Vehicle emission knowledge to improve air quality

A.R.A Eijk[1], M.M.J.F. Verbeek[1], C.Obdeijn[1]*
[1] TNO, Sustainable Transport and Logistics, 2628VK Delft, The Netherlands, Arjan.eijk@tno.nl

Introduction

In recent decades a significant rise in urban mobility occurred, caused by the improved economic situation and increasing level of urbanization. This rise in urban mobility has a substantial impact on the quality of life in urban environments. Negative effects are congestion, increased noise levels and traffic exhaust gas emissions contributing to (local) air quality problems within cities.

To improve air quality in Europe, European air quality requirements were introduced to lower the concentrations of NO_2 and PM_{10}. Similar to many other cities in Europe the large municipalities in the Netherlands like Amsterdam, Rotterdam and Utrecht still need to reduce NO_2 concentrations in order to meet these European requirements. Confronted with the current economic recession, the municipalities aim to spend their budget efficiently by implementing traffic pollution reduction measures with high cost efficiency.

Traffic is an important source of emissions and can contribute significantly to local air pollution. In the past, many different measures were defined to reduce these traffic emissions, but the effects of these measures on local air quality were not well known. TNO developed a methodology which quantifies the effects of air quality measures. In the city of Amsterdam this methodology was successfully applied and as a result the effectiveness of the air quality programme of the city of Amsterdam was increased by 50% while saving approximately 40 million Euros as well.

Reducing air pollution

Local air quality can be improved by reducing the traffic emissions. This can be achieved by various measures like reducing the amount of traffic, optimizing the traffic flow or influencing the vehicle fleet composition. Examples are green waves, dynamic traffic management on network level, stimulating the purchase of new vehicles with low emissions (electric, Euro 6 or Euro VI), stimulating the removal of old “high emitting” vehicles. The (cost) effectiveness of these measures on local air quality can only be quantified if the “real world” vehicle emissions of the specific vehicle classes are known. TNO has measured emissions of thousands of vehicles over the past 25 years and gained detailed insight in vehicle emissions under real world driving conditions. Furthermore an insight in a city’s composition of the vehicle fleet and its contribution to the air pollution is of utmost importance to determine the most effective and cost efficient measures. TNO developed a methodology which combines the knowledge of real world vehicle emissions with the actual composition of the vehicle fleet in a city. This results in an overview of the contribution of different vehicle classes to the air pollution.

Vehicle fleet composition

The vehicle fleet composition in a specific city of interest is investigated by installing license plate cameras at various locations within this city. These locations are chosen based on representativeness of the vehicle fleet for the city or where air quality standards are not yet met. The license plate camera’s register 24 hours a day for at least one week license plates of all passing vehicles. Based on the license plate numbers, technical information from the (Dutch) road administration authority is obtained to categorize each individual vehicle in vehicle type and emission classes. This information results in an overview of the vehicle, fuel and emission classes and their relative shares at the specific locations.

Subsequently average emissions for every single vehicle class, for example light duty passenger petrol cars Euro 2, are calculated. Combining the knowledge of vehicle emissions with emission dispersion, (local) air quality and the composition of the vehicle fleet, results in an overview of the relative contribution of every vehicle and emission class to the air pollution at a specific location in the city. Combining several locations can provide an average impression of

the vehicle fleet composition and their relative contribution to air pollution. An example of such an overview is presented in Figure 1.

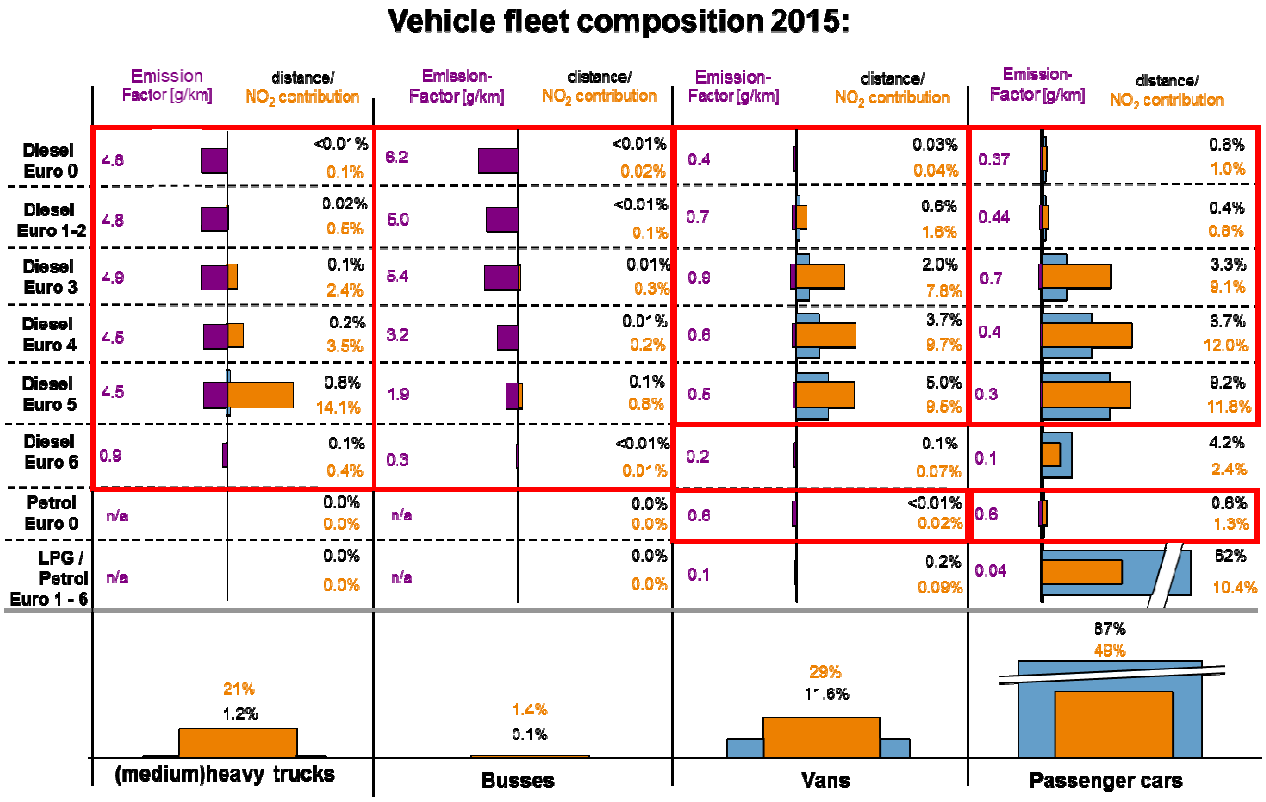

Figure 1: Vehicle fleet composition and their relative contribution to NO_2 concentrations for a large city in the Netherlands

Figure 1 presents the contribution of vehicle classes to the air pollution and their share in the kilometres driven within a large city in the Netherlands. The four different columns present the different vehicle types: trucks, buses, vans and passenger cars. The vehicle types are divided into the different Euro classes (Euro 0 means all vehicles before the introduction of the Euro 1 emission standard), presented in the rows Diesel Euro 0 to LPG/Petrol Euro 1-6. For each class the emission factor (g/km), the relative share in vehicle kilometres driven and the relative contribution to the NO_2 concentration is shown. For example: Euro 3 diesel passenger cars have a relative share of 3.3% of the vehicle kilometres driven, but a relative share of 9.1% to the traffic contribution of the local NO_2 concentrations. Vehicle emission regulations focus on NOx emissions, air quality standards focus on NO_2 concentrations. Therefore the NOx and direct NO_2 tailpipe emissions of vehicles were taken into account and together with insight of dispersion of vehicle emissions and air quality (chemical balance of NO and NO_2), emission models of NOx and NO_2 emissions were used to derive a relation between NO and NO_2 tailpipe emissions and the local NO_2 concentrations as measured on several locations in large cities. The same figure can be calculated for PM_{10} or black carbon to evaluate effects on PM_{10} or black carbon.

This information was the start for a number of cities in the Netherlands to define measures to improve the air quality in these cities. These measures vary from subsidizing the purchase of electric vehicles to the implementation of low emission zones. Measures were defined to influence the relatively most polluting vehicle classes (depending on vehicle kilometres travelled and the corresponding emission factor of the specific class), to gain a significant impact on the air quality.

Effectiveness of measures, predicting future vehicle fleets

The effects of measures to reduce traffic emissions can be calculated using the current vehicle fleet composition. However, it's more interesting to predict these effects in two or three years. The implementation and start of measures takes time and many measures will become fully effective after at least one or two years. In the meantime, even without any local measures, the vehicle fleet will change. Older vehicles will disappear and new clean vehicles will be introduced. This can be taken into account by predicting the future vehicle fleet composition. Based on the current vehicle fleet composition in a city, historical data of general developments of the vehicle fleet composition, taking into account increasing vehicle life time, European and or national policy the vehicle fleet composition can be predicted quite well.

This future fleet composition can be used as a basis to calculate the effects of measures to improve the air quality. For example, the introduction of an environmental zone will effect the vehicle fleet composition. Depending on the future fleet composition, a specific part of the vehicle fleet will not be allowed to enter the environmental zone. These vehicles will likely be replaced by newer vehicles and the emissions of the older vehicles will be replaced by emissions of newer ones. By predicting this specific change in vehicle fleet composition the reduction of the vehicle fleet emissions can be calculated. Figure 2 explains the shift in vehicle fleet composition and the effects on vehicle fleet emissions using a simplified example.

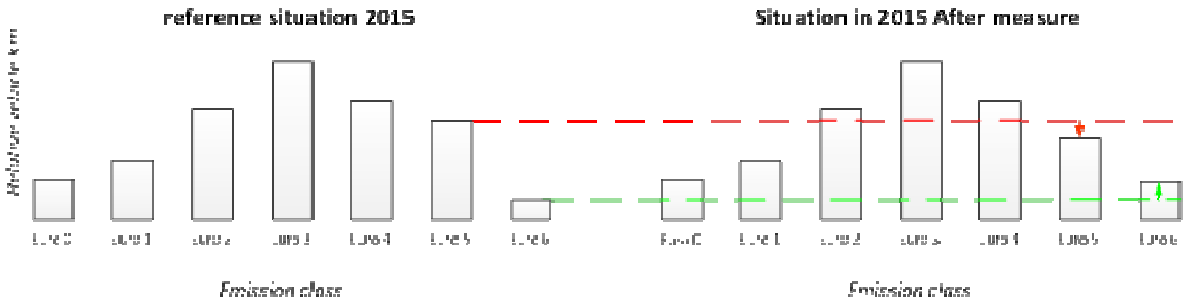

Figure 2: Simple example of emission reduction by shifting Euro 5 vehicles to Euro 6 vehicles. This can be achieved by stimulating the purchase of Euro 6 vehicles instead of Euro 5 vehicles

The vehicle emissions of the total vehicle fleet before and after a specific air quality measure can be calculated. The reduction of the total traffic emissions is the result of a specific measure. This information can be used to calculate the effects on local PM_{10} or NO_2 concentrations

In various cities this method was used to evaluate the costs and the reduction in µg/m3 NO_2 and PM_{10} of a large number of measures, resulting in a cost efficiency per measure. This cost efficiency is defined as the price in Euros per reduction of 1 µg/m3 NO_2 or PM_{10}. The different measures are ranked from high cost efficiency to a low cost efficiency, to give the municipalities an insight in the most cost efficient measures. The municipalities are currently in the stage of selecting and carrying out the most cost efficient measures to meet the air quality limits. In this way accurate knowledge of real world vehicle emissions directly contributes to efficient measures to reduce traffic air pollution

Conclusions

The methodology described in this paper can be used to evaluate (cost) effectiveness of all kind of air quality measures even before introduction. This allows cities to optimize their air quality programmes by selecting the most (cost) effective measures. In the city of Amsterdam the methodology proved to be very effective by increasing the effect of the air quality programme by 50% while saving approximately 40 million Euros. Insight in local fleet composition and detailed knowledge of real world vehicle emissions are a prerequisite for reliable results.

References

Verbeek, M.M.J.F, (2011), Actualisatie effecten van verkeersmaatregelen luchtkwaliteit voor de Gemeente Amsterdam, TNO rapport MON-RPT-2010-03057