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Calibration of a microscopic simulation model for emission calculation

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ABSTRACT

Emissions by road traffic can be reduced by optimising traffic control. The impact of this optimisation on emission can be analysed *ex ante* by simulation. The simulation programs used for this analysis should be valid with respect to the traffic characteristics that determine the emissions. Thus calibration of the parameters is a prerequisite. In most cases, volumes, travel times and queues are used to calibrate simulation models, rather than detailed driving characteristics such as speed and acceleration patterns. However, these driving behaviour parameters determine the vehicular emissions to a great extent.

A study was carried out in which the driving behaviour parameters in a microscopic simulation model (VISSIM) were calibrated using real trajectories collected by image processing at an intersection in Rotterdam. The sensitivity of the simulation results for driving behaviour parameters was investigated. The most influential parameters were identified and adjusted to ensure that the simulation results were consistent with the observed traffic and could provide valid estimations of the total production of emissions.

1. Introduction

Emissions and fuel consumption on urban streets are strongly determined by the details of the driving behaviours. In the 1980s of the last century, the optimisation program of traffic control TRANSYT (Robertson et al., 1980) already had an option to optimise the fuel consumption. TRANSYT calculated the fuel consumption as a function of full and partial stops. Nowadays it is well known that fuel consumption depends on the speed, acceleration pattern of a trip, characteristics of the car, the weather and the road. The pollutant emissions during a trip are determined by the same characteristics as mentioned above. The emissions increase by highly dynamic driving with frequent acceleration and deceleration activities (transient state driving), very high and low average speeds, and with many stops. Over the past few years, some microscopic simulation models have been developed to estimate the emissions based on the driving characteristics. Viti et al. (2008) gave an overview of the different models that have been developed for the estimation of emissions (and fuel consumption) based on speed and acceleration patterns of vehicles. The emission model VERSIT+ is currently considered as one of the better state-of-the-art emission models (Smit et al., 2005). This model uses an extensive set of parameters to describe a driving profile and vehicle characteristics. It takes microscopic driving characteristics into account, such as instantaneous speeds and accelerations. The VERSIT+ model is similar to the PHEM model (Passenger car and Heavy duty vehicle Emission Model) as described by (Hausberger, 2003). In order to match real-life emission, multiple regression has been used to determine the emission rates

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using an extensive database measured from real driving profiles. The input for the estimation of emissions by VERSIT+ is the detailed driving patterns of speeds and speed changes. This means that the speed and accelerations as given by the simulation program should be sufficiently accurate to determine the effects of traffic measures and to decide the best options for emission reduction.

Reducing traffic emissions by adaptation of traffic management and control measures is a promising option. Especially traffic control can be optimised to reduce the number of decelerations and accelerations for, in particular, heavy vehicles. The traffic engineer should be able to predict what the effects are of the modification of the traffic control (e.g. Van der Meer, 2007; CROW, 2010; Hirschmann and Fellendorf, 2010). Optimal decisions about traffic measures can be taken when the impact on emissions of the different alternatives can be determined in advance. This requires a model that provides valid estimations of emissions. However, several evaluation studies of traffic control with respect to emissions use a simulation program without calibrating the local traffic characteristics and specific driving population.

Calibration of various parameters in a simulation model is required in order to achieve sufficiently valid outcomes in the context of the application purpose. The default values provided by the software developers for these parameters are only applicable to rather specific circumstances, which are often not specified in detail by the software provider. The number of user-adjustable parameters is usually quite large and the calibration process is fairly complex considering the many parameter combinations. Experienced users adapt and adjust a certain number of parameters such that the program can behave as required by a specific application, but this 'calibration' is in general quite opportunistic rather than systematic. Even if a procedure of calibrating model parameters is effective enough for obtaining realistic macroscopic traffic characteristics such as throughput and capacity, it may not be sufficient for more subtle performance measures, such as traffic emissions.

In order to get a valid simulation of emissions, the characteristics of the simulated vehicle trajectories should be similar to reality. Even if some macroscopic traffic characteristics such as queues, travel times are valid outcomes of a simulation program, it is not guaranteed that the more detailed characteristics like speed and acceleration profiles are sufficiently realistic to predict the emission. In order to get valid estimations of the emissions, the calibration has to be carried out in terms of realistic vehicle trajectories.

In a case study the authors have observed that the default parameter setting of the micro-simulation programs VISSIM and AIMSUN did not give realistic results on the trajectory level (Wilmink et al., 2009). It was clear that the default parameter settings did not give valid outcomes for the estimation of emissions. The study reported in this article explains how a calibration can be done in order to find sufficiently realistic traffic characteristics on the level of speeds and accelerations. We did not try to give better-calibrated parameters for generic applications but just wanted to show how a microscopic calibration could be done. Furthermore, this study shows the impact of the calibration on the emission estimation.

Section 2 discusses the question whether models that have been calibrated for macroscopic traffic characteristics are also valid to calculate more subtle performance measures. The methodology for calibrating a microscopic simulation model for emission assessment is described in Section 3. Section 4 presents the results of the calibration. Section 5 analyzes the consequences of the calibration for the estimation of emissions and the last section gives the conclusions and a discussion.

2. Calibration for detailed microscopic driving patterns

A microscopic model such as VISSIM is often calibrated by comparing measured and simulated travel times and delays (Wu et al., 2003; Park and Qi, 2005), travel time distributions (Kim et al., 2005), or saturation flows rates (Asamer et al., 2011 and Asamer and van Zuylen, 2011). However, completely different trajectories can lead to the same travel time and different driver behaviour can lead to the same saturation flow, delays and queues. The parameter setting that optimises the fit between the simulation and observed traffic characteristics is in general not unique (e.g. Asamer et al., 2011). A simulation model that has been calibrated for macroscopic traffic characteristics like travel times, queues or saturation flow still has no guarantee that the microscopic characteristics like the properties of the trajectories are also realistic. Within the space of feasible parameters, a further calibration is needed to get also realistic microscopic characteristics of trips. Emissions depend on the detailed behaviour of vehicles: acceleration, speed, deceleration and higher order terms determine emissions and fuel consumption (e.g. Keller and De Haan, 2004). The sensitivity of emissions for the detailed driving pattern requires a simulation that is also valid for these microscopic characteristics (Hirschmann and Fellendorf, 2010).

Fig. 1 shows the difference between classical calibration and microscopic calibration using trajectories.

Fig. 2 gives the frequency of speeds occurring at a certain distances from the stop line. A lighter colour indicates a high frequency. Fig. 2b shows the speed profiles observed in reality and (Fig. 2a) shows the profile simulated in VISSIM for traffic on an intersection in Rotterdam in The Netherlands. For the VISSIM simulation only a minor calibration was applied of two-car following parameters to obtain the correct saturation flow. Most parameters were kept on the default values. There is a significant difference between the two figures indicating that it can be expected that the emissions calculated from the simulated trajectories will be different from reality. VISSIM with the default parameters gives less variability in speeds occurring on a certain distance of the stop line and a larger deceleration on a shorter distance of the stop line than what was observed in reality.

From this it can be concluded that a simulation program calibrated by the classical method probably is not valid for traffic emission simulation. Accelerations and speed profiles as can be derived from vehicle trajectories, should be calibration tar-