

Validation of the Microscopic Traffic Flow Model VISSIM in Different Real-World Situations

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Abstract:

This paper presents the possibilities of validating the microscopic traffic flow simulation model VISSIM, both on a microscopic and a macroscopic level. VISSIM implements a psycho-physical car-following model and thus provides a very realistic driving behavior. The complex model offers - but also requires - many model parameters that can be calibrated using measurement data from driving experiments. Some examples of how certain parameters influence driving behavior are given by comparing a simulated approach-and-following-process with records from a probe vehicle. The model parameters can be adjusted to reflect different traffic situations. As examples, the model is validated using measurement data taken from a German freeway and from a US freeway, where driver behavior as well as traffic regulations are substantially different.

Keywords:

traffic flow simulation, microscopic simulation, model calibration, model validation

1 INTRODUCTION

Traffic flow simulation models are established tools for assessing the impacts of planned measures like changing infrastructure or special equipment of drivers like intelligent cruise control. Depending on the scope of investigation, different levels of detail are necessary in modeling infrastructure and vehicles. For simulation of large road networks, the family of macroscopic flow models is the common choice, and microscopic models are more often used for studying the traffic flow in smaller areas, but then in greater detail. However, microscopic models have increased their area of application since more computing power is available, and especially for the investigation of intelligent transport systems that influence the individual driver's behavior, the use of a microscopic model, i.e. one that models individual vehicles, is necessary.

Naturally, microscopic models require more effort in calibration due their larger number of model parameters. Up to now, the adaptation of a microscopic model to a local situation was time consuming and often the necessary measurement data was difficult to obtain. So, for one of the first car following models presented by Herman and Gazis (1) the model parameters were calibrated using a mechanical device between two cars to measure distance and speed difference. The lack of more general data limited the use of many models to a traffic environment where they originally were developed and validated. Today, much more measurement data is available through the upcoming of intelligent transportation systems. Intelligent cruise control systems have sensors to measure speed and distance of the preceding car and can thus provide a solid database for the calibration of car-following models. Other approaches include GPS-based equipment of probe vehicles to measure the behavior of even more than two vehicles at a time (2). And finally, the implementation of many highway control systems provide a huge amount of macroscopic field data for the validation of simulation results.

To make use of all these sources of data, the simulation model must be flexible enough to allow the calibration of as many observable values as possible. Models based on regression analysis of measurement data alone like the T3-model proposed by Bleile (3) are inherently not able to model the causal connections between traffic situation and driver reaction, and thus they cannot be adapted to different situations by adjustment of single model parameters. Most of the common microscopic models are based on explicit models of car-following behavior. These models have different levels of complexity, ranging from simplistic models proclaiming a fixed speed-distance-relationship for all traffic situations to models with dedicated behavior modeling for different situations based on psychological research.

In this paper, the car following model of the microscopic simulation tool VISSIM is explained and its ability to adapt to different driving behavior is investigated. The model parameters used for calibration will be identified and finally two calibration efforts of the model for German and US freeway traffic are validated by comparing measured field data with simulation results.

2 THE TRAFFIC MODEL IN VISSIM

The traffic flow model in VISSIM is a discrete, stochastic, time step based microscopic model, with driver-vehicle-units as single entities. The model contains a psycho-physical car following model for longitudinal vehicle movement and a rule-based algorithm for lateral movements. The model is based on the continued work of Wiedemann (4, 5).

The basic idea of the Wiedemann model is the assumption that a driver can be in one of four driving modes:

- **Free driving**, i.e. no influence of preceding vehicles observable. In this mode the driver seeks to reach and maintain a certain speed, his individually desired speed. In reality, the speed in free driving cannot be kept constant, but oscillates around the desired speed due to imperfect throttle control.
- **Approaching**, i.e. the process of adapting the driver's own speed to the lower speed of a preceding vehicle. While approaching, a driver applies a deceleration so that the speed difference of the two vehicles is zero in the moment he reaches his desired safety distance.
- **Following**, i.e. the driver follows the preceding car without any conscious acceleration or deceleration. He keeps the safety distance more or less constant, but again due to imperfect throttle control and imperfect estimation the speed difference oscillates around zero.
- **Braking**, i.e. the application of medium to high deceleration rates if the distance falls below the desired safety distance. This can happen if the preceding car changes speed abruptly, or if a third car changes lanes in front of the observed driver.

For each mode, the acceleration is described as a result of speed, speed difference, distance and the individual characteristics of driver and vehicle. The driver switches from one mode to another as soon as he reaches a certain threshold that can be expressed as a combination of speed difference and distance. For example, a small speed difference can only be realized in small distances, whereas large speed differences force approaching drivers to react much earlier. The ability to perceive speed differences and to estimate distances varies among the driver population, as well as the desired speeds and safety distances. Because of the combination of psychological aspects and physiological restrictions of the driver's perception, the model is called a psycho-physical car-following model.

In case of multi-lane roads a hierarchical set of rules is used to model lane changes. A driver has a desire to change lane if he has to drive slower than his desired speed due to a slow leading vehicle or in case of an upcoming exit with a special deceleration lane. First, the driver checks whether he can improve his present situation by changing lanes. Then he checks whether he can change without generating a dangerous situation. On German freeways an additional rule forces a driver to go back to the right lane if his situation there is not worse than on his present lane. Similar special rules are implemented for trucks, where traffic regulations specify a certain lane use.

For implementation of the model, time is incremented in small discrete steps. Obviously, time steps of more than one second would not be appropriate for the level of detail of the psycho-physical model. VISSIM offers the user to select a time step between 0.1 and 1.0 second. The time step influences the resulting driver behavior, because smaller time steps allow an earlier and therefore smoother reaction to the driving action of the preceding vehicle. For a further description of the model refer to (6).

3 MICROSCOPIC CALIBRATION OF THE TRAFFIC FLOW MODEL

Since car following behavior is the core of traffic modeling in microscopic models, most model parameters influence the longitudinal dynamics of single vehicles. Calibration of these parameters requires measurements on the level of single vehicles, i.e. data about headways, perception thresholds and driver characteristics have to be available. The following diagrams show how the four-mode-model described above is able to reproduce the real-world process of a faster car approaching a slower vehicle and finally following it. The x-axis shows the speed difference with the right part representing that the vehicle under observation is faster than the preceding vehicle, and the y-axis shows the headway of the vehicles. The leftmost diagram shows a measured maneuver, and the two diagrams on the right show the modeled process with two extreme settings of the stochastic influence on the driver. The amount of random oscillation differs from driver to driver, with the commuter driver population displaying a more disciplined behavior than non-commuters. Otherwise, the high traffic volumes observable in these periods would not be possible.

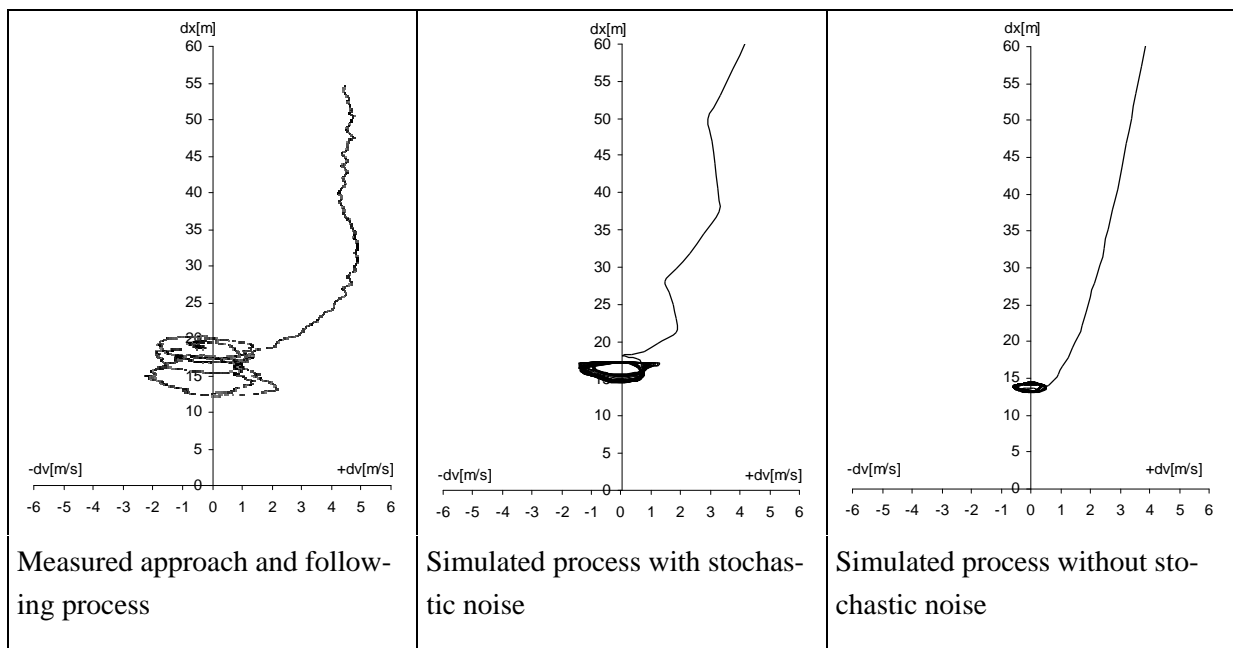


FIGURE 1. Comparison between measured and simulated car-following processes

In addition to the car-following model parameters, the selected time step is important for the quality of the simulation. Smaller time steps allow a more realistic modeling of acceleration. If a time step of one second is used, drivers are forced to overreact in some situations in order to compensate for the

increased reaction time. This effect must be taken into account when realistic quantitative modeling of acceleration is crucial, as it is with microscopic emission models. For combination with these models, time steps of about 0.2 seconds should be used. Similar problems arise if extremely high traffic volumes are to be modeled. To ensure a stable traffic flow above 2,000 veh/h in the simulation, a higher temporal resolution than one second is required.

The following diagrams illustrate the influence of the temporal resolution on the quality of very microscopic car following behavior. Both diagrams show the speed profile of a simulated vehicle that follows a leading vehicle. The speed profile of the lead vehicle was recorded during an experimental trip in urban traffic. The upper diagram represents the results at a time step of one second, the lower one is simulated with a time step of 0.1 second. Obviously the modeling quality of the second simulation is higher, since in the one-second case some unrealistic peaks can be seen which result from the over-reaction described above. However, for most applications, the quality would be sufficient. Otherwise, the time step can be reduced to give more realistic results, but that requires a proportionally increased computing time.

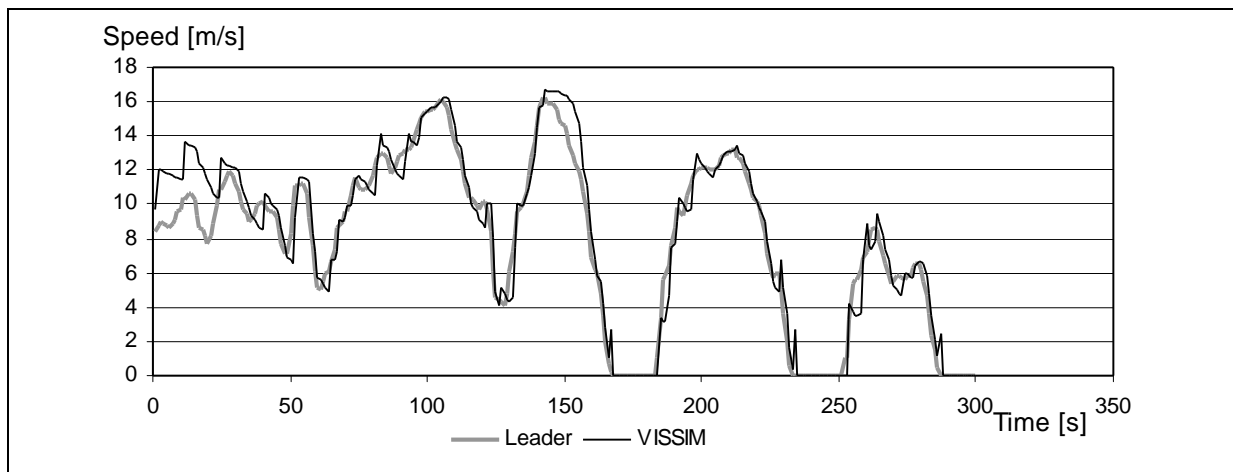


FIGURE 2a. Speed profile simulated in time steps of 1.0 second

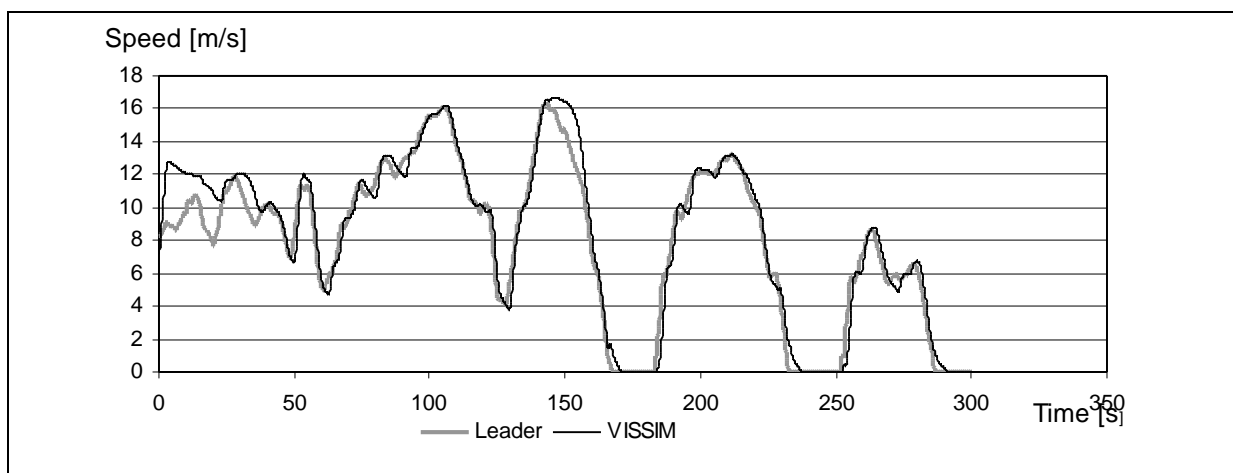


FIGURE 2b. Speed profile simulated in time steps of 0.1 second

It will be difficult for model users to provide measurement data for this kind of calibration at the microscopic level. However, the possibility to adapt to different driving styles is necessary, e.g. to provide different calibrated sets of default parameters for different countries with the model. Whether the car-following model is appropriately calibrated for a given situation can be checked by validating the simulation results on a macroscopic level.

4 MACROSCOPIC VALIDATION OF SIMULATION RESULTS

4.1 German Autobahn

The VISSIM car-following model was originally designed to model driver behavior on German freeways. There is no general speed limit on German freeways, but more and more parts of the network, especially the highly congested ones, are limited to 120 km/h. As a result of German driving behavior, the maximum flow on a single lane is about 1,800 veh/h.

To produce the results shown in the next two diagrams, the car-following model parameter were set to the German standard values deduced from headway and speed measurements on freeways. The distribution of desired speeds was taken from a study conducted for the German Highway Agency (7). The time step was set to 1.0 second. In the first diagram the speed-flow-relationship is shown. The measurement data is taken from a study conducted at the University of Bochum (8). For the observed two-lane freeway, VISSIM is able to reproduce both the speeds at different volumes and the capacity at about 3,500 veh/h, what is a typical value for German non-commuter traffic.

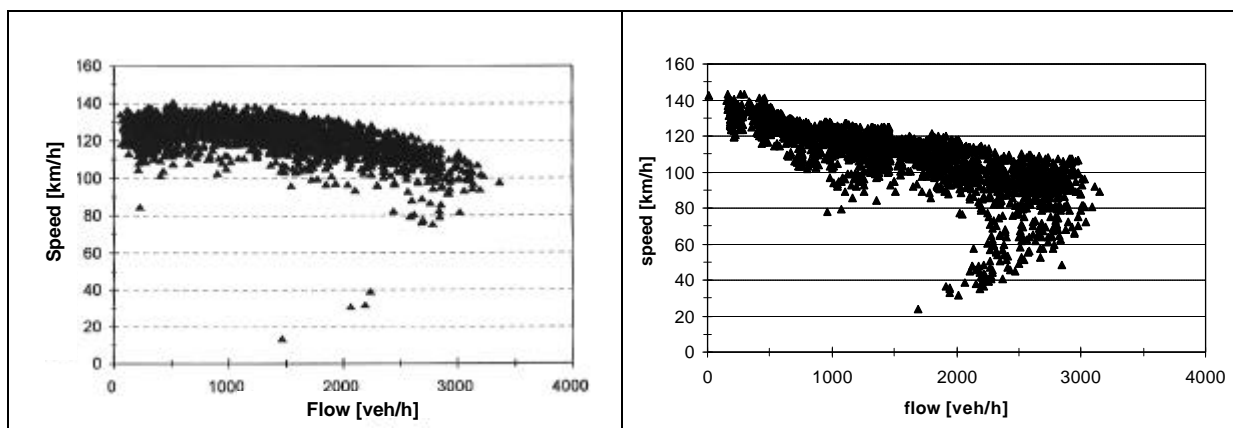


FIGURE 3 Speed-flow relationship on two-lane German freeway; measurement on the left, simulation result on the right.

To validate the lane-changing behavior, the distribution of the total volume to the single lanes is examined. The following diagram shows the use of lanes for a range of volumes on a three-lane freeway, on the left empirical data taken from (7), and on the right the simulation results. Each data point represents a time interval of five minutes. Both diagrams are very similar, indicating that the lane-

changing algorithm performs well. One of the most important input parameters for lane usage is the distribution of desired speeds. If the distribution is narrow, vehicles tend to use the lanes more uniformly. But the diagrams show the typical case in Germany: at higher volumes most of the volume is on the leftmost lanes, because desired speeds are widely spread and it is not allowed to overtake on the right lanes.

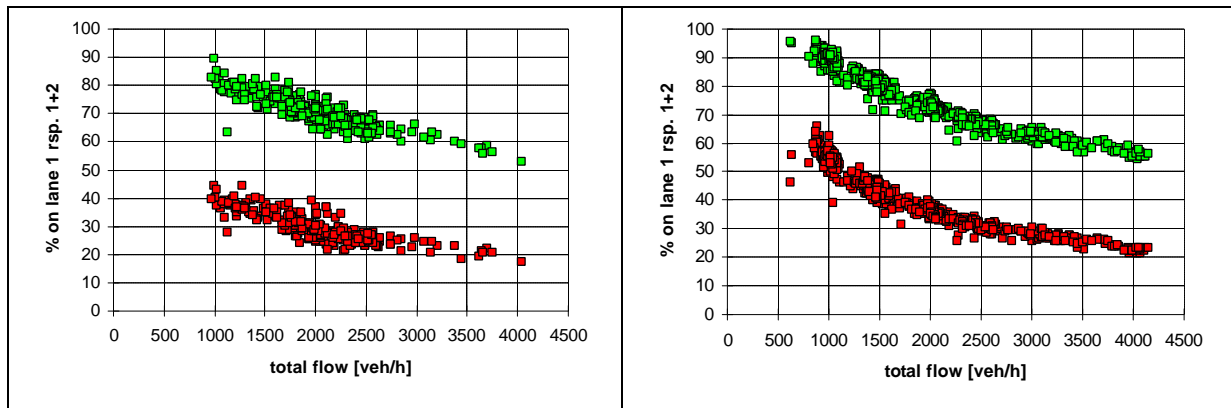


FIGURE 4. Measured (left) and simulated (right) lane use on three-lane German freeway

4.2 US Freeway

Driving behavior on US freeways is different than driving on German highways. Firstly, there is a general speed limit and secondly lane usage is not as strictly regulated. This results in substantially higher capacities on US freeway lanes. In order to model the American driving style for high traffic volumes, the car-following parameters are tuned to provide a tighter following process, i.e. smaller safety distances and less random oscillations. Combined with a time step of 0.2 seconds, lane capacities of up to 2,700 vehicles per hour could be reached.

The following diagrams compare simulation results to measurement data gathered on Interstate 15 north of San Diego (data provided by Caltrans, California Department of Transportation, San Diego, California). At the point of the measurement site, traffic flows on five lanes. The measurement does not cover the whole range of possible traffic situations, but it can clearly be seen where the traffic flow changes from stable to unstable conditions around 12,000 veh/h. The simulation model covers all possible traffic situations. As with the real-world data, the traffic flow becomes unstable at 12,000 veh/h or 2,400 veh/h/lane. Also, the speed-flow-relationship is met well.

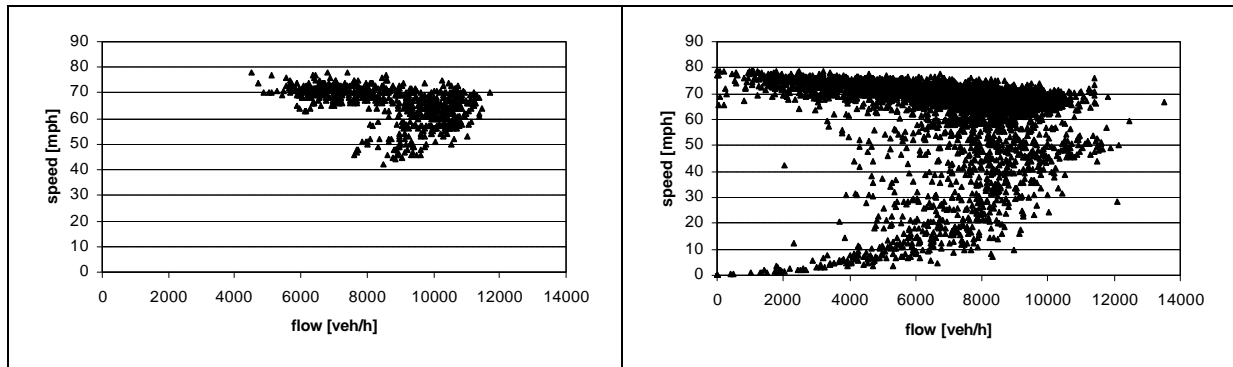


FIGURE 4. Speed-flow relationship on five-lane US freeway; measurement on the left, simulation result on the right.

5 CONCLUSION

Both microscopic calibration and macroscopic validation results show, that simulation tools based on the psycho-physical car-following model can reproduce traffic flow very realistically under different real-world conditions. Therefore, it is possible but also necessary to adapt the model to the local traffic situation; at least national traffic regulations and driving styles must be taken into account.

Adaptation of the model can be based on microscopic data gathered by probe vehicles equipped with electronic sensors or on macroscopic flow data, as it is normally available from measurement sites. For German and US traffic conditions, standardized sets of calibration parameters for VISSIM are available. In the near future, similar sets for British and French freeway conditions will be available.

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