Atmospheric Environment 44 (2010) 2943–2953

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Review

Validation of road vehicle and traffic emission models – A review and meta-analysis

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ARTICLE INFO

Article history:
Received 8 October 2009
Received in revised form
12 April 2010
Accepted 12 May 2010

Keywords:
Road traffic
Emission model
Accuracy
Validation
Error
Greenhouse gas

ABSTRACT

Road transport is often the main source of air pollution in urban areas, and there is an increasing need to estimate its contribution precisely so that pollution-reduction measures (e.g. emission standards, scrapage programs, traffic management, ITS) are designed and implemented appropriately. This paper presents a meta-analysis of 50 studies dealing with the validation of various types of traffic emission model, including 'average speed', 'traffic situation', 'traffic variable', 'cycle variable', and 'modal' models. The validation studies employ measurements in tunnels, ambient concentration measurements, remote sensing, laboratory tests, and mass-balance techniques. One major finding of the analysis is that several models are only partially validated or not validated at all. The mean prediction errors are generally within a factor of 1.3 of the observed values for CO_2, within a factor of 2 for HC and NO_x, and within a factor of 3 for CO and PM, although differences as high as a factor of 5 have been reported. A positive mean prediction error for NO_x (i.e. overestimation) was established for all model types and practically all validation techniques. In the case of HC, model predictions have been moving from underestimation to overestimation since the 1980s. The large prediction error for PM may be associated with different PM definitions between models and observations (e.g. size, measurement principle, exhaust/non-exhaust contribution).

Statistical analyses show that the mean prediction error is generally not significantly different ($p < 0.05$) when the data are categorised according to model type or validation technique. Thus, there is no conclusive evidence that demonstrates that more complex models systematically perform better in terms of prediction error than less complex models. In fact, less complex models appear to perform better for PM. Moreover, the choice of validation technique does not systematically affect the result, with the exception of a CO underprediction when the validation is based on ambient concentration measurements and inverse modelling. The analysis identified two vital elements currently lacking in traffic emissions modelling: 1) guidance on the allowable error margins for different applications/scales, and 2) estimates of prediction errors. It is recommended that current and future emission models incorporate the capability to quantify prediction errors, and that clear guidelines are developed internationally with respect to expected accuracy.

1. Introduction

The estimation of traffic emissions has become increasingly relevant in the discussion of air quality problems, climate change and mitigation policies, due to the continued growth in vehicle use and the deterioration in driving conditions (congestion). As many authorities find it difficult to meet their environmental targets (e.g. air quality standards, national emission ceilings), reliable emission inventories are more necessary than ever for ensuring that the road transport contribution is correctly assessed. To accurately represent real conditions, inventories should take into account the effects of local-scale traffic measures and technological developments on fuel consumption and emissions (e.g. Noland and Quddus, 2006). Emission calculations should therefore be sensitive enough to estimate the effects of several measures, such as intelligent traffic light control, dynamic speed limits, ramp metering, etc.

In order to address these requirements, road traffic emission estimations and inventories are compiled using specialised traffic

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1352-2310/$ – see front matter
doi:10.1016/j.atmosenv.2010.05.022