should be a part of the set of input parameters, which will enter the process of calibration. The examined car-following input parameters affect the capacity of intersections and results show that it is necessary to revise the range of input values of one of the observed car-following input parameters.

***Keywords:*** *car-following input parameters, input parameters for the process of calibration, VISSIM*

## Analiza utjecaja parametara kolone vozila na modelirano vrijeme putovanja

Prethodno priopćenje
Postupak kalibracije je uvjet primjenjivosti prometnih modela u lokalnim uvjetima. Izbor ulaznih parametara koji će ući u postupak kalibracije utječe na uspješnost postupka kalibracije, pa je cilj odabrati parametre koji imaju veći utjecaj na rezultate modeliranja. U ovom radu detaljnije su analizirani parametri kolone vozila i njihov utjecaj na modelirano vrijeme putovanja. Eksperimetalna baza bilo je jednotračno kružno raskrižje, a kao alat prometnih simulacija služio je VISSIM mikrosimulacijski model. Rezultati pokazuju da parametri kolone vozila trebaju biti u skupu ulaznih parametara koji će ući u postupak kalibracije. Promatrani parametri kolone utječu na propusnu moć raskrižja, a rezultati pokazuju da je potrebno revidirati raspon ulaznih vrijednosti jednog od analiziranih parametara.

***Ključne riječi:*** *parametri kolone vozila, VISSIM, ulazni parametri za postupak kalibracije*

## 1 Introduction

For the evaluation of existing and newly designed traffic structures, computer traffic modelling is being used more and more often. Stochastic, discrete microsimulation traffic models intended for short term planning and analysis in real time show a large potential. A basic condition for the successful application of traffic models is their calibration, that is, adjustment of model parameters to the characteristics of the local network and its users.

The choice of input parameters and their possible values used in the process of calibration directly influences the success of the calibration process. A vast number of input parameters and large ranges of values lead to a huge number of combinations of parameters, which need to be analyzed, making it a very time consuming work. On the other hand, the exclusion of influential parameters from the analysis and/or use of input parameter ranges, which do not include optimal values, will not lead to the expected results of model calibration even if successful optimisation methods are used.

One of the basic criteria for the optimisation of a set of input parameters is the analysis of the real traffic situation which is being observed. While there is no point of analyzing parameters of changing lanes on one-lane parts of road network, analyzing a set of parameters modelling a queue of vehicles in all segments of a network is definitely important. The car-following model is an integral part of every microsimulation model.

This paper shows the results of the analysis of the influence of car-following parameters on the output modelling results for the exact traffic situation at a given site. For the purpose of analysis, the VISSIM microsimulation traffic model has been chosen.

## 2 Modelling of car-following input parameters – overview

A vehicle is classified as being in a queue (following vehicle) if achieving the desired speed is conditioned by the speed of a leading vehicle [1]. From the 1950s until today, scientists have developed a significant number of models that can model the car following behaviour [2, 3, 4]. However, experts are still very interested in this area since no one has created a model, which would be able to model human behaviour in all its diversity.

The GaziS-Herman-Rothery (GHR) model was launched in 1958 [1] and was based on modelling of the following vehicles' behaviour. The symmetrical model uses the same, while the asymmetric model uses different acceleration and deceleration values. Based on the GHR model, the Model of Response to Stimuli (Chandler, 1985) was developed. The model of safety distance (Kometani and Sasaki, 1959) and the innovated model (Gipps, 1981) are based on the assumption that the following vehicle attempts to maintain a safe distance from the vehicle, which precedes it in a queue. The first psycho-physical model (Michaels, 1963) is based on the observation of differences of speed rates between the leading and following vehicle and adjustment of driving (speeding up or slowing down) to the perceived traffic conditions (Leutzbach, 1988). Representative examples of psycho-physical models are models developed by Wiedemann (1974, 1999), Wiedemann and Reiter (1992) and Fritzsche (1994).

Model groups using elements of *fuzzy logic* introduce modelling based on rules of behaviour, defining some basic concepts such as "too close", "too fast" and the appropriate responses to such situations through *fuzzy sets* [5]. Functions of probability distribution are used for modelling the perception of observed variables, e.g. speed of a leading vehicle.

Difficulties in modelling human behaviour are unpredictability and changeability, not only in the context of different drivers' reactions, but also in the light of different reactions of the same driver under different circumstances. The time of drivers' reaction is a parameter with a significant influence on functional features of a network such as capacity and delays. A longer time of reaction requires a larger time gap for entering a major flow or changing lanes and bigger security distance between vehicles in a queue.

There are two basic groups of parameters which influence the time of drivers' reaction: individual characteristics (age, sex[1], behaviour in risky situations, driving skills, tiredness, stress, alcohol, drugs, psychological pressure, characteristics of a vehicle) and external factors and their subjective perception (time of day, road conditions, complexity of traffic situation, meteorological conditions, clarity, visibility). Researches show that traffic jam has a considerable influence reaction time [6, 7]. Drivers waiting in lines for longer periods of time tend to exhibit riskier behaviour and accept a smaller time gap for entering a major traffic flow. According to a study made in Australia [9] duration of waiting at an entrance into a roundabout has a significant influence on reduction of acceptable time interval [8, 9]. Forcing of a time gap exists even in regular traffic conditions, and in conditions of a large traffic jam it grows 6 ÷ 12 % [10]. Research of the influence of waiting time on entrance capacity of circular intersections [7] shows that the waiting time has the biggest influence on time gaps in the interval[2] from 2 to 5 s. Driving style, and consequently the reaction time, is also influenced by cultural differences, thus there is a noticeable diversity between drivers in different countries and territories. Because of that, calibration and verification in local conditions are a basic condition of applicability of traffic models.

A longer time of reaction in a simulation of a traffic flow results in a reduction of modelled capacity. Computing the traffic flow parameters with a constant reaction time gives only a rough approximation from the aspect of microsimulation, but it offers satisfactory results for the calculation of the macro-output results [1].

Existing car-following models are based on a collision evasion scenario. Updating the existing car-following models includes modelling of safe and unsafe behaviour of a driver. The presumption that in regular traffic conditions drivers will not exhibit unsafe behaviour has not shown to be true.

[1] Researches show [8] that more experienced drivers and men drive on a smaller distance within a queue. Drivers with more than 59 years of age approximately drive with 23 % larger distance than those being in the age between 23 and 37.

[2] A very long waiting interval may cause a very small number of drivers to use an interval shorter than 2 s. An interval longer than 5 s will be used by a majority of drivers in regular traffic conditions.

Modelling the influence of pedestrians on a car queue and capacity of an intersection is a subject of researches given in [11, 12].

## 3 Wiedemann Car Following Model

The VISSIM traffic model uses the Wiedemann psycho-physical car-following model as a sub-model for modelling the longitudinal motion of vehicles. Drivers' behaviour modelling is described with four driving regimes: free driving, approach to a car queue, driving in a queue and braking (Fig. 1).

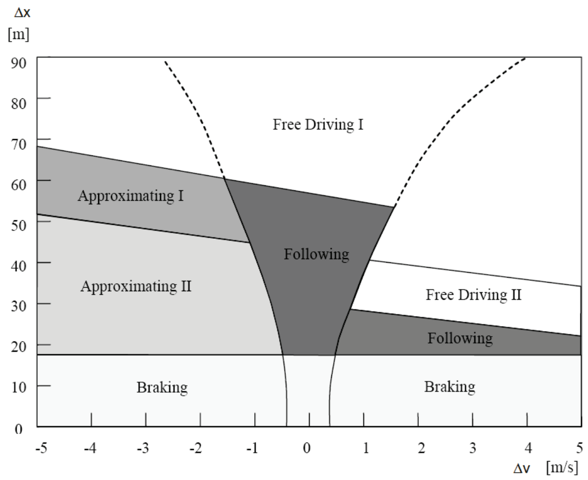



**Figure 1** Wiedemann Car Following Model [13]

Based on differences in speed, four distances between the leading and the following vehicles are defined – desired distance, risky distance, safe distance and stopping distance – and mathematically described in [13]. Based on perception and identification of driving regime, driver makes a decision about an action that will be taken – accelerating, slowing down or keeping the current driving style.

In the VISSIM microsimulation tool, the car-following input parameters of the Wiedmann psycho-physical model are described by three parameters: Average standstill distance (*ax*) − defines the average desired distance between stopped cars, Additive part of desired safety distance (*bx_add*) and Multiplicative part of desired safety distance (*bx_mult*). These parameters affect the computation of the safety distance.

The distance d between two vehicles is computed using this formula [14]:

$$d = ax + bx, \tag{1}$$

where:
*ax* is the standstill distance (P5 in Tab.1),

$$bx = (bx\_add + bx\_mult * z) * \sqrt{v}, \tag{2}$$

*v* is the vehicle speed, m/s,
*z* is a value of range [0,1] which has a normal distribution with mean 0,5 and standard deviation of 0,15,
*bx_add* is the additive part of the desired safety distance (P6 in Tab. 1),

*bx_mult* is the multiplicative part of the desired safety distance (P7 in Tab. 1).

## 4 Choice of input parameters for VISSIM calibration

The first choice of input parameters for the calibration process and their ranges is made based on the real intersection in question, the input parameters available in VISSIM and calibration experiences [13, 15] and is shown in Tab. 1.

**Table 1** Choice of input parameters for calibration of VISSIM model

| P | Input parameters | Range | Step | Default |
|---|---|---|---|---|
| P1 | Simulation resolution | 1 ÷ 10 | 1 | 5 |
| P2 | Number of observed proceeding vehicles | 1 ÷ 4 | 1 | 2 |
| P3 | Max look ahead distance (m) | 100 ÷ 300 | 1 | 250 |
| P4 | Min look ahead distance (m) | 0 ÷ 20 | 1 | 0 |
| P5 | Average standstill distance (m) | 1 ÷ 3 | 0,1 | 2 |
| P6 | Additive part of desired safety distance (m) | 1 ÷ 5 | 0,1 | 2 |
| P7 | Multiplicative part of desired safety distance (m) | 1 ÷ 6 | 0,1 | 3 |
| P8 | Desired speed (km/h) | 25 ÷ 50 | 10* | 40** |

* VISSIM calculates the parameter of the desired speed as a distribution of speed whose selected speed value is a value of central tendency.
** The given speed is selected based on measuring velocity on access roads of the observed intersection.

Apart from P1 parameter which determines resolution of simulation – how many times a position of every entity (vehicle, pedestrian,...) is calculated within one second of a simulation, all other parameters chosen for the calibration process are in service of the examined location and drivers' behaviour (maximum and minimum visibility, car queue). The car-following parameters described by formulas (1) and (2), are selected for detailed analysis and marked with P5, P6 and P7 in Tab. 1.

The final choice of model input parameters which will enter the process of calibration will be made on the basis of previous analysis of influence of particular parameters on simulation results.

VISSIM has, and continuously develops, a significant number of traffic indicators, which can be analysed in a process of traffic modelling. The chosen output indicator is the time of driving between measuring points.

## 5 Case study

For the calibration of the model, it is necessary to choose those input parameters, from the whole set of input parameters, which have the largest influence on modelling results.

Testing the influence of particular parameters on modelling results precedes the process of model calibration. The aim of this paper is to make a documented assessment about whether car-following input parameters can or cannot be excluded from a collection of model input parameters which will enter the process of calibration.

The basis for the analysis of the influence of car-following input parameters on modelling results was a one-lane roundabout with a primary functional level in the traffic network of the city of Osijek. The microsimulation modelling was done using VISSIM.

Modelling of travel time in the observed roundabout was done, while values of car-following input parameters were varied and the rest of input parameters had predetermined (default) values. The results of the modelled average time for different values of car-following input parameters are shown in Fig. 3 and commented.

### 5.1 Microsimulation modelling of travelling time in a roundabout

Creation of a model (Fig. 2) includes defining the geometrical characteristics of the examined extent of the road network, traffic control, priority rules, traffic volume and traffic distribution of vehicles and pedestrians.

On March 3rd 2010 between 3 pm and 4 pm, an on-filed compilation of data for the purpose of forming a VISSIM model was done by counting traffic on the road and recording traffic from the roof of the building next to the intersection.

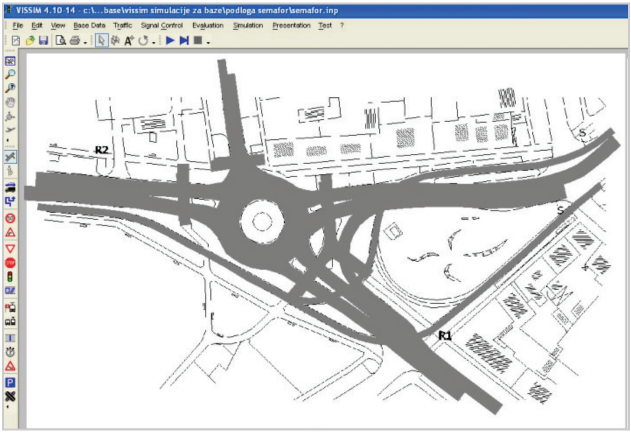



**Figure 2** Layout of the model of the observed intersection in VISSIM

The driving time between measuring points was measured with a stopwatch from two vehicles marked with small flags. Both measuring points were within the reach of the camera on the roof of the building. Driving times between measuring points were measured with a stopwatch from marked vehicles, and they were used for control and calibration of driving times recorded by the camera. The average value of measured driving time recorded by the camera between chosen measuring points in real traffic conditions within the examined hour was 21,8 s.

### 5.2 Analysis of influence of car-following input parameters on modelling results

Car-following input parameters directly influence traffic indicators like average speed of traffic flow, intersection capacity, delays, etc. In the examined microsimulation traffic model, the values of the car-following parameters (P5, P6 and P7 in Tab.1) were varied within the designated ranges. Other values of model input parameters remained unchanged, i.e. they had their default values. The intention was to analyze the influence of values of car-following parameters on modelled driving time between measuring points by variation of these values. Traffic simulations were done based on the one hour interval, similar to the on-field measurement.

Results of the modelled driving time obtained by varying the values of one parameter are shown in Fig. 3. From the diagram in Fig. 3, it is obvious that variations in the values of the observed parameters for a default time distribution (set 4) do not provide a clear insight into the dependence of driving time and the observed parameters.

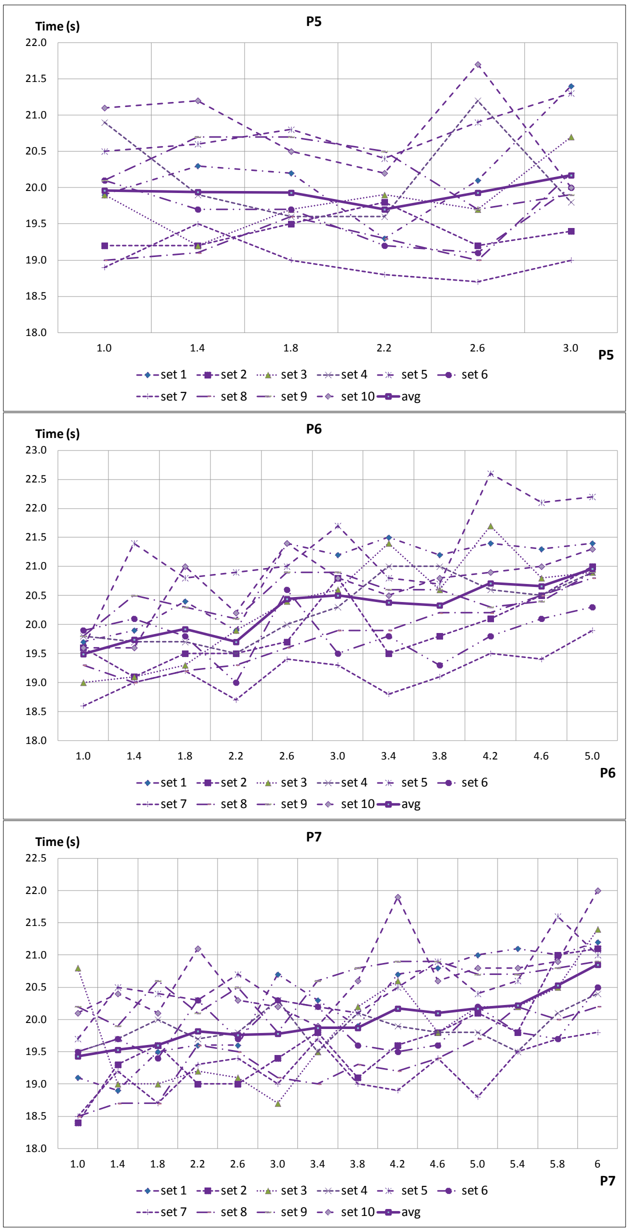



**Figure 3** Driving time for different values of one car-following parameter

Mean values obtained by analysing 10 different scenarios (different time distributions) show that the dependency of driving time on each of the monitored parameters has a positive trend.

The simulation results obtained by varying two parameters for default time distribution are given in Fig. 4.

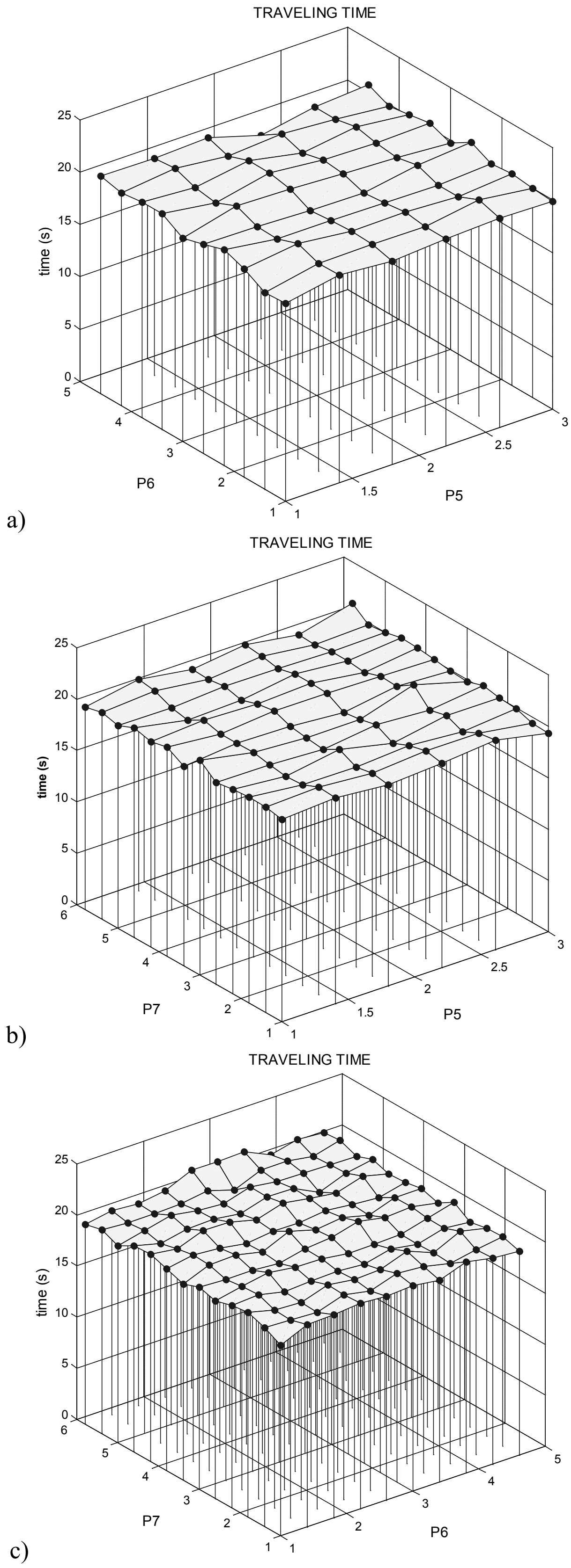



**Figure 4** Driving time for different values of two car-following parameters

An interesting insight can be obtained by analyzing the diagrams for the number of vehicles the model could not generate in the designated simulation time (one hour). From the diagram in Fig. 5, it is obvious, that for values of parameter P6 of 4 and larger than 4, the number of vehicles that could not enter the intersection during the simulation is 25 or more. Such a number of vehicles may influence results of the simulation of examined driving time between measuring points. Having in mind that the recorded number of vehicles de facto went through the circular intersection in the examined time interval, it can be concluded that values of P6 parameters larger than 4, with default values of other parameters, significantly reduce the modelled capacity of the intersection. From Fig. 5 it is evident that even maximum values of parameters P5 and P7 do not have such an influence on the modelled capacity of the examined roundabout.

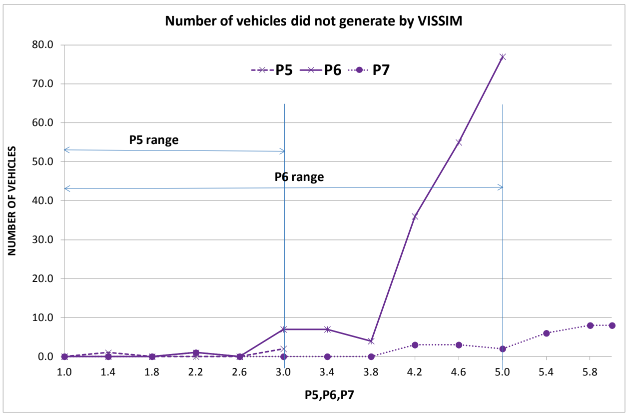
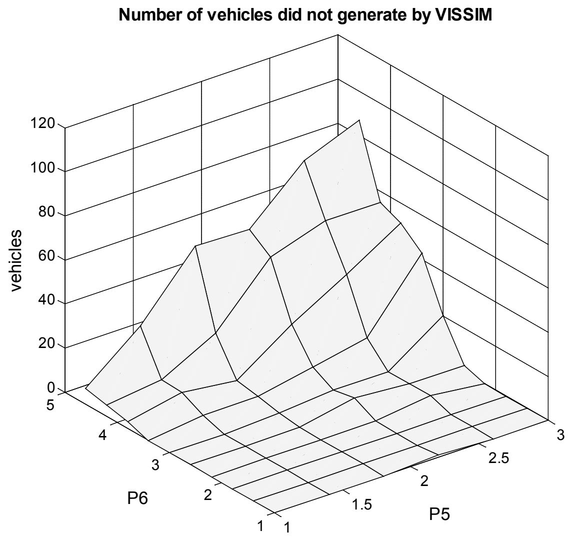



**Figure 5** A number of vehicles the VISSIM did not generate in a designated time for different values of parameters

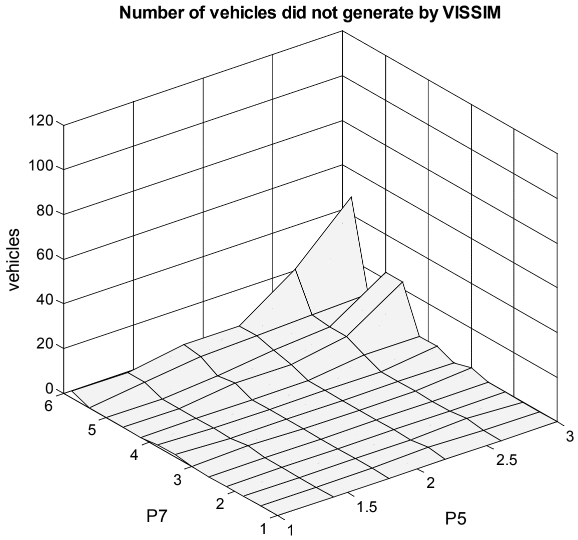
From the diagram showing the number of vehicles not generated by the model during the simulation for variations of values of two parameters (Fig. 6), diagram P5 ÷ P6 (Fig. 6a) shows a larger number of remaining vehicles for parameter values P5 > 2,2 and P6 > 3,8. In the diagram P5 ÷ P7 (Fig. 6b) a simulated capacity of the intersection is reduced only for maximal values of parameters P5 and P7. Diagram P6 ÷ P7 (Fig. 6c) shows reduced capacity of the examined intersection for parameter values P6 > 3,4 and P7 > 4,6. Results provided in diagrams exhibited in Figs. 5 and 6 suggest that, for the studied problem, the range of parameter P6 should be reduced to a maximum value of 4. Larger values of P6 result in a modelled capacity of the intersection being smaller than the real one.

## 6 Discussion

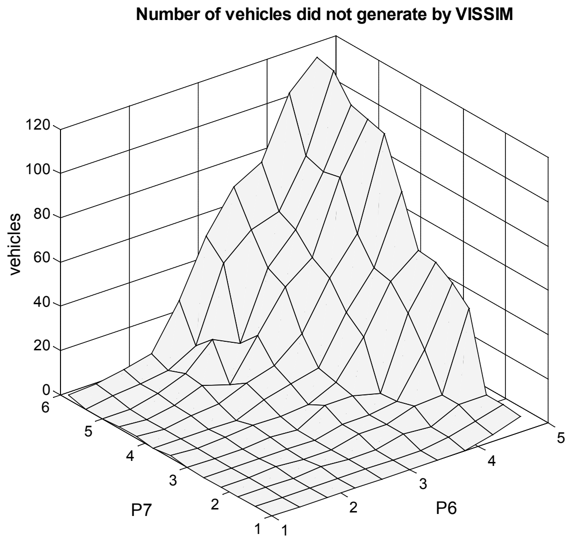
Information from diagrams of the number of vehicles the model could not generate in the designated simulation time (Figs. 5 and 6), gives us a more comprehensive insight into diagrams of simulated driving times (Figs. 3 and 4). It is necessary to bear in mind that this is a stochastic modelling problem and the model includes distribution of values of certain input parameters and generators of random numbers. An example is the speed of vehicles, which has a normal distribution with mean value being the selected speed. An example of a generator of random numbers is the generation of different dynamics of inflow of vehicles during the time of simulation. Generation of random numbers of vehicles within traffic distribution is determined by the "random seed" parameter, but the same chosen value of that parameter provides the same and reproducible traffic image which is a precondition for output traffic indicators of a model, like the driving time, to be comparable.




a)




b)




c)

**Figure 6** A number of vehicles that VISSIM did not generate in a designated time

By changing values of the parameter "random seed", a fine calibration of the model can be achieved, that is, a better overlapping of simulated traffic image and dynamics of vehicle inflow with the one observed in the field in the examined time interval. This will produce modelling results which provide a better approximation of the actual traffic situation.

Maximum simulated driving time, for the default temporal distribution of traffic load, obtained by an analysis of car-following input parameters (21.4 s) is shorter than the average measured time "in situ" (21,8 s) by 1,8 %, which would be a good result if the model generated the entire traffic volume. The model indicates that for this combination of input parameters, 71 vehicles are left outside the intersection, which represents a huge difference compared to the number of vehicles that went through the intersection in the actual conditions at the site. The capacity of one-lane circular intersections in local conditions is within expected limits and it is comparable with experiences worldwide [16].

Development of computer technologies goes in direction of making direct connection of materials recorded by traffic cameras and microsimulation models, which enable precise repetition of a particular traffic image. A precisely repeated traffic image does not give a calibrated model, but with calibration of the model it can provide good modelling of traffic indicators (functional, economic, environmental, safety).

Output modelling results are influenced by two more parameters – minimum headway distance and minimum gap time. They can have constant values valid for the model, but they can also be regulated for every conflict area separately (e.g. entrances into intersections), which is proven to be a valuable possibility. Minimum headway distance is a function of geometrical characteristics of the examined conflict area, secured visibility and traffic regulation, and a minimum gap time is under the influence of drivers' reaction time, which depends on drivers' characteristics, as well as on traffic and road conditions. Assigning constant values to the examined parameters for the whole model would reduce flexibility of the model, especially when it comes to detailed analysis of an individual entering into the intersection. Recorded material of the traffic in the field was a valuable basis for the choice of values of minimum headway distance and minimum gap time for every entry of the modelled roundabout. Along with that, it is important to bear in mind, that a minimum gap time shorter than 2,5 s is not realistic [43]. Model approximation in modelling acceptable time gap is such that an available time gap, which is shorter than designated minimum gap, stops a vehicle from a side road at the stop line, and the one longer than the designated minimum will let a vehicle from the side road into a conflict area. Researches [8, 9, 10] show that in reality it is not so, but rather there is a significant variability of acceptable time gap and there is an effect of forcing a time gap present, especially in conditions of a traffic jam.

## 7 Conclusions

Application of traffic models, including microsimulation, in professional practice depends on the success of calibration process. The choice of model input parameters, which are to be used in a calibration process, and their ranges, is a particularly sensitive question. The success of the optimisation process of input parameters values in the calibration process also depends on the choice of input parameters and their ranges. A proper choice of input parameters is a crucial precondition of a successful calibration. This paper offers a more detailed analysis of influences of car-following input parameters on modelled driving time between measuring points.

The experimental basis was a one-lane roundabout, and the microsimulation modelling was done using VISSIM.

Results of the analysis show:

- Car-following input parameters have a significant influence on simulation results and they have to be optimized by a calibration process.
- It is recommended that the range of parameter "Additive part of desired safety distance" is to be reduced to a maximum value of 4, since larger values result in a modelled capacity of an intersection smaller than the actual one.
- Besides analysis of optimal values of input parameters and modelled traffic indicators, the number of vehicles that the model did not manage to generate in the designated simulation time is valuable information, since it provides an insight into the modelled capacity of intersection.
- The calibration of model is not done by analysis and variation of car-following input parameters, because the value of the examined traffic indicator (driving time between measuring points), which was the closest to the measured one, is reached in modelled conditions of a smaller capacity of the intersection than the actual one. The set of relevant input parameters for the calibration process needs to include other model parameters (Tab. 1).
- It is recommended to consider parameters of minimum headway distance and minimum gap time for every entrance into an intersection separately.

Further research will include the calibration of a microsimulation model with the chosen input parameters and correct ranges and validation of the model in actual traffic conditions.

## 8 References

[1] Olstam, J. J.; Tapani, A. Comparison of Car-following models, Swedish National Road and Transport Research Institute, Project VTI meddelande 960 A, Linköping, Sweden, 2004.
[2] Brackstone, M.; Sultan, B.; McDonald, M. Motorway driver behaviour: studies on car following. // Transportation Research Part F. 5, (2002), pp. 31-46.
[3] Dia, H.; Panwai, S. Comparative Evaluation of Microscopic Car-Following Behavior. // IEEE Transactions on Intelligent Transportation Systems. 6, 3(2005), pp. 314-325.
[4] Schulze, T.; Fliess, T. Urban Traffic Simulation with Psycho-Physical Vehicle-Following Models. // Proceedings of the Winter Simulation Conference, December, 1997, Atlanta, USA.
[5] Tamás, B.; Tamás, P. Development and evaluation of a Fuzzy-based Microscopic Vehicle-following model. // Transportation Engineering. 36, 1-2(2008), pp. 15-19.
[6] Akçelik, R.; Besley, M. Acceleration and deceleration models, 23rd Conference of Australian Institutes of Transport Research, Monash University, Melbourne, Australia, December 2001.

[7] Shiftan, Y.; Polus, A.; Shmueli-Lazar, S. Evaluation of the Waiting-Time Effect on Critical Gaps at Roundabouts by a Logit Model. // European Journal of Transport and Infrastructure Research. 5, 1(2005), pp. 1-12.
[8] Bunker, J. M.; Troutbeck, R. J. The probability of delay to minor stream drivers at a limited priority freeway merge. // Road &Transport Research. 5, 1(1996), pp.16-25.
[9] Troutbeck, R. J.; Kako, S. Limited priority merge at unsignalized intersections. // Transportation Research Part A. 33, (1999), pp. 291-304.
[10] Hidas, P. Modelling lane changing and merging in microscopic traffic simulation. // Transportation Research Part C. 10, (2002), pp. 351-371.
[11] Tollazzi, T.; Lerher, T.; Šraml, M. The Use of Micro-Simulation in Determining the Capacity of a Roundabout with a Multi-Channel Pedestrian Flow. // Strojniški vestnik-Journal of Mechanical Engineering. 54, 5(2008), pp. 334-346.
[12] Tollazzi, T.; Šraml, M.; Lerher, T. Roundabout Arm Capacity Determined by Microsimulation and Discrete Functions Technique. // Promet-Traffic & Transportation. 20, 5(2008), pp. 291-300.
[13] Kim, S. J. Simultaneous calibration of a microscopic traffic simulation model and OD matrix, Ph dissertation (2006), USA, Texas A&M University.
[14] Cicu, F.; Illotta, P. F.; Bared, J.; Isebrands, H. VISSIM Calibration of Roundabouts Traffic Performance. // Transportation Research Board Annual Meeting (2011), Washington D.C.
[15] Park, B.; Qi, H. Development and Evaluation of Simulation Model Calibration Procedure. // 84th Annual Meeting 2005*,* Reprint CD-ROM, Transportation Research Board (2005) Washington, D.C.
[16] Ištoka Otković, I. Modeliranje kapaciteta kružnih raskrižja u Osijeku // Tehnicki vjesnik-Tehnical Gazette. 15, 3(2008), pp. 41-47.

**Authors' addresses**

***Irena Ištoka Otković, Ph.D.***
J. J. Strossmayer University of Osijek
Faculty of Civil Engineering
Drinska 16a
31000 Osijek, Croatia
e-mail: iirena@gfos.hr

***Tomaž Tollazzi, Prof. Ph.D.***
University of Maribor
Faculty of Civil Engineering
Smetanova 17
2000 Maribor, Slovenia

***Matjaž Šraml, Assoc. Prof. Ph.D.***
University of Maribor
Faculty of Civil Engineering
Smetanova 17
2000 Maribor, Slovenia