

# **IMPACT OF 30 KM/H ZONE INTRODUCTION ON VEHICLE EXHAUST EMISSIONS IN URBAN AREAS**

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## **Abstract**

One of the most common traffic management schemes used in Belgium today is the conversion of entire districts, streets or street sections into 30 km/h zones. This is usually done in residential areas where the previous speed limit was 50 km/h. These measures, aimed at increasing traffic safety, are usually seen or even promoted as beneficial to the environment because of reduced fuel consumption and emissions. These claims however are unsubstantiated and stem from the belief that speed reduction measures in urban areas have similar benefits as those on highways. In contrast to this popular belief, wide spread emission estimation methods using quadratic functions such as the Copert/MEET approach would lead us to believe that emissions may rise dramatically. To shed some light on the problem we have calculated emissions for specific types of modern cars with the VeTESS-tool using real-life urban driving cycles. A comparison was then made with artificially modified driving cycles limiting the top speed to 30 km/h where appropriate and elongating the cycle to preserve the original cycle distance.

Results indicate that emissions of most classic pollutants should not be expected to rise or fall dramatically. Nevertheless VeTESS results indicate that some emissions such as PM exhaust from diesels may show a significant decrease, whereas MEET functions assume a moderate increase. Exposure of residents to one of the most toxic components of the urban air pollution mixture may therefore also decrease.

## **1 INTRODUCTION**

Since September 1st 2005 zone 30 stretches are mandatory near all Belgian schools, with some exceptions made for schools on the busiest regional roads. The conversion of entire districts, streets or street sections into 30 km/h zones is usually done in residential areas where the previous speed limit was 50 km/h (e.g. city of Ghent; Int Panis et al, 2005). These measures, mainly aimed at increasing traffic safety, are usually seen or even promoted by local authorities as beneficial to the environment because of reduced fuel consumption and emissions. The claims for these environmental benefits stem from the belief that speed reduction measures in urban areas have similar benefits as those on highways (Int Panis et al., 2006). However, in contrast to this popular belief, wide spread emission estimation methods using quadratic functions such as the

Copert/MEET approach would lead us to believe that emissions may even rise dramatically. Unfortunately the speeds typical for urban traffic (esp. 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 the Copert/MEET approach. Therefore more sophisticated methods are needed to estimate the impact of the introduction of zone 30 stretches on vehicle exhaust emissions in urban areas.

## **2 METHODS**

### **2.1 Description of the VeTESS model**

VeTESS (Vehicle Transient Emissions Simulation Software) 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 (Pelkmans et al, 2004). 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. We used this model to calculate emissions and fuel consumption on a second-by-second basis for specific vehicles on a given speed profile. 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.

### **2.2 Description of the driving cycles**

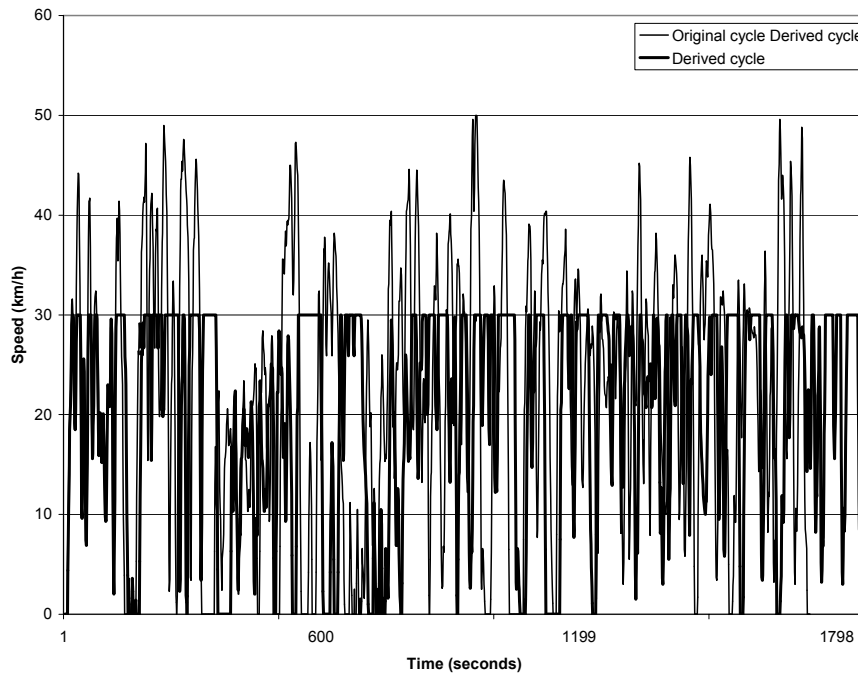
Driving cycles were recorded during on-the-road emission measurements in the cities of Mol (32 474 inhabitants, Belgium) and Barcelona (4.2 million inhabitants, Spain), using three different vehicles: VW Polo (Euro 4, petrol), Skoda Octavia (Euro 3, diesel) and a Citroen Jumper (Euro 3, diesel) light 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 vehicles and set-up of the test cycles.

From each of the 6 different 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. Figure 1 shows an example comparison between one of the original driving cycles and the derived cycle.

Table 1 shows a summary of statistics describing the cycles and the modifications that were made. It is clear from the average speeds and the number of stops that these cycles represent urban trips in heavy traffic.

**Table 1 Summarized descriptive statistics for the urban driving cycles used in this study (Cycles 1-3: Barcelona, Cycles 4-6: Mol). Data for modified cycles in last two columns.**

Cycle N°	Length		Stops	Max a	Max -a	Avg v	Additional length	New avg v
	(s)	(km)						
1	1615	6.6	22	7.8	10.2	14.8	107	13.9
2	1765	7.1	27	7.8	10.5	14.5	72	13.9
3	1475	7.3	22	9.4	15.4	17.8	173	15.9
4	1497	10.5	16	8.3	11.3	25.2	163	22.7
5	2003	10.5	22	6.7	8.8	18.9	68	18.3
6	1735	10.5	22	9	11.3	21.8	125	20.3

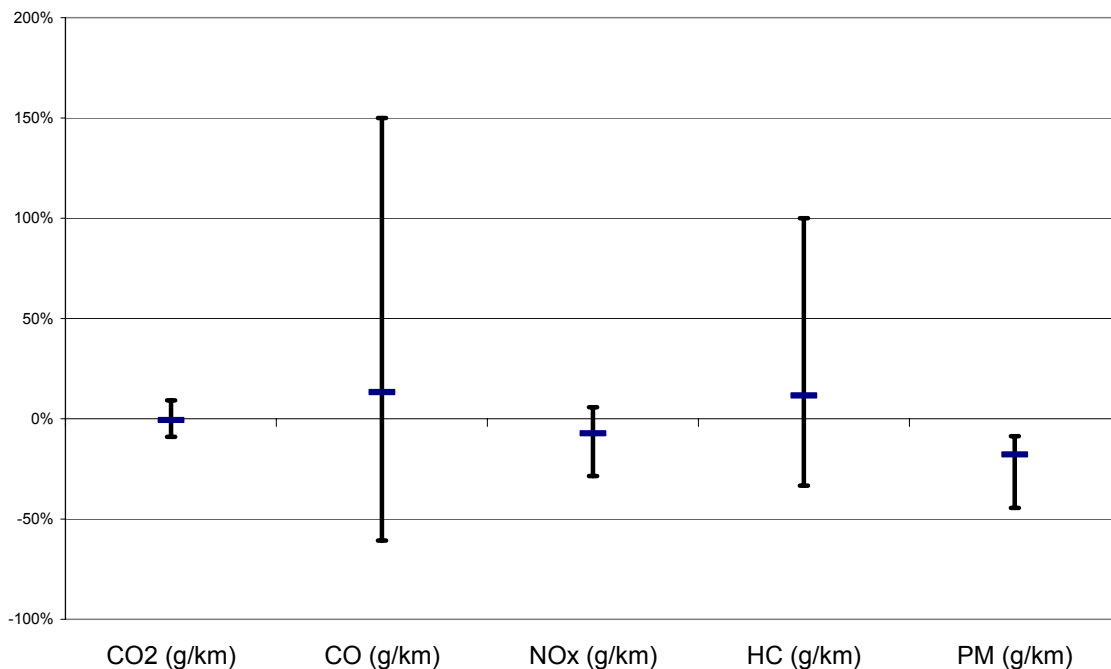


**Figure 1: Example showing the conversion of cycle 6 to a cycle with limited top speed**

### 3 RESULTS

The emissions of each of the three vehicles were modeled 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 2. 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 modeled 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 CO<sub>2</sub> 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<sub>x</sub> 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 modeled emissions of PM in each of the cycles. No PM emissions can be modeled with VeTESS for petrol fueled vehicles (i.e the VW Polo).

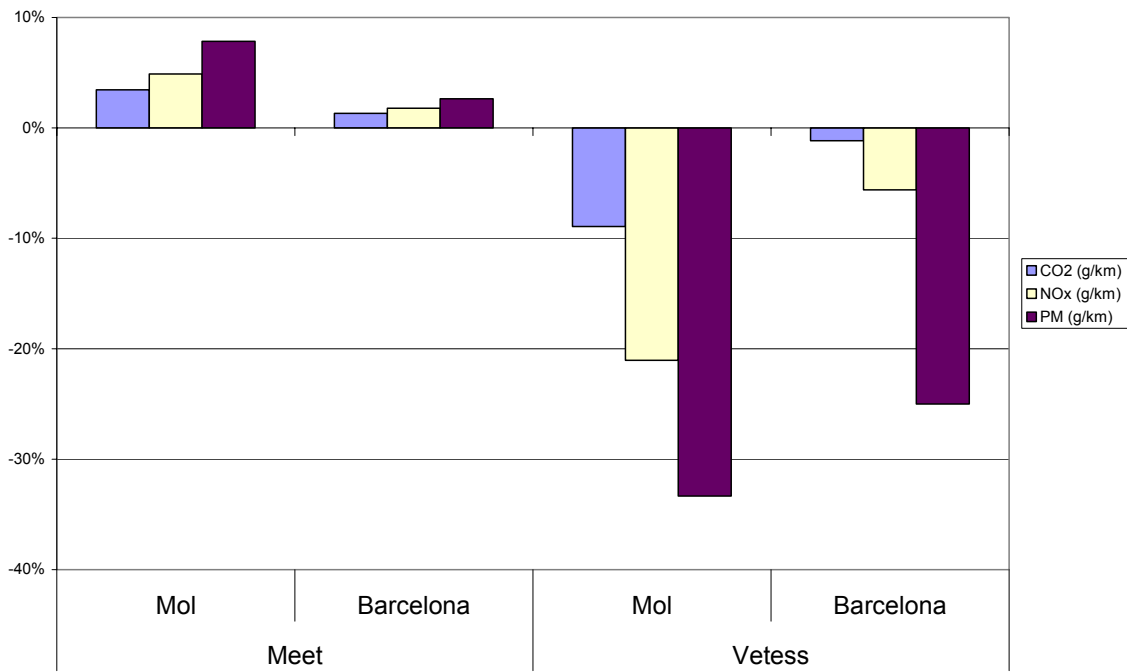


**Figure 2 Estimated relative change in emission for 5 pollutants. Average and range for 18 estimates.**

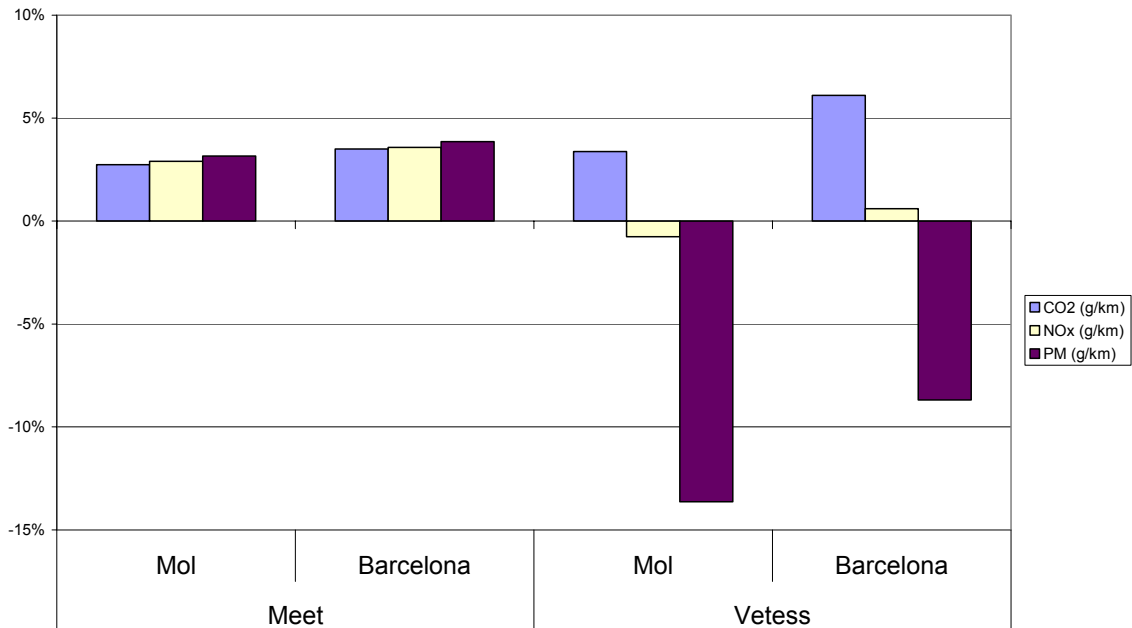
In Figure 3 we present the detailed results for the Skoda Octavia for one representative cycle in each city. The emissions estimates were made with the relevant MEET functions based on average trip speed and with VeTESS on the full speed profile respectively. Results for most other vehicle/cycle combinations 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 quite extreme (e.g. Figure 1) the resulting change in average speed is quite limited (Table 1). 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 CO<sub>2</sub>, NO<sub>x</sub> 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 (i.e additional length

in Table 1). Emissions of CO<sub>2</sub> are marginally smaller and NO<sub>x</sub> emission factors are also lower. The largest reduction however is found for emissions of PM which decrease in most cases by approximately one third.

In Figure 4 we present some detailed results for the light delivery van. In this case the result of detailed emission modeling agrees well with the simpler MEET calculation for CO<sub>2</sub> emissions. Both fuel consumption and CO<sub>2</sub> emissions are projected to increase slightly (~3-5%). Results for NO<sub>x</sub> 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.



**Figure 3** 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)



**Figure 4** Relative change in emissions between two urban driving cycles and a derived cycle limited at 30 km/h (Citroen Jumper Van; Cycle 5: 18.9 -> 18.3 km/h in Mol, Cycle 2: 14.5 ->13.9 km/h in Barcelona)

## 4 DISCUSSION

The emission modeling and results presented in this paper demonstrate that estimating emissions, even of classical pollutants, from vehicles is a complex endeavor. Estimating the impact of policies on emissions proves to be even more difficult (e.g. Cornelis et al, 2005, Int Paris 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. We have tried to shed some light on this problem by applying a very detailed model that can take changes in the speed pattern into account because it models the entire drive train including transient effects in the engine. The obvious disadvantage is that the necessary engine and vehicle data for the model is only available for a limited number of vehicles and it is not feasible to apply this model to look for changes in emissions at the macroscopic emission inventory level. 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 analogues 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 is clearly more relevant to the study of policies than the ability to accurately model older model years.

This being said, there are some important aspects which we have not taken into account and that could potentially invalidate our results and conclusions. Firstly we have not made any changes to the acceleration and deceleration of the driving cycles. This is an implicit assumption that needs to be validated because changes in driving style (e.g. between individual drivers) have a major impact on emissions (De Vlieger et al, 2000). It is generally assumed that reducing the speed limit will also lead to a less dynamic driving style and a more fluent traffic flow. On the other hand it is not unlikely that very low speed limits such as those discussed here irritate people who then try to make up for the time lost by accelerating faster (although they may also simply not obey the speed limit). In cases where the speed limit is imposed by a device in the cars (e.g. ISA) it was shown that some drivers accelerated faster up to the speed limit (Vlassenroot et al., 2006). 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 2006 (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 of vehicle performance and driver behaviour. More importantly, the results of such model studies are, if conducted properly, validated against counted vehicle flows and measured speeds. The results for acceleration however are never validated. It would therefore be questionable to use them as a basis for any emission estimates (Journard, pers. comm., 2005). In addition several authors have found it very difficult or impossible to include acceleration (as the most straightforward variable that describes dynamics) as an input variable for Copert-like emission functions. For example the results of multiple non-linear regression techniques (e.g. Cornelis et al, 2005) are rather disappointing. From this point of view the methods used in this study are certainly justified.

Other types of models may be used to study some other consequences of the zone 30 introduction such as the avoidance of the area by transit traffic or the shift to slow modes by local residents (e.g. the class of "Activity-Based" models; e.g. Beckx et al, 2005, 2006a). But these considerations are far beyond the scope of the study presented in this paper.

One of the most conspicuous differences in driving behaviour, because it is not a continuous variable, is gear shifting behaviour. The decision to shift up or down depends on a combination of technical factors specific to the vehicle (gear ratio, torque, ...) and personal preferences. In this study we have used the default values for each car provided within the VeTESS-tool. It is however possible that imposing a speed limit influences the gear shifting behaviour. Unfortunately, again no data are available to account for this. In a follow-up study different gear shifting strategies (e.g. gentle, aggressive,...) will be used in a sensitivity analysis. In cases where the speed limit is very close to the point where most people shift e.g. between second and third gear, this may have a significant effect on the emissions (Beckx et al, 2006b).

Although the measures discussed are deemed important to reduce accidents, it is unlikely that they will have a significant effect on emissions at a regional or national level. The number of vehicle kilometers affected is likely to be very small. In addition the sign of the changes for most pollutants is not clear from our modeling. Nevertheless it cannot be ruled out that the effect on exposure to PM is important. Our (very limited) set of estimates point to a consistent decrease in PM emissions. Increased concentrations of PM and especially those emitted by road transport have often been blamed to be the cause of adverse health effects. Some epidemiological studies have found significant relationships between health effects and peoples proximity to important sources of traffic related air pollution. There is a growing consensus that the link between health effects and PM concentrations may be causal. Any decrease of PM emissions, concentrated in urban areas with poor mixing (e.g. street canyons) and high densities of people should therefore be considered an important benefit.

## 5 CONCLUSIONS

It is unlikely that imposing strict speed limits in urban areas has a significant influence on emissions of NO<sub>x</sub> or CO<sub>2</sub>. 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.

## 6 ACKNOWLEDGEMENT

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