Quantification of the effect of both technical and non-technical measures from road transport on Spain's emissions projections

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Abstract

Atmospheric emissions from road transport have increased all around the world since 1990 more rapidly than from other pollution sources. Moreover, they contribute to more than 25% of total emissions in the majority of European Countries. This situation confirms the importance of road transport when complying with emission ceilings (e.g. Kyoto Protocol and National Emissions Ceilings Directive).

A methodology has been developed to evaluate the effect of transport measures on atmospheric emissions (EmiTRANS). Its application to Spain in the horizon of 2020 allows the quantification of the effect of several measures on emission reductions.

This quantification was done through scenario development. Several scenarios were calculated considering technical measures (e.g. vehicle scrapping systems, higher penetration of hybrid and electric vehicles, fuel substitution, etc.) and non-technical measures (mileage reduction, implementation of Low Emission Zones and/or Congestion Charges in main cities, reduction of average speeds, logistical improvements that affect heavy duty vehicle load factors, etc.). The scenarios show the effect of each measure on NO_x, SO_2, CO, PM_{10}, $PM_{2.5}$, VOC, CO_2 and CH_4 emissions. The main conclusion is the necessity to combine both technical and non-technical measures to increase global effectiveness. In the analysis of specific pollutants, there is a great dispersion on reduction effects: technical measures are more effective to reduce air pollutants while non-technical measures are better options to reduce greenhouse effect gases (even though they also reduce air pollutants in a less efficient way).
Keywords: emissions, road transport, air quality, green house gases, methodology, policies and measures.

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1 Introduction

In recent years the growing traffic demand combined with an increase in exhaust gas emissions is the main reason for permanent deterioration of air quality in urban areas (Lim *et al* [1], Colvile *et al* [2]). In order to reduce emissions, we need to gain precise information about the emission behaviour of motor vehicles. Vehicle exhaust emissions have been the cause of much concern regarding the effects of urban air pollution on human health (Curtis *et al* [3]) and green house gas (GHG) emissions.

The International Energy Agency's (IEA's) World Energy Outlook Reference Case projects that between 2000 and 2030, transport energy use and CO_2 emissions in OECD countries will increase by 50%, despite recent and ongoing policy initiatives intended to dampen this growth.

As an example, CO_2 emissions from road transport in Spain have increased in an 80% during the period 1990-2005 (fig.1). This percentage is higher than the increase in the number of vehicles in the same period. SO_2 emissions show a sharp decline due to reduction in sulphur content of fuels. Nevertheless, N_2O emissions suffered a strong increase but the amount, in terms of CO_2 equivalent, is significantly lower than CO_2 emissions from road transport. CO and VOC experimented a significant reduction, about 55%. NOx emissions were stabilized while $PM_{2.5}$ have only increased a 25%.

In order to facilitate the analysis of this situation, environmental protection authorities are interested in performing emission and air pollution simulation as well as scenario analysis by means of model based simulation systems (Winiwarter *et al* [4]). Traffic flow models provide a promising approach (Schmidt and Schäfer [5], Xia and Shao [6]), including calculations of air pollutant emissions from all transport sectors (Symeomidis *et al* [7]).

This paper presents a methodology to estimate atmospheric emissions from road transport including the development of a tailored software tool. Pollutants considered are those related to current air quality problems in urban areas (SO_2, NMVOC, NO_X and PM) while N_2O and CO_2 as GHG.

2 Methodology

In the present work, we start analysing the factors that have a relevant influence on emissions from road transport. The main parameters that contribute to emissions from road vehicles have been selected from the methodology developed [8], most of which are included in the EMEP/CORINAIR methodology [9].

Then, we have developed a software tool called EmiTRANS, which allows the inclusion of technical and non-technical measures leaded to quantity their influence in emissions reduction.

The purpose of this tool is to obtain emissions from developed scenarios through Copert4 software (Gkatzoflias *et al* [10]) and other outputs that are useful to get conclusions.

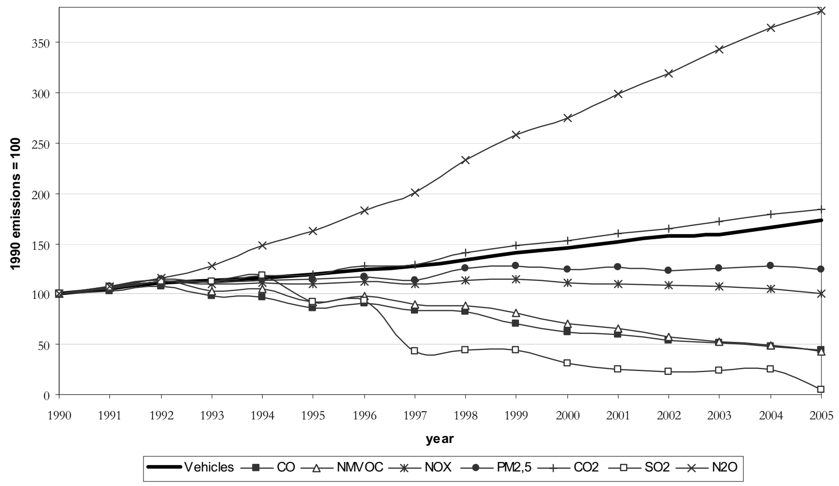

Figure 1: Historic trend of Spanish road transport emissions vs. number of vehicles.

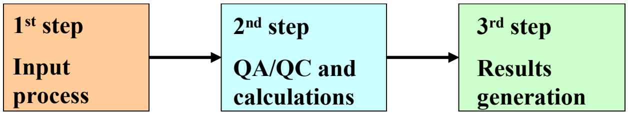

Figure 2: Blocks for running EmiTRANS.

We have also applied EmiTRANS to the case of Spain. This application consists of three blocks, as indicated in fig. 2.

- The first block includes input data. These are divided into six different sectors: passenger cars, light duty vehicles, buses, heavy duty vehicles, mopeds and motorcycles.
- In the second block, implicit variables (those that are not directly used by Copert4, e.g. mileage in units of passenger-km, occupancy rate, load factor, etc.) are transformed into explicit variables (e.g. mileage in veh-km). Afterwards, Quality Assurance/Quality Control (QA/QC) procedures are used (e.g. check that the sum of % is equal to 100, contrast if parameters are in previously assigned range, etc.). Eventually, developed algorithms are applied to obtain outputs.
- In the third block, results are generated according to Copert4 requirements. These outputs are, for instance, number of vehicles for each year by sector, subsector and technology; average speed by type of vehicle; fuel consumption by subsector, etc.

3 Sensitivity analysis

The method has been applied to Spain, carrying out a sensitivity analysis of the factors and using the EmiTRANS tool to develop different scenarios for Spanish road transport emission up to 2020. In order to compare the variation results of the different factors, emissions have been calculated for the road transport sector, no matter the scope of the factor modified (type of vehicle, driving modes, etc.).

The sensitivity analysis has been done according to the changes included in table 1 to identify the influence of several factors in atmospheric emissions.

Table 1: Selection of factors that influence the emissions.

Factor	Sensitivity analyses
Fuel distribution for vehicles	Reference: 46.6% petrol, 53,4% diesel
	30% petrol, 70% diesel
	40% petrol, 60% diesel
	60% petrol, 40% diesel
	70% petrol, 30% diesel
Urban average speed	Reference: 25 km/h
	20 km/h
	22.5 km/h
	27.5 km/h
	30 km/h
Highway average speed	Reference: 105 km/h
	84 km/h
	94.5 km/h
	115.5 km/h
	126 km/h
% of large vehicles	Reference: vehicles with engine cylinder>2 l are 6.2% for petrol and 14.2% for diesel
	Number of large vehicles are tripled
	Number of large vehicles are doubled
	Number of large vehicles are divided by 2
	There are no large vehicles
Number of old passenger cars	Reference: 5,375 M vehicles (26.5%)
	20% substitution by Euro 5 vehicles
	40% substitution by Euro 5 vehicles
	60% substitution by Euro 5 vehicles
	80% substitution by Euro 5 vehicles

Fig. 3 shows the influence on road transport emissions due to slight variations on urban speed for passenger cars. Every pollutant increases when speed is reduced and vice versa. The variation on CO and NMVOC is higher due to inefficient combustion process mainly in spark engines (volumetric efficient has a high influence in urban driving). CO_2 emissions decreased when incrementing the speed due to open throttle condition.

Fig. 4 shows the influence on road transport emissions due to slight variations on highway speed for passenger cars. At the range of reference speed (105 km/h), positive variations increase emissions. For instance, CO_2 emissions experiment a 5% raise when average speed is incremented in a 20%. These results are the consequence of the increasing rolling and drag resistance with the speed. Concerning CO emissions, the enrichment of the mixture at higher speeds causes its large augmentation.

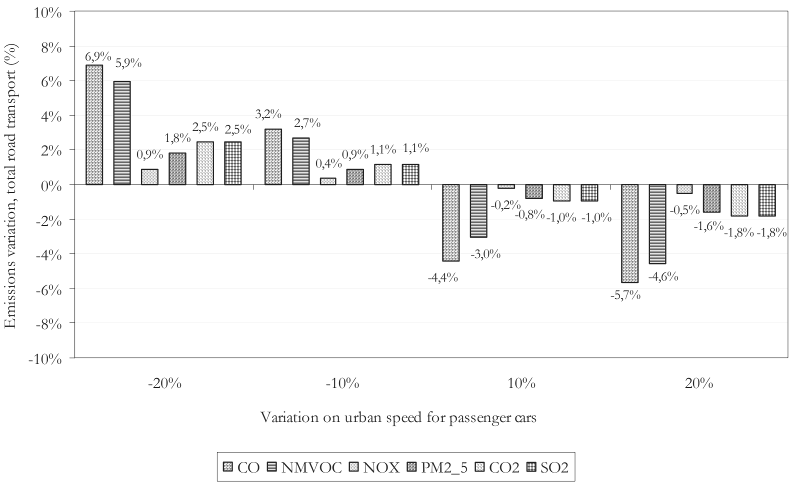

Figure 3: Sensitivity analysis to changes in urban speed. Ref. speed: 25 km/h.

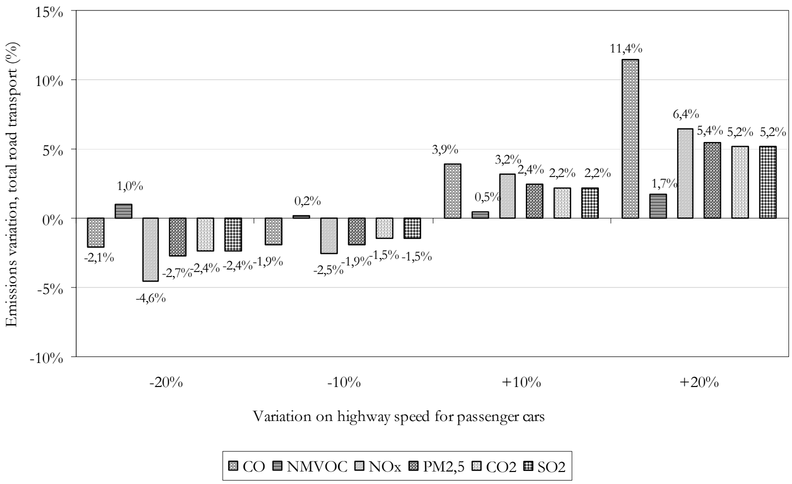

Figure 4: Sensitivity analysis to changes in highway speed. Ref. speed: 105 km/h.

Fig. 5 shows the influence of the load in heavy-duty vehicles on road transport emissions. In this case, mileage per vehicle has been assumed constant for all scenarios; therefore, the amount of tonnes-km of each scenario is different. Considering these hypothesis, NOx and $PM_{2.5}$ emissions increase with the load due to higher torque and fuel injection. CO_2 emissions show a growth of 0.6% when the load achieved 85%. CO and NMVOC are not relevant in diesel engines.

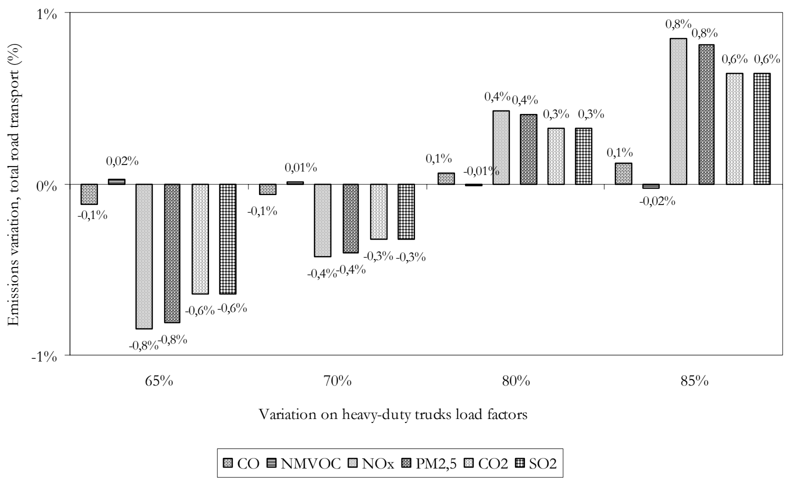

Figure 5: Sensitivity analysis to changes in heavy-duty vehicles load (constant mileage). Ref. load range: 75%.

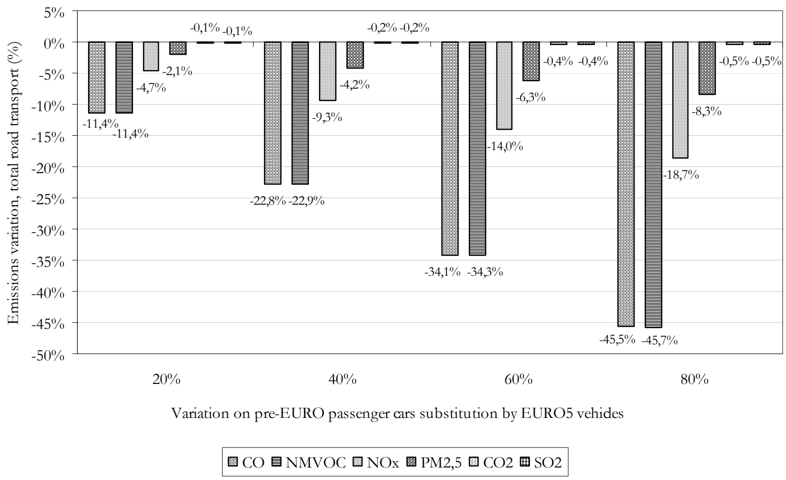

Figure 6: Sensitivity analysis to old vehicles substitution by Euro 5. Ref. case: 26% pre-Euro of passenger car park.

Fig. 6 shows that exhaust technologies have a decisive effect on reduction of every type of road transport pollutant. The high efficiency of three way catalysers decline CO, NMVOC and NOx emissions up to 95% in spark engines. Nevertheless, $PM_{2.5}$ emissions are more difficult to reduce in diesel engines. CO_2 emissions remain almost constant when replacing old vehicles because emission standards did include neither CO_2 limits nor efficiency improvements.

Fig. 7 evidences the proportionality of road transport pollutant emission to mobility variations. Higher mobility of diesel cars is more important to increase NOx and $PM_{2.5}$ in the sector. CO_2 emissions experiment an increment of 6.8% when increasing the mobility a 20%.

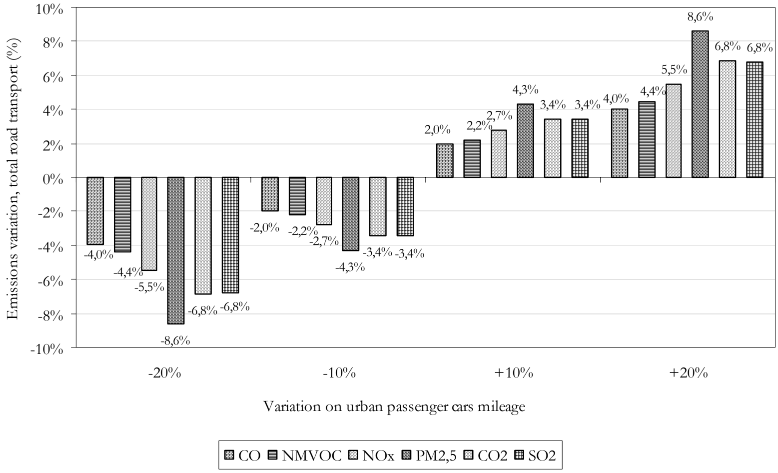

Figure 7: Sensitivity analysis for changes in mobility for passenger cars in urban areas. Baseline: 1070 km/year for gasoline cars and 7954 km/year for diesel cars.

4 Emission scenarios results

Regarding emission projections, the main assumptions for each of the five scenarios are shown in table 2. These assumptions were used to calculate emission projections using EmiTRANS model and Copert4 software as presented in section 2.

Business as Usual (BAU) scenario was defined under the hypothesis of high passenger and freight mobility, non-presence of biofuels and new technologies. The rest scenarios present several improvements related to mobility, penetration of new technologies or biofuel use.

Baseline scenario presents a moderated increment of mobility and includes the effect of Policies and Measures planned by the Spanish Administration. Besides, includes more environmental friendly technologies such as hybrid vehicles, electric vehicles and hydrogen or natural gas vehicles.

Biofuels, New Technologies and Mobility scenarios present improvements in their different fields compare to Baseline scenario.

Fig. 8 displays the results for CO_2 emissions. The largest emissions correspond to the BAU scenario. It does not include any technological measure and the passenger and freight mobility evolve as they did in the past (from 1990-2005). The lowest emissions scenario is the “lower mobility”. This remarks that

Table 2: Selection of factors that influence the emissions.

Scenario	Mobility	Technology in 2020	Power	Biofuels
Business as usual	+4% PC +6% HDV	Same as baseline	Same as baseline	Same as baseline
Baseline	+3.6-0.5% PC +5.1-0.2% HDV	1.4% Electric/H_2 3.2% Hybrid 16% NG urban buses	Petrol: 41%<1,4l; 52% $\in$ (1,4l-2l); 7%>2l Diesel: 86%<2l; 14% >2l	2010: 5.83% 2012: 8% 2016-2020: 10%
Technological	Same as baseline	10% Electric/H_2 20% Hybrid 50% NG urb. buses	Same as baseline	Same as baseline
Lower mobility	No mobility increase	Same as baseline	Same as baseline	Same as baseline
Biofuel promotion	Same as baseline	Same as baseline	Same as baseline	2010: 6.88% 2012: 9.5% 2020: 20%

PC: Passenger cars. HDV: Heavy duty vehicles.

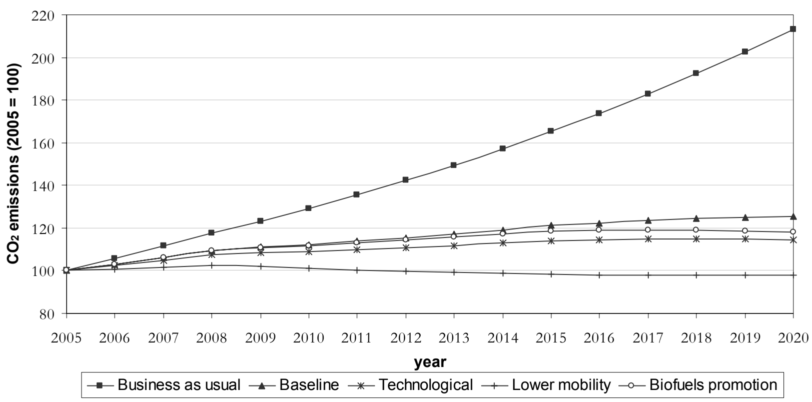

Figure 8: CO_2 emission projections for road transport in Spain.

the most effective measure to reduce CO_2 emissions is mobility cutback. The other scenarios project similar emissions: baseline has higher emissions but not far away from the promotion of biofuels and higher technology penetration. That is, in 2020 emissions under baseline scenario are 25% higher than in 2005 while “technological” and “Biofuel promotion” scenarios only increase a 14 and 18%, respectively.

Emission projections for NOx and $PM_{2.5}$ are shown in figs. 9 and 10. Every measure included in the Baseline scenario related to mobility, new technologies and biofuels yield relevant emission reductions respect to BAU scenario. In 2020, these reductions would be of 54.5% and 41.2% for NOx and $PM_{2.5}$, respectively. The most advantageous scenarios for emission decline, under the assumed hypotheses, are the “lower mobility” followed by “new technologies”.

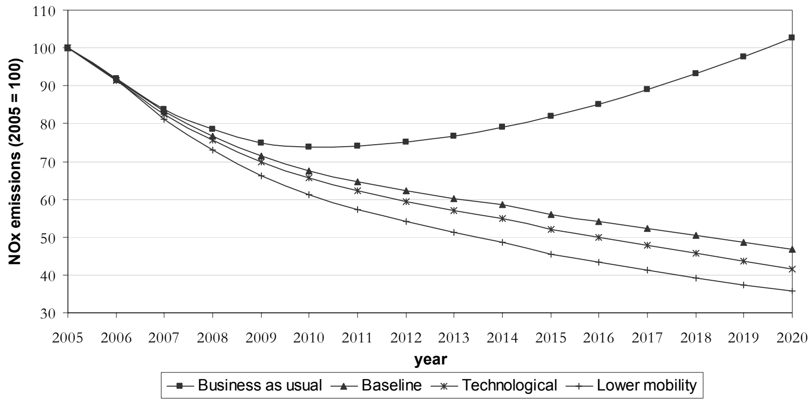

Figure 9: NOx emission projections for road transport in Spain.

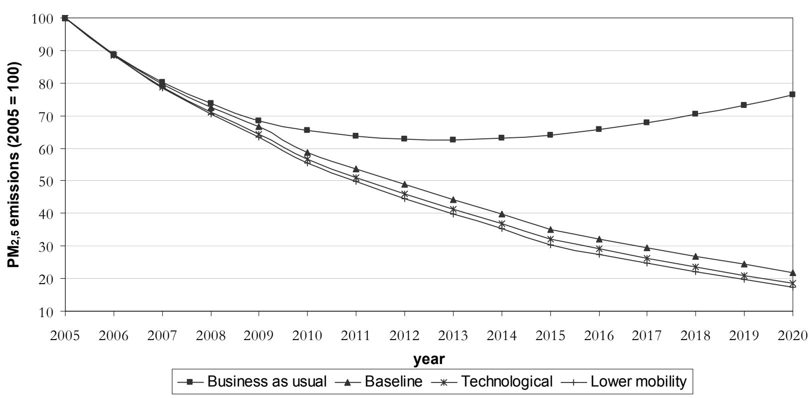

Figure 10: $PM_{2.5}$ emission projections for road transport in Spain.

5 Conclusions

We have developed a model, called EmiTRANS, which is able to estimate the influence of several factors on atmospheric emissions from road transport in a flexible and coherent way. It contributes to incorporate scientific data on decision making process. This methodology has successfully been applied to the case of Spain. It shows the importance of some variables in road transport emissions. According to the sensitivity analyses done, the selected variables (technical and non-technical measures) show clear trends on emissions pollutant. Furthermore, the model is a valuable tool for environmental planning and for the delineation of rational strategy towards the reduction of the atmospheric pollution levels.

This methodology also allows the development of different emission scenarios for future years. The application to Spain for the period 2006-2020 shows that the most effective measures to abate CO_2 emissions are those aimed to reduce passenger and freight mobility while vehicle scrapping systems are also effective to reduce air pollution.

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