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Road transportation emission inventories and projections – Case study of Belgium: Methodology and pitfalls

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ABSTRACT

This paper quantifies the effect of a number of input parameters on the emission levels of road transport emissions calculated by means of a bottom-up methodology. The input parameters considered cover small diesel cars, calculation of additional fuel consumption due to the use of mobile air conditioning in passenger cars and light commercial vehicles, fine-tuning of trip lengths and definition of road types for Belgium in 2010. The effect is significant for CO_2, and even more pronounced for other pollutants such as NO_x, $PM_{2.5}$, and VOCs.

1. Introduction

Nation-wide emission inventories and projections are often used to determine permitted emission levels, and to gain insight into emission levels expected in the future. In this context, transport emission models are applied to provide input. In particular, regarding road transport, emission models generally calculate fuel consumptions and emissions using bottom-up methodologies, starting from the underlying activities – as defined by the vehicle stock and kilometres travelled on the network – and detailed technical emission factors. A well-known tool for road transport emission inventories in Europe is COPERT (Ntziachristos and Samaras, 2010), which is widely used for estimating air pollutant and greenhouse gas emissions from road transport required in the annual emission inventories of European Environment Agency member countries.

COPERT calculates emissions from automobiles, light and heavy duty vehicles, including busses, mopeds and motorcycles. The emission factors are subdivided according to cylinder capacity or weight class, fuel technology, road type (urban, rural, highway) and emission control technology (e.g. euro norms). Emissions include hot emissions, cold start overemissions – emitted during the warming-up phase – and non-exhaust emissions – caused by fuel evaporation and wear of brakes and tyres (Ntziachristos and Samaras, 2010). Several input parameters are necessary in the calculations, but as these also determine the resulting emissions, possible over- or underestimates of road transport emissions can occur. Here we discusses a number of parameters influencing the uncertainty of the models' outcome.

2. Methodology

We estimate road transport emissions within E-Motion Road, a framework designed to calculate energy consumption and emission for road transport. E-Motion Road calculates bottom-up energy consumption and emissions for automobiles, light commercial vehicles, busses and coaches, heavy duty vehicles and mopeds and motorcycles. It not only focuses on drawing up inventories, but also enables projections to be made of energy consumptions and emissions. Future scenarios include alternative fuel technologies such as hybrids (both charge sustaining and plug-in hybrids) and hydrogen. E-Motion Road

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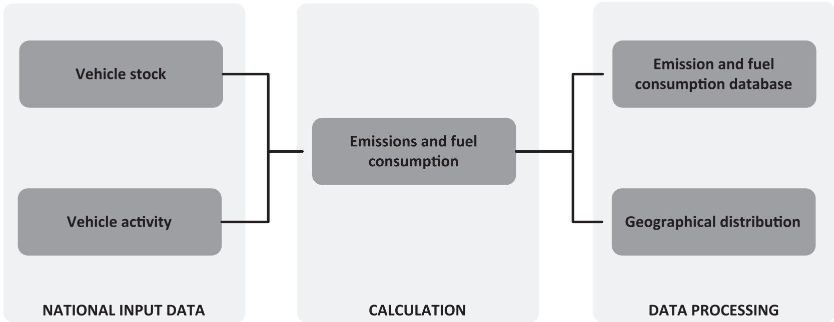

Fig. 1. The E-Motion Road framework.

includes exhaust emissions of the pollutants CO, NO_x, VOS, CH_4, N_2O, NH_3, $PM_{2.5}$, NO_2, CO_2, SO_2, Pb, Cd, Cu, Cr, Ni, Se and Zn, as well as non-exhaust emissions of the pollutants TSP (suspended particles), PM_{10}, $PM_{2.5}$, PM_1, $PM_{0.1}$, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, fluoranthene, indeno(1,2,3-cd)pyrene, Pb, Cd, Cu, Cr, Ni and Se. Here we concentrate on CO_2, NO_x and $PM_{2.5}$, the most prominent.

The bottom-up methodology deployed is outlined in Fig. 1. The national input data include the vehicle stock by vehicle type, fuel type and vehicle size broken down by cylinder capacity and age, and the vehicle activity distributed across the main road segments of the network. Here we focus on Belgium.

To estimate fuel consumptions and emissions we use the functions from the COPERT 4 methodology (Ntziachristos and Samaras, 2010). However, E-Motion Road tailored the COPERT 4 methodology to permit projections to be made, and to estimate the effect of various policy measures on future energy consumptions and emission levels. For example, E-Motion Road takes into account the use of biofuels and alternative motor fuels. Additionally, efficiency improvements of Euro VI vehicles are accounted for and also the effects of side skirts for heavy duty vehicles. COPERT 4 Furthermore, E-Motion road allows calibration of fuel consumption factors based on CO_2 monitoring values of new car registrations in Belgium. In addition, E-Motion Road enables geographically mapping of emissions based on road network information, which permits detailed air quality modelling.

We evaluate a set of pitfalls when calculating road transport emissions with a COPERT-based emission model, such as E-Motion Road. Kouridis et al. (2010) have already estimated uncertainty resulting from the input parameters used in the COPERT 4 model. They consider the bulk of model's uncertainty to be due to specifications of the hot emission factors and cold-start overemissions, the breakdown of the vehicle population into vehicle subcategories and technologies and the annual mileages, the travel speed of cars and the mean trip distance. As E-Motion Road is based on the COPERT 4 methodology, these model inputs influence results generated by E-Motion Road, and thus have to be considered carefully. The vehicle fleet data is, however, gathered from national data and assembled to provide the required level of detail, and is therefore not subject to sensitivity analyses in the present research. Consequently, the variability of the model's outcome is evaluated for hot emission factors, cold-start overemission factors, speed profiles and trip lengths.

The impact of varying input parameters on Belgian transport emissions is retrospectively assessed for 1993 to 2010, and for projections for 2015, 2020, 2025 and 2030. The analyses are based on a baseline scenario for transport as defined in BIOS-ES (Pelkmans et al., 2011). Future vehicle activity estimations are based on projections by the Flemish Traffic Centre, taking into account socio-economic prognoses, demographic forecasts and planned transport infrastructure. The activity growth figures for Flanders were extrapolated for the other Belgian regions (Van Mierlo et al., 2011). Projections of the vehicle stock are derived from the historic fleet and assumptions regarding survival rates of vehicles, and the composition of the fleet of newly bought vehicles as specified in De Vlieger et al. (2009).

3. Results

Table 1 shows that by 2030 34.7% of the diesel passenger cars in the Belgian fleet or 22.2% of the passenger cars will be small diesel vehicles (cylinder capacity below 1.4 l), a category included in E-Motion Road. In COPERT 4 however, this category is not provided by default for vehicles older than Euro 4. Based on fuel consumption monitoring of newly registered vehicles, these smaller cars consume about 22.6% less fuel, and thus emit less CO_2 than medium-sized diesel cars as defined in COPERT 4.

The effects of adding this category of car to the hot emission factors are summarized in Table 2. A decrease up to 5.80% of the CO_2 emissions of all cars and a corresponding decrease of 2.80% of all road transport related CO_2 emissions are observed. Consequently, not including this distinction in the hot emission factors for small diesel passenger cars causes a substantial overestimation of the fuel consumption and the fuel-based emissions.[1]

[1] Emission factors for small diesel cars for Euro 4 and later are included COPERT 4 as from version 10 (Katsis et al., 2012).