

CAN WE ESTIMATE PM-EMISSION REDUCTIONS FROM SPEED MANAGEMENT POLICIES ?

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ABSTRACT

Speed reduction measures are commonly introduced to increase traffic safety. Recently many urban streets or entire districts were converted into 30 km/h zones and in many European countries the maximum speed of lorries is under discussion. Reducing the maximum speed is seen as beneficial to the environment because of reduced fuel consumption and lower emissions. These claims however are often unsubstantiated. We calculated emissions for specific vehicles with a microscopic model using real-life driving cycles and compared the results with those from MEET. Although emissions of most classic pollutants should not be expected to rise or fall dramatically, the conclusion for PM could be different. The effects of speed reduction schemes on PM emissions from trucks on highways are ambiguous, but detailed modelling results indicate that the PM exhaust from diesel passenger cars may show a significant decrease in urban areas converted to 30 km/h zones.

1. INTRODUCTION

In June 2005 the Flemish transport Minister proposed to lower maximum speed for trucks on highways from 90 to 80 km/h. This resulted in a wave of critique from stakeholders. Reference was made to time and economic losses and doubts were cast over the assumed environmental and safety benefits. Unfortunately scientific analysis was either ignored or unavailable in the discussion. Similarly, low speed zones (30 km/h) around schools and residential areas, intended to increase traffic safety, are vigorously opposed by people claiming that this will exponentially increase exhaust emissions.

2. METHODOLOGY

To shed some light on the problem we calculated emissions with the microscopic VeTESS-tool using real-life driving cycles and compared the results with those obtained using MEET-like methodologies. VeTESS was developed within the European project Decade as a vehicle level tool for the simulation of fuel consumption and emissions for real traffic transient vehicle operation. It is specifically designed to calculate dynamic emissions, and thereby reaching higher accuracy than traditional emission simulation models including those using steady state engine maps. The calculations in this vehicle simulation tool are based on a detailed calculation of the engine power required to drive a given vehicle over any particular route. This includes the rapidly changing (transient) demands placed on the engine. We used this model to calculate emissions and fuel consumption on a second-by-second basis for specific vehicles on a given speed profile. Urban driving cycles were recorded during on-the-road emission measurements in the cities of Mol (Belgium) and Barcelona (Spain), using three different vehicles: VW Polo (Euro 4, petrol), Skoda Octavia (Euro 3, diesel) and a Citroen Jumper (Euro 3, diesel) light commercial vehicle. We believe these vehicles are representative for an important fraction of current car sales in Belgium. We refer to Pelkmans et al. (2004) for a detailed technical description of the VeTESS-model, the vehicles and set-up of the test cycles.

From each of the 6 different urban driving cycles we derived a modified version in which the top speed was limited to 30 km/h without changing the acceleration or deceleration. The length of time driven at the new top speed was elongated where appropriate to preserve the original cycle distance. The effect on the average speed however is limited. For trucks the VeTESS model was run with a compilation of speed profiles measured on Flemish highways in normal traffic. The maximum speed is legally limited to 90 km/h and the average real speed is approximately 86 km/h. Small variations that occur between 85 and 90 km/h can be attributed to the presence of other vehicles. The measured speed profiles were converted to lower speeds to reflect a change in the legal speed limit. The speed variation was left unchanged whereas the average speed was decreased to 77 km/h.

3. RESULTS AND DISCUSSION

The emissions of each of the three light vehicles were modelled with each of the 6 available urban driving cycles, resulting in 18 emission estimates for a reduction of the top speed from 50 km/h to 30 km/h. Overall results are summarized in Figure 1. Positive values indicate that emissions go up when the new speed limit is implemented. Negative values indicate that pollutant emissions decrease. Results for CO and HC differ widely between

vehicles and cycles. Because emissions of these pollutants are very low in modern cars, we believe that they are not modelled with sufficient accuracy to lend credibility to the relative changes shown in the graph. (Even a 100% increase represents only a tiny amount of pollutants emitted, close to the smallest amount that can be measured; Pelkmans, pers. comm., 2005.) For the emissions of CO₂ and hence fuel consumption it was found that the change to the driving cycle only had a limited impact, either positive or negative, on the emission. Emissions decreased for both cars, but increased for the LGV. For the emissions of NO_x the LGV mostly showed a small increase whereas the results for the cars indicate moderate to important decreases of the emission. Both diesel vehicles (Octavia and Jumper) showed a moderate or large decrease in the modelled emissions of PM in each of the cycles. No PM emissions can be modelled with VeTESS for petrol fuelled vehicles (i.e the VW Polo).

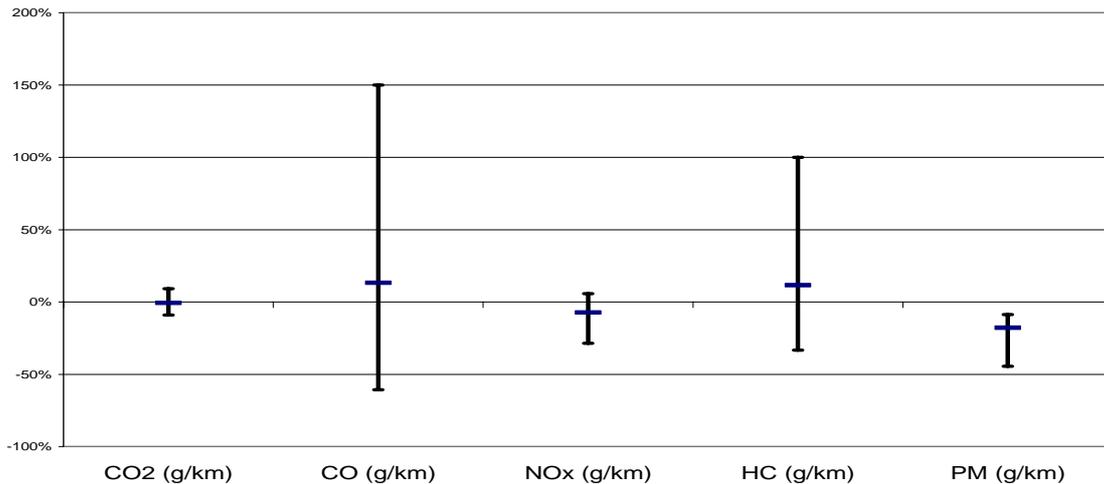


Figure 1 Estimated relative change in emission for 5 pollutants. Average and range for 18 estimates.

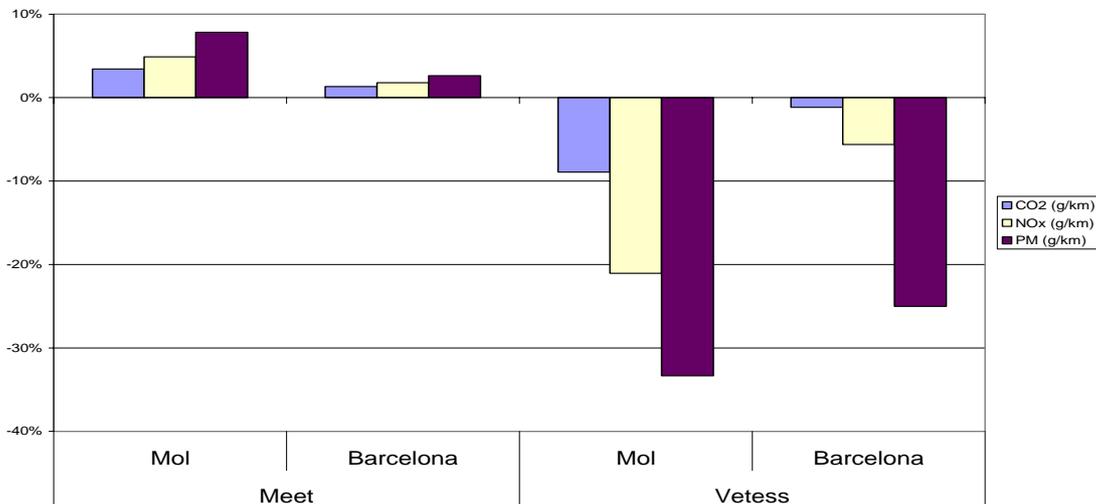


Figure 2 Relative change between two normal urban drive cycles (up to 50km/h) and drive cycles limited at 30 km/h (Skoda Octavia; Cycle 4: 25.2->22.7 km/h in Mol, Cycle 1: 14.8->13.9 km/h in Barcelona)

In Figure 2 we present the detailed results for the Skoda Octavia for one representative cycle in each city. The emissions estimates were made with the relevant MEET functions based on average trip speed and with VeTESS on the full speed profile respectively. Results for most other vehicle/cycle combinations yield similar results. Not surprisingly, the MEET methodology results in a slightly higher estimate for the emissions. The small difference can be attributed to the fact that although the derived driving cycle may seem very different the resulting change

in average speed is quite limited. The results from the VeTESS model runs are less straightforward to interpret or explain because a large number of factors contribute and interact. Nevertheless it is clear that emissions of CO₂, NO_x and PM decrease in each situation for this specific vehicle. This is the combined result of lower top speeds, longer driving periods at 30 km/h and extended driving to reach the end of the cycle. Emissions of CO₂ are marginally smaller and NO_x emission factors are also lower. The largest reduction however is found for emissions of PM which decrease in most cases by approximately one third. The result of detailed emission modelling for the delivery van agrees well with the simpler MEET calculation for CO₂ emissions. Both fuel consumption and CO₂ emissions are projected to increase slightly (~3-5%). Results for NO_x emissions are mixed because the small increase evident from the MEET functions is not reproduced by VeTESS which indicates insignificant changes. For the PM emissions, this vehicle would show an important decrease (although smaller than for the passenger cars) under the speed-limited driving cycle.

Table 1. Relative emissions for different trucks (VeTESS results)

90 km h ⁻¹ → 80 km h ⁻¹	CO ₂	NO _x	PM
IVECO Eurocargo 7500 kg	84%	71%	84%
IVECO Eurocargo 12,000 kg	86%	72%	100%
MAN 30,000 kg	91%	89%	103%
Scania 30,000 kg	90%	85%	n.a.

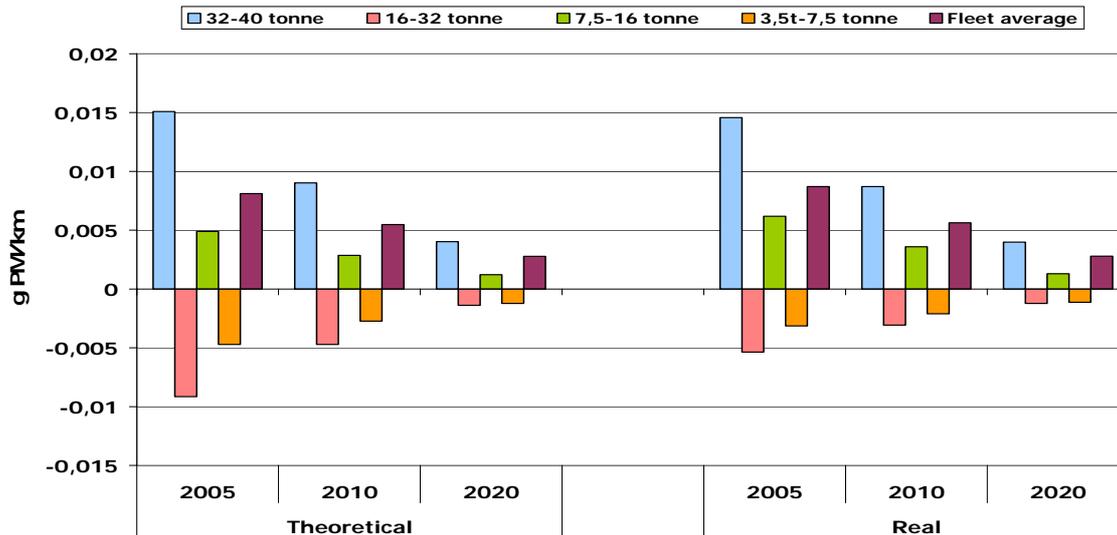


Figure 3. Absolute difference in the PM fleet emission factors for the 3.5-32 tonne trucks, 90 km/h compared to 80 km/h (Theoretical) and 86km/h to 77 km/h (Real) (VITO TEMAT model, 2006)

Summarizing the results for trucks we can say that the total CO₂ emission would decrease by approximately 10 %, a trend that is consistent for all weight classes and years (Table 1). Results from the Belgian MEET-based TEMAT model confirm the results for CO₂ which makes the results more credible. In absolute numbers the CO₂ emission factors would on average drop by approximately 100 g/km if the policy resulted in a decrease from 90 to 80 km/h. Using more realistic estimates of the impact of the policy on real traffic speeds yields a reduction of only 50 to 70 g/km. Emission factors of NO_x show a decrease for all types of trucks available in VeTESS (Table 1). In sharp contrast the Belgian MEET-based TEMAT model simulates an increased emission for the heaviest trucks (32-40 tonnes, +0.2 – 0.5 g km⁻¹) even resulting an increased fleet averaged emission factor. The results for PM are even more confusing (Figure 3). PM emission factors decrease for the 3.5-7.5 and 16-32 tonnes weight classes and increase for the 7.5-16 and 32-40 tonnes weight classes. All changes (increases and decreases) become smaller in the future. Because of the dominance of the largest trucks the fleet average emission factor also increases. A high R² was reported in MEET for this emission function, indicating it was based on a small sample. The lack of consistency between the effects for the different classes indicates a large uncertainty.

The results presented here demonstrate that estimating emissions from vehicles is a complex endeavour. Estimating the impact of policies on emissions is even more difficult (Int Panis et al, 2005). In the case of a severe decrease of the urban speed limit, neither the naïve assumption that emissions will decrease nor the straightforward (but methodologically unjustified) application of the MEET methodology seem to be correct. The use of the detailed microscopic emission model has the obvious disadvantage that the necessary engine and vehicle data is only available for a limited number of vehicles. Nevertheless the detailed analysis of the behaviour of these vehicles emissions' is relevant for two reasons. First the available data used for this study are from quite popular vehicles that represent analogous models from other brands as well as other cars with similar engines. Secondly the engines and after treatment technology of these modern cars is a fair proxy to what may become the average fleet in the near future. This being said, there are some important aspects which we have not taken into account. We have not made any changes to the acceleration and deceleration behaviour in the selected driving cycles. This is an implicit assumption that needs to be validated. Unfortunately we cannot take this into account in this study because detailed (i.e. measured) data are currently lacking. A large scale monitoring programme will start later in 2007 (Broekx, pers. comm., 2006). Theoretically this problem can be circumvented by using microscopic traffic simulation models that generate instantaneous speed estimates (and hence also acceleration) for individual vehicles. Unfortunately detailed as the models may seem at first glance the acceleration estimates are largely based on very rough estimates that have never been validated (Joumard, pers. comm., 2005, Int Panis et.al, 2006, Beckx et al, 2006).

Considering highway speed reduction for trucks, we find that emissions of CO₂ decrease but emissions of NO_x and PM could increase, which is consistent with the results from other studies. The choice of gear features among the most prominent changes to the driving pattern and is likely to be influenced by changes to the speed limit. Although this may be more important in urban locations than on highways. The VeTESS model was therefore used to study the effect of different gear shifting strategies in connection with different speed limits. Our conclusions were confirmed for any gear shifting strategy for any speed reduction down to 80 km/h. These results were presented to and discussed with both individual manufacturers and the ACEA expert group. It is clear that they design and build long distance haulage trucks to minimize fuel consumption at the most prevailing speed limits in Europe (80 km/h on highways). The optimum is between 80 and 85 km/h which confirms our findings.

4. CONCLUSIONS

It is unlikely that strict speed limits in urban areas have a significant influence on emissions of NO_x or CO₂. Concerning the impact on emissions of PM VeTESS results indicate that the exhaust from the diesel vehicles may show a significant decrease, whereas MEET functions assume a moderate increase. The effect on emissions of PM should be confirmed by further research, also focusing on the impact of acceleration or gear shifting behaviour. All results for trucks consistently indicate that lower maximum speeds for trucks on motorways result in lower emissions of CO₂. Results for NO_x and PM are not consistent. Estimating impacts of speed management policies on emissions will remain very complex even when second order effects are ignored.

5. ACKNOWLEDGEMENTS

The authors wish to thank Luc Pelkmans for making the VeTESS model and driving cycles available.

6. REFERENCES

- Beckx, C., Int Panis, L., De Vlioger, I. and Wets, G. 2006. Influence of gear changing behaviour on fuel-use and vehicular exhaust emissions. In: Proceedings of the 8th International Symposium on Highways and the Urban Environment. Rauch S. & Morrisson G. (eds.), Chalmers University. (in press)
- Int Panis, L., Cosemans, G., Torfs, R., Liekens, I., De Nocker, L., Broekx, S. and Beckx, C., 2005. Mobelee: effect of a local traffic plan on exposure to local air pollution. VKM-THD Mitteilungen, Heft/Volume 85/II, pp.13-21.
- Int Panis, L., Broekx, S., Liu, R. 2006. Modelling instantaneous traffic emission and the influence of traffic speed limits. Science of the Total Environment 371(1-3), 270-285
- Int Panis, L., De Vlioger, I., Pelkmans, L., Schrooten, L. 2006. Effect of speed reduction on fuel consumption and emissions of heavy duty lorries in Belgium. In: Proceedings of the 8th International Symposium on Highways and the Urban Environment. Rauch S. & Morrisson G. (eds.), Chalmers University. (in press)
- Pelkmans, L., Debal, P., Hood, T., Hauser, G., Delgado, M. R. 2004. Development of a simulation tool to calculate fuel consumption and emissions of vehicles operating in dynamic conditions. SAE 2004 Spring Fuels & Lubricants, 2004-01(1873), SAE Int., Warrendale, PA, (USA).