Calibration of a Microscopic Model of an Urban Traffic Network

Ivana Cavar, Zvonko Kavran and Natalija Jolic
Faculty of Transport and Traffic Sciences, University of Zagreb, Zagreb HR-10000, Croatia

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Abstract: Traffic simulation models have the potential to provide an objective, cost-effective and flexible approach to assessing system design, traffic operations and management strategies. In that regard, the calibration and validation of simulation model is crucial for appropriate decision making process. This paper presents an application of microscopic simulation model calibration and validation procedure for a multimodal urban traffic network. Model is developed by VISSIM and VISSIG software tools.

Keywords: Microscopic simulations, multimodal urban traffic, traffic planning and modeling, urban transport.

1. Introduction

With the rapid advancement of computer technology, numerical modeling has become a valuable tool in the design and evaluation of scenarios across different engineering disciplines, including traffic engineering. Traffic simulation models may be used to evaluate the impacts of changes to both network infrastructure (e.g. adding a road to a network), traffic control devices (e.g. implementation of public transportation priority at signalized intersections), and advanced forms of ITS (e.g. evaluating the impact of cooperative mobility measures as implementation of vehicle-to-vehicle (V2V) communication).

There are three basic levels of traffic simulation models: microscopic, mesoscopic and macroscopic. A macroscopic traffic simulation model describes the entities and their activities at a low level of detail [1]. The approach is used to capture traffic dynamics of large networks covering big geographic area in lesser detail, reducing data requirements, and providing greater flexibility for calibration of the model.

Microscopic simulations are high fidelity models capable of representing the individual characteristics of the traffic elements at a high level of detail. Mesoscopic traffic simulation models use a mixture of techniques. These models describe some elements of the traffic system at a high level of detail but represent the interactions at a relatively lower level of detail than microscopic traffic simulation models.

The paper presents researches focusing on a microscopic modeling and calibration of an urban traffic corridor situated in the City of Zagreb, capital and largest city of the Republic of Croatia. According to the results of the last official census that was held in 2011, the population of the City of Zagreb is 792875 inhabitants and motorization level is increasing (From 2002 till 2007, average annual growth of motorization was 20 vehicles per 1000 inhabitants) [2]. In Zagreb, there are 15 tram lines and more than a hundred bus lines (including bus lines that operate in Zagreb County).

The paper is organized as follows: Section 2 describes simulation model; section 3 gives overview of applied model calibration procedure; section 4 describes results of modeling and calibration procedure, while section 5 includes conclusion remarks.
2. Simulation Model Description

Focus corridor is situated at the north-east part of the city and is 5.6 km long (Fig. 1). Three tram lines are passing the entire corridor and one tram line passes only partially. Also, two tram lines and five bus lines intercept corridor. At the west end of corridor, there is a three-line wide roundabout and at the east end, there is the public transport terminal where tram lines terminate. Along corridor, there are 8 signalized intersections and 8 tram stops for each tram line direction, mainly located before or after the intersection.

The traffic network model has been developed in VISSIM software (Figs. 1-2). For this purpose, the necessary data were collected in order to create a high-quality model that will simulate the behavior of private car users and urban public transport. Running speed and dwell times were obtained by GPS devices and traffic count data were collected at each intersection. A total of 8 signaling devices with fixed exchange of signaling programs have been modeled in VISSIG tool (Fig. 3).

![Part of Kralja Zvonimirova street network model.](image1)

![City map with corridor location and VISSIM network model.](image2)

![Modeling of signal devices.](image3)
3. Model Calibration

After the modeling process, the next step was model calibration, referring to comparison of real-life measured data and data obtained by the simulation. The calibration can be considered successfully obtained when the determination coefficient between model and collected data is close to unity.

For model calibration, it is necessary to determine those parameters of the model that can be analyzed and compared with the collected data. It is important to emphasize that data used for the calibration cannot be used as input data for the simulation model. After calibration, the model is translated from general form into specific form adjusted to local conditions.

For this model, two sets of parameters are necessary:
- Data about private transport;
- Data about public transport.

Parameters used for models calibration are listed hereafter.

3.1 Average Waiting Time

For not signalized intersections average waiting time is described as [3]:

\[
d_1 = \frac{3600}{C_i} + 900 \times T \times \left[ \frac{Q_i}{C_i} - 1 + \sqrt{\left(\frac{Q_i}{C_i} - 1\right)^2 + \frac{3600 \times Q_i}{6C_i^2}} \right] + 5 \text{ [sec/veh]}
\]

\(Q_i\): the traffic flow [vehicles/hour];
\(C_i\): the capacity [vehicles/hour];
\(T\): the duration of the period of analysis [min/60min].

For signalized intersections [3] average delay for vehicle “d” is determined as the sum of 3 elements:
- \(d_1\) (uniform delay, delay in operation of uniform arrivals)
- \(d_2\) (incremental delay, delay in operation of random arrivals)
- \(d_3\) (initial queue delay, delay due to the queue of the previous period)

\[
d = d_1 + d_2 + d_3\]

\[
d_1 = \frac{0.5C \left(1 - \frac{Q_i}{C_i}\right)^2}{1 - \left[\min \left(1, X\right) \frac{Q_i}{C_i}\right]}
\]

\[
d_2 = 900T \left[ (X - 1) + \sqrt{(X - 1)^2 + 8klX} \right] \frac{1}{c^T}
\]

\[
d_3 = \frac{1800Q_i(1 + u)t}{c^T}
\]

where:
- \(C\): cycle time;
- \(g\): actual green;
- \(X\): level of saturation;
- \(l, k\): corrective coefficients;
- \(c\): capacity of lane [vehicles/hour];
- \(T\): duration of the period of analysis [min/60min].

3.2 Average Queue Length

For not signalized intersections, average queue length is considered to be [3]

\[
N_{95,i} = 900 \times T \left[ \frac{Q_i}{C_i} - 1 + \sqrt{\left(\frac{Q_i}{C_i} - 1\right)^2 + \frac{3600 \times Q_i}{150 \times T}} \right] \times \frac{C}{3600}
\]

where:
- \(N_{95}\): 95th percentile represents the number of vehicles in queue;
- \(Q_i\): traffic flow [vehicles/hour];
- \(C_i\): capacity [vehicles/hour];
- \(T\): duration of the period of analysis [time] \((T = 0.25\) for a period of 15min);

For signalized intersections, procedure involves the calculation of two different situations and the adoption, for the next steps, of the highest value among the two:
- The first takes into account the queue which is created during the green light.

\[
n_1 = f \left(\frac{C - v}{2} + r\right)
\]

where:
- \(f\): incoming traffic flow;
- \(C\): cycle time of traffic light;
- \(v\): effective green;
- \(r\): redlight time interval.
- The second takes into account the only red light time period:

\[
n_2 = f (C - v)
\]

where:
- \(f\): incoming traffic flow,
C: cycle time of traffic light,
ν: effective green.

To obtain the queue length in meters $\text{Max} (n_1; n_2)$ has to be multiplied by the average length of the vehicle, fixed equal to 5.6 m and then divided by the number of lanes.

The model was calibrated on the basis of average waiting time (Fig. 4) and queue length on each intersection (Fig. 5).

Compared, calculated and simulated, values of queue length gave $R^2 = 0.9246$ and RMSE (Root Mean Square Error) of 2.88 veh / line while for waiting time these values were $R^2 = 0.9421$ and RMSE 23 sec/veh.

For the public transport data about timetable, average speed and dwell time on each stop were collected. Average speed and dwell time were collected by GPS logger and data about timetable are publicly available. The model calibration was based on the travel time for each tram line on the corridor with $R^2$ equal to 0.902 and RMSE of 6.84 sec/vehicle.

Consequently, we can consider the model as affordable due to the values of $R^2$ and RMSE obtained.

4. Results Analysis

After the data input, modeling process and calibration, microscopic model was set to simulate traffic conditions for corridors afternoon peak period. Based on GPS tracks analysis afternoon peak period for corridor is considered to be between 15:30 and 17:00h [4].

Based on simulation results Level of Service (LoS) was determined for each intersection (signalized and not signalized) according to Ref. [3]. Due to very high correspondence between average waiting times obtained by the simulation and evaluated on real data, to evaluate the LoS, we used a weighted average, where $F_i$ is the real flow at the intersection $i$, and $\sum T_{mi}$ is the sum of simulated and calculated average waiting times at the intersection $i$.

$$\text{LoS} = \frac{\sum_i T_{mi} \cdot F_i}{\sum_i F_i}$$

Fig. 4  Calibration parameter waiting time [sec/veh].

Fig. 5  Calibration parameter queue length [veh/line].

<table>
<thead>
<tr>
<th>LoS Signalized intersection</th>
<th>Not signalized intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td>A  ≤10 sec</td>
<td>≤10 sec</td>
</tr>
<tr>
<td>B  10-20 sec</td>
<td>10-15 sec</td>
</tr>
<tr>
<td>C  20-35 sec</td>
<td>15-25 sec</td>
</tr>
<tr>
<td>D  35-55 sec</td>
<td>25-35 sec</td>
</tr>
<tr>
<td>E  55-80 sec</td>
<td>35-50 sec</td>
</tr>
<tr>
<td>F  ≥80 sec</td>
<td>≥50 sec</td>
</tr>
</tbody>
</table>

Table 2  Average traveling speeds for private cars and public transport during the peak periods [km/h].

<table>
<thead>
<tr>
<th>Direction east -west</th>
<th>Direction west-east</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>Tram</td>
</tr>
<tr>
<td>18.242</td>
<td>9.4</td>
</tr>
<tr>
<td>24.29</td>
<td>Tram</td>
</tr>
<tr>
<td>10.9</td>
<td></td>
</tr>
</tbody>
</table>

Based on the simulation results, we can say that public transport travel times are at an inadequate level for public transport to be competitive to the private one (Tables 1-2).

Based on corridor microscopic network model and its calibration, we can now simulate different system design, traffic operations and management strategies to find the best one.
5. Conclusions

This paper proposed a calibration procedure for the multimodal urban traffic network microscopic simulation model. The level of detail used in simulation is justified in regard with the simulation goal. The proposed calibration procedure is demonstrated via a case network that involves multiple steps, and the calibrated model showed reasonable performance in replicating the observed flow condition. Model calibration is an important step of model building allowing simulation model to represent traffic system at adequate level of reliability and supporting decision making process at highest level.

References