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Real road network application of a new microsimulation tool: TRITONE

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Abstract

The aim of the paper is to carry out a comparative study of 13 different traffic flow models available in TRITONE, a new road traffic simulator that specializes particularly in quantitative road safety assessment. After a short introduction on a traffic flow modelling, a description of the TRITONE functionality is given and various types of behavioural models available in this tool are presented in brief. Then a part of Poznan (Poland) network that served as the study area, was illustrated. The following section lists all the models used in the research and provides a comparison of the results obtained with these models. The article ends with conclusions on the results' quality of individual models.

1. Introduction

A reliable description of traffic flow is a nontrivial problem. A lot of models have been proposed so far, unfortunately, none of them can be considered as an ideal or, at least, universal one [5]. In general, traffic flow models can be grouped into four main categories depending on the level of detail [14,15]: macroscopic, mesoscopic, microscopic, and submicroscopic. On the one hand, macroscopic models can be applied when a general

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evaluation of the traffic flow is required while more detailed information about the behaviour of individual vehicles is outside the interest. These models are often used for regional transport planning. On the other hand, microscopic models are cable of precisely representing the traffic and its evolution, taking into account physical properties of the infrastructure and the real behaviour of drivers [4]. These models allow the analysis of the movement of each vehicle in the network, thus delivering estimated, but reliable and detailed, information about the behaviour of each single vehicle. The main drawback of the microscopic models is their demand on very detailed data and high computational power, which limits its applicability to small areas.

2. Tritone

TRITONE [8] is a road traffic flow simulator developed at the University of Calabria (UNICAL). As a microscopic simulation tool, it provides a very detailed insight into the movement of individual vehicles and the interaction between them. It also enables a user to observe changes of different aggregated traffic characteristics. TRITONE includes vehicles of different types and can simulate traffic at both, signalized (fixed-time programs) and unsignalized intersections.

TRITONE was created with the aim of becoming a leading tool in the area of road safety, and hence allows, in particular, the evaluation of various parameters related to the current road safety indicators (such as DRAC or TTC) [1, 8]. Such indicators help to find hazardous places with high likelihood of road accidents and thus allow the construction of a safer road infrastructure.

The use of a micro-simulator requires a more detailed description not only of the supply but also of demand [4]. One can provide these data in a form of several OD matrices. For instance, one matrix for the morning, midday and afternoon traffic, alongside with a curve representing the distribution of flows in the course of a day. Additionally, a description of the typological distribution of vehicles and an estimate of the typological distribution of drivers. All that data is used then to generate vehicles and their routes.

One of the strengths of TRITONE is providing the user with the possibility of choosing a particular model for each of the following five behavioural model types:

- car-following – each driver wants to drive at a speed appropriate to his/her driving style, vehicle performance and road parameters; if there is a preceding vehicle, the driver may have to slow down and adjust its speed (or alternatively change the lane),
- lane-changing – at each time step, a driver decides whether or not to change the lane; the decision is made based on the necessity, desirability and possibility of the manoeuvre,
- overtaking – at each time step, a driver decides whether or not to overtake; the decision is made based on the necessity, desirability and possibility of the manoeuvre,
- gap-acceptance – each driver determines the feasibility of lane-changing or overtaking manoeuvres based on the minimum time interval that takes into consideration the movement of other potentially conflicting vehicles

- intersection-crossing – describes drivers' strategies for crossing an unsignalized or signalized intersection.

This set of five categories tries to cover the most important aspects of the driving behaviour. TRITONE offers a wide range of different car-following models (physical, psycho-physical and capacity-based [16,19]) and at the same time enables a user to include additional customized models. The next two types of models (i.e. lane-change, overtaking) are derivatives of the fourth one, the gap-acceptance model. All of these models are highly customizable (through a user-friendly graphic interface) to give a designer the highest decision-making autonomy. The calibration of the models has been carried out for several years based on the results of numerous experiments conducted at the Department of Urban Planning at the University of Calabria.

Driver-vehicle pairs are described with a set of data that can be classified into three categories:

- technical parameters of a vehicle (length, maximum speed, maximum acceleration, current location and velocity),
- behavioural parameters of a driver-vehicle object (psychophysical perception of the driver, driver's memory, acceleration as a function of the current speed in relation to the desired speed and the speed limit),
- information about the environment (time-distance relations with the neighbouring vehicles, current time, traffic lights signals, etc.).

Results of microsimulation may be presented as a 2D or 3D visualization, or through various diagrams or tables. One can obtain information on:

- individual vehicles (number of vehicles, average speed, average delay, total distance travelled, waiting time in a queue, number of passes, total stop time),
- route information (average time of travel),
- safety performance indicators (DRAC, TTC, PSD, MADR [1,8]),
- the course of traffic flow (second by second),
- accidents (the time of accident, location, duration, length of the resulting queues),
- environmental effects (emissions per vehicle, total emissions per section/arc/node, indicators of environmental criticality).

3. Study area

For this comparative study, a road corridor along Garbary Street in Poznan (Poland) was chosen. The corridor includes seven intersections, five of which are signalized (Fig.1):

1. Estkowskiego-Małe Garbary-Garbary
2. Garbary-Piaskowa (unsignalized)
3. Garbary-Grochowe Łąki
4. Garbary-Szyperska
5. Garbary-Szyperska-Północna
6. Garbary-Zajezdnia (unsignalized)
7. Garbary-Szelągowska-Armii Poznań

The model of the road network consisted of all streets in this area. One of the simplifications was the exclusion of tram communication along Estkowskiego-Małe Garbary. Additionally, the pedestrian traffic was also excluded. The model of the road network was built as a graph consisting of nodes (representing intersections) and links (representing sections of a road between consecutive intersections).

Detailed information on the traffic lights programs was collected along the volume counts. Since TRITONE does not allow the modelling of the red/amber signal between red and green, the red/amber signals were replaced with red. In the case of the unsignalized intersections, appropriate road signs (i.e. priority, give way or stop) were placed at intersections' inlets.

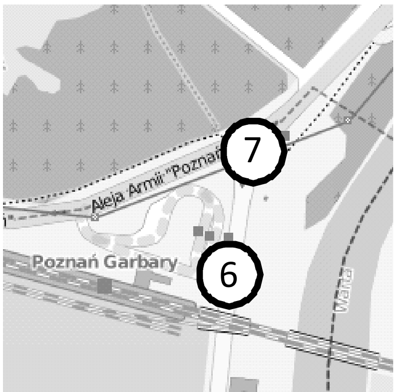


Fig. 1. Study area

In order to estimate the volume and distribution of traffic, series of measurements were taken at each intersection (nodes 1-7). The measurements were performed manually for each intersection inlet with the distinction of vehicle types (P – passenger car, L – light duty truck, H – heavy duty truck, Ht – heavy duty truck with a trailer, C – bus/coach, M – motorbike, and B – bicycle) and manoeuvre types (L – left turn, S – straight ahead, and R – right turn).

The traffic volume was counted on a working day during the afternoon rush hour in good weather conditions. As the counting was made during high traffic, the obtained traffic flows were close to the capacities of the intersections.

Obviously, there were small discrepancies in traffic flow observation data on individual links in the measurement data. They consist of the differences between the number of vehicles entering a given link at one intersection (through intersection outlets) and the number of vehicles exiting this link at the successive intersection (through intersection inlets). This was mainly caused by the impossibility of conducting manual measurements for all the intersections at once. However, these discrepancies were of minor importance.

The traffic volumes measured at intersections were used to generate vehicles and their routes. Several steps had to be taken in order to ensure maximum conformity of the planned routes with the real ones. Firstly, it was assumed that each vehicle enters the network in one of the boundary nodes and then drives through the network until reaching any of the boundary nodes, where it exits the network. During the crossing each of the intersections a driver selects one of possible manoeuvres. The selection is stochastic and depends on the measured turning ratios. Secondly, the vehicles' flow, regarding both its volume and vehicles' type distribution, incoming from each boundary node was assumed to be equal to the measured flow at a respective inlet of the nearest intersection.

4. Simulation results

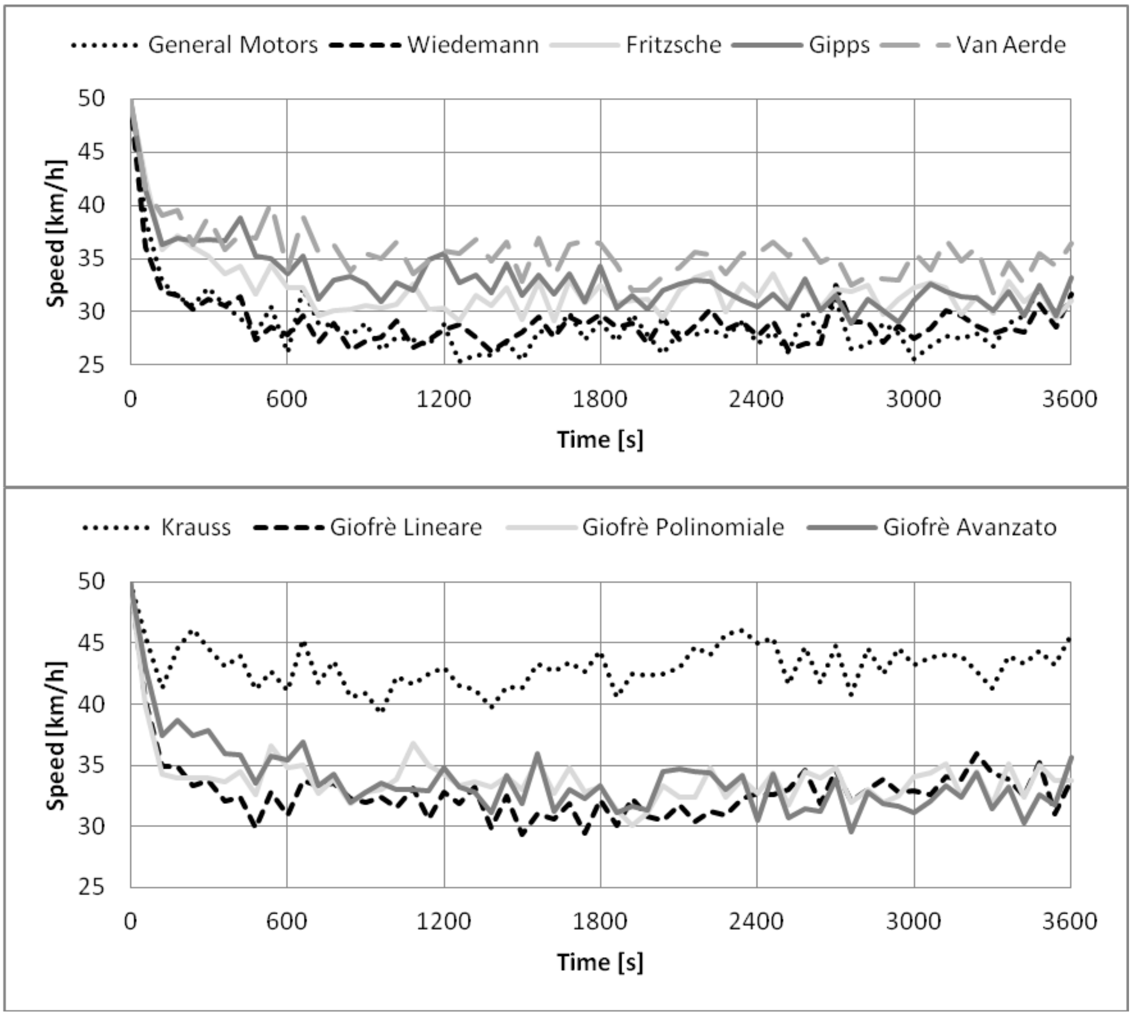
In order to choose among the different car-following models available in TRITONE, a simulation scenario, that represents one hour of the afternoon peak traffic, was prepared and run for each of the following models:

- General Motors [5,6],
- Gipps [4,7,16],
- Van Aerde [18,20],
- Yang [22],
- Fritzsche [4,12,16],
- Wiedemann [4,10,16,19,21],
- Krauss [4,13],
- FreSim and Intras [11,18],
- NETSIM [3],
- CORSIM [9, 17],
- Giofrè Linear [2],
- Giofrè Polynomial - a modified version of the Giofrè Linear,

- Giofrè Advanced - a model derived from General Motors and Krauss.

In the course of this study, a comparison of different global statistics, calculated for the entire road network, was carried out. The comparison takes into account the behavioural diversity of various models.

Average speed. In almost all models, the average speed was between 25 and 37 km/h. The only exception here was Krauss model, with the average speed oscillating between 40 and 45 km/h, which resulted in very smooth traffic. General Motors model and Widemann model were the ones with the lowest average velocity, slightly above 25 km/h. In these models vehicles travelled closer to one another and hence more slowly.



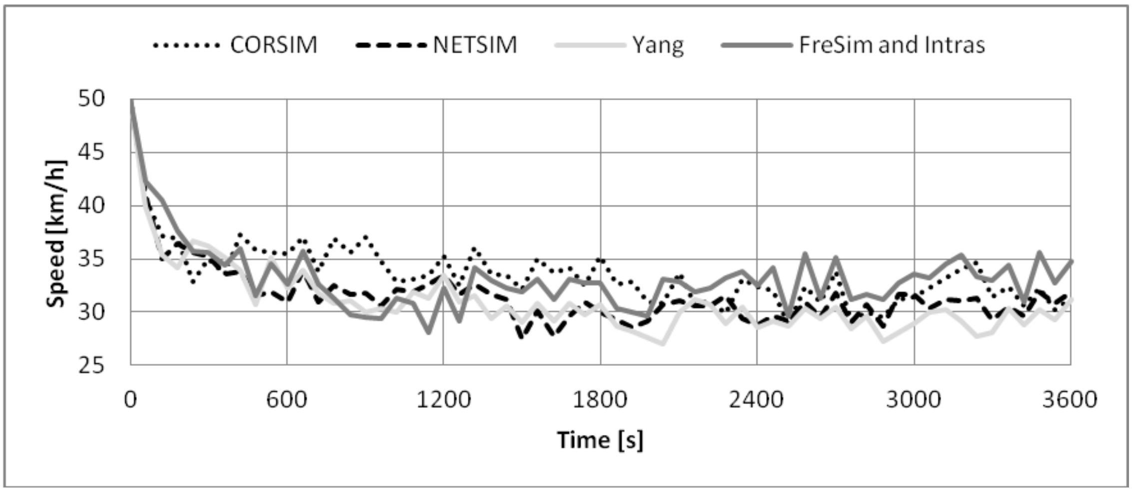


Fig.2. Average speed of vehicles over time

Vehicles entering the network. The highest rates of the inflow occurred in Krauss, Giofrè Advanced, Yang, Gipps and NetSim models. In case of Krauss and Giofrè Advanced models this was caused by the high fluidity of the models, whereas in the other three models, the high density of vehicles (small distances between vehicles) gave the opportunity for more vehicles to enter the network. On the opposite end were the capacity-based models as they impose strict rules on the inflow rate in order to ensure the capacity constraints to be met.

Vehicles in the network. These statistics depend on the number of vehicles that have entered the network and their average speed. The higher the average speed and the fewer vehicles entering the network, the lower the number of vehicles in the network. Krauss model was very fluid and, though the high inflow rate, the number of vehicles in the network was very low. On the other hand, low values of this statistic occurred also for Van Aerde, Giofrè Linear and Polynomial models. However, in these cases, the true reason of that was a very low inflow rate rather than the fluidity of the models themselves. On the opposite end, there were Yang, NETSIM and Gipps models, which allowed high inflow rate (almost like Krauss model) and at the same time were not so fluid (the average speed was substantially lower than in Krauss model). This led to the highest number of vehicles in the network among the models at the end of the simulation.

Total length of queues. This variable was calculated as the sum of the lengths of all queues in the network. The general observation was that the higher the inflow rate, the longer the queues. Therefore, the shortest queues were for the capacity constrained models, such as Van Aerde, Giofrè Linear and Polynomial models. Concerning the models with the highest input flows, only Krauss model had very short queues (as this model behaved very smoothly), whereas other models (i.e. Gipps, NETSIM and Yang models) had the longest queues. In case of these three models, small distances between vehicles caused frequent "stop and go" phenomena.

DRAC - Deceleration Request Avoid Collision. Represents the requested deceleration to avoid collision with the vehicle ahead. This indicator points to the danger of the road network in question, with regard to road safety. In case of all models, this indicator proved that the network is safe (DRAC less than 1.5 m/s2) except for Yang and Giofrè Advanced models, where the indicator shows higher values, but still within the norm.

TTC - Time to Collision. Represents the length of time before the collision with the vehicle ahead. We can distinguish three groups of models with regard to TTC values. In the first one (Van Aerde, Giofrè Linear and Polynomial models), TTC was over 60 s, which was caused by large distance between vehicles. In the second one (CORSIM, FreSim and Intras, and Wiedemann models), TTC oscillated between 50 and 60 s. For the rest of the models, TTC was between 30 and 50, but this still does not indicate any danger.

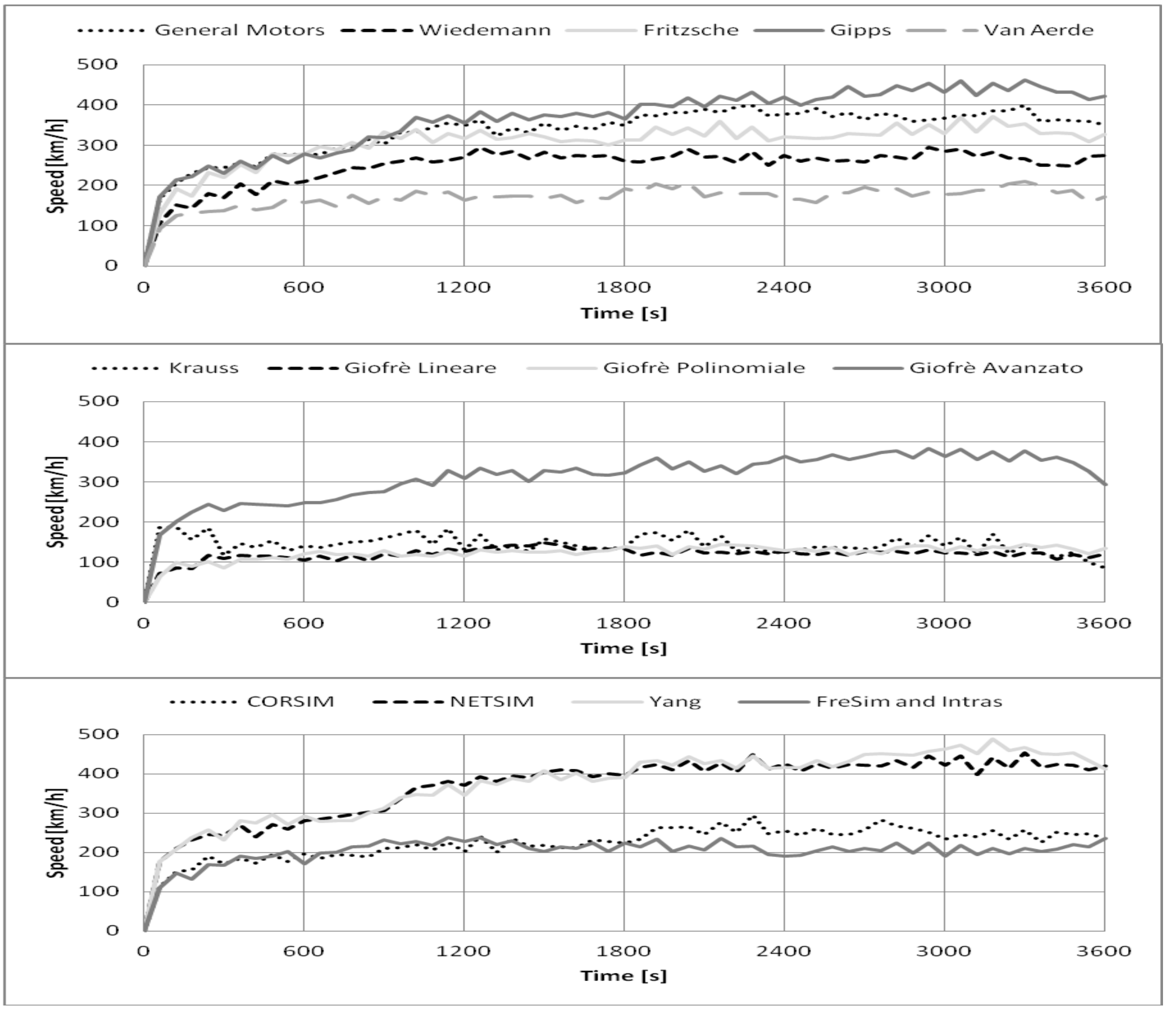


Fig.3. Number of vehicles in the network over time

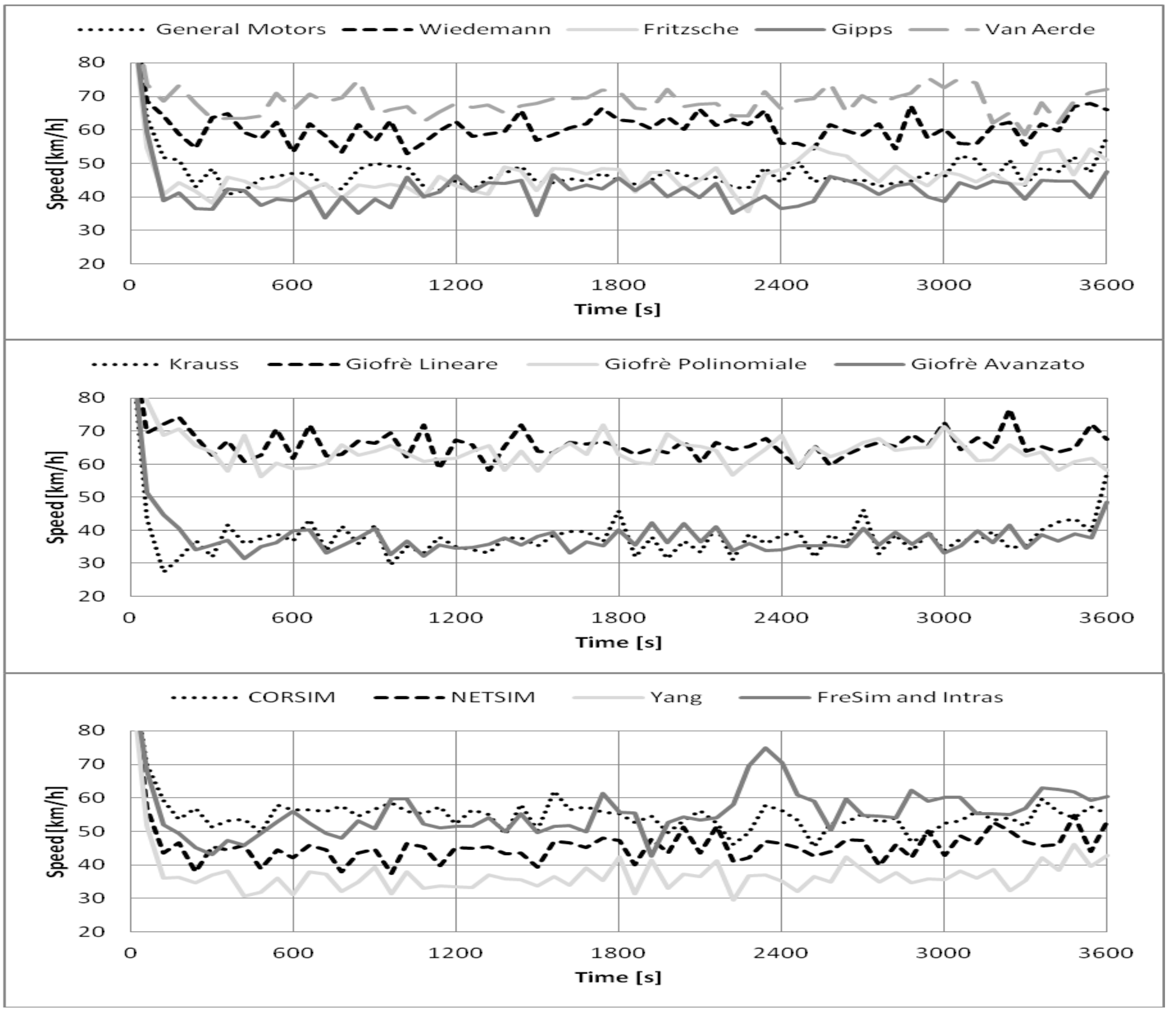


Fig.4. TTC indicator over time

5. Conclusions

Based on the in-depth analysis of the simulation results (including also statistics that were not presented above) one can divide the experimental car-following models into several groups. The first one are capacity constrained models, i.e. Van Aerde, Giofrè Linear and Polynomial, which had the lowest inflow rate (due to the capacity constraints) and therefore a low level of congestions (small number of vehicles in the network, short queues). The second group consists of Fritzsche, Wiedemann, General Motors and Giofrè Advanced models. These models, though logically/mechanically different, gave similar results. Krauss model alone makes up a group that is characterised by extreme fluidity of traffic (the highest input flow and the highest average velocity). The rest of the models, such as Gipps, NETSIM and Yang models, define a group of highly congested models. This, however, is mostly caused by a very small distance between consecutive vehicles. As vehicles travelled closer to one another, more vehicles could enter the network. However, small distances between vehicles resulted in lower average velocity, and finally in the long queues.

Another important aspect of evaluating the models is their validation against the real traffic. The obtained results are not in conformity with the measured data unless the following two necessary conditions are satisfied. First of all, all generated vehicles must enter the network and, secondly, queues at intersection inlets should not lengthen over time (the traffic should be stable). Both conditions are based on the assumption that the traffic flow measured at the junctions does not exceed the junctions' capacities, and therefore, given that the measured volumes are used for traffic generation, the flow ought to be fluid. These conditions were satisfied only by Krauss model, while the other models were not fluid enough to handle this amount of traffic.

Applying the car-following models that showed better performances, in the studied situation, the general compliance of the TRITONE microsimulation model to the experimental data was adequate, allowing the use of TRITONE to traffic flow and travel time evaluation.

References

1. Astarita V. , Giofré V. P. , Guido G. , Vitale A.: Investigating road safety issues through a microsimulation model. Procedia-Social and Behavioral Journal, vol. 20, 2011, pp. 226-235.
2. Astarita V. , Guido G. , Vitale A. , Giofré V. P.: A new microsimulation model for the evaluation of traffic safety performances. European Transport/Trasporti Europei, 2011, to appear in print.
3. Aycin M.F., Benekohal R.F.: Comparison of Car-Following Models for Simulation. Transportation Research Record: Journal of the Transportation Research Board, vol. 1678, 1999, pp. 116-127.
4. Barceló J. (Editor): Fundamentals of Traffic Simulation. Springer Science + Business Media, LLC 2010.
5. Brackstone M., McDonald M.: Car-following: a historical review. Transportation Research Part F 2, 1999, pp. 181-196.
6. Gazis, D., Herman R., Rothery. R.: Nonlinear follow-the-leader models of traffic flow. Operations Research, 9 (4) , 1961, pp. 545–567.
7. Gipps P.G.: A behavioural car-following model for computer simulation. Transportation Research Part B: Methodological, vol. 15, issue 2, 1981, pp. 105–111.
8. Guido G. , Astarita V. , Giofré V. P. , Vitale A.: Safety performance measures: a comparison between microsimulation and observational data. Procedia-Social and Behavioral Journal, vol. 20, 2011, pp. 217-225.
9. Halat A., Lieu H., Walker S.: CORSIM - Corridor traffic simulation model. R F Benekohal - University of Illinois, Urbana-Champaign, 1997, p. 570-576.
10. Higgs B., Abbas M.M, Medina A.: Analysis of the Wiedemann Car Following Model over Different Speeds using Naturalistic Data, Procedia of RSS Conference, 2011, pp.1-22.

11. FHWA, Development and testing of INTRAS: a microscopic freeway simulation model. Report FHWA/RD-80/106-108, vol. 1–3, Federal Highway Administration, US-DOT, McLean, Virginia, 1980.
12. Fritzsche H.T.: A model for traffic simulation. Traffic Engineering and Control, vol.35, issue 5, 1994, pp. 317-321.
13. Krauss S., Wagner P., Gawron C.: Metastable states in a microscopic model of traffic flow. Physical Review E, 55 (5), 1997, pp. 5597–5602.
14. Maerivoet S., De Moor B.: Transportation Planning and Traffic Flow Models. Internal Report 05-155, ESAT-SCD (SISTA), K.U.Leuven, Leuven, Belgium 2005.
15. Maciejewski M., Maciejewski M.: Przegląd i porównanie mikroskopowych modeli przepływu ruchu. Procedia of XI TransComp Conference – 2007, 2007, pp. 15-20.
16. Olstam J-J, Tapani A.: Comparison of Car-following models. VTI Meddelande 960A, Swedish National Road and Transport Research Institute, Linköping, Sweden, 2004.
17. Owen L.E., Zhang Y., Rao L., McHale G.: Street and traffic simulation: traffic flow simulation using CORSIM. WSC '00 Proceedings of the 32nd conference on Winter simulation, 2000, pp. 1143 - 1147.
18. Rakha H., Crowther B.: Comparison and Calibration of FRESIM and INTEGRATION Steady-State Car-Following Behavior. Transportation Research Part A: Policy and Practice, vol.37, nr 1, 2003 , pp. 1-27.
19. Schulze T., Fliess T.: Urban traffic simulation with psycho-physical vehicle-following models. Winter Simulation Conference, 1997, pp. 1222-1229.
20. Van Aerde M., Hellinga B., Baker M., Rakha H.: INTEGRATION: An Overview of Traffic Simulation Features. Transportation Research Board Annual Meeting, Washington, D.C., 1996.
21. Wiedemann R.: Simulation des Strassenverkehrsflusses, Schriftenreihe des Instituts für Verkehrswesen der Universität Karlsruhe, Germany, Heft 8, 1974.
22. Yang Qi, Koutsopoulos H.N.: A Microscopic Traffic Simulator for evaluation of dynamic traffic management systems. Transportation Research Part C: Emerging Technologies, vol. 4, issue 3, 1996, pp. 113–129.