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Improved road traffic emission inventories by adding mean speed distributions

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Abstract

Does consideration of average speed distributions on roads—as compared to single mean speed—lead to different results in emission modelling of large road networks? To address this question, a post-processing method is developed to predict mean speed distributions using available traffic data from a dynamic macroscopic traffic model (Indy) that was run for an actual test network (Amsterdam). Two emission models are compared: a continuous (COPERT IV) and a discrete model (VERSIT+ ^{macro}). Computations show that total network emissions of CO, HC, NO_x, PM_{10} and CO_2 are generally (but not always) increased after application of the mean speed distribution method up to +9%, and even up to +24% at sub-network level (urban, rural, motorway). Conventional computation methods thus appear to produce biased results (underestimation). The magnitude and direction of the effect is a function of emission model (type), shape of the composite emission factor curve and change in the joint distribution of (sub)-network VKT (vehicle kilometres travelled) and speed. Differences between the two emission models in predicted total network emissions are generally larger, which indicates that other issues (e.g., emission model validation, model choice) are more relevant.

Keywords: Emission inventory; Speed variability; Road traffic; Emission model; Road network; Accuracy

1. Introduction

Prediction of road traffic emissions and fuel consumption is becoming increasingly important for evaluation of environmental policies and (proposed) infrastructural developments. The scale of interest varies from local road projects to entire (urban) transport networks and even national or global emission inventories. Around the world, road traffic is the dominant anthropogenic source of air pollution in urban areas (e.g., Fenger, 1999).

Different types of traffic input data are required in the emission modelling process, and the following types may be distinguished: traffic (e.g., traffic volume, traffic composition, average speed) and infrastructure characteristics (e.g., type of road, road length, speed limit, number of traffic lanes). Traffic models are commonly used to generate the required traffic data input to emission models (Smit, 2006). However, the demand for resources (costs, labour, computer runtime) to generate and process traffic data increases with road network size. The extent and the level of detail of traffic data are

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therefore effectively reduced when network size increases. For large (urban) road networks, traffic models usually generate macroscopic traffic data (i.e., traffic stream level) for each road link in the network (e.g., Brindle et al., 2000). With respect to traffic performance, output is typically restricted to estimates of mean link speed, which is at least one of the reasons for the common use of average speed in network emission modelling. For instance, average speed emission models like MOBILE and COPERT, where emission factors ($\mathrm{g\,km^{-1}}$) are a function of average speed are regularly applied in practice (Smit et al., 2007). Average speed is also an important variable in emission modelling because traffic emissions are strongly dependent on speed in a non-linear fashion (e.g., André and Hammarström, 2000). Given the importance of and sensitivity to speed in emission modelling, two requirements are defined for emission modelling:

1. estimated mean link speeds are as accurate as possible and
2. use of the variable "speed" is as realistic as possible.

Inaccurate speed predictions may have a strong effect on predicted emissions. For instance, TRB (1997) conducted a sensitivity analysis on the average speed emission model MOBILE5 and found that an error of $5\,\mathrm{km\,h^{-1}}$ in the estimated value of speed for a freeway caused a 42% difference in CO emission predictions due to the strongly non-linear relationship between emissions and speed. There have been efforts to improve estimates of mean link speed from (static) macroscopic traffic models using traffic data that are relatively easy to obtain (e.g., Dowling and Skabardonis, 1992; Nesamani et al., 2007). Alternatively, dynamic macroscopic traffic models can be used, as is done in this paper.

With respect to the second point, the use of a single (mean) speed for all vehicles on a section of road may potentially lead to significant errors in the emission prediction process. In practice, each vehicle within the traffic stream will have its own average speed due differences in driving style, engine performance, level of congestion, weather conditions and so forth. So, in reality a distribution of average speeds would apply to a traffic stream. The use of average speed distributions instead of a single mean speed may improve emission predictions for large networks since this would be closer to reality.

This paper will focus on the second requirement and will investigate if consideration of average speed distributions on road links (instead of a single mean link speed) in emission modelling of a large urban network leads to different results and, given the extent of these differences, if it is likely to be a relevant issue.

It is noted that the use of mean speed distributions in emission modelling does not *explicitly* take into account the effect of different driving dynamics at a particular mean speed (e.g., constant speed versus high levels of speed fluctuation) on vehicular emissions. This affects the accuracy of emission predictions at a local scale. Driving dynamics are, however, to some extent *implicitly* included, as lower mean speeds in the real world are naturally the result of more speed fluctuation, idle time, etc. As long as the speed distribution method is used to compute total emissions for large road networks, or substantially large parts of a road network (e.g., $1\,\mathrm{km^2}$ grid cell), the (random) error introduced by not fully accounting for vehicle-specific driving dynamics should more or less average out.[1] This is because some links will experience higher than average vehicle dynamics and some will experience lower than average driving dynamics.

2. Methodology

2.1. Traffic model

To generate the required traffic data for the emission models, the traffic model Indy has been used. Indy (Bliemer et al., 2004) is a macroscopic dynamic multi-user class traffic assignment model that contains advanced dynamic traffic modelling techniques for analysing congested networks and for evaluating the impact of traffic scenarios on traffic management, route guidance and road pricing. In contrast to static traffic modelling, Indy predicts how traffic flows and speeds vary over time and it contains state of the art queuing models to accurately predict blocking back effects and estimate the corresponding delays and queue lengths (Bliemer, 2007). By taking into account these congestion effects, Indy is able to provide more accurate traffic data compared to conventional macroscopic static traffic models.

[1]Assuming that emission factors are based on driving cycles with approximately average driving dynamics at each mean speed.