COMPARISON OF MICROSCALE TRAFFIC EMISSION MODELS FOR URBAN NETWORKS

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1. Introduction

Traffic is the major source of air pollution in many cities. Despite recent efforts to improve air quality, some issues (usually related to NO_X and PM) remain in urban areas worldwide. Non-compliance with ambient air quality standards is often linked to traffic-related hot-spots. The assessment of potential solutions for such locations requires high-resolution spatial/temporal models that can successfully capture the complexity of traffic emissions and provide accurate inputs for detailed micro-scale air quality models. These estimations are based on individual driving profiles, which, in turn, are significantly influenced by traffic and road conditions. There are several approaches that can be used for this purpose. Among them, modal emission models are able to compute emission rates as a function of specific engine or vehicle operating modes with high temporal resolution (seconds). They are suitable for this kind of analysis.

The aim of this work is to obtain and compare detailed traffic emission predictions from two modal emission models in different urban network configurations in Australia and Spain.

2. Methodology and Results

This study compares the results of two micro-scale modal emission models, the Australian PΔP (Power-delta-Power) (Smit, 2013) and the simplified version of the European PHEM (Passenger Car and Heavy Duty Emission Model), PHEM-light model (Hausberger & Krajzewicz, 2014).

For the comparison of both emission models, driving patterns for individual vehicles were generated with the traffic micro-simulation model VISSIM (Fellendorf & Vortisch, 2010) providing speed-time profiles with 1 second resolution (example in Fig. 1) under different traffic congestion conditions (Quaassdorff et al., 2016) for two hot-spot areas located in Brisbane and Madrid.

Fig. 1. Speed-acceleration-time profile for a car in a saturated traffic scenario -S1- in Brisbane (Australia)

To understand the response of these emission models, vehicle classes considered in both models were mapped to a common classification (using power-to-mass ratio) to ensure a consistent comparison.

Power is one of the fundamental parameters in emission calculations, and this variable is significantly affected by acceleration-deceleration behavior (e.g. Fig. 2).

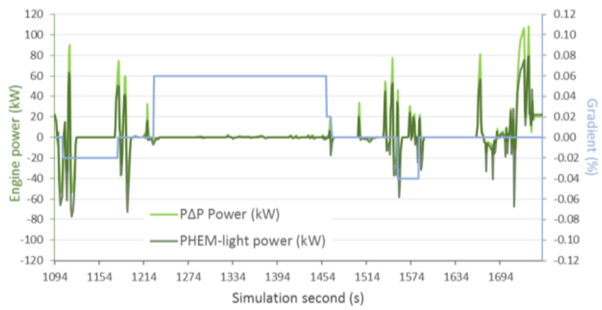

Fig. 2. Engine power (kW) and road gradient (%) for S1

Detailed estimations of NO_X emissions and fuel consumption (FC) for diverse vehicle types were compared (Fig. 3) in order to assess differences and to identify the most important variables involved in the emission calculation.

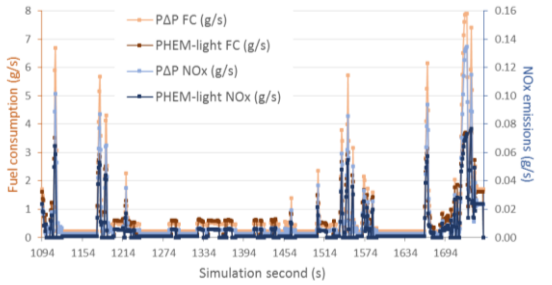

Fig. 3. NO_X and FC emission (g/s) comparison for S1

Our test suggest that satisfactory results can be achieved with any of the models, if reliable information on the vehicle fleet composition and vehicle characteristics is provided. Also, the instantaneous emission profiles for individual driving patterns are very sensitive to speed-acceleration profiles, vehicle mass and road grade, which are essential variables for the emission calculation. The second-by-second emission results provided by both emission models coupled to the instantaneous position provided by the traffic simulation model can be used to produce emission maps (e.g. Fig. 4) with meters and seconds resolution that may be suitable for high-resolution air quality modelling (e.g. Computational Fluid Dynamics -CFD- modelling).

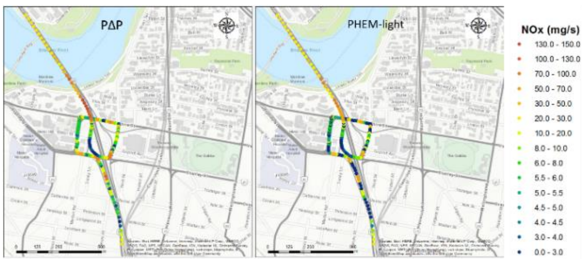

Fig. 4. PΔP and PHEM-light NOx emission distribution

This methodology has been successfully applied to different types of road network and different levels of congestion (Fig. 5). The results point out the importance of congestion, road gradient, vehicle load and power for the emission calculation. Maximum NO_X emission rates for the saturated traffic scenario (S1) with variable gradient, up to 134.5 and 76.8 mg/s calculated with PΔP and PHEM-light respectively. Whereas, in the free-flow scenario (S2) with constant gradient, NO_X emission maximums are 71.3 and 48.8 mg/s correspondently. These differences are due to the power calculation variation between models (Fig. 2). PHEM-light tends to predict lower power values than PΔP and this is reflected in emission results. This is due to differences in vehicle parameters. For the same Power-to-Mass ratio, Australian vehicles are larger and present higher engine power than EU ones.

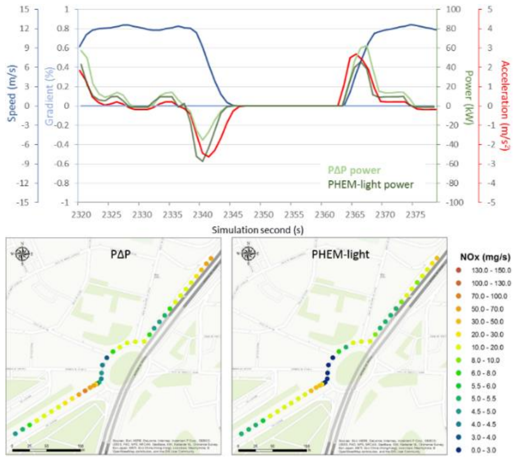

Fig. 5. Traffic profile and NOx emission distribution for a free-flow traffic scenario -S2- in Madrid (Spain)

3. Conclusions

The analysis of emission estimations for driving patterns under different traffic conditions points out the importance of an accurate definition of the model parameters for a specific vehicle fleet. In particular, large differences in the results are observed due to differences in Power-to-Mass ratios considered for each vehicle category. In this sense, a larger number of vehicle classes included in a particular model implies a better chance to provide representative emissions estimates. Therefore, it is essential to define power and load parameters as accurately as possible for each vehicle class (in addition to realistic driving patterns) to obtain accurate emissions regardless of the specific model being used. The results are useful for model validation purposes with real-world measured data.

Modal models are a promising option to obtain high resolution emission estimates (meters and seconds) for different traffic scenarios for CFD air quality modelling in urban areas.

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