5.24 DYNAMIC MODELLING OF TRANSIENT EMISSIONS AND CONCENTRATIONS FROM TRAFFIC IN STREET CANYONS

Clemens Mensink, Guido Cosemans, Luc Pelkmans
Flemish Institute for Technological Research (Vito), Mol, Belgium

INTRODUCTION

In the EU 5th framework project DECADE (2001-2003) a new methodology has been developed to calculate in detail the engine power required to drive a given vehicle over any particular route. It includes the rapidly changing (transient) demands placed on the engine, an area that has proved an obstacle to accurate simulations in the past. Together with the associated speed profiles, the actual power demands allow a detailed calculation of emissions and ambient air concentrations in street canyons. This makes the methodology a valuable tool for detailed assessments of the ambient air quality impact of e.g. street design (traffic lights, road bumps, busy crossings), driving patterns, driving behaviour and fleet composition.

In this paper we show the consecutive steps that are needed to apply the methodology developed within the DECADE project. In section 2 we discuss the methodology. In a first step, speed profiles and GPS locations are recorded. These profiles are input to the thoroughly validated VeTESS (Vehicle Transient Emissions Simulation Software) model that calculates the emissions per second for CO_2, CO, NO_x, THC and PM (Pelkmans, 2003). The tracks are visualised on a map and embedded in the urban canopy using cadastral input data and 3D street canyon information of the built up areas considered. The emission data and speed profiles, combined with traffic fleet data for the road considered, are transformed into input for the OSPM model (Berkowicz, 1998) to calculate the ambient air concentrations at any arbitrary point along the track. Resulting concentrations can be compared with the limit values given in the EU directives.

In section 3 we show results for a 4.5 km track located in the City of Antwerp. NO_x concentrations for 6 fleet composition scenarios have been compared, as based on the speed profiles and engine power spectra of two passenger cars, one bus, one van and one city truck. Results show exactly where on the route the hot spots are located and where and when exceeding of the limit values can be expected.

METHODOLOGY

The methodology to calculate the transient emissions and concentrations from traffic in street canyons consists of the following steps:

Recording of speed profiles and position tracking

For a selected route, the speed (km/h), and position (lat-lon coordinates) are recorded using one or two GPS receivers and an optical speed meter. From these data the distance travelled (m) from the starting point is calculated. Figure 1 shows a typical example of a speed profile and distance travelled for a specific vehicle. The data were recorded with a frequency of 1 Hz on the track located in the City of Antwerp (see section 3).

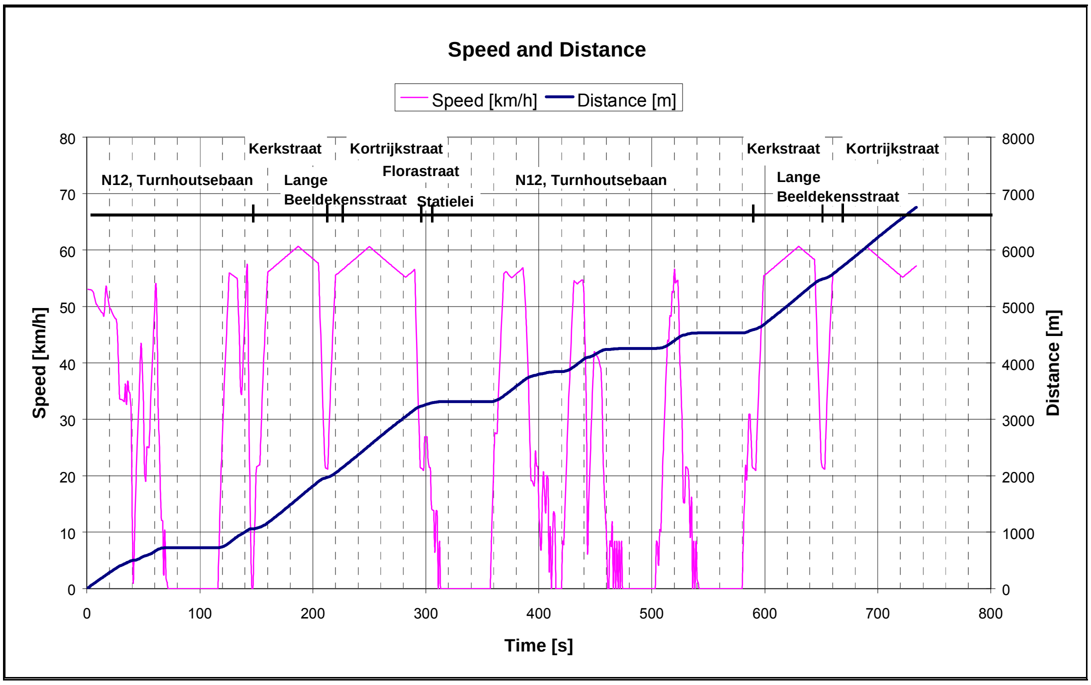

Figure 1. Speed (km/h) and distance travelled (m) vs. time for a specific vehicle and a specific duty cycle

Emission calculation

The second step is the calculation of transient emissions for a specific vehicle or engine. The VeTESS model calculates the emissions per second for CO_2, CO, NO_x, THC and PM for specific traffic situations, using the speed profiles and associated accelerations as input. In this way VeTESS looks at the actual fuel consumption and pollution generated on a specific duty cycle.

Emission allocation

In a next step the emissions calculated per second are allocated to the selected route. The GPS data are converted from lat-lon coordinates to Lambert coordinates (km). The accuracy of the GPS readings in street canyons varies between 0.5 to 20 m (due to wall reflections) and the accuracy of the speed meter is 1%, thus a corrective filtering is needed in order to represent the distance travelled correctly on the routing map. The digital routing map is derived from high quality land register maps showing details of the street canyons and the built up area. By dividing the emissions per second through the actual speed, the emissions per meter can be obtained.

Emission integration

Up to now, we have been working with the emissions of a single car for a single speed profile. The emissions per meter calculated by VeTESS are averaged for a number of speed tracks in order to obtain a more general driving pattern for the selected track. In this way the effect of arbitrary stand stills (e.g. due to traffic lights) is smoothened. The emissions per meter are then integrated over a distance of 75 meter to obtain a sliding average, revealing the density of emission peaks from the original recordings and making the input more suitable for air pollution calculations in a street canyon. A next integration step is the extension of the emissions from a specific vehicle to emissions from a representative fleet by combining the emission from a number of representative cars. Scenario's can be defined at this stage. A final integration step relates the actual measured emissions with emissions at any particular time of the day. This can be obtained by measuring or modelling the hourly variations in traffic flow or traffic intensity at various locations on the selected track for the selected period of time (e.g. one year).

Calculation of air pollution concentrations

In a final step we use a street canyon model to calculate air pollution concentrations. In our case we used the OSPM model. From the air quality management and assessment requirements as provided by the EU directives (96/62/EC), it follows that the atmospheric dispersion model must calculate a time series of (half)hourly concentrations over a period of one year at a height of 1.5 m to 4 m above the ground and on both sides of a street canyon. For doing this, OSPM needs a time series of the emissions that influence the receptor and a time series of the relevant hourly meteorological data during one year. OSPM produces a time series of calculated pollutant concentrations. From this time series, relevant statistical parameters can be calculated to compare their values with the limits imposed by the air quality standard.

Scenario calculations

Due to the powerful combination of transient micro-scale emission calculations and air quality impact modelling, a wide range of scenario's can be defined and their impact on human health and the environment can be evaluated. Scenario's can be defined to evaluate:

- driving behaviour and driving patterns or cycles (gear shifting)
- optimal vehicle use
- engine composition and scaling (engine rating, power, torque, gear ratio's)
- load impacts (mass or number of passengers)
- impact of traffic measures (e.g. speed limiting)
- impact of street design (traffic lights, road bumps, roundabouts)
- impact of fleet composition
- use of (alternative) fuels (electric, hybrid, fuel cells)
- impact of auxiliaries (e.g. air conditioning equipment)

RESULTS AND DISCUSSION

Definition of fleet composition scenario's

The use of the methodology is demonstrated for a selected route in the City of Antwerp (depicted in Figure 3). The total length of one circuit was 4.5 km. As an example of the outcome of the methodology we show NO_x concentrations for 6 different fleet composition scenario's. These fleets are composed of combinations of 5 vehicle types for which speed profiles have been measured and emissions have been calculated using VeTESS. Air quality is then calculated for the six different traffic fleet scenario's as defined in Table 1. It is assumed that the different fleets transport the same amount of persons and load, but are varying in the number of petrol and diesel cars, the use of buses, vans and trucks. In scenario 1 all vehicles consists of petrol cars. In scenario 2 all vehicles are diesel cars. In scenario 3 there is an equal share of petrol and diesel cars. In scenario 4, 50% of the persons are transported by bus, replacing 15 cars by 1 bus. In scenario 5, 5% of the cars are replaced by vans, able to transport a load of 500 kg each. In scenario 6 the total load transported by the vans in scenario 5 is transported by city trucks.

Table 1. The distribution of a traffic flow of 2000 vehicles/hour over the different types of cars in scenarios 1 to 6.

Scenario	**Passenger car 1** *Polo 1.4 16V* *Petrol/Gasoline*	**Passenger car 2** *Golf 1.9TDi* *Diesel*	**Bus 15 passengers** *MAN_A12_City bus* *(Euro 2 Diesel Engine)*	**Van (Load 500 kg)** *Citroen Jumper*	**City Truck (Load 3000 kg)** *IVECO Eurocargo*
1	2000				
2		2000			
3	1000	1000			
4	500	500	67		
5	475	475	67	100	
6	475	475	67		17

Calculation assumptions

Within the Decade-project, the computation of the impact of the vehicle emissions on air quality is restricted to the air quality in the street canyon where the emissions take place. The contribution from background concentrations is therefore not taken into account. Receptors were placed every 25 meters along the Antwerp route, at a height of 1.5 m above the ground. This gives 180 receptors. For each receptor, a street canyon description (street geometry, orientation, traffic density, building height, emissions) is generated as required by OSPM. The average building height over the track was 14.4 m. The hourly meteorological data of the year 1998 measured along the Zwijndrecht meteorological tower in Antwerp was used. For each receptor, a time series of hourly NO_x concentrations was calculated for the left hand side of the road, and another time series for the right hand side of the road. From each time series, the average concentration over one year and the hourly concentration that is exceeded 18 times a year ($P_{99.79542}$), were computed, according to EU directive 1999/30/EC.

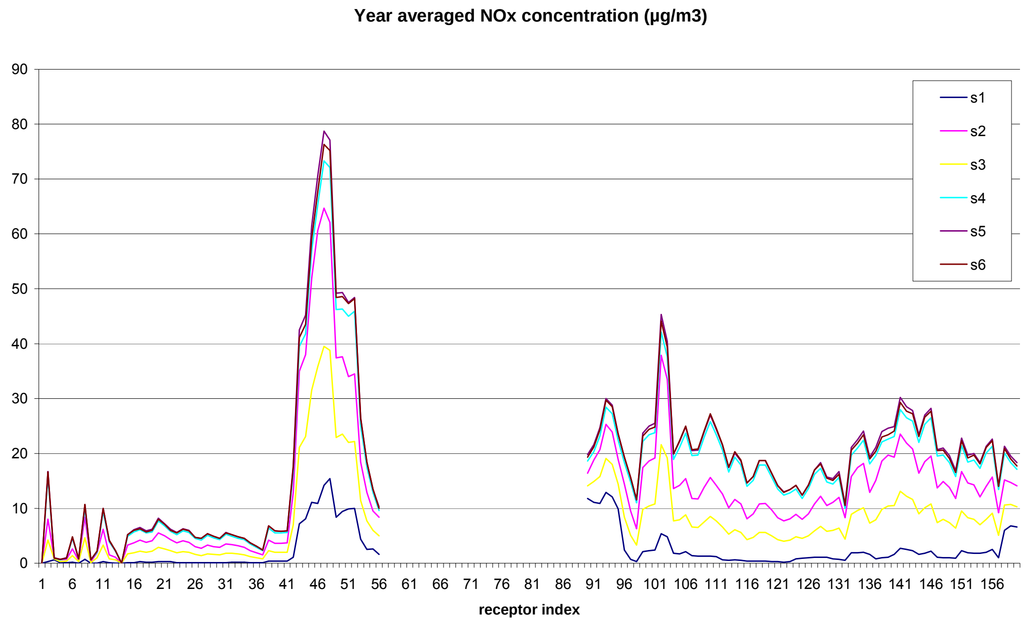

Figure 2. Calculated yearly averaged NO_x (µg/m³) concentrations for the 6 scenario's.

Results for a selected route in the City of Antwerp

The Antwerp route was selected so as to contain different types of street canyons and driving patterns. Figure 2 shows the yearly averaged NO_x concentration for the six scenario's. Only the larger value of the two road sides is shown. Figure 3 shows the locations along the track where the yearly averaged NO_x concentrations exceeds the future limit value of 40 µg/m³ for scenario 6.

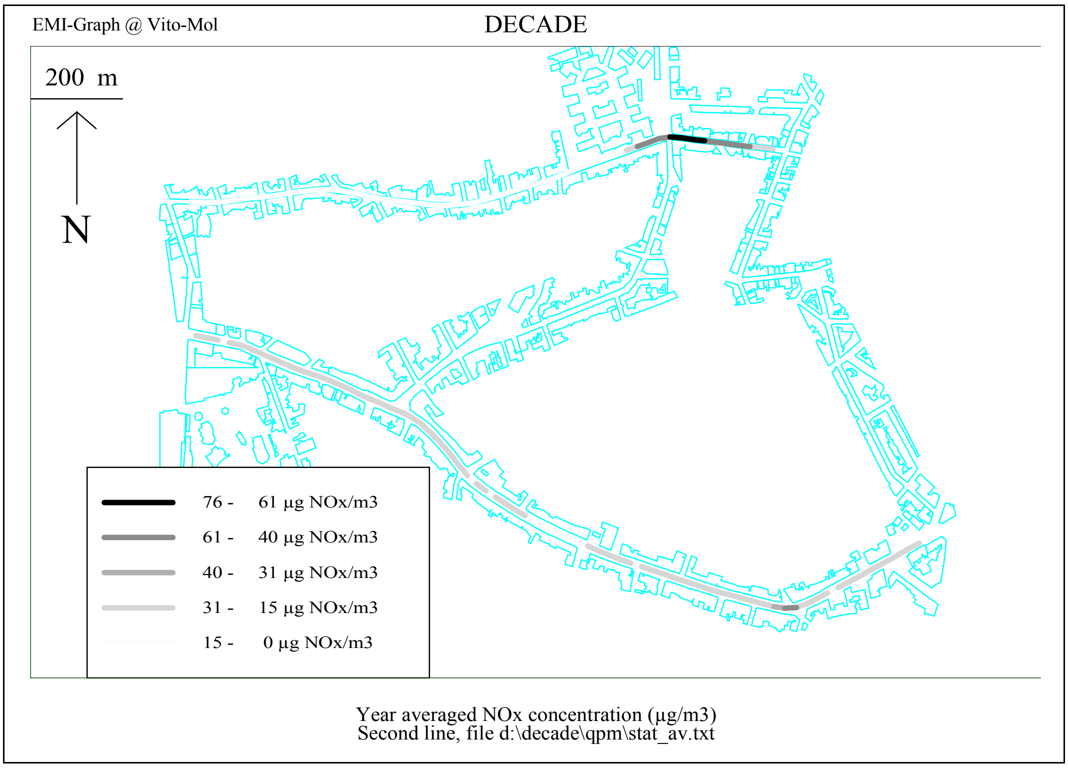

Figure 3. Concentration map for yearly averaged NO_x (µg/m³) for fleet scenario 6.

CONCLUSIONS

The VeTESS model calculates in detail traffic emissions for a specific vehicle as based on the engine power required to drive the vehicle over any particular route. This information can be used to built various scenario's in which traffic situations, driving patterns, technological measures and vehicle concepts can be evaluated. The emissions can then be used as input in air dispersion models, which result in pollution concentrations. Results show exactly where on the route the hot spots are located and where and when exceeding of the limit values can be expected.

REFERENCES

Berkowicz, R., 1998, Street scale models, In*: Urban Air Pollution – European Aspects*, J. Fenger, O. Hertel and F. Palmgren (eds.), Kluwer Academic Publishers, Dordrecht, pp. 223-251.

DECADE: http://www.cle.de/umwelt/decade/edecade.htm

Pelkmans L (ed.), 2003, DECADE technical Report TR9: Comparative Assessment, EU Project NNE5-1999-00270.