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PM, NO_x and CO_2 emission reductions from speed management policies in Europe

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ABSTRACT

Speed reduction measures rank among the most common schemes to improve traffic safety. Recently many urban streets or entire districts were converted into 30 kph zones and in many European countries the maximum permissible speed of trucks on motorways is under discussion. However, besides contributing to traffic safety, reducing the maximum speed is also seen as beneficial to the environment due to the associated reduced fuel consumption and lower emissions. These claims however are often unsubstantiated.

To gain greater insight into the impact of speed management policies on emissions, this paper examines the impact on different traffic types (urban versus highway traffic) with different modelling approaches (microscopic versus macroscopic). Emissions were calculated for specific types of vehicles with the microscopic VeTESS-tool using real-world driving cycles and compared with the results obtained using generalized Copert-like macroscopic methodologies. We analyzed the relative change in pollutants emitted before and after the implementation of a speed reduction measure for passenger cars on local roads (50–30 kph) and trucks on motorways (90–80 kph). Results indicate that emissions of most classic pollutants for the research undertaken do not rise or fall dramatically. For the passenger cars both methods indicate only minor changes to the emissions of NO_x and CO_2. For PM, the macroscopic approach predicts a moderate increase in emissions whereas microscopic results indicate a significant decrease. The effects of specific speed reduction schemes on PM emissions from trucks are ambiguous but lower maximums speed for trucks consistently result in lower emissions of CO_2 and lower fuel consumption. These results illustrate the scientific uncertainties that policy makers face when considering the implementation of speed management policies.

1. Introduction

Road transport provides economic and social benefits for the entire society. Unfortunately, traffic also causes a number of unwanted effects like congestion, traffic accidents and traffic related air pollution. To counter these negative impacts, local policy makers in Europe have introduced, amongst other measures, permanent or temporary speed restrictions aimed at improving traffic flows, traffic safety or both.

The conversion of entire districts, streets or street sections into 30 kph zones is usually done near schools or in residential areas where the previous speed limit was 50 kph. These measures, mainly aimed at increasing traffic safety and promoting cycling or walking, are usually seen or even promoted by local authorities as being also beneficial to the environment because of reduced emissions and lower exposure of inhabitants or other road users (Joumard, 1987; Anderson et al., 1997; Int Panis et al., 2010). The claims for these environmental benefits stem from the belief that speed reduction measures in urban areas have similar benefits as those on motorways (Keller et al., 2008; Keuken et al., 2010). However, in contrast to this popular belief, wide spread emission estimation methods using quadratic functions, such as the European Copert/MEET approach (Ntziachristos, 2009) predict that emissions may even rise dramatically and for this reason urban speed reduction policies are sometimes vigorously opposed. Copert (Computer Program to calculate emissions from road traffic) is based on average speed emission factors to estimate emissions on a macroscopic level (e.g. the national level; see examples in Beckx et al., 2009). Unfortunately, the speeds typical for urban traffic (especially congested traffic) are very close to or lower than what is usually considered to be the minimum average trip speed for which relevant estimates can still be made using this macroscopic approach. Therefore, more sophisticated methods are needed to estimate the impact of the

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introduction of low speed zones on vehicle exhaust emissions in urban areas. Using microscopic models permits for the accounting of lower average speeds which may also be associated with less variability resulting in environmental benefits (Int Panis et al., 2006; Beusen et al., 2009).

Similarly, the reduction of the maximum speed of trucks is under discussion in several European countries. Reducing the speed limit for trucks from 90 to 80 kph is seen as beneficial for traffic safety and for the environment (Dijkema et al., 2008). However, this implementation often results in criticism from (economic) stakeholders and policy makers in relation to time and economic losses, in addition to casting doubts over the assumed environmental and safety benefits. Unfortunately, scientific analysis is often unavailable or ignored in the political discussions on this theme.

In this paper, we shed some light on the environmental impacts of speed management policies by presenting the results from two different approaches: a sophisticated vehicle based microscopic emission modelling approach based on detailed second-by-second driving cycles (using the VeTESS model) and the traditional macroscopic approach based on average speeds (using a Copert-type model). The impact of speed measures on vehicle emissions is evaluated with both modelling approaches in two different settings (urban versus highway). Both types of models have some drawbacks but by combining results of two complementary models we can gain a better and more robust understanding of the potential impact of different speed management policies on exhaust emissions.

2. Methodology

In this section, we describe the modelling approaches and driving cycles that were used to examine the impact of speed reduction measures on vehicle emissions.

2.1. Description of the modelling approaches

For the microscopic emission modelling we used the VeTESS model (Vehicle Transient Emissions Simulation Software) that was developed within the European project ‘Decade’ (Pelkmans et al., 2004). It simulates fuel consumption and emissions during transient vehicle operation. VeTESS is specifically designed to calculate dynamic emissions, and thereby aiming at higher accuracy than traditional emission simulation models using steady state engine maps (Ajtay and Weilenmann, 2004). We briefly describe the approach used to obtain the dynamic microscopic emission model but refer to Pelkmans et al. (2004) for a full description.

The VeTESS simulation procedure assumes that a vehicle engine moves through a series of ‘‘quasi-steady-state’’ conditions, described by a combination of engine speed and torque, whereby the engine power and speed are calculated based on the second-by-second duty cycle of a vehicle. The emissions and fuel consumption associated with each of these combinations is then derived from the so-called emissions maps. In reality, the production of pollutants depends to a large extent on the rate of change of load. Some of the emissions are generated by the change itself, rather than as a function of a series of steady states. Considering modern engines and their emission control equipment, dynamic, or transient, effects must be definitely taken into account when assessing the emissions. Variations of engine load and engine speed require a high level of flexibility in regard to the control of the fuelling system. In the particular case of spark ignition engines with three-way catalysts, transient operation complicates the formation of a stoichiometric air–fuel mixture which negatively affects the performance of the catalyst. Other controls like exhaust gas recirculation valves (a technique that reduces NO_x emissions by recirculating a portion of the exhaust gas back into the engine) or turbochargers (a compressor driven by exhaust gases that compresses ambient air resulting in a greater amount of air entering the cylinder) and their transient behaviour can also have an important impact on emissions. The steady state engine maps in VeTESS are therefore supplemented by a parameter measuring dynamic engine performance. The parameter chosen is torque change, which is linked to a specific change in throttle position. These torque changes can occur immediately, while a speed change is merely the consequence of a torque change. Starting from a steady state condition at a certain speed and torque, the torque is suddenly changed (in a step of about 0.2 s) to a different torque at the same constant speed. The emissions and fuel consumption related to this step change are recorded as an integrated value over 15 s to compensate for the delay and response time in the emission measurements (exhaust pipe, transport of the sample gas to the analyzers and analyzer response). All measurements included in VeTESS were performed under hot conditions with a minimum mileage of 5000 km to avoid running in effects of engines and catalysts. Cold start effects are not accounted for in VeTESS.

VeTESS simulations for fuel consumption and CO_2 emissions have a high accuracy (generally within 5%) for the three control vehicle technologies when the gear shifting strategy is properly matched. The introduction of transient corrections increases the calculated fuel consumption by around 6% for the diesel vehicles, compared to 10% for the gasoline vehicle. The simulation of NO_x and PM emissions from diesel technologies generally has an accuracy of 10–20%. The introduction of transient corrections increases the calculated PM emissions for the diesel vehicles by around 15%. Transient corrections only have a minor impact on the calculated NO_x emissions for the diesel vehicles, but are more important for CO and HC emissions.

The VeTESS model has recently been used to study the effects of different policies on transport emissions (e.g. Pelkmans et al., 2005; Beevers and Carslaw, 2005; Beckx et al., 2010). A good review of microscopic emission models and a full discussion of the advantages and drawbacks of dynamic versus static modelling can be found in Ajtay and Weilenmann (2004). Work similar to the VeTESS modelling used in this paper has been carried out on vehicle specific second-by-second emissions (e.g. Chen and Yu, 2007; Silva et al., 2006).

For the macroscopic approach, the Copert/MEET methodology was adopted. This approach, mainly used to make national emission inventories (see e.g. Kelly et al., 2009), is based on average speeds and corresponding average speed emission factors to calculate vehicle emissions for groups of vehicles and for larger study areas. Because this approach is well known and easier to understand compared to the microscopic emission modelling, we will not discuss this method in detail. Copert uses functions that predominantly have a quadratic form, emission estimates therefore tend to be much higher at very low and very high speeds. We refer to Ntziachristos (2009) for a good description of the emission factors and applied modelling parameters. The model was recently updated to include all new results of the ARTEMIS and PARTICULATES projects.

2.2. Description of the driving cycles

2.2.1. Urban driving cycles for passenger cars and light duty vehicle

Urban driving cycles were recorded during on-the-road emission measurements in the town of Mol (Belgium, 32474 inhabitants) and the city of Barcelona (Spain, 4.2 million