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Uncertainty and Sensitivity Analysis of National Road Transport Inventories Compiled with COPERT 4

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Abstract

COPERT is used by 22 out of the EU27 member states for the official submission of road transport inventories to international conventions. This study aimed at quantifying the uncertainty of road transport inventories in the case of two countries that use COPERT. The uncertainty of the emission factors was quantified by analysis of the variance in the relevant experimental information used to develop the emission factors. The uncertainty in the input data was determined by comparing information from different national and international sources. In this process, the sensitivity of the model output to its inherent parameters and the input variables was quantified. This provides useful guidance on how to reduce the uncertainty of the inventory.

Keywords: emission factors; emissions; inventory; pollutants

1. Introduction

This paper presents the results of a study funded by the Joint Research Centre / Institute for Environment and Sustainability on the calculation of the uncertainty of road transport inventories compiled with COPERT 4. The uncertainty originates from (a) the uncertainty in the model formulation and (b) the uncertainty of the input data. In emission models, the main internal parameter is the emission factor, i.e. the unit of emission per unit of activity (g/km, g/h, g/ton-km, etc.). The uncertainty in emission factors originates from the experimental data, i.e. the variance in the emission level of different vehicles and engines. The uncertainty of the input data originates from a poor knowledge of the stock characteristics and the activity pattern in a country. In fact, it is impossible to know exactly the actual operation of all vehicles in a country and the quality of the statistics of the operational vehicle stock varies from country to country. This study characterizes the uncertainty of both the internal parameters of COPERT 4 and the input data in case of two countries, with variable degree of statistics quality.

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2. Method

2.1. Model uncertainty

The estimation of the uncertainty of the internal parameters (emission factors) has been based on experimental data. For hot emission factors and fuel consumption, log-normal probability distributions were developed for fourteen different speed classes. In the absence of robust experimental data for cold start, the standard deviation over mean of the hot emission factors has been used in this case, also assuming log-normal probability functions.

2.2. Input data uncertainty

The uncertainty in the stock data has been assessed by collecting information from different national and international sources, and by building detailed models to disseminate this uncertainty down to technology level. In one of the countries the stock was rather well known. The main uncertainty originated from the allocation of some unidentified vehicles to the different classes, as well as uncertainty in the allocation of heavy duty vehicles to the different weight categories. In the other country, the uncertainty also incurred due to the unknown age distribution of vehicles. The age distribution was modeled by a Weibull function within given age distribution boundaries.

2.3. Monte Carlo simulations

The analysis has been performed in two steps. First, a screening analysis (Morris et al., 1991) identified the most influential input parameters. Then, a variance based sensitivity analysis technique (FAST) quantified the importance of the influential inputs that drive the uncertainty of the road transport emissions (Saltelli et al., 1999). In total, the uncertainty of 51 items (input variables and internal parameters) was quantified. About 500 runs were executed for the screening analysis (qualitative analysis) and 6000 runs were conducted for the FAST (quantitative analysis). FAST was executed twice, once by accepting all runs and once by rejecting those runs that gave fuel consumption beyond a certain range of the statistical one. The filtered approach was adopted because calculations that would give total fuel consumption values much different to the statistical one would in any case be rejected by the inventory compiler.

3. Results

The screening test identified that 16 and 17 items were responsible for more than 90% of the total uncertainty in the countries with good and poor statistics, respectively. Hot and cold-start emission factors were identified as influential parameters in both cases. In the country with poor statistics, user-defined variables such as the distinction of vehicles to different types and technologies, the mileage function with age, the mean trip distance, etc. were responsible for most of the uncertainty of the total calculation. In principle, in the country with good statistics most of the uncertainty originates from the model and there is little that an inventory compiler can do to reduce this uncertainty. However, in the country with poor statistics, improving the stock and activity description is required to reduce total uncertainty. The actual uncertainty of the calculation depended on the pollutant considered and the country. For the calculations filtered for fuel consumption, the coefficient of variation was below 10% for the fuel consumption and CO_2 calculation in both countries, and NOx and PM emissions for the country with good statistics. It was between 10% and 20% for VOC, CO, and NOx and PM for the country with poor statistics, and above 20% for CH_4 and N_2O. The total uncertainty of greenhouse gases was dominated by CO_2.

4. References

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