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Reduction of errors when estimating emissions based on static traffic model outputs

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Abstract

The rapid growth of traffic congestion has led to an increased level of emissions and energy consumption in urban areas. Well designed infrastructure and traffic controllers along with more efficient vehicles and policy measures are required to mitigate congestion and thus reduce transport emissions. In order to evaluate how changes in the traffic system affect energy use and emissions, traffic analysis tools are used together with emission models. In large urban areas emission models mainly rely on aggregated outputs from traffic models, such as the average link speed and flow. Static traffic models are commonly used to generate inputs for emission models, since they can efficiently be applied to larger areas with relatively low computational cost. However, in some cases their underlying assumptions can lead to inaccurate predictions of the traffic conditions and hence to unreliable emission estimates. The aim of this paper is to investigate and quantify the errors that static modeling introduces in emission estimation and subsequently considering the source of those errors, to suggest and evaluate possible solutions. The long analysis periods that are commonly used in static models, as well as the static models' inability to describe dynamic traffic flow phenomena can lead up to 40 % underestimation of the estimated emissions. In order to better estimate the total emissions, we propose the development of a post processing technique based on a quasi-dynamic approach, attempting to capture more of the excess emissions created by the temporal and spatial variations of traffic conditions.

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Keywords: Emissions modeling, Air quality, Traffic modeling

1. Introduction

The growing need of travelling, which is one of the main characteristics of our modern societies, has led to highly congested urban areas with high pollutant levels. Efficient usage of our transport systems, by good traffic planning, control and development of traffic policy measures, is nowadays even more essential than earlier. In order to evaluate how changes in the traffic system affect energy use and emissions, traffic analysis tools are used together with emission models. Depending on their level of detail, emission models can be distinguished in instantaneous and aggregated

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models. Instantaneous emission models calculate emissions second by second, based on vehicle trajectories derived from floating car measurements or microscopic traffic models. However, such trajectory data is not available from traffic models commonly applied to larger urban areas. Alternatively, aggregated emission models that are based on traffic activity aggregated in time and space, can be applied at regional and national levels. While instantaneous models rely on microscopic traffic flow models outputs, aggregated emission models rely on aggregated macroscopic traffic data that can be attained from macroscopic traffic assignment models. Specifically, in large urban areas, static traffic assignment models are mainly used for this purpose, since they can efficiently be applied to larger areas with relatively low computational cost.

Static assignment models are used at a strategic level in order to assess long-term effects of changes in the transportation infrastructure. However, their underlying assumptions can lead to inaccurate predictions of the traffic conditions. By using static models, many important dynamic traffic flow phenomena, such as the formation and the propagation of queues, cannot be taken into account. Each link's travel time is associated with a volume delay function (VDF) that depends only on the flow traversing that specific link, and the link is modeled independently of the other links' traffic conditions. In this way, queue spill-back is not explicitly considered, and hence congestion appears at the wrong location, specifically at the bottleneck instead of upstream the bottleneck. However, during an air quality analysis, the accurate determination of the congested traffic state and its location is essential, since air quality effects are location specific. Therefore, the spatial average travel times and consequently the average link speeds, computed by static models, may be insufficiently accurate for use in emission modeling, especially in congested networks.

Additionally, another inability of static models that can also lead to incorrect emission estimations, is related to the temporal resolution of the analysis period. Static assignment models consider a stable demand during a fixed time period, commonly covering a period of several hours, (in Sweden a three hour period is used when modeling the morning peak in Stockholm) and the results are expressed in temporal mean values. Thus, if the speed fluctuation is high, which is not uncommon during a three hour morning peak period, average speed and flow cannot capture the speed variations and consequently emissions based on the average traffic conditions may be inaccurate. The difficulty of using mean speeds and flows as input to emission models have been discussed in several papers (Nesamani et al., 2007; Muller-Perriand, 2014; Ryu et al., 2015).

While static models describe a mean traffic state over a longer time horizon, dynamic modeling approaches allow the traffic conditions to be described for shorter time periods. Also, blocking back of the queues, as traffic demand exceeds capacity, and dispersion of the queues when demand is below the capacity, can be modeled. Therefore, dynamic modeling approaches are better suited to model changes in traffic conditions, and are well equipped to model both the spatial and temporal distribution of congestion. Trying to take advantage of the dynamic modeling benefits that potentially can improve emission estimation, Smit et al. (2008), Aguilera and Lebacque (2010) and Borge et al. (2012) applied dynamic traffic models in order to generate inputs for emission models. Furthermore, Wismans et al. (2013) performed a comparison between the emission prediction based on static and dynamic models. From an emission modeling perspective, it was clearly shown that there is large absolute difference between modeled emissions depending on whether static or dynamic models are used.

Nevertheless, while dynamic approaches provide mechanisms for high resolution modeling of both the spatial and temporal congestion's distribution, it is important to recognize that they heavily rely on the availability of high resolution data, both in terms of demand and calibration data. Additionally, in general a unique equilibrium solution does not exist for dynamic traffic assignments, which may create difficulties during the comparison of different policy measurements. Finally, complexity issues make dynamic modeling computationally expensive and time consuming to calibrate, and hence static assignment models are still the main tool for traffic analysis in larger urban areas. Therefore, it is of interest to consider how the output from a static model can better be explored in the emission modeling process, in order to improve the quality of the emission estimations.

The aim of this paper is to investigate and quantify the errors that the average speed and flow outputs of static modeling introduce in the emission estimation process. Subsequently, considering the type and the nature of those errors, our aim is also to suggest and evaluate improvements in the modeling process. The paper is structured in the following way: Section 2 gives a short description of aggregated emission models and how they can be applied to outputs from static traffic models. The paper continues with an overview of methods for post-processing of static modeling results in Section 3. In Section 4 the different sources of errors (temporal and spatial) of emission estimations from static models are presented, together with computational examples for a motorway stretch in Stockholm. In