Street Emissions Celing exercise

Phase 2 report

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ETC/ACC Street Emission Ceiling (SEC) exercise

Phase 2 report

Final Report, July 2005

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Foreword

This report has been prepared by the task team of the Street Emission Ceilings exercise of the European Topic Centre on Air and Climate Change (ETC/ACC). It is based on the work performed by the Aristotle University Thessaloniki (AUT), the Norwegian Institute for Air Research (NILU), the National Institute for Public Health and the Environment (RIVM) and the Institute of Environmental Sciences Energy Research and Process Innovation (TNO). It is the phase 2 final report.

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Executive Summary

Traffic related air pollution is still one of the most pressing problems in urban areas. Evidence of the adverse health effects of fine particulate matter is continuously emerging and the fact that most of the traffic related emissions are in the fine particulates range ($<PM_{2.5}$) is of particular concern. Population exposure to increased pollutant concentrations in densely populated urban areas is high and thus the improvement of air quality is imperative since most air quality limit values under the new air quality directives pertain to health and apply everywhere except at workplaces, hence also in streets as the most typical example for urban hotspots. The SEC project analyses the excess concentrations observed at urban hotspots and attempts to formulate a generalised approach that can be used by local authorities in their efforts to reduce local air pollution. At the same time, SEC aims to support the CAFE program and provide a basis for the inclusion of the local scale into the full Integrated Assessment Modelling chain currently applied at European scale to study present and future air quality and air emission reductions.

As a first step and in order to study the excess concentrations observed at street/road side (traffic) stations and test the appropriateness of the overall approach and the specific models and tools against measurements, it was necessary to determine a number of cases where the data available would enable such a test basis and would be representative in order to allow for a generalisation of the results. Detailed quality controlled hourly traffic and meteorological data as well as street and urban background level concentrations (ideally $PM_{2.5}$, PM_{10}, NO_2, NO_x, CO and background O_3 were required) and appropriate street geometries were not readily available. Often enough the location of the stations was a limiting factor for the analysis. Furthermore, the lack of detailed traffic data as well as incomplete datasets was also a problem often encountered. Nevertheless, three case studies were singled out as most appropriate and for which an hourly data analysis for a full year was performed: Marylebone Rd. (London), Hornsgatan street (Stockholm) and Frankfurter Allee (Berlin). The data analysis considered annual and monthly averages and average diurnal variations separately for weekdays-weekends and summer-winter periods. This detailed analysis allowed for an evaluation of the emission factors for heavy and light duty vehicles and also elucidated the effect of re-suspension PM with respect to vehicle PM emissions.

Comparison of the delta (street minus background) concentration ratios (PM/NO_x and CO/NO_x) with the corresponding emission ratios enabled the site specific characteristics to emerge (e.g. importance of re-suspension PM) and provided a basis of assessment for the air quality model applications that followed. Furthermore, the appropriateness of the emissions factors could be directly compared against the concentrations observed and for PM the importance of non-tail pipe PM emissions (tyre and brake abrasion, road wear and dust re-suspension) was particularly noted. Moreover, as the streets in the cities considered had different characteristics the influence of parameters such as height/width ratio, traffic speed and composition (different HDV percentages), wind and dispersion parameters, could be also evaluated.

Further to the concentration and emission ratio comparisons performed with data from individual sites, a “global” analysis was also performed using a number of stations across 5 European countries. The comparison showed a fair agreement between the concentration and emission ratio of CO/NO_x at a country level, suggesting that the measured concentrations originate from traffic-related emissions. The NO_x/PM and PM/CO emission ratios estimated by the TRENDS model were over- and underestimated respectively. This work highlighted once again the importance of PM emissions from gasoline-fuelled vehicles and non-exhaust sources.

The data collected and studied for Marylebone Rd. (London), Hornsgatan street (Stockholm) and Frankfurter Allee (Berlin), were further processed and the datasets were made available to interested institutes for performing a model intercomparison exercise. This exercise provided an insight in the level of uncertainty that is inherent in the various model calculations and a first estimate of the uncertainty that enters from the street level, into a complete regional-urban-street scale model application. Moreover, the large number of models that participated (13) and the variety of cases available enabled an evaluation of model performance, bearing in mind the restrictions of the input data. Finally, as the OSPM model was applied by three different institutes a different “modeller” intercomparison emerged with interesting results related to user-sensitivity analysis.

In parallel to the above data analysis and modelling activities, the theoretical basis for the classification of street types was developed. This “street typology” should allow for a generalised methodology to determine the local emission reductions needed to reach certain air quality thresholds. In the development of the typology methodology, the balance had to be maintained between model accuracy, requiring many explicit and continuous parameters, and simplicity, which demands giving preference to classified parameters. A first selection of the key parameters sufficiently characterising the various street classes resulted in the distinction of twelve street types. The classified parameters (represented by ranges of values) consisted of geometry (street canyon or not), fraction of HDVs, traffic behaviour (speed), distance of the receptor from the road axis. The only parameter retained as an explicit continuous one was daily traffic intensity. The candidate parameters were assessed in terms of their importance to air pollution, their suitability for air quality modelling and the availability of data (on specific streets and statistics across Europe). A further criterion was whether the particular parameter could be altered by specific measures, as for example the percentage of HDVs is important since it is a vehicle category with significant air emissions but technological improvements related to emission reduction for HDVs and private cars follow different tracks in time.

As an application of the typology, annual mean concentrations were calculated with the simplified air quality model CAR and then empirical relationships were used to compute exceedance days. The region chosen for the application was an arbitrary location in Flanders (Belgium). However, the methodology needs to be further applied to different types of streets in a reasonable number of countries before it is revised for the possible inclusion of new parameters and the parameter ranges are confidently defined.

Chapter 1: Report on data analysis and comparison with emissions estimates

1.1 Introduction

This report presents the work carried out, as part of the “Street Emission Ceilings” (SEC) project, to use existing monitoring data from selected quality monitoring stations as a basis for testing street scale models as well as COPERT 3 emission factors for road vehicles.

The primary objective of the Street Emission Ceilings (SEC) project is to develop a method for determining what local emission reductions in streets are needed to reach certain air quality thresholds, e.g. limit values. In particular, SEC has two purposes namely (a) Use by local authorities and (b) Use in Integrated Assessment Methodology (IAM) for CAFE.

Purpose 1: Use by local authorities

Most of the limit values under the new air quality directives pertain to health and they apply everywhere except at workplaces, so also in streets. Hence city authorities have to identify streets where limit values may be exceeded. Some countries use models for making surveys of levels in busy streets throughout the country, but most countries do not have such models. The first objective of the SEC project is to make easy-to-use model assessment systems available to local authorities for estimating air pollution levels in streets, with the purpose of identifying potential problem situations.

Purpose 2: Use in IAM for CAFE

In the developments of EU legislation prior to CAFE, Integrated Assessment Modelling has been carried out with RAINS. It focused on the regional scale concentrations in Europe, in line with the analyses needed for CLTRAP, which dealt primarily with long-range transport and the impact on vegetation and ecosystems. In CAFE, population exposure and compliance with limit values are of prime importance, hence urban levels and hotspots should be included in the assessment. For this purpose, JRC has set up the City-Delta study, targeted at modelling the urban background levels in Europe in order to provide an urban module for use in IAM. Analogously, SEC aims to provide robust street modelling techniques that can be used in IAM.

Chapter 1 summarises the work done under the subtasks 3 and 4 of the SEC project:

Subtask 3: Analysis of excess concentrations in streets
Subtask 4: Local (street) emissions estimates

Subtask 3 has selected well defined station pairs from cities in Europe, a station pair being a street level station together with a nearby urban background station which represents well the contribution to the air pollution concentrations at the street station which do not come from the traffic in the street itself. There were several prerequisites for selecting a station pair to participate in the study:

- As a minimum, quality controlled hourly concentrations of NO_x, NO_2 and PM_{10} had to be available for a whole recent year at both stations of the pair. It was considered important that $PM_{2.5}$ was also measured, while CO data were considered useful as well;
- Traffic data (volume, speed, heavy-duty fraction) should be available, as well as meteorological data from a nearby station measuring the meteorological parameters above the roof level of the area.

Station pairs in London, Berlin, Hannover, Stockholm, and (nearby) Oslo have been selected. Station pairs in Prague, Thessaloniki, Madrid, Milan, Paris, Helsinki and Copenhagen have also been investigated. The result of this investigative phase is that data have been collected so far from London, Berlin, Stockholm, Oslo, Hannover, Madrid and Thessaloniki. Only London, Berlin, Stockholm, Hannover and Oslo have close to full data coverage of air pollutants as well as traffic and meteo data and data from these pairs have been fully analysed (see below). Traffic data are (partly) missing from the Madrid, Milan, Copenhagen and Paris pairs and data from these pairs have not yet been subject to the analysis of this project. Helsinki seems to have full coverage and data from this pair are being made available from the data provider for a full year up to March 2004. A suitable station pair has recently been established in Prague and it is foreseen that data from this pair will be available in 2005.

The main result of the data calculation/analysis process is the calculation of “delta concentrations” (DeltaC) and “delta ratio” (DR) for each pair:

DeltaC: the street station minus the background station concentrations, for each hour of the year.
Delta ratio (DR): the ratio between the NO_2 and PM deltas on the one hand and the NO_x delta on the other hand, also this for each hour of the year.

NO_x is used as the “reference” compound because it is purely a primary composite pollutant and it is considered that the emission factor for NO_x from road vehicles is the one with the lowest uncertainty (among the compounds selected for this study).

The DeltaCs and DRs are presented as average values per hour of the day (thus as average daily variations), for four combinations of season and time of the week: Summer and winter workdays and weekend days.

The DRs are the output from subtask 3 that provides a basis for the testing of COPERT 3 vehicle exhaust emission factors (also ratios) in subtask 4. Additionally, by comparing the $PM_{2.5}$ and PM_{10} DRs, estimates can be derived of the non-exhaust emissions of PM.

At present, this analysis has been carried out for the situation at the Stockholm, London, Berlin, Oslo and Thessaloniki station pairs and the results are presented in this report.

Section 1.2 of this report presents a summary of the subtask 3 work and section 1.3 a summary of the subtask 4 work.

1.2 Analysis of excess concentrations in streets

1.2.1 Introduction

As already mentioned, the primary objective of subtask 3 is to study excess concentrations at street/road-side (traffic) stations over and above the urban background concentrations in the area where the hotspot station is located.

The work procedure is to select, based upon knowledge of monitoring stations and data in AirBase as well as through contact with data providers in cities where the team is aware of good monitoring activities relevant for this project, a number of stations pairs (street/road-side hotspot station and representative urban background station) in several cities geographically distributed throughout Europe. The selection of cities should reflect the varying meteorological and source structure situations in Europe.

The results of the analysis in this subtask should:

- contribute to knowledge of (relative) emission factors for vehicles, by comparing PM, NO_2 and NO_x concentrations, as a function of vehicle distribution in traffic
- contribute to the analysis of the road dust re-suspension source, by comparing $PM_{2.5}$, PM_{10} and NO_x concentrations, together with meteorological data
- provide a basis for model-measurement comparisons / model validation.

1.2.2 Selection of station pairs

1.2.2.1 Features of traffic related PM in Europe, from existing material

PM is measured mainly as PM_{10}, although the number of $PM_{2.5}$ stations is now rapidly increasing.

Figure 1.1 shows a summary of PM_{10} data for 2001 reported to AirBase from 25 countries, in total 818 stations. The figure shows the importance of the regional and urban background (UB) contributions to the concentrations close to streets. On average for all these stations (rightmost columns in the figure), the UB concentration makes up about 79% of the traffic station concentrations (and the rural background makes up about 80% of the UB concentration). This importance of the background is a special case for PM_{10}. For NO_2, the importance of the background is much smaller (see Figure 1.1).

Note that Figure 1.2 presents, for each station type, the variability in concentrations across Europe. Some rural background stations have higher concentrations than urban and even traffic stations and this reflects that they are located in different areas and cities.

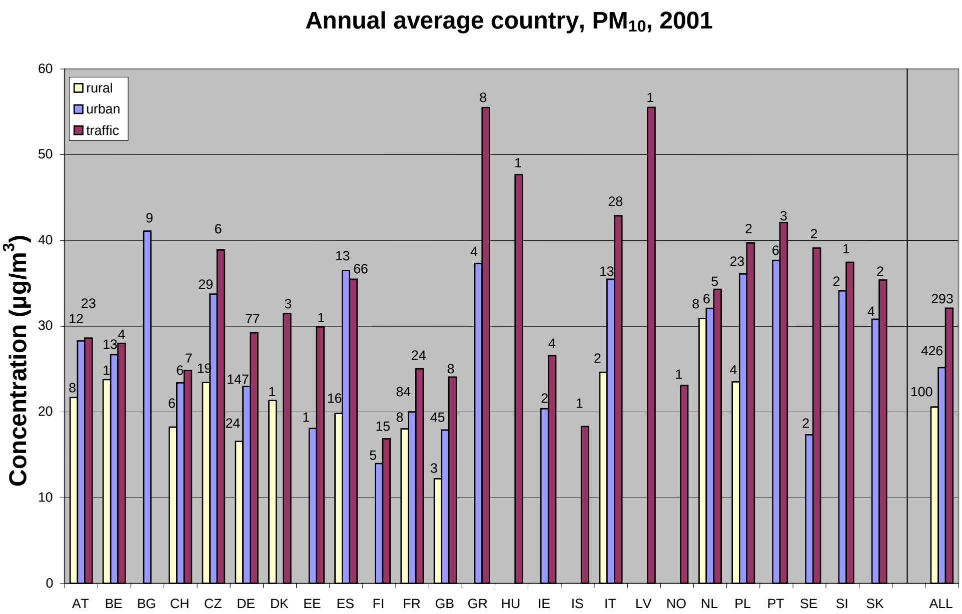
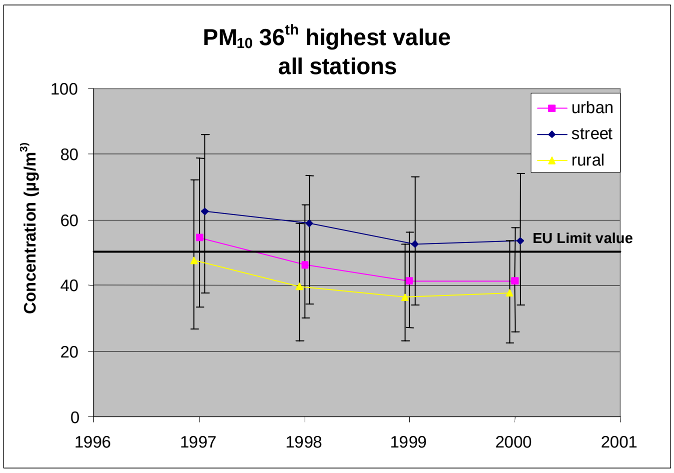


Figure 1.1. Country- average PM_{10} concentrations (annual average) for rural, urban background and traffic stations, 2001 AirBase data (number of sites on top of bars).

AirBase contains data from a fair number of cities where PM_{10} is measured continuously at least at one traffic and one UB station. These are listed in Table 1.1. For 2001, 14 cities in Europe reported such PM_{10} data. For NO_2, the number of cities with such station pairs is larger. The table contains coordinates, so it is possible to see how close the stations are located in the city, to see if they really constitute "station pairs".

For the PM Position Paper which has been prepared as a final draft by the CAFE PM Working Group (http://europa.eu.int:8082/comm/environment/air/cafe/pdf/working_groups/2nd_position_paper_pm.pdf) a selection of these station pairs, plus some other data were studied, in order to identify more clearly the additional PM_{10} burden at traffic exposed sites from AirBase and to remove the ambiguity of comparing hotspot data from one city with back-ground data from another. From the resulting 89 station pairs, PM_{10} ratios for annual means were calculated. For conurbations where more than one urban background site was available, the average of the sites was taken to represent the urban background. The distance between the two stations in each pair was not considered. They may be in the same area and they may be fairly widely apart, so they may not all be "good" station pairs.



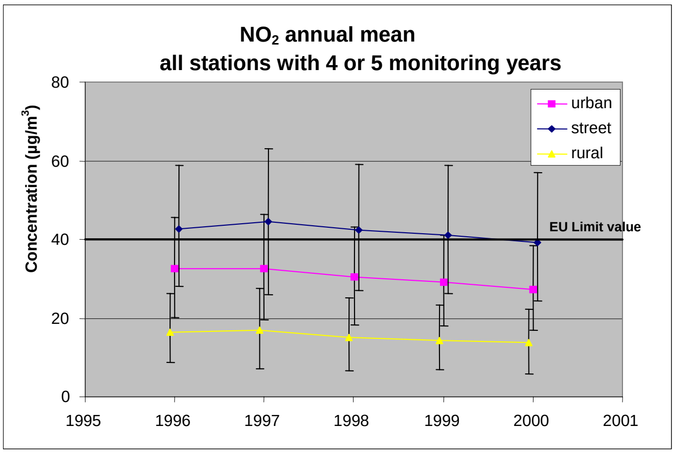


Figure 1.2. Concentrations of PM_{10} (36^{th} highest day) and NO_2 (annual average) at stations in AirBase 1995-2000, averaged over each station type (rural, urban, traffic).

A frequency distribution of the ratios is presented in Figure 1.3. The ratios of the annual means span a considerable range from 1.9 to 0.7 and the majority of the ratios are above 1, indicating a higher PM_{10} burden at traffic exposed sites compared to the urban background. The arithmetic mean of the ratios is 1.34 (1.3 in a similar evaluation from 2000 data pairs, N = 37) with a standard deviation of ± 0.25. The cases with ratio less than 1 indicate higher concentrations at the urban background locations compared to the traffic exposed locations, which obviously excludes the use of these station pairs for this kind of analysis.

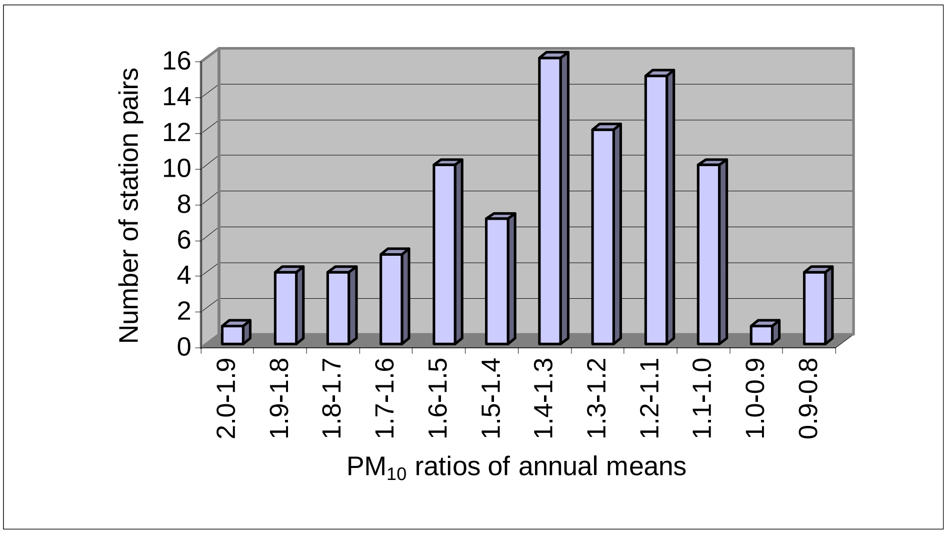


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Figure 1.3. Frequency distribution of ratios of PM_{10} levels (annual means, µg/m³) at traffic exposed sites and in the urban background. Data from AirBase, 2001. Only pairs of data from the same city were taken into account. N = 89.

In the majority of cases, the number of "exceedance days" at traffic exposed sites is also considerably higher compared with to urban background (Figure 1.4). On average, there were 11.6 extra exceedance days (range up to 43 days).

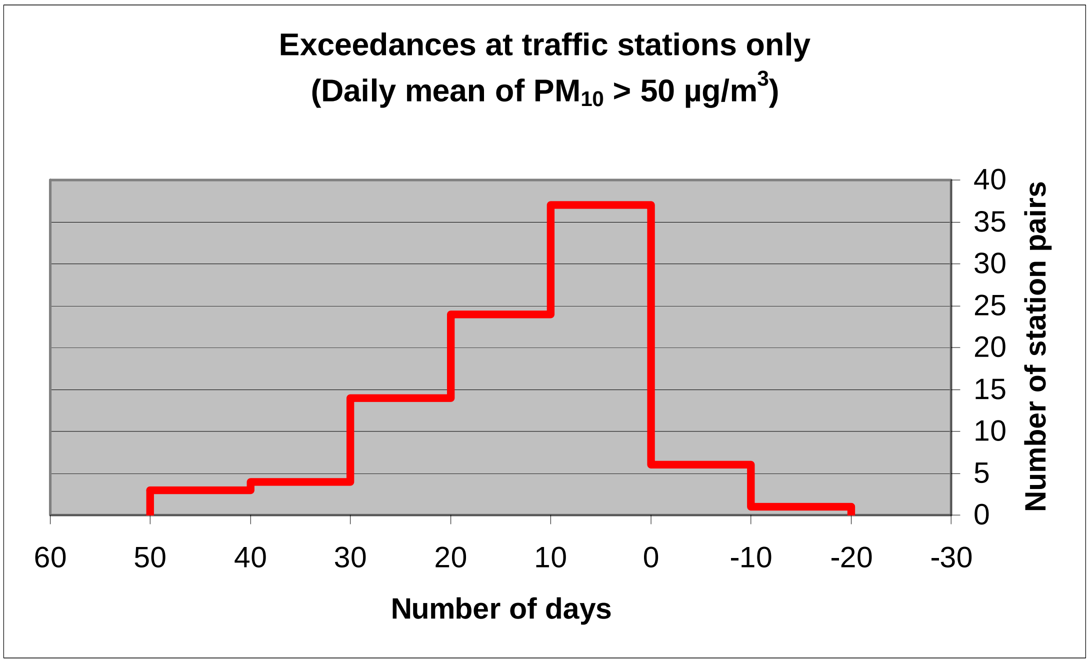


Figure 1.4. Extra days of PM_{10} daily means > 50 µg/m³ at traffic exposed sites compared to the urban background. Data from AirBase, 2001. Only pairs of data from the same city were taken into account. N = 89.

The relationship between the annual average PM_{10} concentration and number of exceedances of the stage 1 and stage 2 short term (daily) limit values is shown in Figure 1.5, for street/road side (traffic) stations. The figure shows that the spread around the regression line is fairly limited, but that there are stations where the short term levels fall considerably above the line.

A special case is Hornsgatan in Stockholm, which shows up in the figure as the spot with very high short term value, i.e. the 36th and the 8th highest day. This is most probably due to road dust emissions created by the extensive use of studded tyres. Streets in Nordic countries are not well represented in AirBase. More street stations from Norway, Sweden and Finland would probably show similar feature as Hornsgatan. Other stations that are well above the regression line are Spanish stations, where the problem of re-suspended dust is also pronounced, although from a very different source.

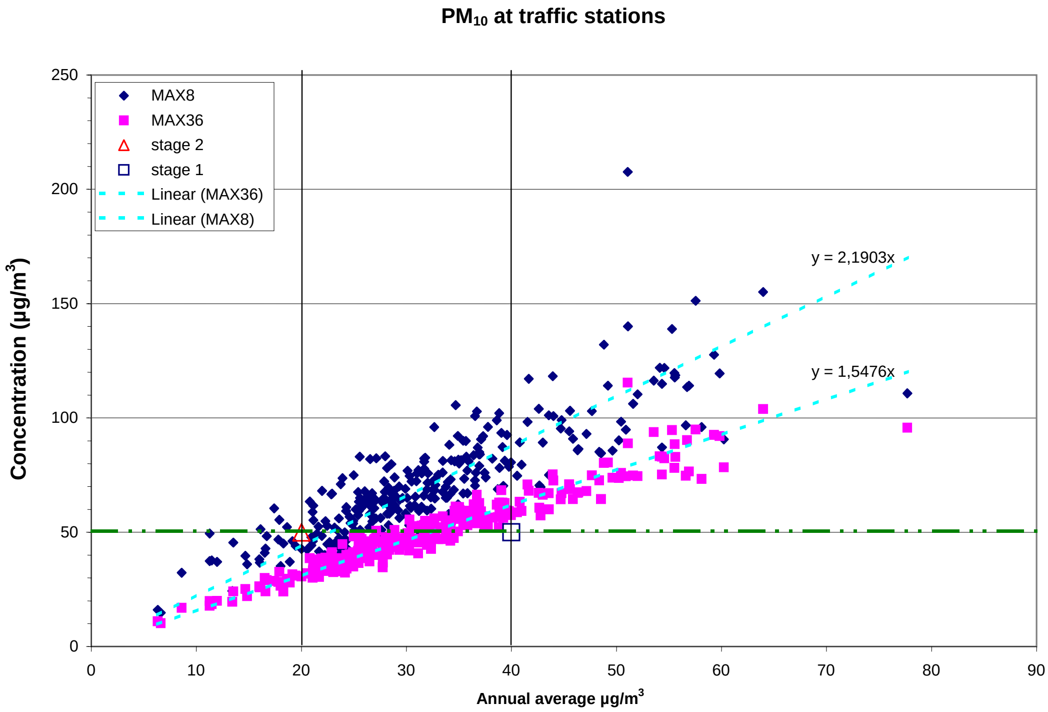


Figure 1.5. Exceedances of PM_{10} annual and short term limit values (stage 1, squares and indicative values of stage 2, rhombus) at European street monitoring stations for the year 2001. Annual average vs highest 36th and 8th daily mean.

1.2.2.2 Selection of station pairs for this study

At station pairs to be selected for further analysis in this project, data from monitoring of the following parameters should all be available, as hourly averages over a period of at least several months, preferably one full year, as a minimum:

Concentration data: - PM_{10}, NO_x, NO_2, preferably also $PM_{2.5}$, O_3, CO

Traffic data: - traffic volume

- traffic speed
- vehicle composition
- data related to re-suspension (e.g. studded tyre use)
- preferably also cold start fraction
- vehicle fleet data (age, technology,…).

Street/station configuration: - width, number of lanes, height of buildings, gradient
- station location relative to street: distance to kerb, intersection

Meteorological data: - wind speed and direction, temperature, preferably also parameters related to dispersion.
The wind and temperature data should be representative for the area where the station are located and not situated within the street area.

Table 1.3 gives an overview of station pairs which have been analysed in this project: station pairs in Stockholm, Berlin, London, Oslo and Thessaloniki.

Data from the Goettinger Strasse station pair in Hannover has recently been made available to this project and has been analysed. Apparent data quality issues have not yet been solved, which prevents the results to be used in the current report.

For Prague, available data series were evaluated, but a suitable station pair with traffic data is not available so far. A new station pair has been established recently (spring of 2004) which could provide suitable data for this project. Madrid, Milan, Copenhagen and Paris were also investigated for suitable station pairs. Those were found, but for most of these cities the necessary traffic data were not available. Thus these cities could not be considered in the current analysis. There are additional station pairs with data available in Helsinki, London, Madrid and Athens from campaigns carried out as part of the OSCAR project (http://www.eu-oscar.org/).These are 2-month long measurement periods during winter and summer separately.

Data from all these cities and station pairs would broaden the assessment and could be added to this analysis at a later stage.

Table 1.1. Selected station pairs and data years.

City	**Street station**	**Street type**	**Background station**	**Annual average daily traffic (AADT) vehicles/day**	**Data collected**	**Year**	**Period**
Stockholm	Hornsgatan	Canyon	Roof-top (near street)	34,800[1]	A.Q.: PM_{10}, $PM_{2.5}$, NO_2,, NO_x Traffic: Vol., Speed, Composition Met. Data: Wind speed, Wind dir. Modelling available	2000	January - December
Oslo	Skaarer	"Open"	Ground level station nearby	35,900	A.Q.: PM_{10}, NO_x, NO_2, Traffic: Vol., Speed, Composition Met. Data: Wind speed, Wind dir. Modelling to be done	2002	January - April
Berlin	Frankfurter Allee	Canyon	Ground level station in the area	56,000	A.Q.: PM_{10}, NO_x, NO_2, CO Traffic: Vol., Speed Met. Data: Wind speed, Wind dir., Radiation, Temp., Delta temp. Modelling??	2002	January - December
Thessaloniki	Ermou street	Close to street crossing	University, Thessaloniki	13,500[2]	A.Q.: PM_{10}, NO_x, NO_2 Traffic: Vol., Speed, Composition Met. Data: Wind speed, Wind dir., Temp.	2001	January - December
London	Marylebone Rd.	Canyon	Ground level station nearby (Bloomsbury)	85,500	A.Q.: PM_{10}, $PM_{2,5}$, NO_2, NO_x, NO, CO, SO_2, O_3 Traffic: Vol., Speed, Composition Met. Data:	2000	January - December

[1] Traffic was only counted in one direction during this period, but manual and more detailed traffic counts indicate that this direction has about 5% to 10% higher counts compared to the other direction. Nevertheless the counted number for 2001 (17,400) has been multiplied with a factor 2 to evaluate the total number of vehicles in Hornsgatan.

[2] The station at Ermou street is located close to a roundabout. Even though 13,500 cars pass the station in the Ermou street, there is 22,500 cars passing close to the station when the roundabout is included.

1.2.3 Data analysis

The basic objective of subtask 3 is to study the excess concentrations at street hotspot (traffic) stations (DeltaC: street concentration minus UB concentration) calculated from carefully selected station pairs, to provide the basis for:

- evaluation of vehicle class emission factors, such as from COPERT
- comparison for dispersion/calculation models for street/road (line) configurations
- estimation of emission factors for resuspended road dust.

For the *validation of emission factors*, the following analysis of the data is carried out:

- The data collected from the station pairs include, to the extent available, hourly time series for an entire recent year, of concentrations, traffic parameters and meteorological parameters (as listed in section 1.2.2.2);
- To some extent, from some of the cities, some of the parameters are only available as daily data, or even annual data (i.e. for traffic parameters);
- From the data available, the following is calculated:
  - annual and monthly averages;
  - average variation over the hours of the day (24 hours) and maximum concentration per hour;
  - this calculation is made for separate periods: winter and summer, workdays and weekends. Such a distinction separation enables the evaluation of emission factors for light and heavy duty vehicles separately and also elucidates the effect of the re-suspension PM source, as separate from the vehicle exhaust source.

These calculations are made for combinations of data series, resulting in the following “end” results:

- concentration statistics for each time series separately (e.g. $PM_{2.5}$ at the street station and background station separately);
- “Delta concentrations” (“DeltaC”: street – background);
- “Delta ratios” (DRs): ratio between the DeltaCs, for each component compared to the DeltaNO_x.

In terms of providing the background for validation of emission factors, the DRs provide the main basis for comparison between the emission factors from various emission factor databases and the key results provided by the analysis in this report.

The DeltaC results themselves could also provide a basis for emission factor validation for individual streets, if a dispersion model for the street had already been validated, using for instance tracer substances emitted with known source strength.

For the *validation of line source dispersion models*, for street canyons or "open" street locations, the time series of concentrations and DeltaC provide the basis for this.

The database prepared under this project includes data from a number of carefully selected station pairs from various cities. The street canyons have different dimensions, the traffic amount varies over a large range and the climate/ meteorological conditions also vary over a large range. Therefore, this database enables the comparison of DeltaCs for various compounds ($PM_{2.5}$, PM_{10}, NO_x, NO_2, CO) for differing streets, traffic and dispersion conditions characterised by parameters such as e.g. height/width ratio, traffic speed, average wind and dispersion parameters.

1.2.4 Synthesis of results from the selected station pair data analysis

The purpose of this synthesis chapter is to present extracted and summarised data from each station pair considered suitable for comparison, in such a way which is appropriate and sufficient for use in further subtasks of the project.

1.2.4.1 Station metadata

This includes the following:
- street/building topography
- street and urban background station locations
- traffic characteristics of the street
- meteorology characteristics of the area
- measurement methods and QA/QC procedures

Table 1.4 summarises the essential station metadata.

Table 1.2. PM measurement methods.

Station pair	Method	Correction factor	Data used
Stockholm	TEOM		Uncorrected data used
London	TEOM	PM_{10}: 1.3 $PM_{2.5}$: 1.0	Corrected data used
Oslo	Street: TEOM Background: Partisol	PM_{10}: 1.1	Uncorrected data used
Berlin	Beta absorption	N/A	Corrected data used
Thessaloniki	Beta absorption		Uncorrected data used

Data quality

The quality of the data and the QA/QC procedures used to produce the final time series that were used in this project, is the reponsibility of the providers of the data. Many of the stations from which data were reported are stations which are also included in the AirBase database of the EEA-ETC/ACC. It was assumed that the quality of the air pollution concentration data was generally good and that proper QA/QC procedures had been used. When working with the data, to some extent the data were checked for peaks, holes, time consistency and other irregularities. Some problems were encountered and were evaluated to have little consequence to the correctness of the results obtained from analysing the time series.

Regarding the traffic data, it was concluded that the data quality needs to be checked. This is especially so for the data on the heavy duty (HDV) fraction.

Brief evaluation of the station pairs

Stockholm

The Hornsgatan station pair represents a well defined street canyon in a central urban area in a Scandinavian capital city, with 2-way traffic. The street has a gradient of about 2%. The background station is on a roof-top nearby and thus well located. The meteorological data are from this station. The compound and time coverage is good. NO_x, NO, NO_2 and CO are measured on both sides of the street. The measurements on the uphill side of the street were selected for this analysis, because the pollutant coverage was better there (as it included PM_{10} and $PM_{2.5}$ measurements). Time series were available for two years (2000 and 2001) and the year 2000 was selected because of the availability of $PM_{2.5}$ data and the otherwise fairly complete time series of the needed parameters. The traffic data covered only the uphill traffic. These data were multiplied by a factor 2, to obtain a good estimate for the full traffic volume in the street. Annual average daily traffic (AADT) is 34,800. Manual counting and automatic counting from periods when the traffic counters at all lanes were working properly showed that the traffic in the westerly direction is about 5% to 10% higher compared to the eastward traffic, as an annual average. Average speed is 45 km/h and the heavy duty fraction is 5%. The number of heavy duty vehicles in Hornsgatan are almost entirely ethanol fuelled city buses. The diesel (taxi) fraction of light duty vehicles is about 5%.

At this station pair, there is considerable contribution to PM_{10} from suspension of road dust, created by the use of studded (spiked) tyres on a substantial fraction (about 70%) of the light duty vehicles.

London

The Marylebone station pair represents a well defined, horizontal street canyon in central London, with 2-way traffic. The background station, Bloomsbury, is an urban background station and is located 2km east of Marylebone Rd., but was the closest urban background for which data was available. The meteorological data are from station 1.89 miles east of the Marylebone canyon. Its representativeness must be evaluated. Data were available for the years 2000 and 2001. The year 2000 was chosen because of the best coverage of pollutant compounds. $PM_{2.5}$ and ozone were measured at both stations. The traffic data are fairly complete and of good coverage. AADT is 85,500. The average traffic speed is about 40 km/h and the heavy duty fraction is 10.3%.

Berlin

The Frankfurter Allee station pair represents a well defined, horizontal street canyon in a central urban area, with 2-way traffic. Data is available for 2002. $PM_{2.5}$ is not measured, only PM_{10} measurements are available. The background station is at Neukölln, Nansenstrasse, 3.7 km away from Frankfurter Allee. Hourly traffic data include total vehicle count. The velocity is given as average speed for each hour and for each direction, there is no hourly data collected for Frankfurter Allee. The heavy duty fraction is given as a constant value. The AADT is 56,000, the average traffic speed is 40 km/h and the heavy duty fraction is 4.8%.

Thessaloniki

The Ermou pair repesents a situation where the street station is located at the mouth of a street where it enters into a round-about. The background station for NO_x and NO_2 is an urban background station located 700 meters away from the street station. The background station for PM_{10} is located outside town, thus this pair does not represent a well defined street configuration suitable for model testing, but the data can be used for DR calculations as a basis for validating emissions factors, providing the traffic flow passing near the station (which includes both the traffic in the Ermou street itself as well as the traffic in the roundabout) can be well defined in terms of traffic volume, speed and heavy duty fraction.

Oslo

The measurement campaign providing the data was carried out to measure the concentrations as a function of distance from the road. The pair represents a well defined horizontal highway situation with high traffic speed (average about 90 km/h) in a suburban area. The concentrations were measured at 3 distances downwind of the main wind direction and at a background station well upwind of the road. Here the measurements span only about 3 months (winter conditions). Meteorological and traffic data are fully covered. AADT is 35,900, the average speed is 91 km/h and the heavy duty fraction is 6.0 %.

A shortcoming here is that, due to the fact that not enough instruments were available, the PM_{10} at the background station was measured as 12-hour averages and not hourly, as was done at the road station.

As in Stockholm, a fraction of the vehicles use studded tyres, so there is a significant contribution to PM concentrations from suspension of road dust originating from the wear of the road surface (asphalt) by the tyres. The fraction of cars using studded tyres in Oslo was about 25% in 2002, while in Stockholm this fraction is much higher, about 70%.

Table 1.3. Overview of stations pair metadata.

City	Year	Station pair		Street topography			Traffic			Meteorology[a] (annual average)	
		Street	Background	Width (m)	Building height (m)	No. of traffic lanes	AADT veh/day	Aver. speed (km/h)	HDV fraction (%)	Wind speed (m/s)	Temp (°C)
Stockholm	2000	Hornsgatan	Roof	22	20	4	34,800	47	5.0	3.5	10.7
London	2000	Marylebone Rd.	Bloomsbury	35	22	6	85,500	40	10.3	5.2	12.2
Oslo	2002	Skaarersletta	Nordby	19.4	0	4	35,900	91	6.0	1.2	0.1
Thessaloniki	2001	Ermou	University, Thessaloniki	40[b]	25	4	22,500	19	9.6	2.1	17.3
Berlin	2002	Frankfurter Allee	Neukoelln station	42	21	6	56,000	40	4.8	2.9	9.8

[a] Representative for the area where the station pair is located.
[b] Station located at end of street canyon.

1.2.4.2 Synthesis of air pollution concentrations

Annual averages

Table 1.4 gives summarised long term averaged data (annual averages, or in case of Oslo, winter average), for DeltaC and DRs, for the station pairs with such data available so far.

The fairly large differences in DeltaC values reflect mainly the differences in AADT and whether it is a street canyon or open road, as well as the vehicle speed and the heavy duty vehicle (HDV) fraction and also differences in the average wind speed. For PM_{10}, the differences between station pairs also reflect the use (or not) of studded tyres.

Note that the PM_{10} data made available for the SEC project is not entirely consistent in terms of correction factors for measurements methods. London and Berlin data has been corrected, the other station data were delivered uncorrected. This obviously affects the DR for PM_{10} and needs to be considered when comparing the DR from the different station pairs.

In the DR values, the AADT, street configuration and wind speed differences are in principle eliminated and the differences should reflect the differences in average emission factor ratios for the traffic flows due to differences in speed and HDV fraction.

The DR values for $PM_{2.5}$ for Marylebone Rd. are some 20% higher than in Hornsgatan. The traffic speed is about the same in the two streets. HDV fraction is twice higher in Marylebone (and in Hornsgatan the HDV vehicles are dominated by buses run on ethylene with low PM emissions) while the road dust contribution should be higher in Hornsgatan because of the studded tyres used there. These two influences seem to be of the same magnitude and even each other out on the annual scale.

The DR values for NO_2 cover quite a large range. The DR is lowest in Marylebone Rd. and highest in Ermou Street, more than 3 times higher. The delta values and DRs for NO_2 are affected by the ozone concentrations in the area and in the street air, which is again affected by the road configuration (street canyon or not), which needs to be taken into account when comparing DRs for NO_2 in different streets.

The DR values for PM_{10} are high in Hornsgatan and Skaarer near Oslo, as expected, where studded tyres are used. It is also surprisingly high in Frankfurter Allee in Berlin.

The DR values are studied in more detail in the section below, based upon short-term data.

Hourly averages

Table 1.5 gives summarised short-term averaged data for DeltaC and DRs for the Stockholm, Oslo, London and Berlin station pairs.

DR values are given for 4 traffic situations: winter workdays and weekend days and summer workdays and weekend days. By doing this, the effects on emission factors by temperature and road dust emission can be studied. Also, by separating workdays from weekend days, differences due to HDV fraction differences can be studied, enabling validation of light duty and HDV emission factors separately.

In Figures 1.6 – 1.9, DeltaC and DR data (relative to NO_x), are shown for Hornsgatan Stockholm, Marylebone Rd. London, Frankfurter Allee Berlin and Skaarersletta near Oslo. Data are presented in terms of average numbers per hour-of-day, for winter and summer conditions and workdays and weekend days separately.

In Figures 1.10 – 1.13, data from these plots are extracted further, to give the average of the DRs for the middle 6 hours of the day (typically 10-15 o' clock, but can be one hour earlier or later, depending on the rush hours of the particular case study/street), for each of the season/workday-weekend combinations. This is shown for Hornsgatan, Marylebone Rd., Frankfurther Allee and Skaarersletta. The 6 middle-of-the-day hours have been selected to exclude the rush hours as well as with a view to the variation of the DRs over the day, so that a period with the smallest inter-hour variation in the DR is selected. This is done to select a period with as stable conditions as possible both regarding emissions and atmospheric conditions. The result of this is that the DRs will then be representative for emission and atmospheric conditions which can be reasonably well characterised, again enabling a better comparison with emission factor measurement/model based ratios.

There are significant differences in DRs between the four station pairs. Many of these are explained by the differences in traffic parameters and conditions, while some differences are surprising.

First we can compare Hornsgatan with Marylebone Rd., which have similar traffic speed, but Marylebone has twice the HDV fraction:

- The summer $PM_{2.5}$ DRs are much higher for Marylebone than for Hornsgatan, while the winter DRs are quite similar. The higher summer DRs in Marylebone could be explained by the higher HDV fraction (as well as the fact that the buses in Hornsgatan are ethanol fuelled). The similar winter DRs might be explained, considering that the re-suspension source should be much larger in the studded tyre city of Stockholm than in London, while the HDV fraction is higher in Marylebone.
- For PM_{10}, however, the summer DRs are not so different in the two cities (still more road dust in Stockholm?), while, as expected, the winter DR is much higher in Stockholm (more than 3 times higher!), again due to the road dust source.
- For NO_2, surprisingly, the DRs are higher in Stockholm than in London (while Marylebone in London has double the HDV fraction and is more southerly as well). Both places, the summer DR is higher than the winter DR, possibly reflecting the higher available ozone concentration in summer. The DRs are not much different on weekends than on workdays.

Frankfurter Allee in Berlin has 5% HDV fraction, same as in Hornsgatan, while Marylebone has 10%. The traffic speed in Frankfurter Allee is similar to the other streets.

- Frankfurter Allee has about twice as high PM_{10} DR compared to Marylebone. It would be interesting to test this result against emission factor models, that this is the result of the lower HDV fraction.

- Frankfurter Allee also has much higher NO_2 DR compared to Marylebone Rd.. Also this result should be tested against emission factor models. The differences between workday and weekend DRs are larger than in Marylebone Rd., and are similar to those for Hornsgatan.

At the Skaarer station pair, the PM_{10} DR for winter conditions is high, as expected due to use of studded tyres and at about the same level as in Hornsgatan in Stockholm. In Oslo, the fraction of cars using studded tyres was about 25% in 2002, while in Stockholm it was considerably higher in 2000 (about 70%). That the PM_{10} DR still is about the same at Skaarer reflects the higher traffic speed there (91km/h as opposed to 45 km/h in Hornsgatan). Higher speed causes increased road wear and road dust emissions. The NO_2 winter workday DR is lower than in Hornsgatan, while the weekend DR is a bit higher than in Hornsgatan. The effect of the open road configuration at Skaarer compared to the Hornsgatan street canyon will be evaluated. It would, however, be interesting to test this result against emission factor models, whether this difference can be explained by the differences in speed and HDV fractions in the two streets.

The emission factor for re-suspension of road dust can be estimated by comparing the DR from PM_{10} verses the $PM_{2.5}$, looking at differences between winter and summer. Considering the difference between the Scandinavian stations and stations in other countries, the re-suspension factor related to the use of studded tyres can be estimated. As the SEC project data become more complete, including more station pairs and $PM_{2.5}$ data, this will enable the estimation of an emission factor for re-suspension factors.

These results are compared to emission factor ratios from emission factor models in section 1.3. Additional data from further inclusion of street pairs will provide an improved basis for emission factor validations.

1.2.4.3 Estimation of the PM re-suspension source

The DR values for PM_{10} relative to those for $PM_{2.5}$ give a basis for estimating the re-suspension source.

In Marylebone Rd., with no studded tyres (Figure 1.12), the DR for $PM_{2.5}$ and PM_{10} are both about the same for summer and winter, indicating that the PM sources in the street (vehicle exhaust, brake and tyre wear and dust re-suspension) are of about the same magnitude compared to the NO_x emissions irrespective of season (it is not likely that the average NO_x emissions factor differs much between summer and winter).

The DR for PM_{10} is 1.75 times higher than the DR for $PM_{2.5}$ in the summer and 2.08 times higher in the winter, averaged about 1.90 times higher. This gives the estimate that the re-suspension PM_{10} source in Marylebone Rd. is of about equal magnitude as the other particle sources (exhaust, brake and tyre wear). It will be further evaluated whether the summer/winter difference in this factor is significant and could be explained.

In Frankfurter Allee in Berlin, where studded tyres are also not used (Figure 1.11), there is also no summer-winter difference in the DR for PM_{10}. Here $PM_{2.5}$ has not been measured throughout the year, but results from shorter campaigns here could be looked into. The DR for PM_{10} is more that 2 times higher than in Marylebone Rd. in London. This, combined with the lower HDV fraction in Frankfurter Allee, indicates a much larger non-exhaust/re-suspension PM source there than in Marylebone Rd..

Looking at Hornsgatan in Stockholm with studded tyres use (Figure 1.10), there are large winter-summer differences in DR, especially for PM_{10}, but also for $PM_{2.5}$. Road dust re-suspension in streets where studded tyres are used affect also the $PM_{2.5}$ level. The DR for $PM_{2.5}$ is 1.5 higher in winter than in summer.

The DR for PM_{10} is, averaged over all days, 3.3 times higher than DR for $PM_{2.5}$ in summer and 6.5 times higher in winter. The DR for PM_{10} is 3.0 times that in the summer, averaged over all days.

This indicates a road dust re-suspension source in Hornsgatan which is responsible for a considerable $PM_{2.5}$ emission even in summer and a very strong PM_{10} emission in winter and a significant source also in summer.

These estimates of the magnitude of the PM re-suspension source compared to the exhaust/brake/tyre wear PM source will be studied further, as soon as data from Goettinger Strasse and Helsinki have also been analysed. Based upon such analysis the re-suspension source can be quantified relative to the exhaust/brake/tyre wear source.

Table 1.4. Synthesis of long-term average data.

Street	Period	AADT (veh./day)	Speed (km/h)	HDV (%)	WS (m/s)	DeltaC (Street – background)[a] (μg/m^3)				Delta ratios		
						NO_x	NO_2	$PM_{2.5}$	PM_{10}	$PM_{2.5}/NO_x$	PM_{10}/NO_x	NO_2/NO_x
Hornsgatan	Year 2000	34,800	45	5.0		155	29.8	5.2	24.5	0.033	0.158	0.192
Skaarersletta	Winter 2002	35,900	90	6.0		104[b] 144[c]	14.3[b] 19.7[c]	-	31.3[c]	-	0.217	0.14[b] 0.14[c]
Marylebone Rd.	Year 2000	85,500	40	10.3		305	33.7	11.7	20.5	0.038	0.067	0.110
Ermou Street	Year 2001	22,500	20	9.6		39.6	15.7	-	36.9[d]	-		0.396
Frankfurter Allee	Year 2002	56,000	45	4.8		59	16.5	-	9.6	-	0.163	0.279

[a] Difference between annual average at street station and annual average at background station.
[b] Based on hourly data.
[c] Based on 12 hours average data (daytime only).
[d] Background station for PM_{10} at Thessaloniki is outside town and hence not suitable for this study.

Table 1.5. Synthesis of short-term average data (hour, day).

Street	Period	DeltaC (Street – background)[a] (µg/m³)				Delta ratios			Limit value indicators, annual based			
		NO_x	NO_2	$PM_{2,5}$	PM_{10}	$PM_{2,5}/NO_x$	PM_{10}/NO_x	NO_2/NO_x	NO_2 –18. hour	PM_{10} –35. day	$PM_{2.5}$ –35. day	PM_{10} –7. day
Hornsgatan 2000	Summer Workdays	237	48.0	7.2	23.3	0.030	0.098	0.202	136	88	21	127
	Summer Weekend	138	34.4	3.1	10.7	0.023	0.078	0.249				
	Winter Workdays	271	40.9	10.9	67.8	0.040	0.251	0.151				
	Winter Weekends	180	29.5	7.9	55.1	0.044	0.306	0.165				
Skaarersletta Jan – Mar 2002	Winter Workdays	159	18.4	-	-	-	-	0.117	84[b]	41 [b]	-	84 [b]
	Winter Weekends	60.1	10.7	-	-	-	-	0.179				
Marylebone Rd. 2000	Summer Workdays	460	61.7	18.7	34.2	0.041	0.075	0.134	239	67	37	89
	Summer Weekend	214	29.4	9.9	16.4	0.047	0.077	0.138				
	Winter Workdays	400	44.5	15.6	31.0	0.039	0.078	0.111				
	Winter Weekends	212	37.4	7.9	17.2	0.037	0.081	0.106				
Ermou Street 2001									173	53	-	117

Frankfurter Allee 2002	Summer Workdays	97.9	34.1	-	15.9	-	0.16	0.35	127	162	-	227
	Summer Weekend	45.6	20.5	-	8.4	-	0.19	0.45				
	Winter Workdays	107.4	21.3	-	19.7	-	0.18	0.20				
	Winter Weekends	50.6	11.9	-	8.9	-	0.18	0.23				

[a] Delta for each separate hour, then averaged over the included hours.
[b] Only from 4 winter months.

Hornsgatan, Stockholm

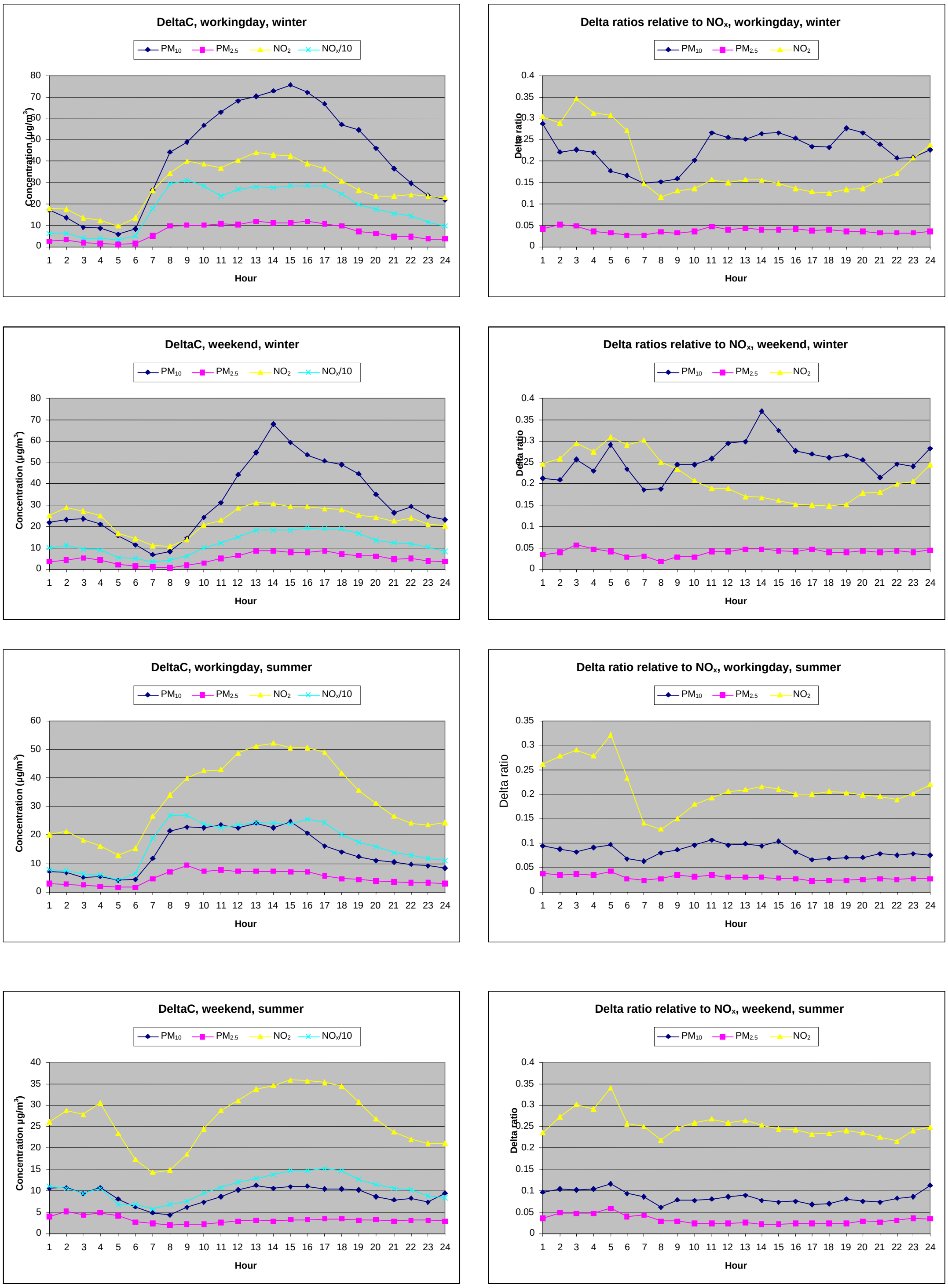


Figure 1.6. Average concentration variation over the day, Hornsgatan, Stockholm, DeltaC and delta ratio (DR) relative to NO_x.

Marylebone Rd., London

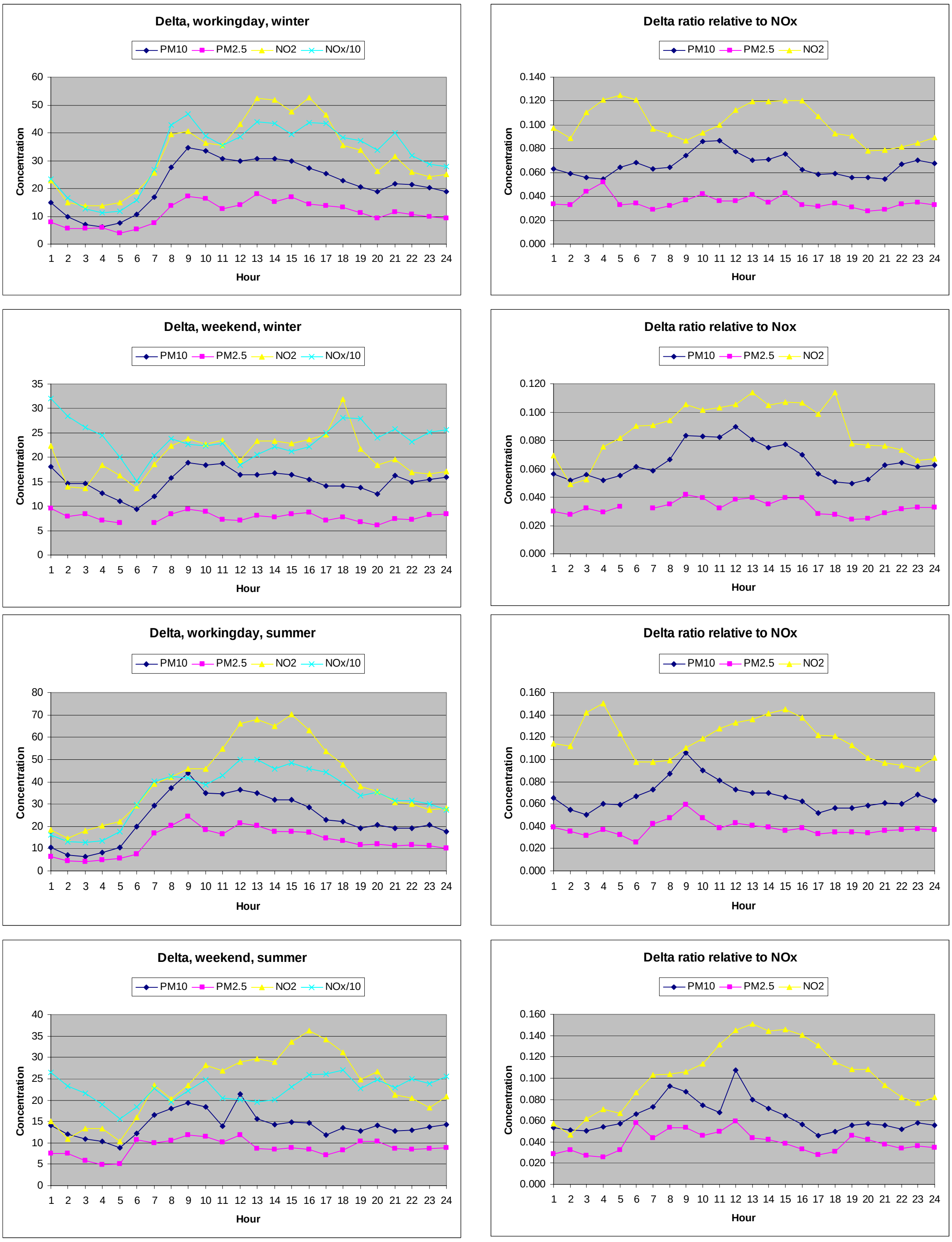


Figure 1.7. Average concentration variation over the day, Marylebone Rd., London, DeltaC and delta ratio relative to NO_x.

Frankfurter Allee, Berlin

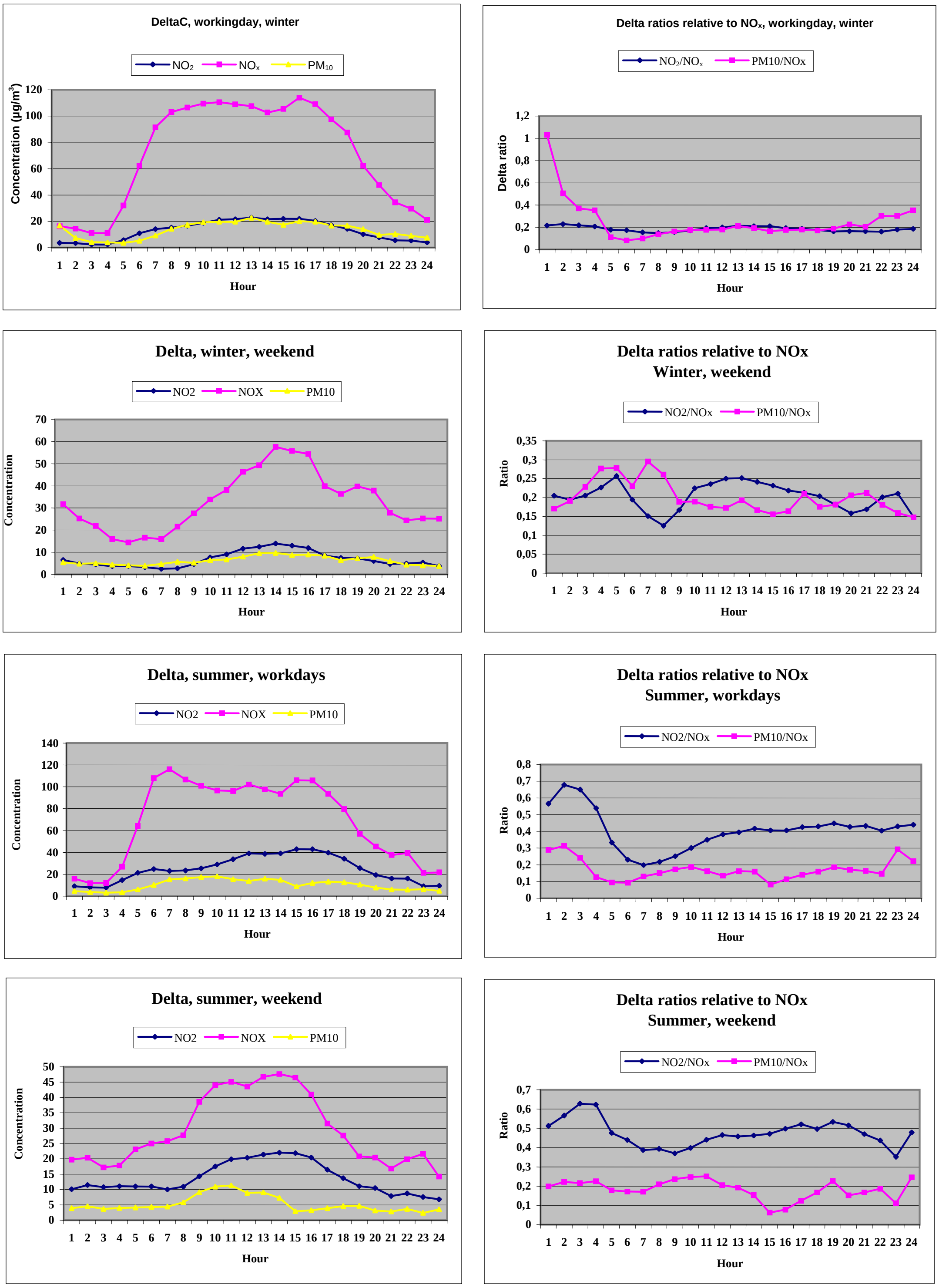


Figure 1.8. Average concentration variation over the day, Frankfurter Allee, Berlin, DeltaC and delta ratio relative to NO_x.

Skaarersletta, Oslo

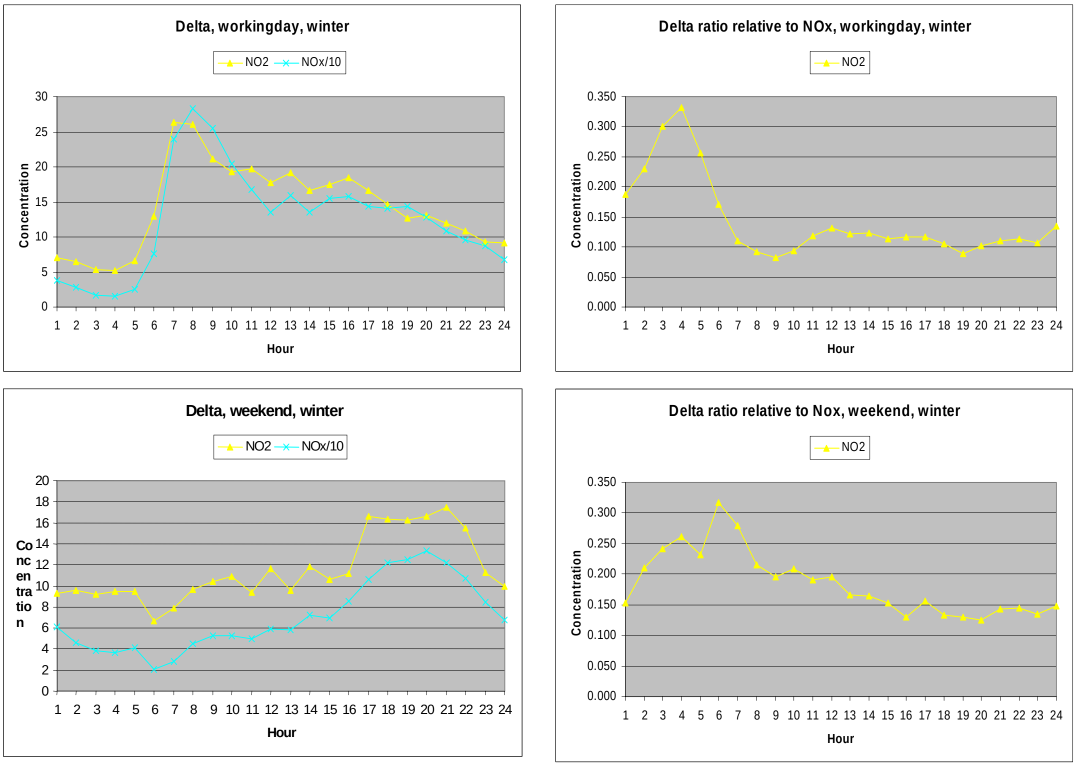


Figure 1.9. Average concentration variation over the day, Skaarersletta, Oslo, DeltaC and delta ratio relative to NO_x. These graphs are for only four months of data (January – April).

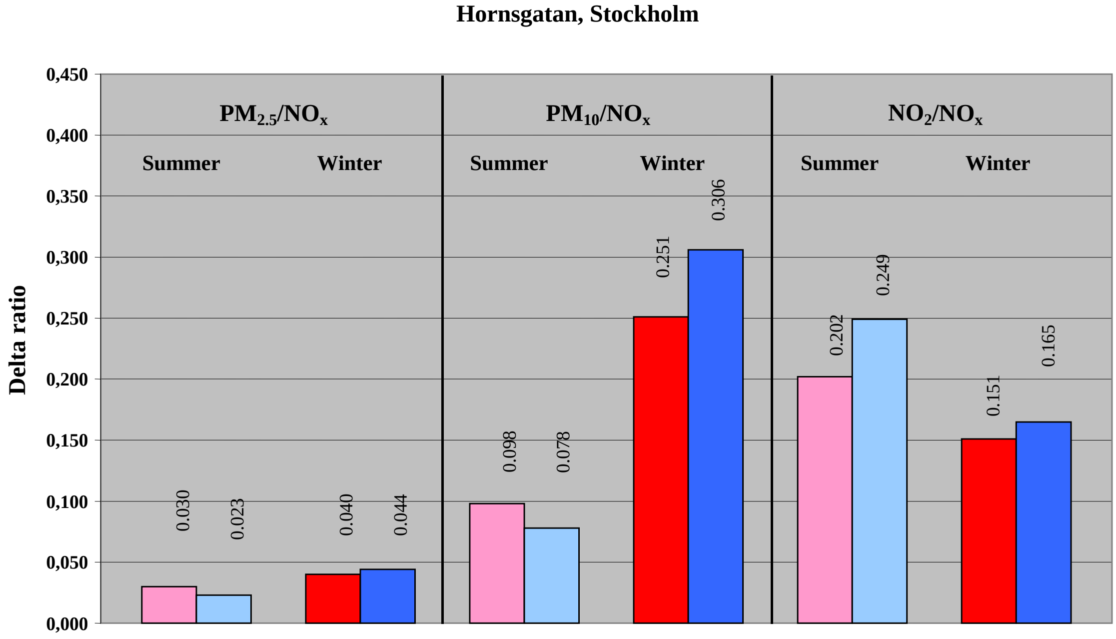


Figure 1.10. Delta ratios for $PM_{2.5}$, PM_{10} and NO_2 relative to NO_x, for Winter and Summer conditions at Hornsgatan. Red columns: workdays. Blue columns: weekend days.

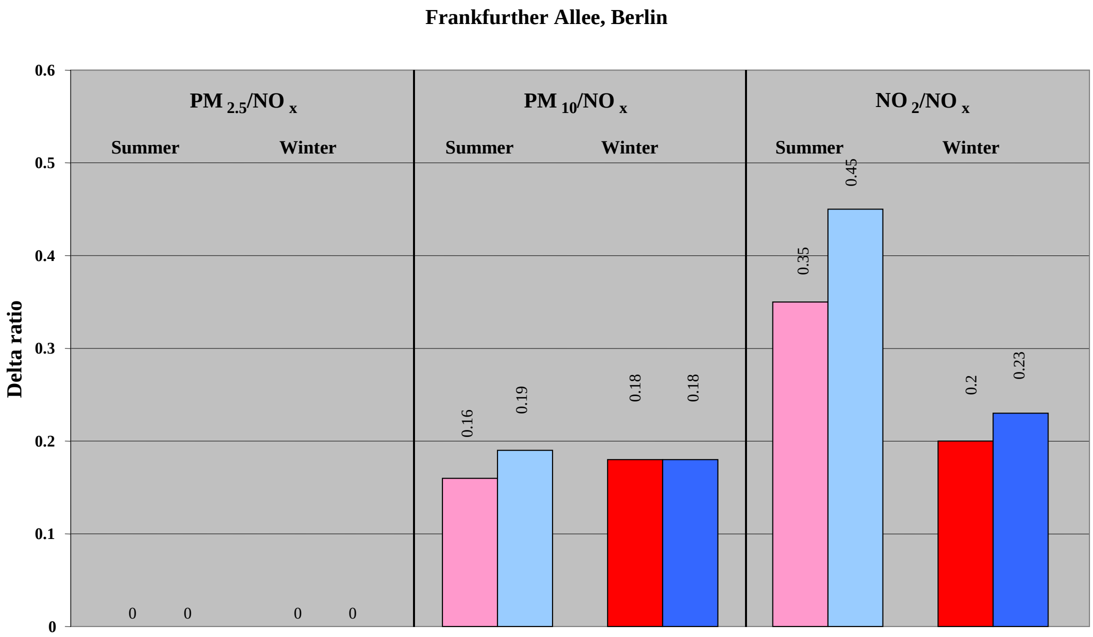


Figure 1.11. Delta ratios for PM_{10} and NO_2 relative to NO_x, for Winter and Summer conditions at Frankfurter Allee. Red columns: workdays. Blue columns: weekend days.

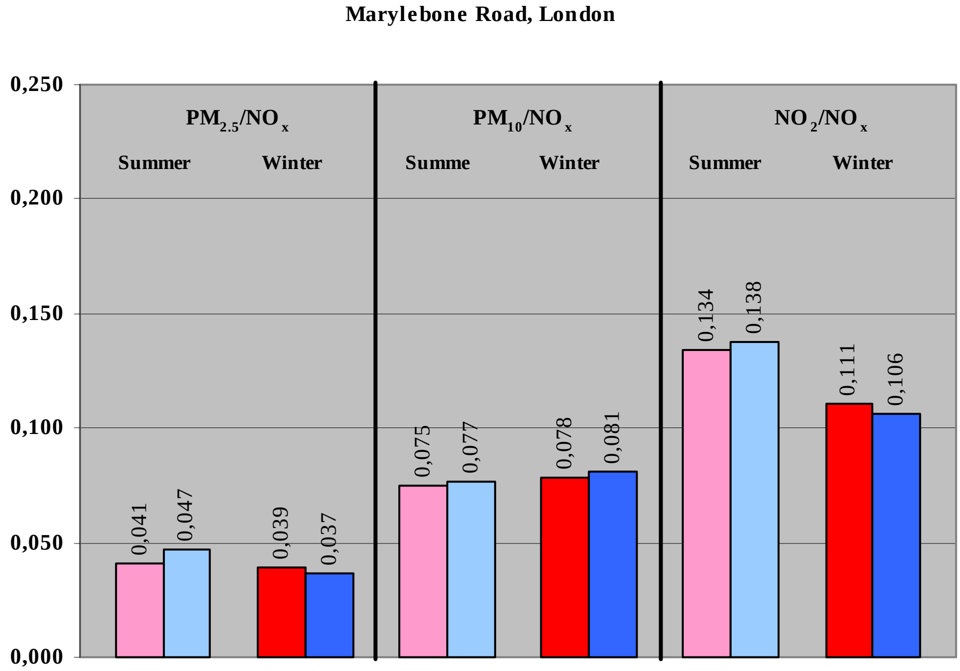


Figure 1.12. Delta ratios for $PM_{2.5}$, PM_{10} and NO_2 relative to NO_x, for Winter and Summer conditions at Marylebone Rd. Red columns: workdays. Blue columns: weekend days.

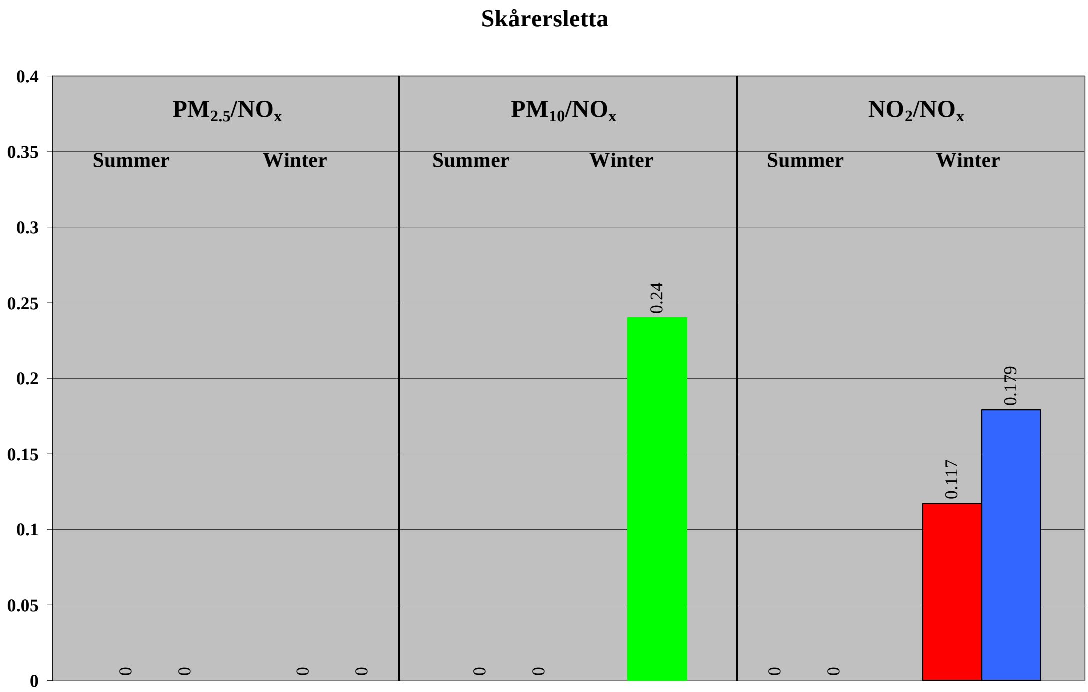


Figure 1.13. Delta ratios for PM_{10} and NO_2 relative to NO_x, for Winter conditions at Skaarersletta. Red columns: workdays. Blue columns: weekend days. Green column: whole all weekdays.

1.3 Local emission estimates

1.3.1 Introduction

The present subtask aims at contributing to the analysis of excess concentrations by providing data derived from emission estimation models to be compared with monitored data. For the interpretation of the analysis of excess concentrations in terms of local emission estimates, the application of the COPERT 3 methodology for the estimation of street emissions from road transport has been used. For this purpose a local scale calculation module was derived from COPERT, which was able to account for street level activity data. Traffic data monitored at the selected street stations (traffic volume and speed, vehicle composition) are used as input to the calculation module. The traffic volume is usually split into two major vehicle types, i.e. passenger cars and heavy duty vehicles (HDV), differentiated by the different vehicle length. In order to further distribute the number of cars monitored into all COPERT categories, accounting thus for the various vehicle classes and technologies, results from the TRENDS model were also used.

1.3.2 Hornsgatan, Stockholm

1.3.2.1 Basecase

Using the composition of the Swedish vehicle fleet for the year 2000 extracted from the TRENDS database, the share of each vehicle category is derived. The detailed monthly (Table A.1) and hourly (Tables A.2 & A.3) distribution of traffic into the various vehicle categories is presented in Annex A. (Note: The tables in Annex A are based upon the provided total traffic data, which cover only the traffic in one (the uphill) direction. In Figures 1.14-1.21 and the calculations on which these are based, this traffic is multiplied by 2, to account for the traffic in both directions).

As the street canyon is located in downtown Stockholm, it is assumed that only HDV with a Gross Vehicle Weight (GVW) lower than 16 tonnes were allowed, i.e. the share of HDV with a GVW of 16-32 tonnes and over 32 tonnes was set equal to zero. The 20% share of buses as part of total HDV, given by the TRENDS model, agrees well with the traffic counts in Hornsgatan, which gives 23% (Christer Johansson, personal communication). Added to this, all buses are run on ethanol, which was taken into account using appropriate emission factors. In total, six sets of runs were performed with COPERT, five for the hourly distribution and one for the monthly distribution of traffic emissions. The basic set of runs takes all days of the year into account for the calculations. Two more sets of runs were performed differentiating between workdays and weekends during winter time and another two for summer time. An additional set of runs was performed for the monthly distribution of traffic emissions, considering all days of the year. From the monitored traffic data, average hourly and monthly data were derived for the number of passenger cars, the heavy duty fraction and the average vehicle speed. For the calculations performed, the mileage of the vehicles was set equal to the length of the street canyon (160 m).

As an example of the COPERT application, the composition of the HDV, buses and coaches fleet in January, as its results from the TRENDS database, is presented in Table 1.6 showing the split in the various weight and classes according to legislation.

Table 1.6. Heavy Duty Vehicles, buses and coaches composition, estimated from the TRENDS database for Hornsgatan, Stockholm, for January.

Type	Class	Legislation	Jan
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0
	Diesel 3,5 - 7,5 t	Conventional	6203
		Euro I - 91/542/EEC Stage I	1441
		Euro II - 91/542/EEC Stage II	2063
		Euro III - 2000 Standards	0
	Diesel 7,5 - 16 t	Conventional	6815
		Euro I - 91/542/EEC Stage I	1583
		Euro II - 91/542/EEC Stage II	2266
		Euro III - 2000 Standards	0
	Diesel 16 - 32 t	Conventional	0
		Euro I - 91/542/EEC Stage I	0
		Euro II - 91/542/EEC Stage II	0
		Euro III - 2000 Standards	0
	Diesel >32t	Conventional	0
		Euro I - 91/542/EEC Stage I	0
		Euro II - 91/542/EEC Stage II	0
		Euro III - 2000 Standards	0
Buses - Coaches	Urban Buses	Conventional	3231
		Euro I - 91/542/EEC Stage I	315
		Euro II - 91/542/EEC Stage II	409
		Euro III - 2000 Standards	0
	Coaches	Conventional	808
		Euro I - 91/542/EEC Stage I	79
		Euro II - 91/542/EEC Stage II	102
		Euro III - 2000 Standards	0

The calculated year averaged hourly vehicle emissions of CO, NO_x and $PM_{2.5}$ and the measured DeltaCs of NO_x and $PM_{2.5}$ are presented in Table 1.7. As practically all PM emitted by road vehicles are in the fine fraction, the entire PM emissions are considered as $PM_{2.5}$ and thus PM_{10} emissions are not separately examined in the present study, since the results will be identical to $PM_{2.5}$. From the above emissions and DeltaCs, $PM_{2.5}$ over NO_x and CO over NO_x emission ratios are produced, on an hourly basis and are presented in the same table. It has to be noted that the emissions calculated include hot emissions only as it is assumed that the cold start effect should be negligible in the specific street canyon.

In order to assess the differences between working days and weekends, as well as between summer and winter, hourly emission values and derived ratios are presented in Table 1.8 and Table 1.9.

Table 1.10 shows the calculated monthly variations in the mean hourly traffic emissions of CO, NO_x and $PM_{2.5}$ and the atmospheric concentration deltas of NO_x and $PM_{2.5}$. The derived $PM_{2.5}$ over NO_x ratios are also shown.

Table 1.7. Calculated hourly year averaged traffic emissions versus monitored hourly year averaged delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (µg/m^3)		
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
01:00	435.9	108.8	1.8	0.017	4.007	77.8	3.0	0.039
02:00	382.0	103.8	2.1	0.021	3.682	78.6	3.4	0.043
03:00	306.7	86.4	1.9	0.023	3.549	62.4	2.9	0.046
04:00	262.9	76.2	1.7	0.023	3.451	63.4	2.6	0.041
05:00	191.5	57.2	1.5	0.026	3.347	42.1	1.9	0.045
06:00	219.3	63.8	1.6	0.025	3.435	57.6	1.7	0.030
07:00	618.6	160.3	3.5	0.022	3.859	141.9	3.9	0.027
08:00	1206.8	276.1	6.5	0.024	4.370	208.7	6.3	0.030
09:00	1328.9	300.5	7.4	0.025	4.422	215.0	7.2	0.033
10:00	1183.1	276.7	7.0	0.025	4.275	209.7	6.8	0.032
11:00	1327.0	305.5	7.6	0.025	4.344	195.3	7.4	0.038
12:00	1521.6	334.9	8.4	0.025	4.544	208.7	7.4	0.035
13:00	1698.8	361.7	8.9	0.025	4.697	223.6	8.0	0.036
14:00	1739.1	370.3	9.1	0.025	4.697	223.2	8.2	0.037
15:00	1819.4	383.7	9.4	0.024	4.741	225.7	8.0	0.035
16:00	1990.4	412.6	10.1	0.024	4.824	232.2	8.2	0.035
17:00	2037.0	411.5	9.7	0.024	4.950	224.5	7.3	0.033
18:00	1791.3	363.9	7.9	0.022	4.923	196.2	6.2	0.032
19:00	1467.6	307.8	6.1	0.020	4.768	167.4	5.4	0.032
20:00	1159.8	253.6	4.9	0.019	4.573	150.0	4.8	0.032
21:00	1002.9	217.9	3.8	0.017	4.602	131.8	4.0	0.030
22:00	942.1	204.7	3.5	0.017	4.602	126.0	4.0	0.032
23:00	731.8	163.9	2.8	0.017	4.465	109.1	3.6	0.033
24:00	599.1	139.5	2.3	0.017	4.295	95.9	3.3	0.034

Table 1.8. Calculated hourly average traffic emissions and associated emission ratios for summer and winter working days in Hornsgatan, Stockholm.

	Workdays - summer					Workdays - winter				
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**
01:00	533.2	128.3	2.2	0.017	4.156	458.6	108.7	1.9	0.018	4.220
02:00	349.4	90.2	1.6	0.018	3.873	328.1	82.8	1.4	0.017	3.964
03:00	285.4	80.5	1.8	0.022	3.544	260.5	71.6	1.6	0.023	3.636
04:00	205.9	61.3	1.5	0.024	3.360	194.0	56.2	1.4	0.025	3.453
05:00	171.7	52.2	1.3	0.025	3.291	168.7	49.5	1.3	0.025	3.407
06:00	129.1	41.2	1.1	0.027	3.132	132.6	40.0	1.2	0.029	3.312
07:00	201.0	59.6	1.6	0.026	3.372	190.4	54.1	1.5	0.028	3.517
08:00	763.2	196.6	4.6	0.024	3.881	792.0	194.4	4.4	0.023	4.075
09:00	1503.6	337.3	8.6	0.025	4.457	1646.2	345.5	9.0	0.026	4.764
10:00	1601.8	361.4	9.9	0.027	4.432	1835.2	382.2	10.4	0.027	4.802
11:00	1332.8	315.8	8.9	0.028	4.220	1388.9	318.6	9.0	0.028	4.359
12:00	1415.2	335.6	9.5	0.028	4.216	1409.6	328.9	9.3	0.028	4.286
13:00	1551.8	353.6	10.1	0.029	4.388	1546.5	344.3	10.0	0.029	4.492
14:00	1618.0	363.8	10.0	0.027	4.448	1704.5	365.9	10.4	0.028	4.658
15:00	1682.1	373.8	10.4	0.028	4.500	1746.2	380.1	10.6	0.028	4.594
16:00	1785.3	392.6	10.9	0.028	4.547	1852.4	395.3	10.9	0.028	4.686
17:00	2008.8	432.7	12.2	0.028	4.643	2127.7	442.6	12.2	0.028	4.808
18:00	2096.3	434.6	11.6	0.027	4.824	2127.7	422.3	11.5	0.027	5.038
19:00	1830.3	379.2	9.2	0.024	4.826	1874.4	369.8	8.9	0.024	5.069
20:00	1474.0	316.3	6.8	0.021	4.660	1512.2	308.8	6.6	0.021	4.897
21:00	1175.2	262.5	5.4	0.021	4.476	1189.0	256.1	5.0	0.020	4.644
22:00	1020.6	224.1	4.1	0.018	4.553	1011.4	216.2	3.8	0.017	4.679
23:00	966.9	211.5	3.8	0.018	4.571	943.4	202.0	3.6	0.018	4.670
24:00	761.6	172.4	3.2	0.018	4.418	699.1	156.0	2.7	0.017	4.482

Table 1.9. Calculated hourly average traffic emissions and associated emission ratios for summer and winter weekends in Hornsgatan, Stockholm.

	Weekends - summer					Weekends - winter				
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**
01:00	719.0	162.4	2.6	0.016	4.428	725.6	162.2	2.7	0.016	4.473
02:00	630.5	148.2	2.4	0.016	4.255	671.4	153.6	2.5	0.016	4.370
03:00	620.1	160.4	3.0	0.019	3.867	682.7	165.8	3.3	0.020	4.118
04:00	515.4	137.9	2.5	0.018	3.738	669.6	162.6	3.2	0.020	4.118
05:00	458.9	127.7	2.4	0.018	3.594	495.3	129.3	2.5	0.019	3.832
06:00	289.5	84.4	1.8	0.022	3.429	302.7	84.0	1.9	0.022	3.603
07:00	215.4	66.4	1.7	0.025	3.246	210.4	62.6	1.6	0.026	3.358
08:00	175.9	49.1	1.0	0.020	3.580	188.7	49.8	1.1	0.021	3.787
09:00	226.0	59.7	1.3	0.021	3.788	243.4	61.8	1.4	0.022	3.937
10:00	321.8	81.8	1.6	0.020	3.934	334.3	83.2	1.7	0.020	4.017
11:00	519.1	126.5	2.6	0.020	4.104	535.1	128.8	2.6	0.020	4.155
12:00	832.1	190.7	3.7	0.019	4.363	857.3	194.3	3.8	0.020	4.412
13:00	1139.9	249.3	4.5	0.018	4.572	1190.9	254.0	4.7	0.019	4.688
14:00	1494.6	314.4	5.6	0.018	4.754	1487.9	301.8	5.5	0.018	4.930
15:00	1553.3	325.7	5.6	0.017	4.769	1636.9	325.0	5.9	0.018	5.037
16:00	1580.3	329.4	5.8	0.018	4.798	1668.4	331.3	6.0	0.018	5.037
17:00	1558.6	328.8	5.7	0.017	4.740	1691.2	333.7	6.0	0.018	5.068
18:00	1507.8	318.2	5.6	0.018	4.739	1615.1	323.3	5.9	0.018	4.996
19:00	1325.9	280.7	5.1	0.018	4.723	1423.1	291.3	5.4	0.019	4.885
20:00	1146.3	245.4	4.4	0.018	4.672	1213.0	254.8	4.6	0.018	4.760
21:00	928.0	203.8	3.6	0.017	4.553	981.8	211.6	3.7	0.018	4.639
22:00	811.6	176.9	2.9	0.016	4.587	981.8	211.6	3.7	0.018	4.639
23:00	780.9	172.0	2.9	0.017	4.540	771.0	168.6	2.8	0.017	4.574
24:00	617.5	139.8	2.3	0.017	4.415	595.8	134.4	2.3	0.017	4.432

Table 1.10. Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (μg/m^3)		
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
January	984.9	217.8	5.1	0.023	4.523	168.6	4.1	0.024
February	1068.0	233.5	5.7	0.025	4.573	179.2	6.2	0.035
March	1083.7	237.7	5.3	0.022	4.559	181.6	10.8	0.059
April	1032.0	227.6	4.9	0.022	4.534	180.6	6.8	0.038
May	1084.8	242.4	5.5	0.023	4.476	152.6	5.6	0.037
June	983.1	223.3	5.3	0.024	4.402	141.7	3.5	0.025
July	807.3	194.8	4.7	0.024	4.145	150.1	4.6	0.031
August	1020.5	236.9	6.1	0.026	4.307	167.5	4.7	0.028
September	1077.2	238.3	5.6	0.023	4.519	194.5	5.6	0.029
October	1096.5	239.8	5.5	0.023	4.572	110.4	3.2	0.029
November	1118.3	240.7	5.5	0.023	4.645	104.4	3.7	0.035
December	1018.6	220.3	5.0	0.023	4.623	132.2	3.4	0.026

Figure 1.14 shows the hourly variation over the day of the $PM_{2.5}$ over NO_x concentration ratio against the respective calculated emission ratio. Overall, the modelled emission ratio is lower than the respective calculated concentration ratio. The PM emissions calculated with COPERT do not take into account possible re-suspension of road dust (but only exhaust emissions) and, as a result, the PM emissions calculated might be underestimated. This could explain the generally lower ratio as compared to the respective concentration ratio.

In Figure 1.15, the summer – winter and working days – weekend effects are shown. As expected, the $PM_{2.5}$ over NO_x emission ratio is lower during the weekends, which is consistent with traffic without (or very low) HDV share. On the other hand workdays are associated with higher $PM_{2.5}$ over NO_x emission ratios. The effect of the season is negligible in the calculated emission ratios.

In Figure 1.16, the variation over the year in monthly averages of the concentration ratio between the deltas of $PM_{2.5}$ and NO_x are plotted against the respective calculated emission ratio. This figure provides an explanation for the underestimation shown in Figure 1.14. For the concentration ratio, a seasonal variation is observed (quite stable during summer and almost double in the winter months), which can most probably be attributed to road dust re-suspension during winter, particularly in February-April. In contrast to this, the calculated $PM_{2.5}$ over NO_x emission ratio varies only with the traffic and thus the seasonal variations due to climate and other conditions are not reproduced.

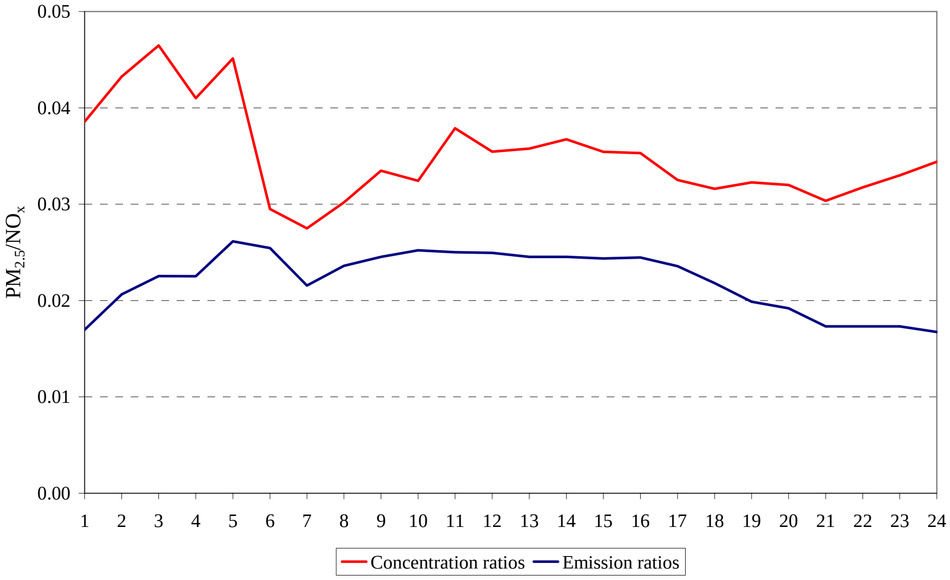
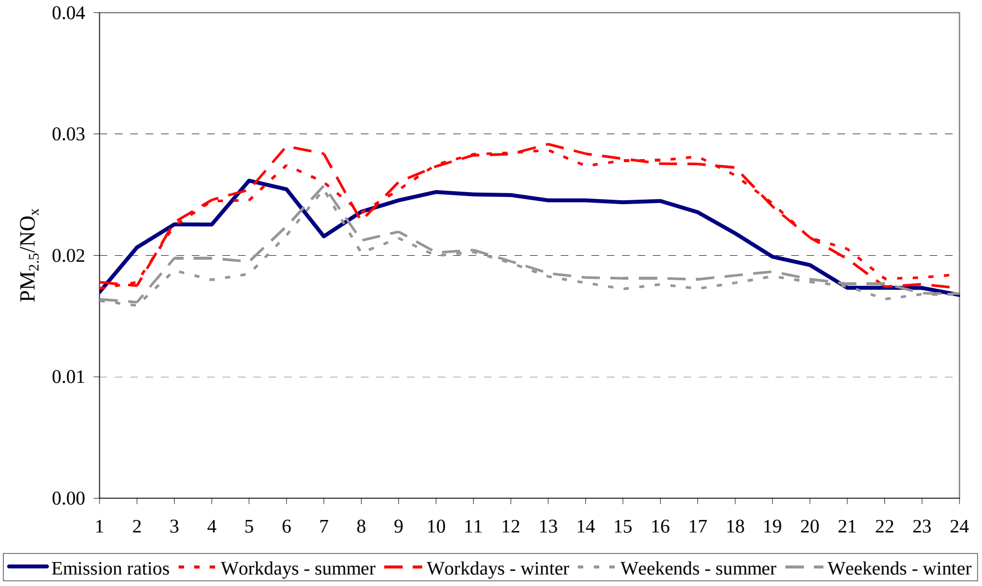


Figure 1.14. Year averaged diurnal variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Hornsgatan, Stockholm.

a)



b)

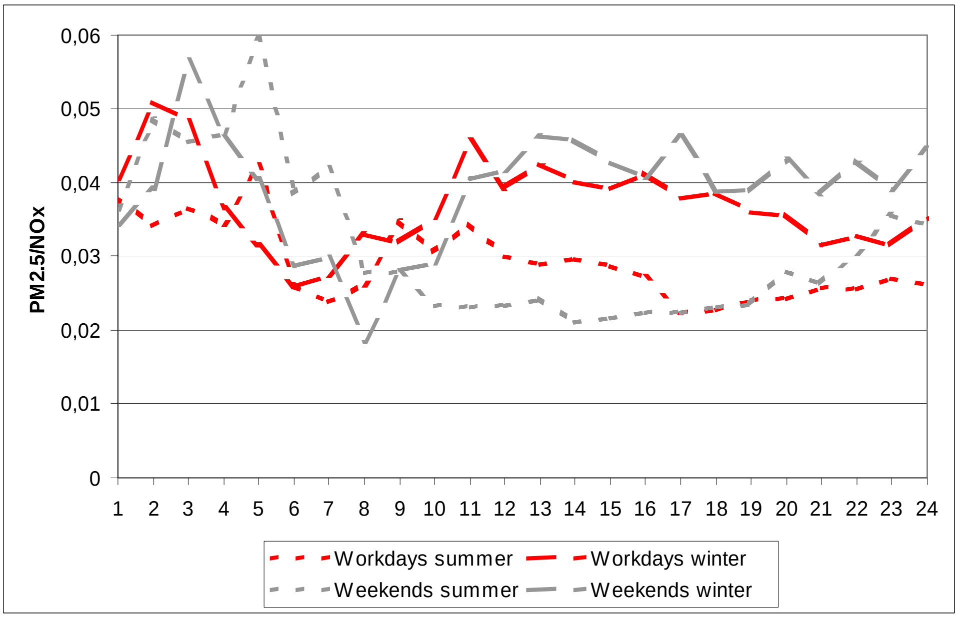


Figure 1.15. Diurnal variation of the $PM_{2.5}$ over NO_x ratios in Hornsgatan, Stockholm a) calculated emissions ratios from COPERT, b) measured ratios.

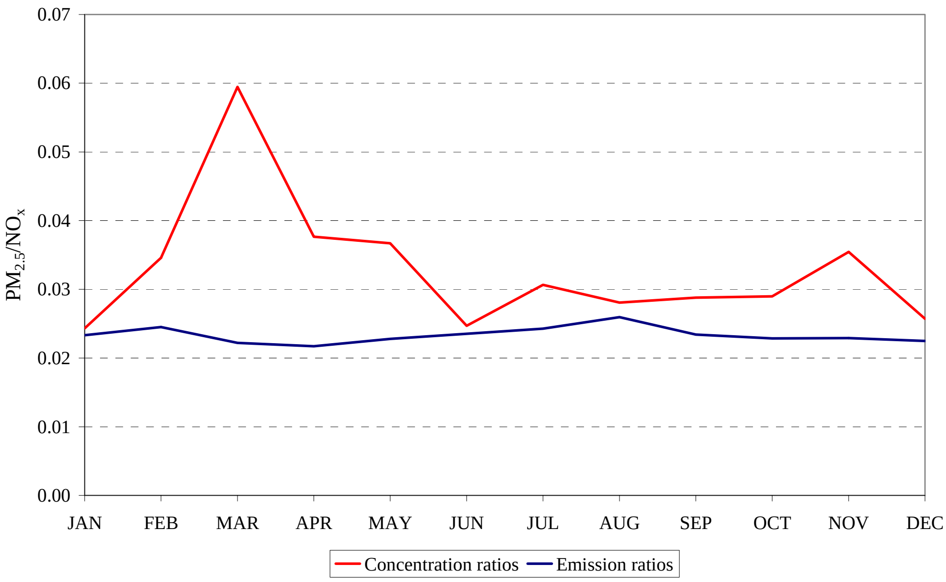


Figure 1.16. Monthly variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Hornsgatan, Stockholm.

1.3.2.2 Alternative runs – Sensitivity analysis

In order to assess the impact of various parameters in the calculated emissions, some older runs performed are presented here. The difference as compared to the basecase is that the HDV share is doubled, all buses run on diesel (instead of ethanol) and the gradient of the road, about 2%, is also taken into account in the calculations. All other parameters of the baseline run remained unchanged.

Similarly to the basecase, two sets of runs were performed with COPERT, for the hourly and monthly distribution of traffic emissions. From the monitored traffic data, average hourly and monthly data were derived for the number of passenger cars, the heavy duty fraction and the average vehicle speed.

The calculated hourly and monthly vehicle emissions of CO, NO_x and $PM_{2.5}$ and the measured DeltaCs of NO_x and $PM_{2.5}$ are presented in Table 1.11 and Table 1.12. From the above emissions and delta concentrations, $PM_{2.5}$ over NO_x and CO over NO_x emission ratios are derived, on an hourly and on a monthly basis and are presented in the same tables.

Table 1.11. Calculated year averaged hourly traffic emissions versus monitored year averaged hourly average delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (µg/m^3)		
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
01:00	457,5	131,3	3,7	0,028	3,484	77,8	3,0	0,039
02:00	397,1	131,4	4,5	0,034	3,023	78,6	3,4	0,043
03:00	308,4	109,5	4,0	0,037	2,816	62,4	2,9	0,046
04:00	271,6	98,8	3,7	0,037	2,749	63,4	2,6	0,041
05:00	190,6	75,7	3,2	0,042	2,518	42,1	1,9	0,045
06:00	218,9	83,8	3,4	0,041	2,614	57,6	1,7	0,030
07:00	642,6	204,9	7,3	0,036	3,137	141,9	3,9	0,027
08:00	1217,8	352,5	13,4	0,038	3,454	208,7	6,3	0,030
09:00	1338,9	387,8	15,3	0,039	3,453	215,0	7,2	0,033
10:00	1189,3	360,4	14,5	0,040	3,300	209,7	6,8	0,032
11:00	1335,1	396,7	15,9	0,040	3,366	195,3	7,4	0,038
12:00	1532,9	433,8	17,3	0,040	3,533	208,7	7,4	0,035
13:00	1714,3	465,7	18,3	0,039	3,681	223,6	8,0	0,036
14:00	1755,0	476,8	18,8	0,039	3,681	223,2	8,2	0,037
15:00	1837,0	492,9	19,3	0,039	3,727	225,7	8,0	0,035
16:00	2016,8	560,8	21,2	0,038	3,597	232,2	8,2	0,035
17:00	2062,0	522,5	19,8	0,038	3,946	224,5	7,3	0,033
18:00	1818,8	452,5	15,9	0,035	4,020	196,2	6,2	0,032
19:00	1494,2	374,2	12,0	0,032	3,993	167,4	5,4	0,032
20:00	1181,4	306,3	9,5	0,031	3,857	150,0	4,8	0,032
21:00	1025,1	256,6	7,2	0,028	3,995	131,8	4,0	0,030
22:00	962,9	241,0	6,7	0,028	3,995	126,0	4,0	0,032
23:00	747,6	193,2	5,4	0,028	3,869	109,1	3,6	0,033
24:00	612,3	163,5	4,4	0,027	3,745	95,9	3,3	0,034

Table 1.12. Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (µg/m^3)		
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
January	1079,5	292,4	10,9	0,037	3,692	168,6	4,1	0,024
February	1165,1	289,6	11,2	0,039	4,023	179,2	6,2	0,035
March	1151,9	307,3	10,7	0,035	3,749	181,6	10,8	0,059
April	1096,3	292,4	10,0	0,034	3,749	180,6	6,8	0,038
May	1188,4	323,5	11,8	0,036	3,674	152,6	5,6	0,037
June	1048,0	294,4	10,9	0,037	3,559	141,7	3,5	0,025
July	862,9	259,8	9,9	0,038	3,321	150,1	4,6	0,031
August	1092,5	322,8	13,0	0,040	3,385	167,5	4,7	0,028
September	1147,2	313,3	11,5	0,037	3,662	194,5	5,6	0,029
October	1166,6	312,8	11,2	0,036	3,730	110,4	3,2	0,029
November	1189,4	313,7	11,3	0,036	3,791	104,4	3,7	0,035
December	1082,8	285,7	10,1	0,035	3,790	132,2	3,4	0,026

Figure 1.17 shows the hourly variation over the day of the $PM_{2.5}$ over NO_x concentration ratio against the respective calculated emission ratio. Overall, there seems to be a fair agreement between the observed and the modelled ratios.

In Figure 1.18, the monthly variation over the year of the concentration ratio between the deltas of $PM_{2.5}$ and NO_x are plotted against the respective calculated emission ratio. A good agreement in the $PM_{2.5}$ over NO_x ratios is observed again, as regards the average value.

Overall, the results indicate that what has been considered in the basecase may either underestimate the HDV fraction or overstate the effect of ethanol buses.

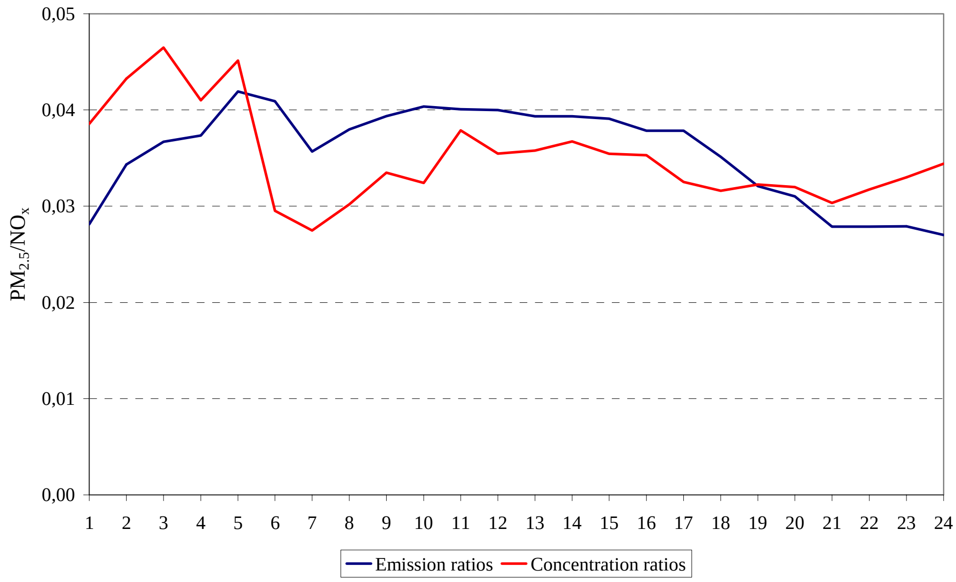


Figure 1.17. Year averaged diurnal variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Hornsgatan, Stockholm.

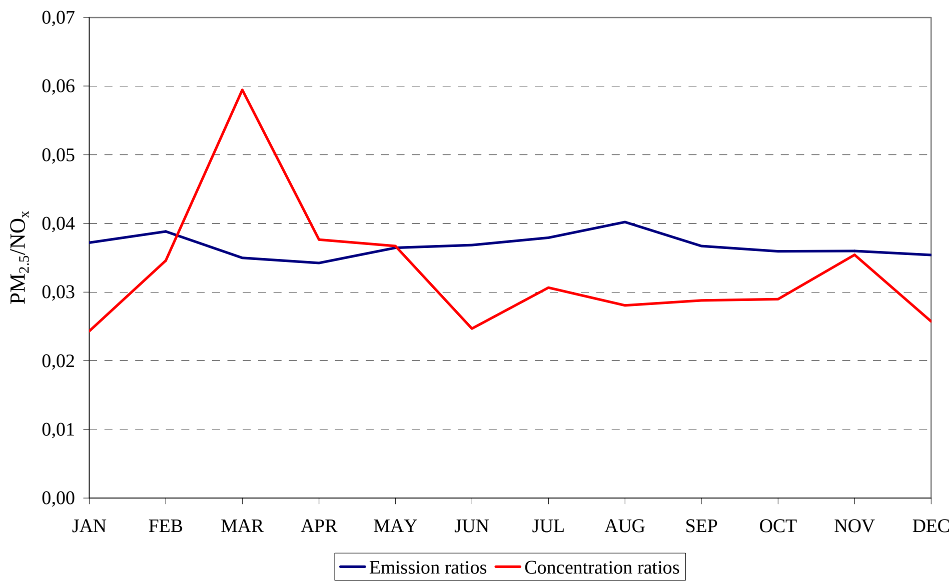


Figure 1.18. Monthly variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Hornsgatan, Stockholm.

1.3.2.3 Impact of road gradient

As mentioned in the previous section, the street has a gradient of about 2%. In order to investigate the impact of the road gradient on the calculated emissions, the above calculations were repeated without the slope correction. The calculated hourly vehicle emissions of CO, NO_x and $PM_{2.5}$ and the measured delta concentrations of NO_x and $PM_{2.5}$ are presented in Table 1.13. Similarly, Table 1.14 shows the calculated monthly variations in the mean hourly traffic emissions of CO, NO_x and $PM_{2.5}$ and the atmospheric concentration deltas of NO_x and PM_{10}.

Table 1.13. Calculated year averaged hourly traffic emissions without slope versus monitored year averaged hourly delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (µg/m^3)		
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
01:00	456,9	128,3	3,5	0,027	3,561	77,8	3,0	0,039
02:00	396,5	127,5	4,2	0,033	3,111	78,6	3,4	0,043
03:00	307,9	105,9	3,8	0,036	2,907	62,4	2,9	0,046
04:00	271,1	95,5	3,5	0,036	2,840	63,4	2,6	0,041
05:00	190,2	72,8	3,0	0,041	2,612	42,1	1,9	0,045
06:00	218,4	80,7	3,2	0,040	2,708	57,6	1,7	0,030
07:00	641,4	198,6	6,9	0,035	3,229	141,9	3,9	0,027
08:00	1214,8	341,4	12,5	0,037	3,559	208,7	6,3	0,030
09:00	1335,3	375,1	14,2	0,038	3,560	215,0	7,2	0,033
10:00	1185,9	348,1	13,6	0,039	3,407	209,7	6,8	0,032
11:00	1331,4	383,4	14,8	0,039	3,473	195,3	7,4	0,038
12:00	1528,5	419,5	16,1	0,038	3,644	208,7	7,4	0,035
13:00	1709,6	450,7	17,0	0,038	3,793	223,6	8,0	0,036
14:00	1750,2	461,4	17,4	0,038	3,793	223,2	8,2	0,037
15:00	1832,0	477,2	17,9	0,037	3,839	225,7	8,0	0,035
16:00	2004,6	513,3	19,3	0,038	3,905	232,2	8,2	0,035
17:00	2056,8	506,6	18,3	0,036	4,060	224,5	7,3	0,033
18:00	1814,8	439,8	14,8	0,034	4,126	196,2	6,2	0,032
19:00	1491,6	364,7	11,2	0,031	4,089	167,4	5,4	0,032
20:00	1179,5	298,8	8,9	0,030	3,948	150,0	4,8	0,032
21:00	1023,8	251,2	6,7	0,027	4,076	131,8	4,0	0,030
22:00	961,6	235,9	6,3	0,027	4,076	126,0	4,0	0,032
23:00	746,7	189,1	5,1	0,027	3,950	109,1	3,6	0,033
24:00	611,6	160,0	4,2	0,026	3,821	95,9	3,3	0,034

Table 1.14. Calculated monthly average traffic emissions without slope versus monitored monthly average delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (μg/m^3)		
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
January	1051,6	283,1	10,1	0,036	3,715	168,6	4,1	0,024
February	1142,2	307,7	11,5	0,037	3,712	179,2	6,2	0,035
March	1121,9	298,1	10,0	0,034	3,763	181,6	10,8	0,059
April	1067,6	283,9	9,4	0,033	3,761	180,6	6,8	0,038
May	1157,5	313,4	11,0	0,035	3,694	152,6	5,6	0,037
June	1020,4	285,1	10,1	0,036	3,579	141,7	3,5	0,025
July	839,7	251,2	9,2	0,037	3,342	150,1	4,6	0,031
August	1063,8	311,5	12,1	0,039	3,415	167,5	4,7	0,028
September	1117,4	303,4	10,7	0,035	3,683	194,5	5,6	0,029
October	1136,3	303,2	10,5	0,035	3,748	110,4	3,2	0,029
November	1158,7	304,2	10,5	0,035	3,810	104,4	3,7	0,035
December	1054,8	277,1	9,4	0,034	3,806	132,2	3,4	0,026

1.3.2.4 Impact of the "Artemis Reduction Factors"

In COPERT, hot emissions estimates for post-Euro I vehicles are calculated on the basis of reductions brought in the emission factors of Euro I vehicles due to the lack of experimental data. In the framework of the DG TrEn project Artemis, it was found that emissions of Euro II heavy-duty vehicles are underestimated by existing emission factor databases, a fact that affects especially NO_x emission levels. Consequently, NO_x emissions calculated with COPERT are expected to be underestimated. In order to investigate the impact of these findings, additional calculations were performed, which are presented in Table 1.15 and Table 1.16.

Table 1.15. Calculated year averaged hourly traffic emissions with "Artemis Reduction Factors" versus monitored year averaged hourly average delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (µg/m^3)		
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
01:00	457,5	132,7	3,6	0,027	3,448	77,8	3,0	0,039
02:00	399,1	141,0	4,6	0,032	2,831	78,6	3,4	0,043
03:00	308,4	111,1	3,9	0,035	2,775	62,4	2,9	0,046
04:00	271,6	100,3	3,6	0,036	2,708	63,4	2,6	0,041
05:00	190,6	77,0	3,1	0,040	2,475	42,1	1,9	0,045
06:00	218,9	85,2	3,3	0,039	2,571	57,6	1,7	0,030
07:00	642,6	207,7	7,1	0,034	3,093	141,9	3,9	0,027
08:00	1217,8	357,8	13,0	0,036	3,403	208,7	6,3	0,030
09:00	1338,9	393,9	14,8	0,038	3,399	215,0	7,2	0,033
10:00	1189,3	366,2	14,1	0,039	3,248	209,7	6,8	0,032
11:00	1335,1	403,0	15,5	0,038	3,313	195,3	7,4	0,038
12:00	1532,9	440,7	16,9	0,038	3,478	208,7	7,4	0,035
13:00	1714,3	472,9	17,8	0,038	3,625	223,6	8,0	0,036
14:00	1755,0	484,1	18,2	0,038	3,625	223,2	8,2	0,037
15:00	1837,0	500,4	18,7	0,037	3,671	225,7	8,0	0,035
16:00	2016,8	569,7	20,6	0,036	3,540	232,2	8,2	0,035
17:00	2062,0	530,1	19,2	0,036	3,890	224,5	7,3	0,033
18:00	1818,8	458,5	15,5	0,034	3,967	196,2	6,2	0,032
19:00	1494,2	378,7	11,7	0,031	3,946	167,4	5,4	0,032
20:00	1181,4	309,9	9,3	0,030	3,812	150,0	4,8	0,032
21:00	1025,1	259,2	7,0	0,027	3,955	131,8	4,0	0,030
22:00	962,9	243,4	6,6	0,027	3,955	126,0	4,0	0,032
23:00	747,6	195,2	5,3	0,027	3,831	109,1	3,6	0,033
24:00	612,3	165,1	4,3	0,026	3,709	95,9	3,3	0,034

Table 1.16. Calculated monthly average traffic emissions "Artemis Reduction Factors" versus monitored monthly average delta concentrations in Hornsgatan, Stockholm.

	Emissions (g)					Concentrations (µg/m^3)		
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**
January	1079,5	296,6	10,6	0,036	3,639	168,6	4,1	0,024
February	1172,3	323,1	12,1	0,037	3,628	179,2	6,2	0,035
March	1151,9	311,4	10,5	0,034	3,699	181,6	10,8	0,059
April	1096,3	296,2	9,7	0,033	3,701	180,6	6,8	0,038
May	1188,4	328,1	11,5	0,035	3,622	152,6	5,6	0,037
June	1048,0	298,7	10,6	0,035	3,508	141,7	3,5	0,025
July	862,9	263,7	9,6	0,036	3,273	150,1	4,6	0,031
August	1092,5	328,0	12,6	0,038	3,331	167,5	4,7	0,028
September	1147,2	317,7	11,2	0,035	3,611	194,5	5,6	0,029
October	1166,6	317,1	10,9	0,035	3,679	110,4	3,2	0,029
November	1189,4	318,1	11,0	0,035	3,739	104,4	3,7	0,035
December	1082,8	289,6	9,8	0,034	3,739	132,2	3,4	0,026

1.3.2.5 Results – Discussion

In Figure 1.19, the results of the above sensitivity analysis are summarised. The hourly variation over the day of the $PM_{2.5}$ over NO_x concentration ratio against the respective calculated emission ratio is plotted for all variants described above.

As expected, NO_x and $PM_{2.5}$ emissions are lower in the case of road without gradient (see also Table 1.13 and Table 1.14). The resulting $PM_{2.5}$ over NO_x ratio is then somewhat lower, as well as when taking the “Artemis Corrections” into account. The latter is the combined result of the higher NO_x emissions and the lower $PM_{2.5}$ emissions.

In both cases the differentiations from the case “with road gradient” are relatively low, mainly because the higher GVW classes of the HDV were excluded from the calculations as explained in 1.0, but also because of the relatively low share of Euro II vehicles in the year 2000.

The exact share of HDVs in the fleet seems to be very significant in assessing the traffic contribution to pollutant concentrations in the atmosphere. This is also indicated by the much higher $PM_{2.5}$ over NO_x ratio when the results of the various scenarios with the increased (double) share of HDVs are compared with those of the basecase.

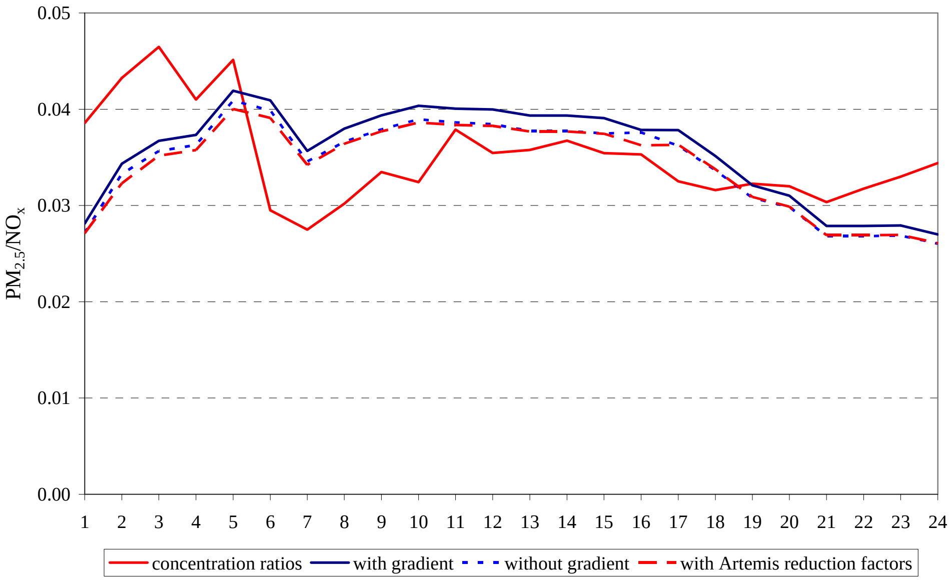


Figure 1.19. Year averaged diurnal variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions for various scenarios and delta concentrations in Hornsgatan, Stockholm.

1.3.3 Marylebone Rd., London

Using the composition of the British vehicle fleet for the year 2000 extracted from the TRENDS database, the share of each vehicle category is derived. The detailed monthly (Table B1) and hourly (Tables B.2 & B.3) distribution of traffic into the various vehicle categories is presented in Annex B.

The traffic station is located close to the centre of London and thus, as in the case of Stockholm, it is assumed that only HDV with a GVW lower than 16 tonnes were allowed, i.e. no HDV with a GVW of 16-32 tonnes and over 32 tonnes were considered. The street has six traffic lanes in total, with different vehicle volumes. From the traffic data monitored, average hourly and monthly data were derived for the number of passenger cars, the number of heavy duty vehicles and the average vehicle speed. Two sets of runs were performed with COPERT, for the hourly and monthly distribution of traffic emissions.

The calculated hourly vehicle emissions and the measured delta concentrations of CO, NO_x and $PM_{2.5}$ are presented in Table 1.17. From the above emissions and delta concentrations, $PM_{2.5}$ over NO_x and CO over NO_x ratios are derived, on an hourly basis and are also presented in the same table.

In the same manner, Table 1.18 shows the calculated monthly variations and the corresponding ratios in traffic emissions and the atmospheric concentration deltas of CO, NO_x and $PM_{2.5}$.

Table 1.17. Calculated year averaged hourly traffic emissions versus monitored year averaged hourly delta concentrations in Marylebone Rd., London.

	Emissions (g)					Concentrations (μg/m^3)				
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**
01:00	9035,4	2483,8	77,3	0,031	3,638	1214,0	224,7	7,6	0,034	5,402
02:00	6360,7	1911,9	59,3	0,031	3,327	892,7	178,9	5,7	0,032	4,990
03:00	4958,2	1603,1	53,5	0,033	3,093	729,4	157,6	5,1	0,032	4,628
04:00	4329,6	1506,2	55,0	0,036	2,874	629,5	150,6	5,5	0,036	4,179
05:00	4233,2	1622,8	65,7	0,040	2,609	577,3	155,0	5,2	0,034	3,725
06:00	6097,3	2473,3	109,2	0,044	2,465	715,5	208,3	7,7	0,037	3,435
07:00	11376,8	4270,1	197,2	0,046	2,664	1207,4	297,2	11,6	0,039	4,062
08:00	14064,6	5271,4	243,2	0,046	2,668	1684,3	358,7	15,8	0,044	4,696
09:00	17901,3	5713,9	285,2	0,050	3,133	1785,6	364,6	18,2	0,050	4,898
10:00	17944,3	5757,5	286,9	0,050	3,117	1467,8	334,9	15,1	0,045	4,383
11:00	19012,9	6051,0	306,8	0,051	3,142	1416,8	340,7	14,5	0,042	4,158
12:00	20298,4	6224,9	319,3	0,051	3,261	1601,9	378,7	16,4	0,043	4,230
13:00	21434,8	6276,2	320,7	0,051	3,415	1750,0	394,4	16,9	0,043	4,437
14:00	21910,1	6168,1	309,9	0,050	3,552	1836,4	386,7	14,9	0,039	4,749
15:00	21885,5	5943,4	291,2	0,049	3,682	1868,9	384,4	15,9	0,041	4,862
16:00	22191,3	5722,5	272,3	0,048	3,878	2130,5	386,9	13,8	0,036	5,507
17:00	22857,4	5458,1	248,3	0,045	4,188	2482,9	385,0	12,9	0,033	6,450
18:00	23611,9	5261,7	228,2	0,043	4,487	2731,9	364,5	12,3	0,034	7,495
19:00	22370,3	4930,6	196,0	0,040	4,537	2592,3	329,9	10,8	0,033	7,859
20:00	19768,0	4462,1	171,0	0,038	4,430	2410,4	315,7	10,2	0,032	7,635
21:00	16857,6	3959,4	149,7	0,038	4,258	2291,6	323,2	10,6	0,033	7,091
22:00	14809,7	3584,5	129,4	0,036	4,132	2027,7	297,6	10,4	0,035	6,814
23:00	14803,0	3582,8	129,3	0,036	4,132	1838,6	276,5	9,8	0,036	6,649
24:00	12755,5	3188,9	107,4	0,034	4,000	1703,8	271,5	9,4	0,035	6,275

Table 1.18. Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Marylebone Rd., London.

	Emissions (g)					Concentrations (μg/m³)				
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**
January	13728,4	3963,3	168,5	0,043	3,464	1651,0	276,7	8,1	0,029	5,967
February	15382,2	4391,8	194,3	0,044	3,502	2687,3	413,4	15,5	0,038	6,500
March	14615,2	4325,6	187,8	0,043	3,379	1468,1	212,9	9,6	0,045	6,897
April	14164,5	4060,1	172,1	0,042	3,489	1553,6	229,5	9,0	0,039	6,771
May	15014,6	4351,4	191,1	0,044	3,451	1299,1	232,3	7,6	0,033	5,593
June	14596,5	4316,1	188,3	0,044	3,382	1710,6	321,4	12,5	0,039	5,323
July	15038,2	4351,0	189,8	0,044	3,456	1267,9	207,7	10,7	0,052	6,104
August	14324,0	4232,0	182,3	0,043	3,385	1544,7	300,6	12,2	0,041	5,139
September	14028,7	4195,5	182,7	0,044	3,344	1653,4	338,1	13,7	0,041	4,890
October	14008,3	4131,6	183,1	0,044	3,391	1383,0	388,0	14,4	0,037	3,564
November	15081,8	4440,5	200,1	0,045	3,396	2267,2	440,4	16,1	0,037	5,148
December	13771,6	3942,5	167,1	0,042	3,493	1531,1	300,6	11,0	0,037	5,094

In Figure 1.20, the hourly variation over the day of the concentration ratio between the deltas of $PM_{2.5}$ and NO_x is plotted against the respective calculated emission ratio. There is a fair agreement between the observed and the modelled ratios as regards the general trend, although the calculated ratio is somewhat higher. This may explained by the fact that NO_x emissions factors for post Euro I HDV in COPERT are underestimated and thus the calculated NO_x emissions are slightly underestimated too (see also sensitivity analysis for Hornsgatan, Stockholm).

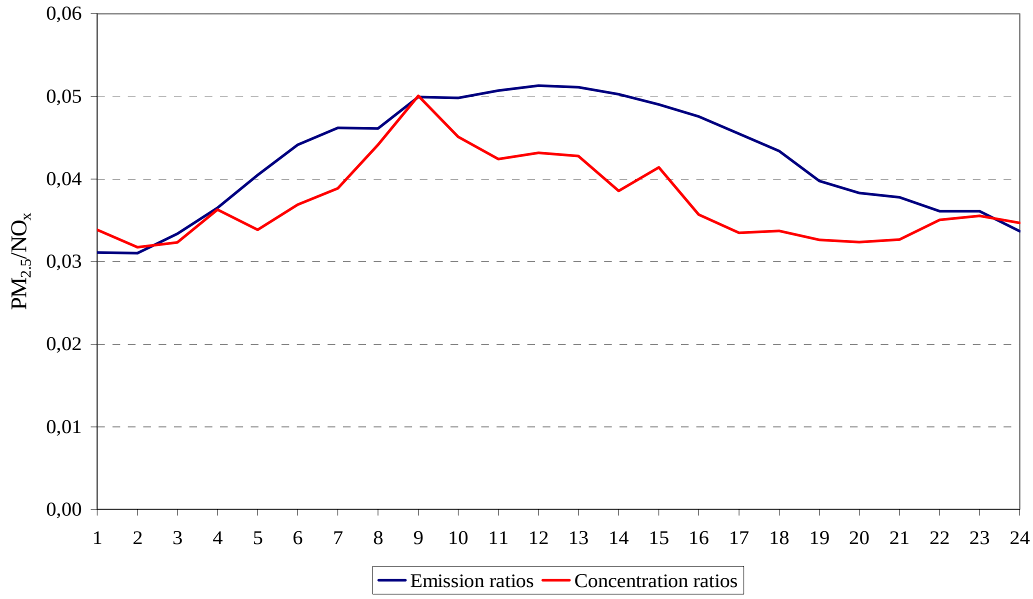


Figure 1.20. Year averaged diurnal variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Marylebone Rd., London.

In Figure 1.21, the monthly variations of the above ratios are plotted. For the concentration ratio a variation over the year is observed, which seems to have a seasonal character, which, contrary to Hornsgatan, shows higher $PM_{2.5}$ in summer. In contrast, the calculated ratio is found quite stable, since during the day it varies only with traffic volume and average speed and thus the seasonal variation could not be reproduced.

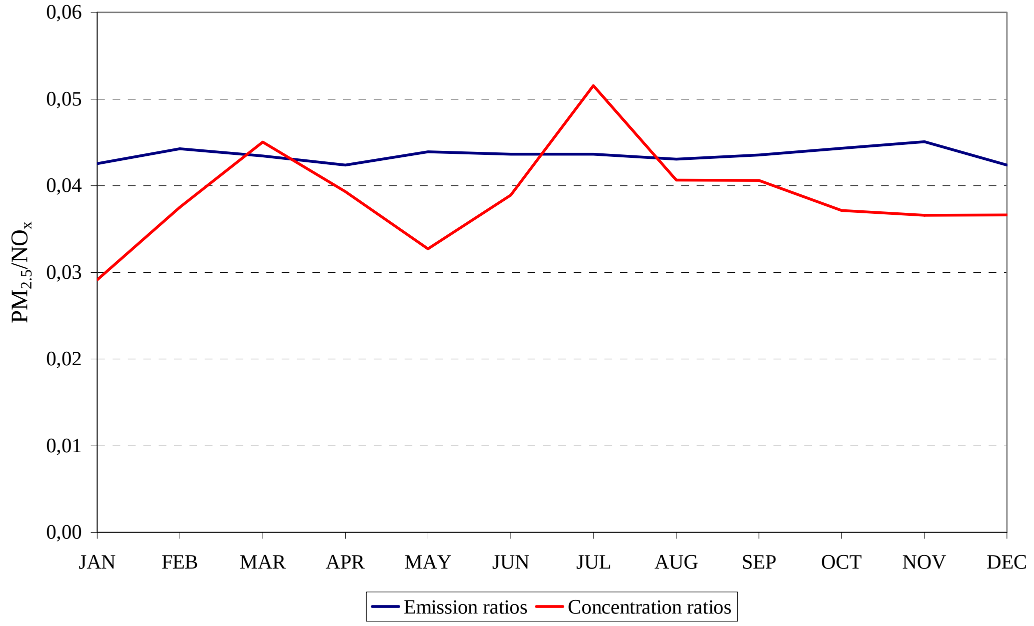


Figure 1.21. Monthly variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Marylebone Rd., London.

1.3.4 Frankfurter Allee, Berlin

Using the composition of the German vehicle fleet for the year 2002 extracted from the TRENDS database, the share of each vehicle category is derived. The detailed monthly (Table C.1) and hourly (Tables C.2 & C.3) distribution of traffic into the various vehicle categories is presented in Annex C.

The traffic station is located in the Frankfurter Allee, a busy main road consisting of 6 lanes in Berlin and thus, as in the case of Stockholm, it is assumed that only HDV with a GVW lower than 16 tonnes were allowed. The road traffic is divided into westbound and eastbound traffic having different vehicle volumes and recorded by automatic detection devices. From the traffic data monitored, average hourly and monthly data were derived for the total number of vehicles and the average vehicle speed. Due to lack of data regarding the variation of the heavy duty fraction, an average value of 4.8% was considered. Four sets of runs were performed with COPERT, for the hourly and monthly distribution of traffic emissions and for both westbound and eastbound traffic.

The calculated hourly vehicle emissions and the measured delta concentrations of CO, NO_x and PM are presented in Table 1.19. As for the specific traffic station no $PM_{2.5}$ concentration was measured, only PM_{10} data are presented below. From the above emissions and delta concentrations, PM_{10} and $PM_{2.5}$ over NO_x and CO over NO_x ratios are derived, on an hourly basis and are presented in the same table.
In addition, Table 1.20 shows the calculated monthly variations and the corresponding ratios in traffic emissions of CO, NO_x and PM.

Table 1.19. Calculated year averaged hourly traffic emissions versus monitored year averaged hourly delta concentrations in Frankfurter Allee, Berlin.

	Emissions (g)					Concentrations (µg/m³)				
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**CO**	**NO_x**	**PM_{10}**	**PM_{10}/NO_x**	**CO/NO_x**
01:00	3426,7	698,8	33,7	0,048	4,903	183,1	19,1	8,8	0,459	9,604
02:00	2354,5	491,2	23,3	0,047	4,794	152,9	16,4	5,0	0,306	9,307
03:00	1661,8	348,9	16,5	0,047	4,762	131,6	14,6	3,4	0,234	9,035
04:00	1252,7	261,7	12,4	0,047	4,787	139,4	18,9	3,4	0,180	7,370
05:00	1242,2	261,4	12,3	0,047	4,751	222,4	39,2	4,3	0,109	5,670
06:00	2158,3	460,1	21,4	0,047	4,691	382,3	65,7	6,3	0,095	5,820
07:00	7766,0	1528,9	75,4	0,049	5,079	473,6	80,4	9,4	0,116	5,891
08:00	10394,2	1842,1	96,7	0,053	5,643	457,0	82,9	12,4	0,149	5,511
09:00	11225,0	1989,3	104,5	0,053	5,643	436,6	85,1	14,2	0,167	5,128
10:00	10798,3	1936,1	101,0	0,052	5,577	458,5	86,7	15,4	0,178	5,289
11:00	10621,0	1995,5	101,4	0,051	5,322	456,2	87,6	15,2	0,174	5,206
12:00	11915,8	2115,9	111,2	0,053	5,631	467,9	89,3	14,8	0,166	5,240
13:00	12037,9	2144,2	112,5	0,052	5,614	488,9	87,9	16,6	0,189	5,563
14:00	12157,5	2201,6	114,3	0,052	5,522	516,3	86,2	15,1	0,175	5,988
15:00	11953,2	2231,7	113,8	0,051	5,356	598,4	90,9	11,3	0,124	6,585
16:00	13532,0	2482,3	127,9	0,052	5,451	670,1	93,1	13,3	0,142	7,200
17:00	15090,4	2624,5	139,6	0,053	5,750	628,5	84,1	13,6	0,161	7,476
18:00	15389,2	2592,7	140,4	0,054	5,936	566,2	73,9	12,3	0,166	7,660
19:00	13649,2	2386,4	126,5	0,053	5,720	513,1	62,3	11,4	0,184	8,242
20:00	12717,9	2231,0	118,1	0,053	5,701	435,1	48,4	9,3	0,192	8,986
21:00	10042,0	1785,7	93,7	0,052	5,624	359,3	38,0	6,7	0,175	9,450
22:00	7385,3	1427,6	71,3	0,050	5,173	332,6	33,9	6,8	0,200	9,805
23:00	5468,1	1091,4	53,4	0,049	5,010	287,5	26,0	6,3	0,241	11,073
24:00	4804,5	962,8	46,9	0,049	4,990	225,8	21,5	5,2	0,240	10,490

Table 1.20. Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Frankfurter Allee, Berlin.

	Emissions (kg)					Concentrations (µg/m³)				
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**CO**	**NO_x**	**PM_{10}**	**PM_{10}/NO_x**	**CO/NO_x**
January	6478.9	1241.6	61.2	0.049	5.218	573.5	57.1	16.9	0.296	10.044
February	5592.6	1071.7	52.9	0.049	5.218	432.4	46.1	3.2	0.069	9.379
March	5276.2	1011.1	49.9	0.049	5.218	451.2	54.8	9.5	0.173	8.236
April	5695.1	1074.9	54.6	0.051	5.298	453.1	59.6	5.9	0.099	7.596
May	6477.4	1222.6	62.0	0.051	5.298	350.8	54.8	8.1	0.148	6.400
June	5743.3	1084.0	55.0	0.051	5.298	291.1	60.6	9.2	0.152	4.807
July	5255.7	992.0	50.3	0.051	5.298	338.4	65.7	8.3	0.126	5.154
August	5446.0	1027.9	52.2	0.051	5.298	308.9	51.2	9.7	0.190	6.039
September	6524.3	1231.4	62.5	0.051	5.298	312.1	56.3	9.9	0.175	5.544
October	6702.7	1265.1	64.2	0.051	5.298	412.2	79.5	10.5	0.133	5.184
November	6754.6	1274.9	64.7	0.051	5.298	422.8	67.5	11.8	0.175	6.266
December	6345.4	1197.7	60.8	0.051	5.298	405.6	53.8	11.4	0.212	7.537

For the reasons explained above, the PM over NO_x ratios are not directly comparable and thus only the CO over NO_x ratios are considered.

In Figure 1.22, the hourly variation over the day of the concentration ratio between the deltas of CO and NO_x is plotted against the respective calculated emission ratio. For the concentration ratio a large variation over the day is observed, which might be attributed to the variation in traffic composition throughout the day, e.g. lower heavy duty fraction in the evening and during the night. This variation, however, could not be reproduced by the emission model as the heavy duty fraction has been kept constant due to lack of more detailed data.

On the other hand, the calculated ratio is quite stable during the day varying with the traffic volume and average speed.

Figure 1.23 presents the monthly variation of the above ratio, where a large discrepancy is observed in January, converging though towards the summer months.

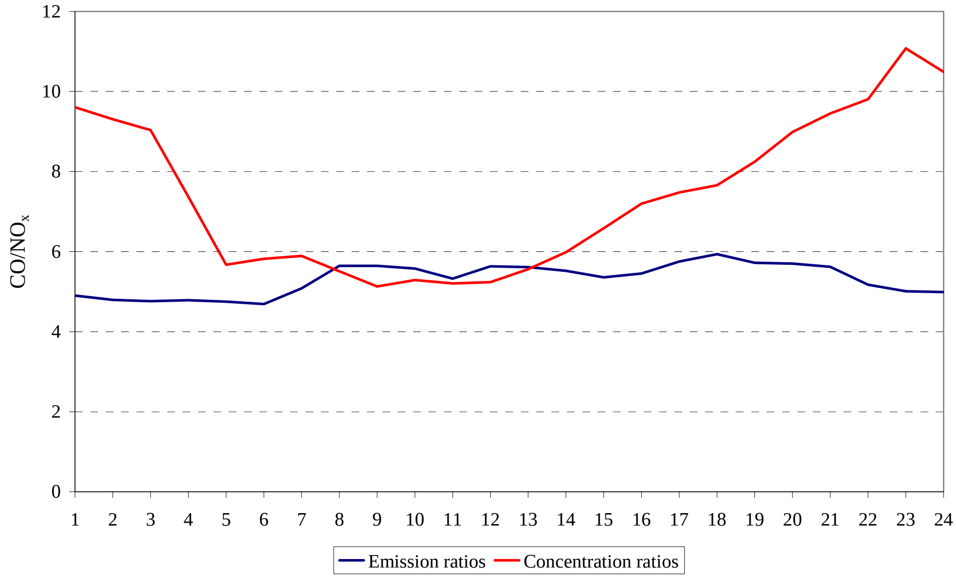


Figure 1.22. Year averaged diurnal variation of the CO over NO_x ratios of traffic emissions and delta concentrations in Frankfurter Allee, Berlin.

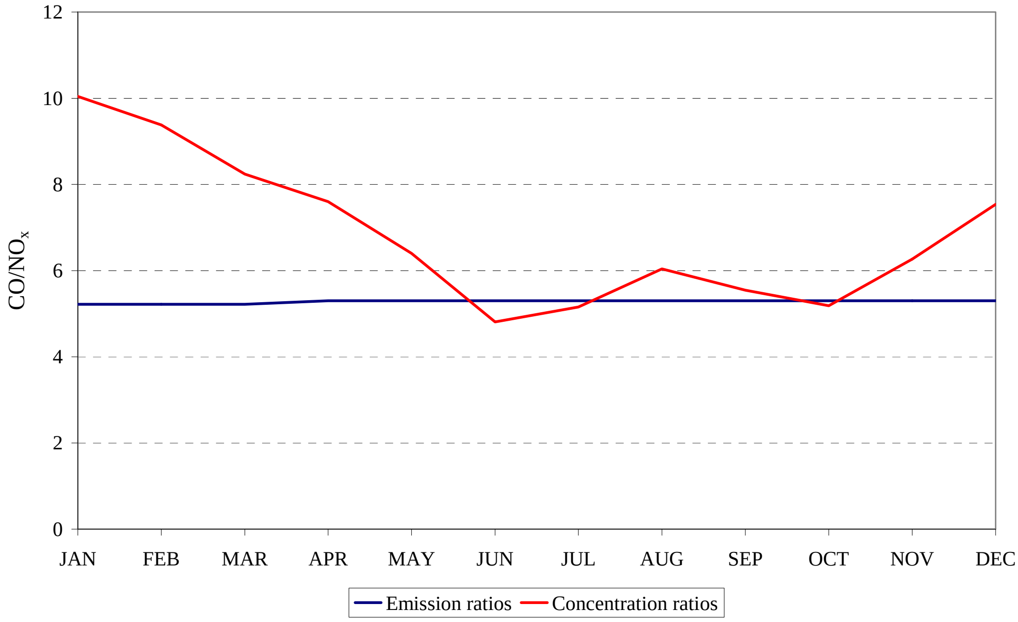


Figure 1.23. Monthly variation of the $PM_{2.5}$ over NO_x ratios of traffic emissions and delta concentrations in Frankfurter Allee, Berlin.

1.4 Summary and conclusions

The investigation of suitable station pairs in Europe has been fairly successful and has resulted in a number of well defined and suitable station pairs, for which data on pollutant concentrations and traffic and meteorological parameters have been transferred to a SEC database. So far the collected data include station pairs in Stockholm, London, Berlin, Thessaloniki, Hannover and Oslo and these have also been analysed (except Hannover data where data quality issues are as yet unresolved) according to the procedures defined for SEC subtask 3. Station pairs in Helsinki, Madrid, Milan, Paris and Praha are considered as good candidates for the further work.

The collected data has been used for comparison study of street scale dispersion models (see chapter 3 and 4).

The data analysis (section 1.2) has produced DRs of concentrations (representing the street traffic's own contribution to the street level concentrations), meaning the concentration of pollutants (PM_{10}, $PM_{2.5}$, NO_2) relative to NO_x. These delta ratios have been calculated for workday and weekend conditions separately, for summer and winter conditions. This represents a basis against which ratios from emission factor databases (such as COPERT 3) can be tested.

The results of this analysis allow an estimation of the strength of the road dust re-suspension source to PM_{10} and $PM_{2.5}$, by comparing DRs for winter/summer/workdays/weekends, for PM_{10} and $PM_{2.5}$. For Marylebone Rd. in London, it is estimated that the re-suspension source to PM_{10} is of about the same magnitude as the combined exhaust/brake/tyre wear source. In Hornsgatan, where studded tyres are used in winter, the re-suspension source dominates PM_{10} relative to the exhaust. The re-suspension source is significant even in the summer and it also gives a significant contribution to $PM_{2.5}$ in the street (see Section 1.2.4.3). Also in Frankfurter Allee in Berlin the re-suspension source is very strong and relatively larger than in Marylebone. This analysis shows that this is a promising method of estimating "emission factors" for the re-suspension source and similar analysis should be done for more streets.

COPERT 3 emission factor ratios have been tested (section 1.3) on data from Hornsgatan, Stockholm and Marylebone Rd., London ($PM_{2.5}$ relative to NO_x) and on data from Frankfurter Allee (CO relative to NO_x). The testing has been done for complete annual time series, as well as separate for summer/winter/workday/weekend conditions. The testing has produced reasonably good results: the calculated emission factor ratios compare in general reasonably well with the measured delta ratios. This comparison shows that there is room for a significant re-suspension source to $PM_{2.5}$ in Hornsgatan.

Chapter 2: Global analysis: Validation of road traffic emission inventories by means of concentration data measured at several air quality monitoring stations

2.1 Introduction

Despite reductions in emissions, road transport is still one of the main causes of exceedances of air quality limit levels, particularly in urban areas. Anthropogenic emissions of carbon monoxide (CO) and nitrogen oxides (NO_x) are precursors for photo oxidant formation, while substantial health risk could be associated with high particulate matter (PM) concentrations in ambient air (Künzli et al., 2000).

Air quality models require emission data of individual compounds, which are calculated by complex emission models and which, in turn, are based on appropriately chosen emission factors. The assessment of road-traffic-related emission factors of pollutants are normally based on exhaust gas measurements of single vehicles on chassis dynamometers using various driving cycles. While dynamometer tests are essential to establish uniform emission standards for regulatory purposes and for testing of new technologies, they do not necessarily reflect the real on-road driving conditions and the level of maintenance of the actual vehicle fleet. Thus, there is a need for on-road emission estimates of air pollutants from the actual vehicle fleet. To this aim the most common approaches are (a) road-tunnel studies, (b) car chasing experiments to better simulate the atmospheric dilution conditions and (c) atmospheric studies at air quality monitoring sites.

As regards the atmospheric studies to evaluate real-world emission factors, the method of ‘inverse modelling’ of atmospheric pollution dispersion models is usually used (Palmgren et al., 1999; Ketzel et al., 2003). Another technique used is the determination of the emission ratios from the concentration ratios measured at a receptor site during extensive campaigns (Klemp et al., 2002; Mannschreck et al., 2002).

While all the above methods require also special measuring campaigns focusing on local emissions (Kühlwein et al., 2002a and 2002b), this paper presents a more global approach, making use of already available measurements stored in a common database. To this aim, comparisons between experimentally determined and modelled CO/NO_x, NO_x/PM and PM/CO emission ratios are performed. It aims at adding to the current knowledge on the use of air quality data for the validation of urban emission inventories by using atmospheric concentration data from several monitoring stations.

2.2 Methodology

2.2.1 Determination of emission ratios using atmospheric concentration measurements

It is known that the large-scale background concentration constitutes an appreciable fraction of the pollutant concentrations in busy streets. In order to estimate the contribution of road traffic to the concentrations, a straightforward and reliable procedure is subtracting the concentrations measured at a background station from concentrations at a nearby traffic station. Hence, the measured concentration of pollutant results from the background concentration plus the traffic contribution, which will be diluted during transport. Under constant background conditions the measured variability of pollutant concentration is due to variations in source strength and dilution.

In those situations where the traffic contribution is much larger than the urban background concentration, the ratios of the concentrations may be assumed to reflect the ratios of the local traffic emissions. Therefore, those days are selected for which the difference between the maximum and the minimum concentration is larger by a factor of ten than the minimum concentration for at least one pollutant. Ratios are then calculated for all individual hours on those days and averaged. In fact, the 50 percentile of the distribution of results is calculated in order to reduce the influence of large fluctuations.

For the present analysis, air quality data for CO, NO_x and PM_{10} at traffic stations in five European countries have been analysed. Urban traffic stations with hourly data for the year 2000 were selected from AirBase, the air quality information system of the European Environment Agency. AirBase contains air quality data for a selection of stations and a number of components and meta information on air quality monitoring networks and stations. The information is collected by the European Topic Centre on Air Quality and is stored and made widely available by means of AirBase, accessible on the Internet (http://air-climate.eionet.eu.int/databases/airbase.html).

The selected stations included 10 German, 13 Spanish, 2 Finnish, 2 Portuguese and 5 British traffic stations. As mentioned above, an appropriate factor of ten was selected in order to distinguish those days with the largest traffic contribution. Emission ratios were then derived for all individual hours on those days, median values were calculated for each hour and averaged over the day for each station. Furthermore, weighted averages were also calculated following the same procedure, but only for those hours of the day with the highest CO concentrations, which is a further indication that traffic contribution is the most significant. The results are summarised in Table 2.1 and Table 2.2, where also the stations with the maximum or minimum ratios are shown for each procedure. As an indication of the consistency of the resulting ratios, the products of the three ratios – ideally equal to unit – may be used. These products have been calculated for all stations and average values over the stations for each country are also presented in the same Tables (under column "Check"). From the resulting values when a simple average (Table 2.1) and a weighted average (Table 2.2) are calculated, it is evident that the average product of the emission ratios in the latter case is closer to unity and thus they will be used for any comparisons in the following sections.

Table 2.1. Summarised results of data analysis from traffic stations in the selected countries. Averages (avg), maxima (max) and minima (min) of emission ratios for all hourly data pair series.

	CO/NO_x			NO_x/PM			PM/CO			Check
	avg	min	max	avg	min	max	avg	min	max	
Germany	6.48	3.85	9.82	4.85	3.44	6.88	0.044	0.023	0.072	1.217
Spain	10.54	5.45	16.92	3.60	1.63	6.12	0.035	0.021	0.058	1.147
Finland	8.46	6.73	10.20	3.72	2.76	4.69	0.040	0.039	0.042	1.200
Portugal	6.41	6.27	6.54	2.32	2.24	2.40	0.066	0.063	0.068	0.976
United Kingdom	4.74	1.69	8.76	10.08	5.03	12.66	0.031	0.020	0.054	1.178

Table 2.2. Summarised results of data analysis from traffic stations in the selected countries. Weighted averages (wavg), maxima (max) and minima (min) of emission ratios for selected hourly data pair series.

	CO/NO_x			NO_x/PM			PM/CO			Check
	wavg	min	max	wavg	min	max	wavg	min	max	
Germany	6.25	4.09	8.81	5.42	3.76	7.71	0.036	0.020	0.048	1.103
Spain	9.42	5.44	12.82	4.18	2.13	6.46	0.031	0.018	0.044	1.078
Finland	6.36	5.15	7.57	4.52	3.25	5.79	0.038	0.034	0.041	1.012
Portugal	6.97	6.78	7.17	2.49	2.37	2.61	0.057	0.053	0.060	0.984
United Kingdom	4.67	1.93	8.61	10.99	6.21	13.46	0.026	0.017	0.045	1.083

2.2.2 Modelled emission data

The calculations presented here have been conducted with the use of the TRENDS (TRansport and ENvironment Database System) model, which is the successor of the FOREMOVE model (FORecast of Emission from MOtor VEhicles), both developed under contract for the Commission of the European Communities (European Commission, 2003; Samaras et al., 1993). TRENDS is a system for calculating a range of environmental pressures due to transport. These environmental pressures include air emissions from the four main transport modes, i.e. road, rail, ships and air.

For the estimation of air pollutant emissions from road transport in urban environments a calculation module was derived following a top down approach. Focus of the calculation was the annual air emissions of CO, NO_x and PM for each of the investigated countries for the year 2000. For air emissions the COPERT 3 calculation module was applied (Ntziachristos and Samaras, 2000). After annual air emissions were estimated on a country basis, a spatial disaggregation module allocated the above annual air emissions to the urban areas of the countries, using the initial COPERT estimates for urban, rural and highway split of the emissions for the different vehicle categories.

The methodological approach used for the calculation of the emissions is briefly described below. Firstly, the appropriate databases for the calculation modules were created. All available databases were used in order to construct the appropriate input for the calculations. In this respect, data concerning vehicle stocks, vehicle new registrations, vehicle usage indicators (such as tonne-kilometres, passenger-kilometres etc.), fuel consumption, technology splits of vehicle fleets for certain years, annual mileage for different vehicle categories, vehicle representative speeds, split of the annual mileage to different road classes, etc were used. Secondly, a System Dynamics Module was established in order to (a) extrapolate the main vehicle categories into the future using data of the past and resulting thus in producing estimates of vehicle stocks per country; (b) simulate the vehicle turnover for the main vehicle categories; and (c) supplement the above with corresponding data on emissions technology parameters which were introduced via a number of suitable implementation tables per country, including simultaneous introduction of different legislation, scrappage schemes, etc. At a final step, the data resulting from the aforementioned processes were adapted in such a way as to produce the input tables for the calculation of annual air emissions required by the methodology of COPERT. These input tables were produced for the year 2000.

2.3 Results and discussion

In Table 2.3, the emission ratios calculated with TRENDS are compared with those obtained from concentration measurements. Figure 2.1 to Figure 2.3 show a graphical representation of the above results for the three ratios investigated. Based on the findings in paragraph 2.2.1 only the weighted average values are used for comparisons with the modelled emission ratios.

Table 2.3. Comparison between emission ratios calculated with TRENDS and concentration ratios resulting from the data analysis from traffic stations in the selected countries.

	CO/NO_x			NO_x/PM			PM/CO		
	avg	wavg	TRENDS	avg	wavg	TRENDS	avg	wavg	TRENDS
Germany	6.48	6.25	7.16	4.85	5.42	13.12	0.044	0.036	0.011
Spain	10.54	9.42	5.25	3.60	4.18	11.60	0.035	0.031	0.016
Finland	8.46	6.36	6.80	3.72	4.52	13.90	0.040	0.038	0.011
Portugal	6.41	6.97	3.90	2.32	2.49	14.72	0.066	0.057	0.017
United Kingdom	4.74	4.67	8.96	10.08	10.99	17.72	0.031	0.026	0.006

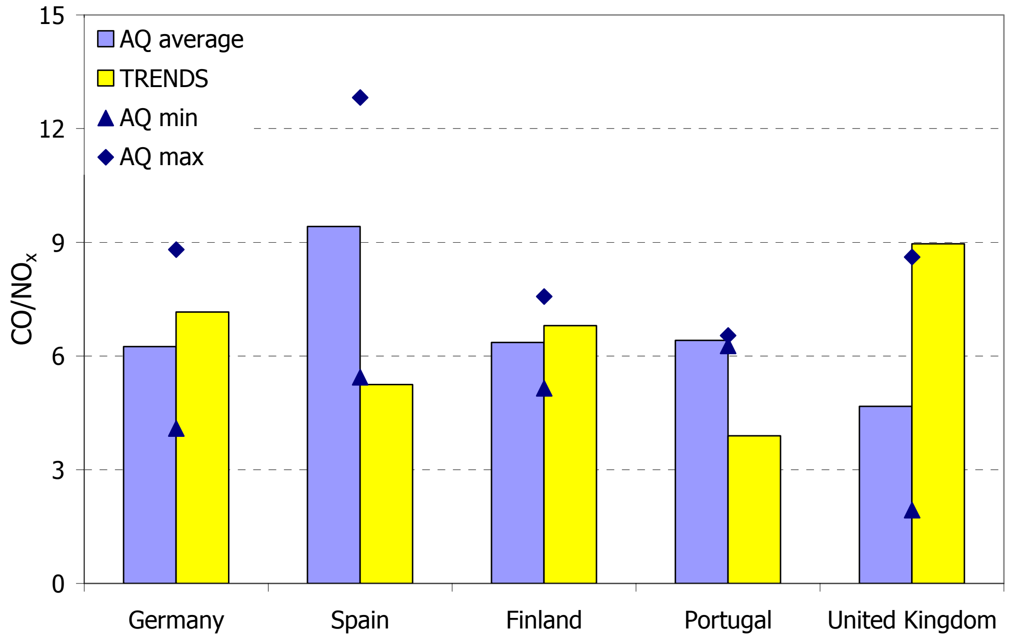


Figure 2.1. Comparison between measured and modelled CO over NO_x ratios for the selected countries. Weighted average (AQ average), maxima (AQ max) and minima (AQ min) versus values calculated with TRENDS.

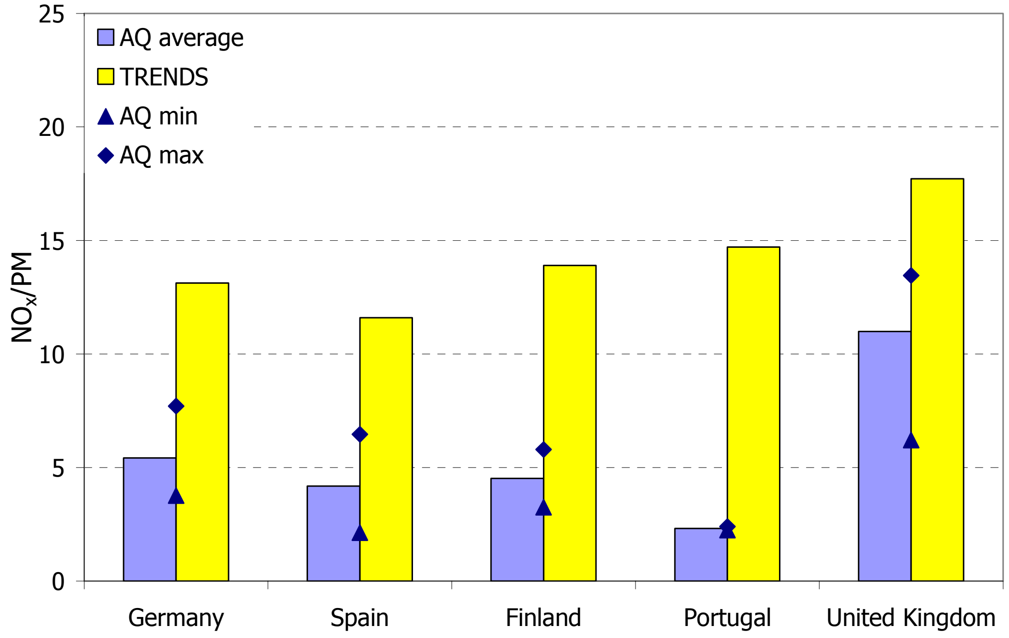


Figure 2.2. Comparison between measured and modelled NO_x over PM ratios for the selected countries. Weighted average (AQ average), maxima (AQ max) and minima (AQ min) versus values calculated with TRENDS.

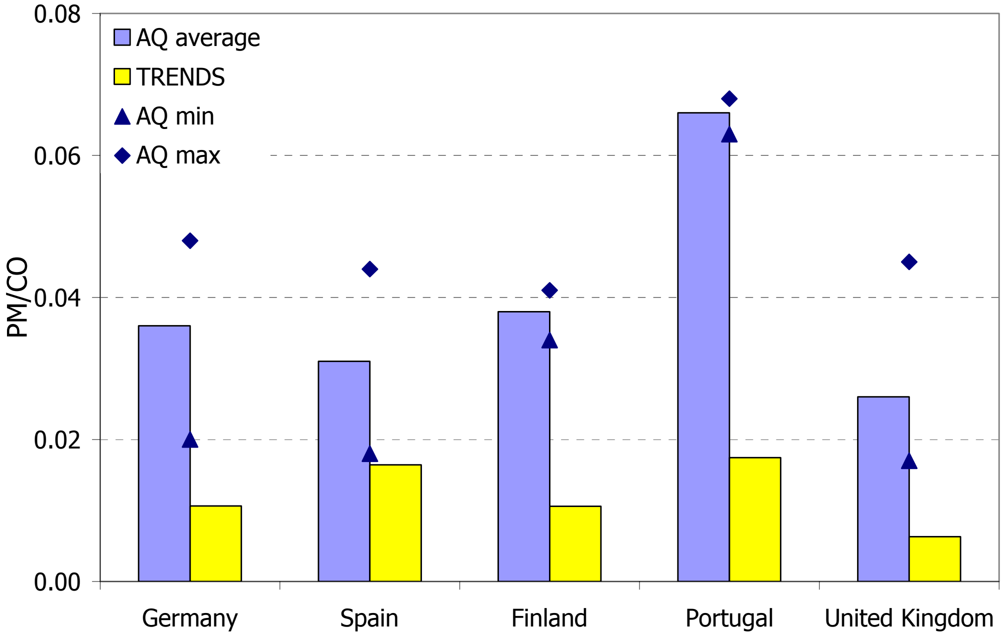


Figure 2.3. Comparison between measured and modelled PM over CO ratios for the selected countries. Weighted average (AQ average), maxima (AQ max) and minima (AQ min) versus values calculated with TRENDS.

Modelled CO/NO_x emission ratios are generally within (or very close to) the range defined by measured air quality ratios. A tendency towards the maximum concentration values may be observed for the northern countries (Germany, Finland and the UK), while this tendency is towards the minimum values for the southern countries (Spain and Portugal). The above do not give a clear indication of whether the modelled CO and/or NO_x emissions are under- or overestimated. Hausberger et al. (2003) suggest that emissions of modern heavy-duty vehicles are underestimated by existing emission factor databases, which affects especially the NO_x emission levels. Consequently, NO_x emission levels of this vehicle category did not decrease since the introduction of EURO 1 limits in real world driving conditions and thus NO_x emissions are expected to be underestimated in TRENDS. This underestimation may explain the slightly higher calculated emission ratios as compared to the average concentration ratios measured for the northern countries mentioned above.

NO_x/PM emission ratios calculated with TRENDS are clearly overestimated, being up to six times higher than the weighted average concentration ratios. Since NO_x emissions are most probably underestimated by TRENDS – as mentioned above – this indicates that PM emissions are also underestimated and that this underestimation should be even higher. With regard to the modelled PM emissions it has to be noted that TRENDS covers solely tailpipe diesel PM, i.e. emissions from gasoline-fuelled vehicles and non-tailpipe emissions (such as from brakes, tire wear, road wear and re-suspension of road dust) are not taken into account. While PM emissions from gasoline-fuelled vehicles are at least two orders of magnitude lower than diesel PM emissions, several studies indicate that non-tailpipe emissions constitute a significant fraction of the total road traffic PM emissions. It is also known that practically all PM emitted by road vehicles are in the fine fraction and thus the entire PM emissions calculated by TRENDS can be considered as $PM_{2.5}$ emissions. Taking the above into account it may be concluded that modelled PM emissions are significantly underestimated.

As a result of the underestimation in the PM emissions calculated by TRENDS the PM/CO emission ratios are underestimated as well since there is no indication of any under- or overestimation of the CO emissions. The respective ratio is well below the observed concentration ratio, being underestimated by a factor of two to four. A recent study showed that, although a valid European-wide $PM_{2.5}$ to PM_{10} ratio can not be proposed, site-specific ratios can be obtained, ranging between 0.57 and 0.85 (Van Dingenen et al., 2004).

Apart from the reasons mentioned above, there might be other reasons possibly contributing to the observed discrepancies. Measuring errors as well as unusual meteorological and traffic conditions may result in ‘outliers’ in the calculated concentration ratios. Meteorological parameters, mainly wind speed and direction, may influence the measured concentrations of pollutants in the atmosphere, particularly as regards the re-suspension and dispersion processes. Whereas the variation in NO_x concentrations is generally limited and is mostly guided by the parallel variations in meteorological conditions, PM varies more, as a result of re-suspension of road dust, especially during the winter months. Special traffic conditions, such as the exclusion of certain vehicles, may lead to ambient air concentrations not representative of the contribution of the entire vehicle fleet. However, other sources of emissions apart from road traffic may add to the emissions concentration in the atmosphere.

On the other side, traffic emissions calculated with TRENDS are a complex function of a large number of parameters, as already mentioned in paragraph 0. As a result, many uncertainties related to the correct estimation of these parameters are introduced in the model. Older technology vehicles, enhanced cold start effects and – probably more important – poorer than expected vehicle maintenance could explain – to a certain extent – the variations.

In view of the above, an assessment of the emission inventories compiled with TRENDS is presented in the following section, in an attempt to make best use of the available data obtained from air quality measurements and – eventually – to calibrate the model.

2.4 Model validation

For the reasons explained in the previous section and in accordance with the results presented above, the CO/NO_x ratio is the most appropriate one for this analysis.
In an attempt to investigate the influence of the share of emissions allocated to urban driving conditions, the share of vehicle-kilometres driven in urban areas was extracted from TRENDS for the major vehicle categories. The country-specific percentage shares are summarised in Table 2.4.

After conducting a number of sensitivity runs with the COPERT model changing the urban shares of the various vehicle categories it was concluded that the emission ratio was most sensitive to changes in the shares of the diesel Light- (LDV) and HDV categories.

Table 2.4 Estimated values of urban share of mileage (in %) driven by the various vehicle categories as used in TRENDS.

	Germany	Spain	Finland	Portugal	United Kingdom
Gasoline passenger Cars	37.2	30.5	30	24	46
Diesel passenger Cars	37.2	68.8	30	24	46
LPG Passenger Cars	0	100	30	0	0
Gasoline Light Duty Vehicles	37.2	42	30	0	46
Diesel Light Duty Vehicles <3,5 t	40.5	78	30	4.3	46
Heavy Duty Vehicles 3,5 - 16 t	40	40	40	20.8	29
Heavy Duty Vehicles >16 t	6.8	24.9	20	20.8	29
Urban Buses	100	100	100	100	100
Coaches	0	0	0	0	0
Mopeds	45	100	20	15.2	100
Motorcycles	18.5	73.7	30	21.8	54

Tables 2.5 summarises the suggested changes in urban shares and the resulting new ratios versus the respective concentration ratios. These values do not differentiate considerably from the 'default' ones, which have been estimated rather than measured.

Table 2.5. Suggested changes in the urban shares of TRENDS and comparison with concentration ratios resulting from the data analysis from traffic stations in the selected countries.

	CO/NO_x	NO_x/PM	PM/CO
Germany			
TRENDS default	7.16	13.12	0.011
+15% for HDV>16 t	6.40	13.28	0.012
Air Quality weighted average	6.25	5.42	0.036
Spain			
TRENDS default	5.25	11.60	0.016
-30% for diesel PC, diesel LDV = gasoline LDV, -20% for all HDV	8.62	12.43	0.016
Air Quality weighted average	9.42	4.18	0.031
Finland			
TRENDS default	6.80	13.90	0.011
Air Quality weighted average	6.36	4.52	0.038
Portugal			
TRENDS default	3.90	14.72	0.017
+15% for all PCs, -15% for HDV>16 t, +50% for mopeds	5.88	15.98	0.017
Air Quality weighted average	6.97	2.49	0.057
United Kingdom			
TRENDS default	8.96	17.72	0.006
+20% for HDV<16 t	8.42	16.95	0.007
Air Quality weighted average	4.67	10.99	0.026

In order to further investigate the reasons contributing to the observed discrepancies, but also in an attempt to quantitatively define the 'outliers' (eventually supporting a better definition of hotspots), data for the individual stations are used. Figure 2.4 presents the case of Germany, where a scatter plot of the CO/NO_x ratios calculated for each station – resulting from the analysis described in paragraph 2.2.2 – is shown. The weighted average over the country is plotted on the same graph, as well as the respective exhaust emission ratio as calculated by TRENDS – resulting from the procedure described above. All station values situated outside an appropriately chosen range, defined here by ±1.5 times the standard deviation (dashed lines), are considered as 'outliers'. Figure 2.5 shows the case of Spain, while the other countries are not shown due to the limited number of stations available. Evidently, the inclusion of as many as possible stations in the analysis will allow for a more thorough assessment.

Once the outliers have been identified, "zooming" in the street level will reveal any special conditions governing the measured concentrations. Prerequisite for this is the availability of hourly concentrations at both the traffic station and a nearby urban background station representing concentrations attributed to sources other than traffic.

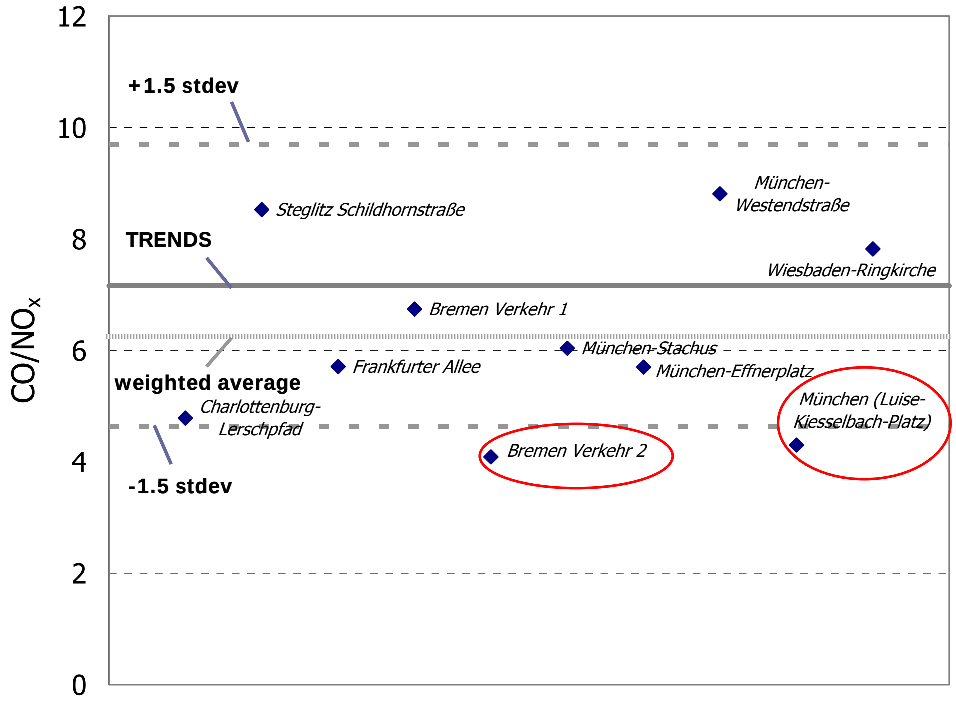


Figure 2.4. Calculated CO over NO_x ratios for the individual stations in Germany against country weighted average and modelled with TRENDS.

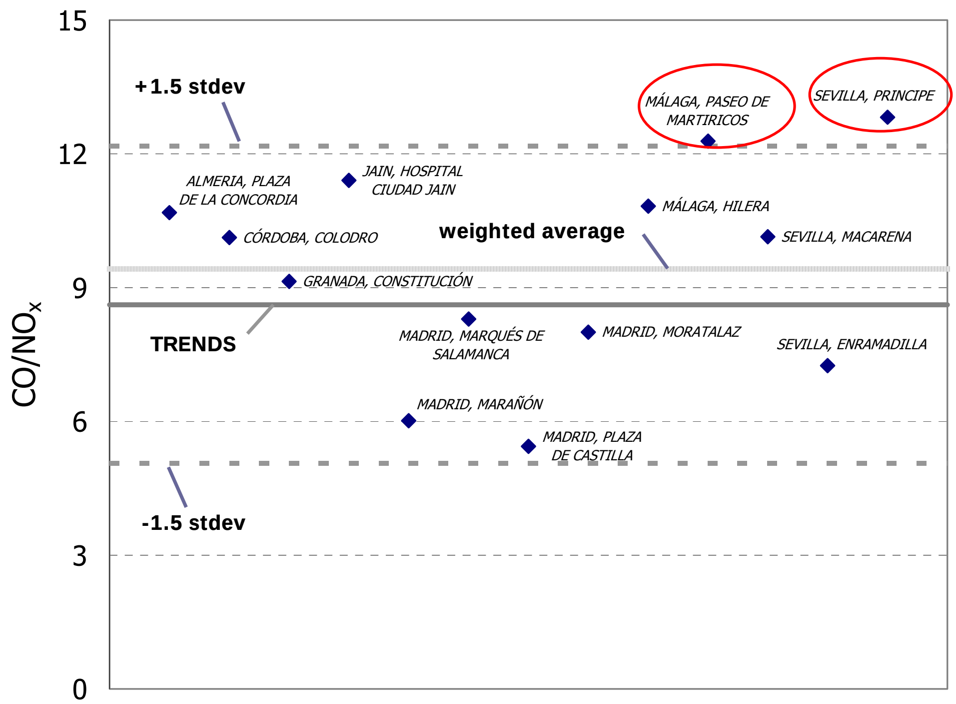


Figure 2.5. Calculated CO over NO_x ratios for the individual stations in Spain against country weighted average and modelled with TRENDS.

In that case the traffic contribution may be calculated by simply subtracting the street concentrations from the background levels. Furthermore, detailed traffic data (traffic volume, fleet composition, average speeds) are necessary in order to enable the calculation of emissions with the COPERT model. Finally, meteorological data (temperatures, wind speed and direction) are particularly relevant to the interpretation and evaluation of various phenomena, such as the re-suspension of road dust and complicated dispersion processes. A further investigation at station level is however outside the scope of the present paper.

2.5 Conclusions and follow-up

In general, the agreement between measured and modelled CO/NO_x emission ratio suggests that the measured concentrations originate from traffic-related emissions. On the other hand, the large underestimation in the modelled PM/CO ratio clearly indicates that emission sources other than exhaust from diesel vehicles significantly contribute to the PM levels at urban hotspots. As diesel PM emissions are constantly decreasing due to technological improvements, PM emissions from gasoline-fuelled vehicles may constitute a considerable fraction of the total PM emitted from road traffic in the near future. Furthermore, primary non-exhaust particles, i.e. particles emitted directly as a result of the wear of surfaces and secondary particles, i.e. those resulting from the re-suspension of previously deposited material, add to the total PM concentrations in the ambient air.

Particle concentrations are measured mainly as PM_{10}, although the number of $PM_{2.5}$ stations is now increasing. However, in order to allow for a more consistent evaluation of the $PM_{2.5}$ emissions provided by TRENDS, more information on $PM_{2.5}$ concentrations needs to be collected at the monitoring sites.

It has been demonstrated that air quality data collected at urban traffic monitoring stations can be used to evaluate emission inventories. As a next step, a calibration of the TRENDS model used to compile the emission inventory is possible with re-allocations of the mileage driven in urban environments based on reasonable assumptions. However, it should be borne in mind that there might also be other reasons possibly contributing to the observed discrepancies between modelled and measured ratios, including meteorological data, other sources of pollution, special traffic conditions, or combination of the above.

In any case, the inclusion of air quality data from as many as possible traffic stations well distributed over the countries will add to the confidence on their consistency and representativeness, reducing thus the noise of the various effects mentioned above. In view of the above it has to be mentioned that the results presented here are indicative and their role is mainly to present a methodology and the potential outcome of its application.

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Chapter 3: Air quality modelling

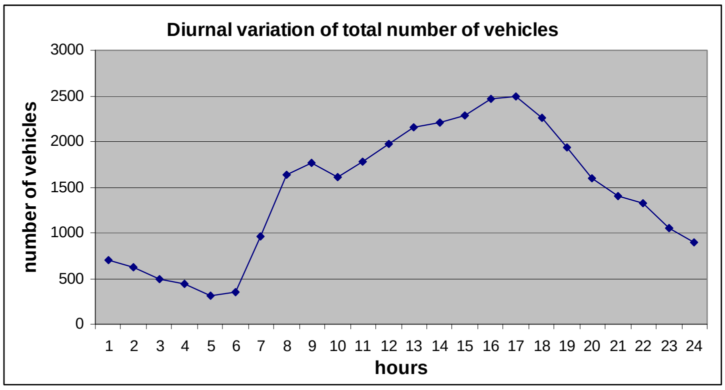
3.1 Introduction

The air quality modelling subtask in 2004 aimed at continuing the work started in 2003 and extending the number of models and cases applied with emphasis on City-Delta cities. Until September 2004, the data available allowed for three case studies, Stockholm (Hornsgatan), London (Marylebone Rd.) and Berlin (Frankfurter Allee). The Operational Street Pollution Model (OSPM) (Berkowicz et al., 1997), the recently developed Semi-Empirical Parameterised Street Canyon Model (SEP-SCAM) (URL1) and the Eulerian three-dimensional, prognostic, CFD model for microscale applications MIMO (Ehrhard et al, 2000), were applied to the three case studies. For all cases, the street emissions were calculated using COPERT 3 methodology and local traffic data.

3.2 The OSPM, SEP-SCAM and MIMO model applications

3.2.1 Stockholm, Hornsgatan

Street level concentrations of NO_2, $PM_{2.5}$ and NO_x in Hornsgatan were calculated for the year 2000. Urban background was assumed to be properly described by the data from the corresponding monitoring station as this was located at roof level above Hornsgatan. Emission data were computed using COPERT 3 and the local traffic data. As the street canyon is located in downtown Stockholm, it was assumed that only HDVs with a Gross Vehicle Weight (GVW) lower than 16 tonnes were allowed, i.e. the share of HDVs with a GVW of 16-32 tonnes and over 32 tonnes was set equal to zero. The road gradient (about 2%) was also taken into account. The assumptions regarding the fleet composition and the additional information concerning the road gradient (this information was made available at a later stage during the course of the SEC project) lead to a slightly different set of emission data compared to that used in the Model Intercomparison study (see chapter 4). Although by considering the road gradient the NO_x emissions increase by ~4% and the $PM_{2.5}$ emissions by ~7%, the overall effect (including the assumption that very large HDVs are not allowed to cross Hornsgatan street) is a reduction of the emissions with respect to those used in the Model Intercomparison study by ~15% for NO_x and ~10% for $PM_{2.5}$. This reduction in emissions leads to slightly reduced concentration estimates compared to those in chapter 4. In Figures 3.2 and 3.3 that follow, the SEP-SCAM and OSPM model runs have been performed using the latest set of emission data, whereas the MIMO model runs were performed using the initial dataset provided for the Model Intercomparison Exercise. However, as the differences are small, the results are comparable. It should also be noted that the COPERT methodology allows for the calculation of $PM_{2.5}$ exhaust emissions from diesel vehicles only.



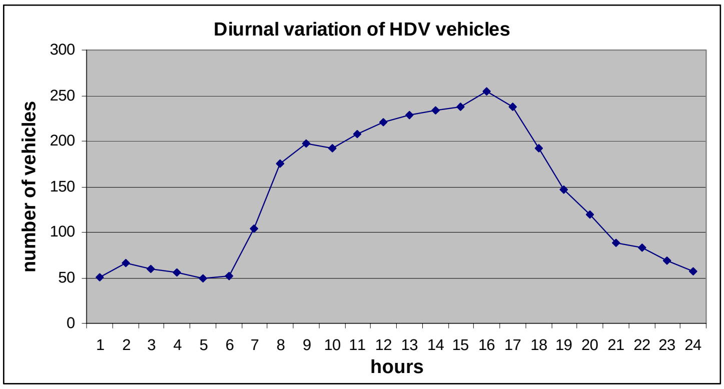


Figure 3.1. Diurnal variation of the total number of vehicles (top) and the HDV (bottom) in Hornsgatan.

The HDV percentage ranges from around 7-8% of the total number of vehicles in the evening hours until around 1:00 am, then rises quite rapidly to around 15 %-16 % in the early morning hours (2:00-6:00 am) and then remains relatively stable (between 10 %-12 %) during the rest of the day.

In Figure 3.2, the OSPM, SEP-SCAM and MIMO results for the average hourly concentrations in 2000 are compared with corresponding values from the traffic (street level) monitoring station. It should be underlined that the microscale flow and dispersion model MIMO was used in the framework of the air quality modelling subtask to calculate normalised concentrations (also referred to as c* values) for NO_x and $PM_{2.5}$ (not NO_2), for 16 wind directions. The different scaling methods to calculate hourly concentration time series from c* values are described in detail in Ketzel et al. (2001). In this modelling subtask, the TPT (Traffic Produced Turbulence) scaling method was used.

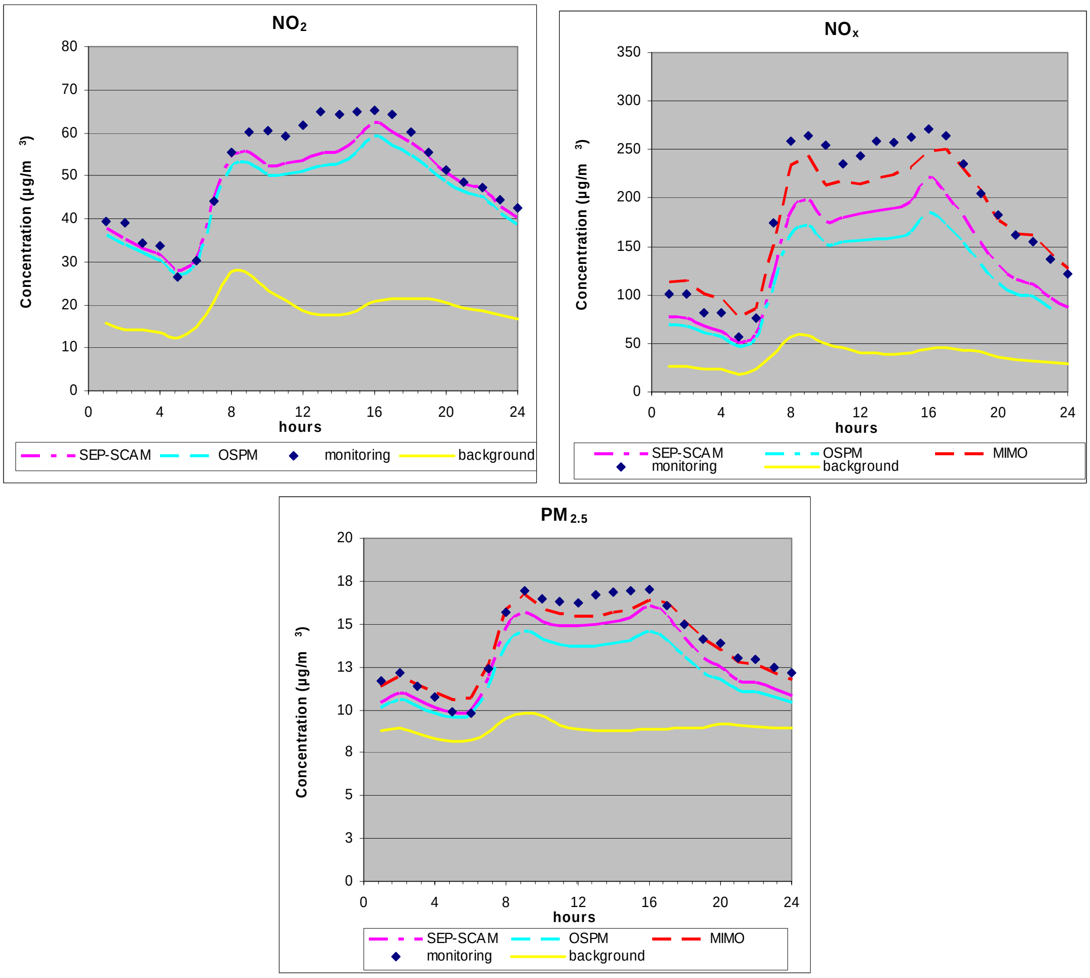


Figure 3.2. SEP-SCAM, OSPM and MIMO results for the average daily variation of NO_2, NO_x and $PM_{2.5}$ concentrations at street level in Hornsgatan in 2000 compared with observations.

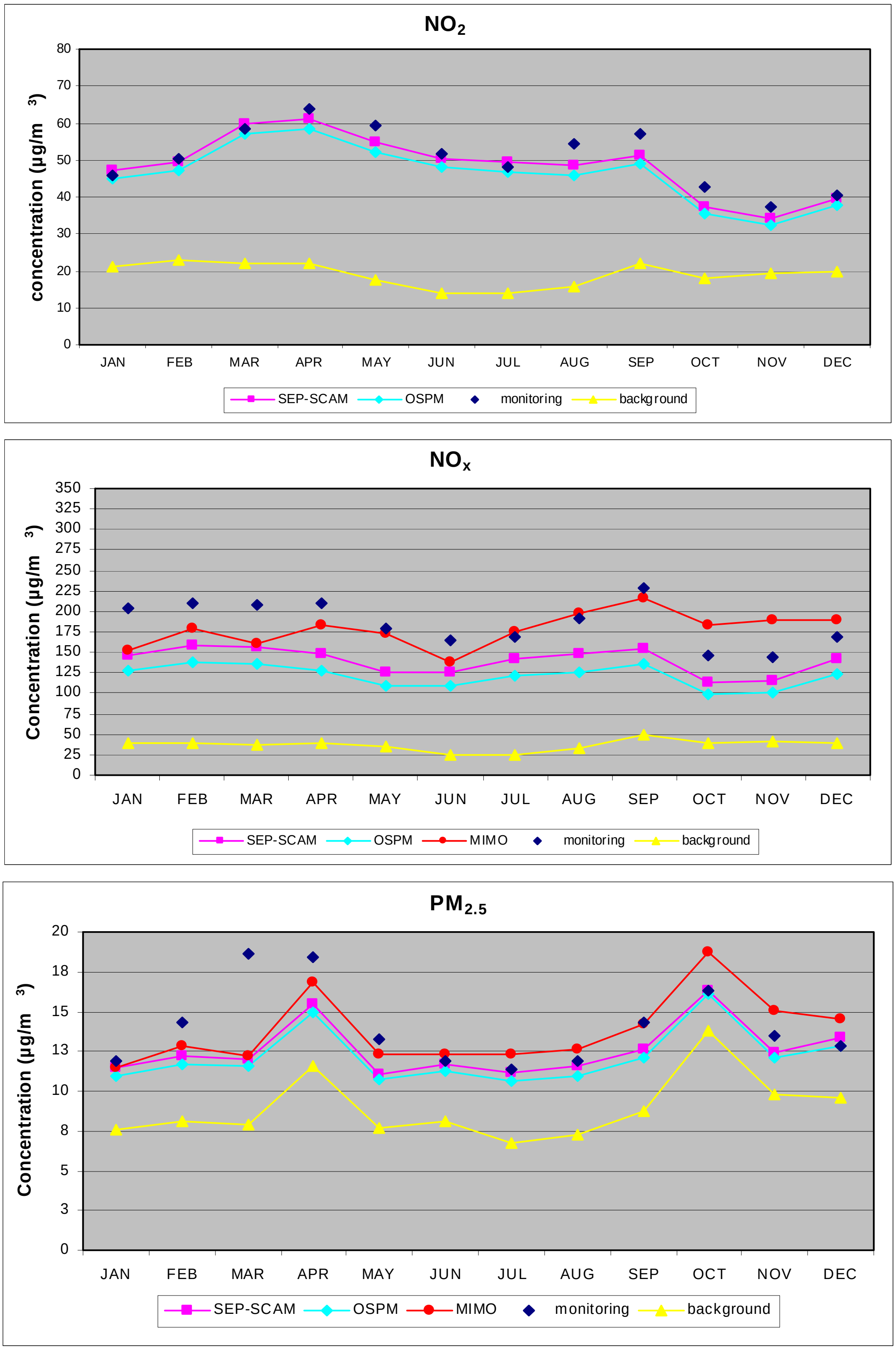


Figure 3.3. SEP-SCAM, OSPM and MIMO results for the monthly variation of NO_2, NO_x and $PM_{2.5}$ concentrations at street level in Hornsgatan in 2000 compared with observations.

Results show that the diurnal patterns of the observed concentrations are generally underestimated by all models. Overall, all three models provide a good impression of the observations, closely following the diurnal and monthly patterns observed in the monitoring data. The slightly increased emissions used in the MIMO model runs lead to higher concentration estimates and thus provide a better impression of the average daily variation for NO_x and $PM_{2.5}$ concentrations at street level, compared to the other two models. Comparing the semi-empirical model results, OSPM underestimates the actual concentrations more than the SEP-SCAM model. This is due to the additional concentration increment that is calculated by SEP-SCAM in order to consider the dependence of the flow regime on the aspect ratio and the fact that the traffic emissions are not uniformly distributed across the canyon. This factor is directly proportional to the emissions and hence larger concentrations are observed mainly during the day, when the traffic intensity is higher. Overall, in the case of $PM_{2.5}$, the underestimation of the model results compared to the measurements may indicate that emission sources other than diesel vehicles (e.g. contributions of gasoline vehicles) should also be taken into account in the calculations. An even greater underestimation is observed for NO_2 and especially NO_x for OSPM and SEP-SCAM. As was also discussed in the model intercomparison session during the 9th Model Harmonisation Conference, this may be due to a general underestimation of NO_x emissions. The ARTEMIS project findings and other emission factors are being compared with those used by the COPERT methodology, in order to study this possibility further.

3.2.2 Berlin, Frankfurter Allee

Street level concentrations of NO_2, PM_{10}, NO_x and CO in Frankfurter Allee were calculated for 2002 using SEP-SCAM, OSPM and MIMO models. Urban background was assumed to be properly described by the data from the corresponding monitoring station, although this was located at a distance of 2km from Frankfurter Allee. Emission data were computed using COPERT 3 and the local traffic data. It should again be noted that these emission data account for the $PM_{2.5}$ exhaust emissions of diesel vehicles only.

As the detailed hourly counts for the number of HDV were not entirely reliable, an average factor of 4.8 % was suggested by the data provider and used for the model calculations. This percentage varies from 5.6 % on working days (Mo-Fr), to 3.4 % on Saturdays and 2.6 % on Sundays and public holidays. Compared to Hornsgatan, the HDV percentage in Frankfurter Allee is quite low. Although the number of vehicles moving along Frankfurter Allee is significantly higher than that moving along Hornsgatan (56,000 vehicles per day, compared to 35,000), differences in the vehicle fleet (vehicle classes), the lower percentage of HDV and the different height-to-width aspect ratio, lead to lower concentrations in Frankfurter Allee.

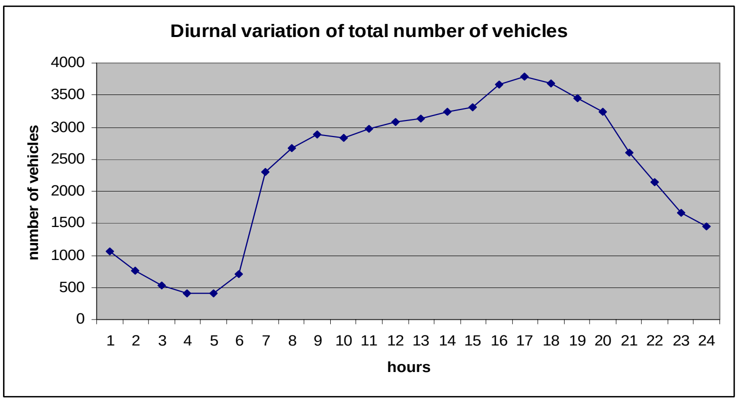


Figure 3.4. Diurnal variation of the number of vehicles in Frankfurter Allee.

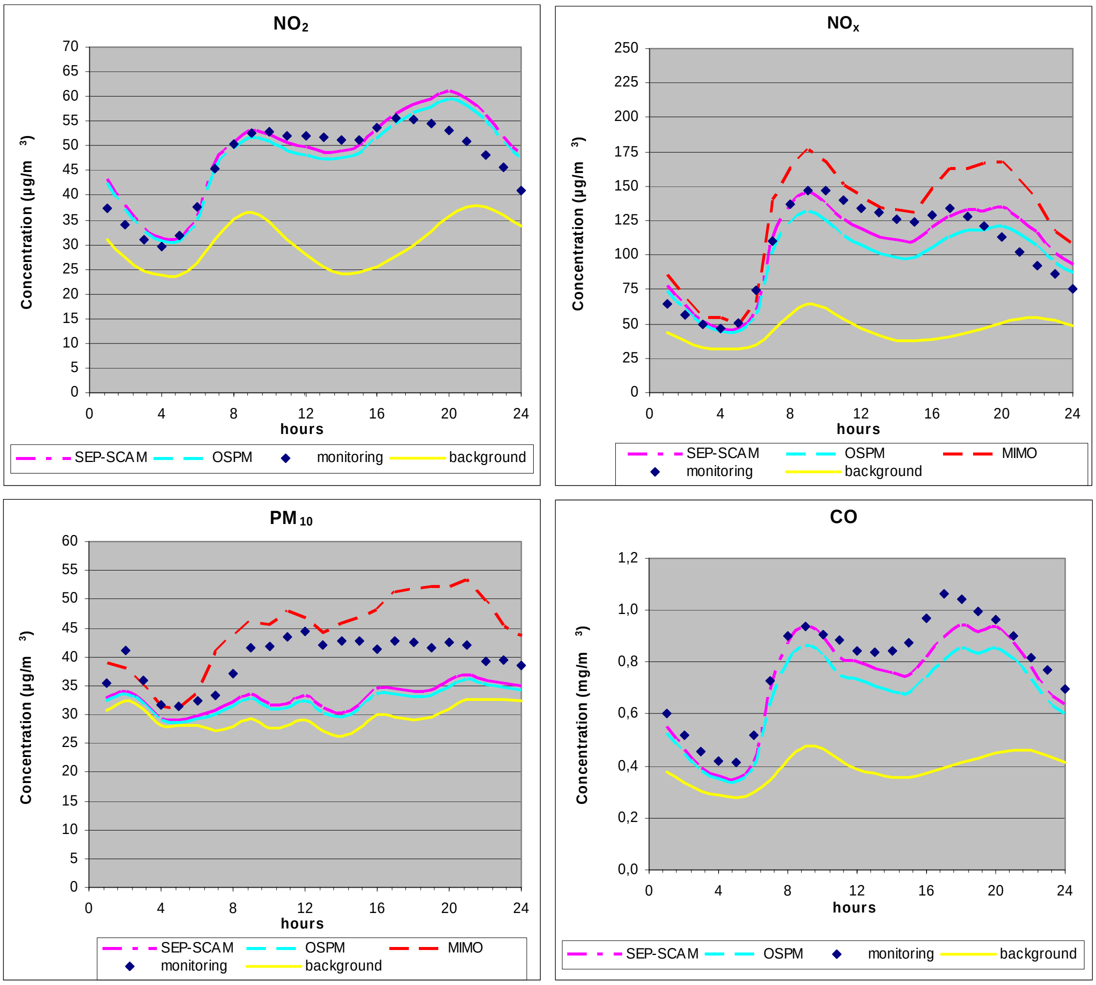


Figure 3.5. SEP-SCAM, OSPM and MIMO results for the average daily variation of NO_2, NO_x PM_{10} and CO concentrations at street level in Frankfurter Allee in 2002 compared with observations.

All three model results provide a very good impression of the observations, closely following the diurnal and monthly patterns observed in the monitoring data. Results show that MIMO generally overestimates slightly the observed concentrations, while on the other hand SEP-SCAM and OSPM underestimate them. Furthermore, SEP-SCAM produces slightly higher concentrations than OSPM (this is further explained in section 3.2.1 - Hornsgatan case study analysis).

The slight underestimation in the CO and NO_x concentrations computed by the SEP-SCAM and OSPM models may be due to an underestimation of the average height of the buildings adjacent to the street. The data source used estimated the height to be around 21m, whereas other data sources indicate that it may even be around 30m. For PM_{10}, the monitoring data reveal a diurnal pattern that is rather unusual for a traffic station, but a similarly strange pattern is also observed for the background concentrations. It is not clear what local effects produce these patterns. However, the calculated data closely follow the monitoring data pattern and the underestimation observed in the modelled results is to be expected, since only $PM_{2.5}$ diesel vehicle emissions are considered.

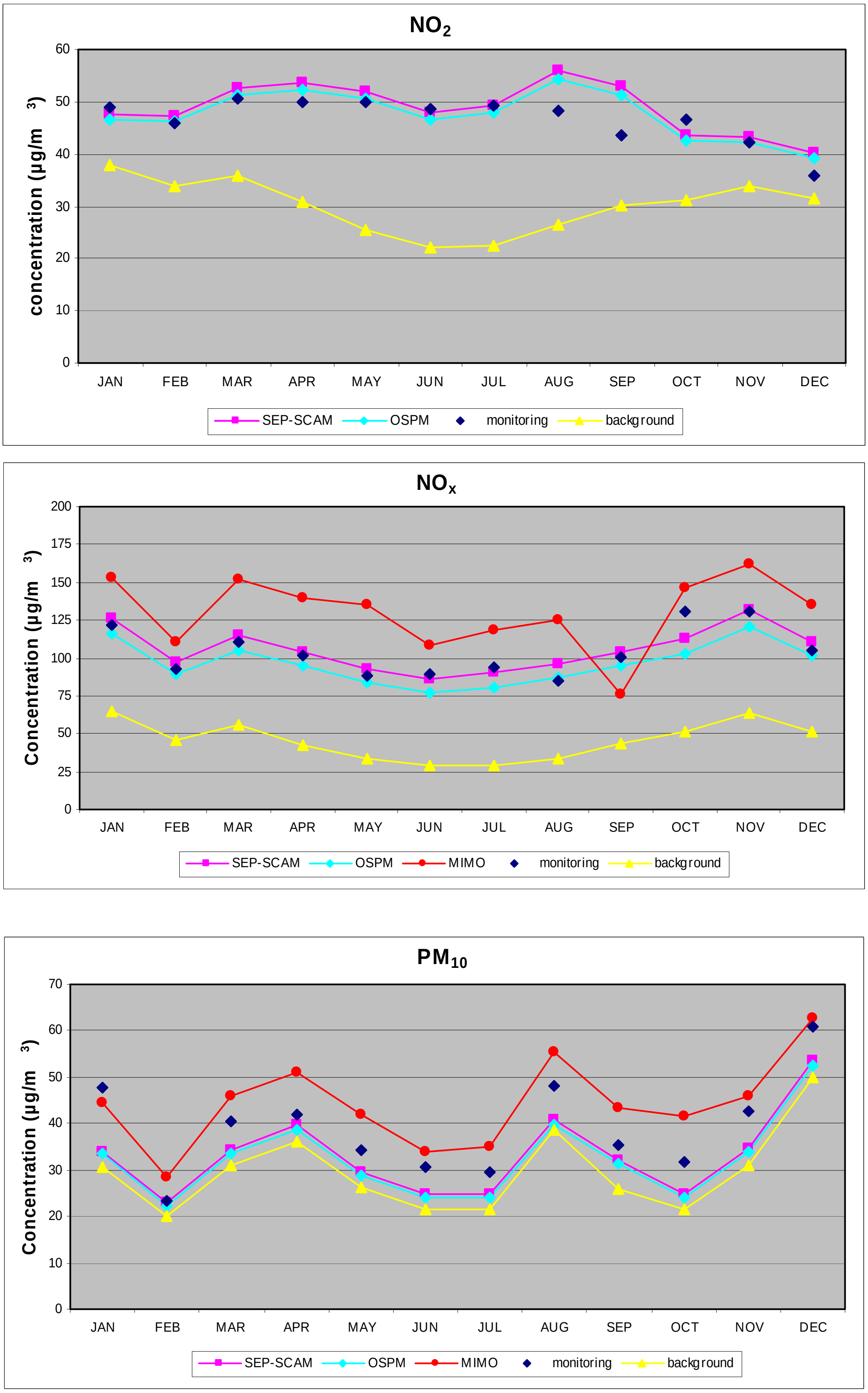


Figure 3.6. SEP-SCAM, OSPM and MIMO results for the monthly variation of NO_2, NO_x, PM_{10} and CO concentrations at street level in Frankfurter Allee in 2002 compared with observations.

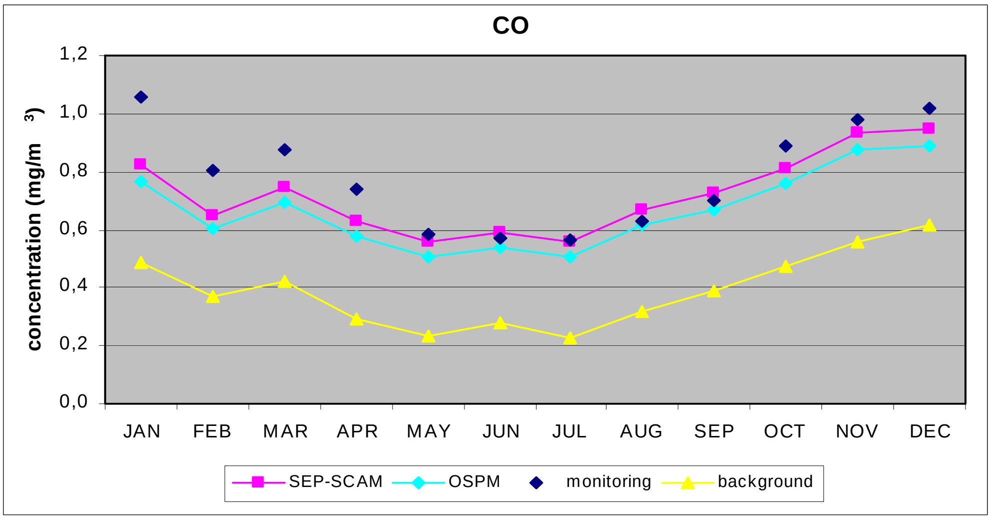
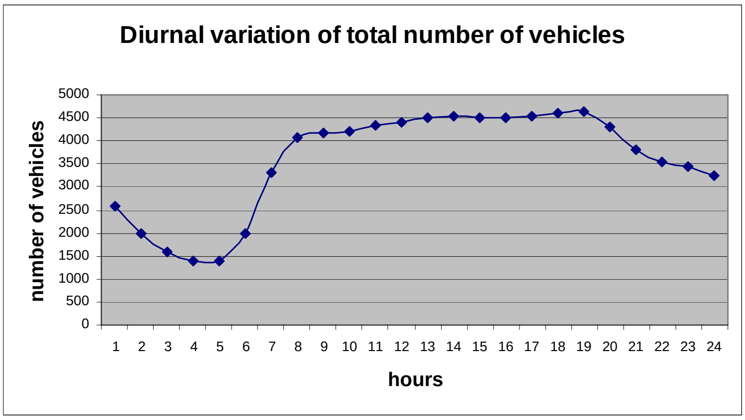


Figure 3.6. (continued).

3.2.3 London, Marylebone Rd.

Street level concentrations of NO_2, PM_{10}, NO_x and CO in Marylebone Rd. were calculated for 2000.



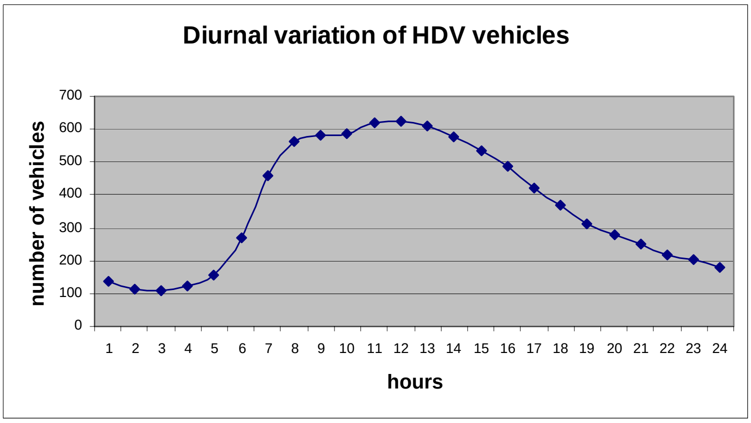


Figure 3.7. Diurnal variation of the total number of vehicles (top) and the HDV (bottom) in Marylebone Rd..

Urban background concentrations were assumed to be properly described by the data from the urban background monitoring station in Bloomsbury. This is located at a distance of 2 km east of Marylebone Rd. and was the only station that could be used for the analysis, as there was no other urban background station located closer. Similarly, the meteorological data was obtained from a station located 3.7 km away from Marylebone Rd. at 43 m above the ground, as no other roof level meteorological station was located closer by.

Emission data were computed using COPERT 3 and the local traffic data. It should once again be noted that these emission data account for the $PM_{2.5}$ exhaust emissions of diesel vehicles only. The HDV percentage in Marylebone Rd. is high compared to other case studies and ranges between 11-14% of the total number of vehicles during the day and then drops to vary between 5-9% during the evening and early morning hours (17:00-9:00). Although the average number of vehicles moving along Marylebone Rd. per day is 85,500 and therefore high and comparable to that of Frankfurter Allee (56,000), the measurements show significantly higher concentrations in London compared to Berlin for all pollutants. The large number of HDV, in conjunction with the low vehicle speed during the day (average speed of 35 km/h between 9:00-17:00) and the smaller road width (but similar building height) could be the reasons behind these high concentrations.

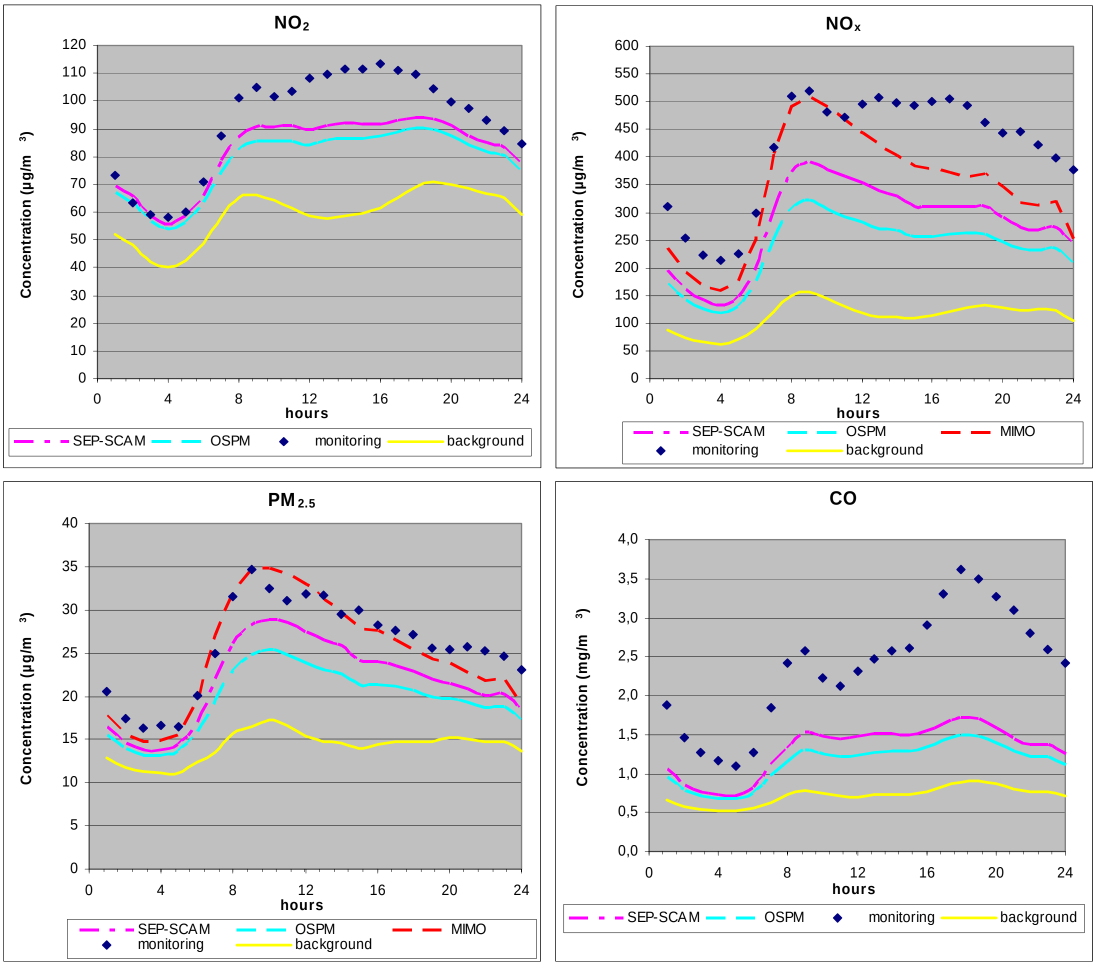


Figure 3.8. SEP-SCAM, OSPM and MIMO results for the average daily variation of NO_2, NO_x $PM_{2.5}$ and CO concentrations at street level in Marylebone Rd. in 2000 compared with observations.

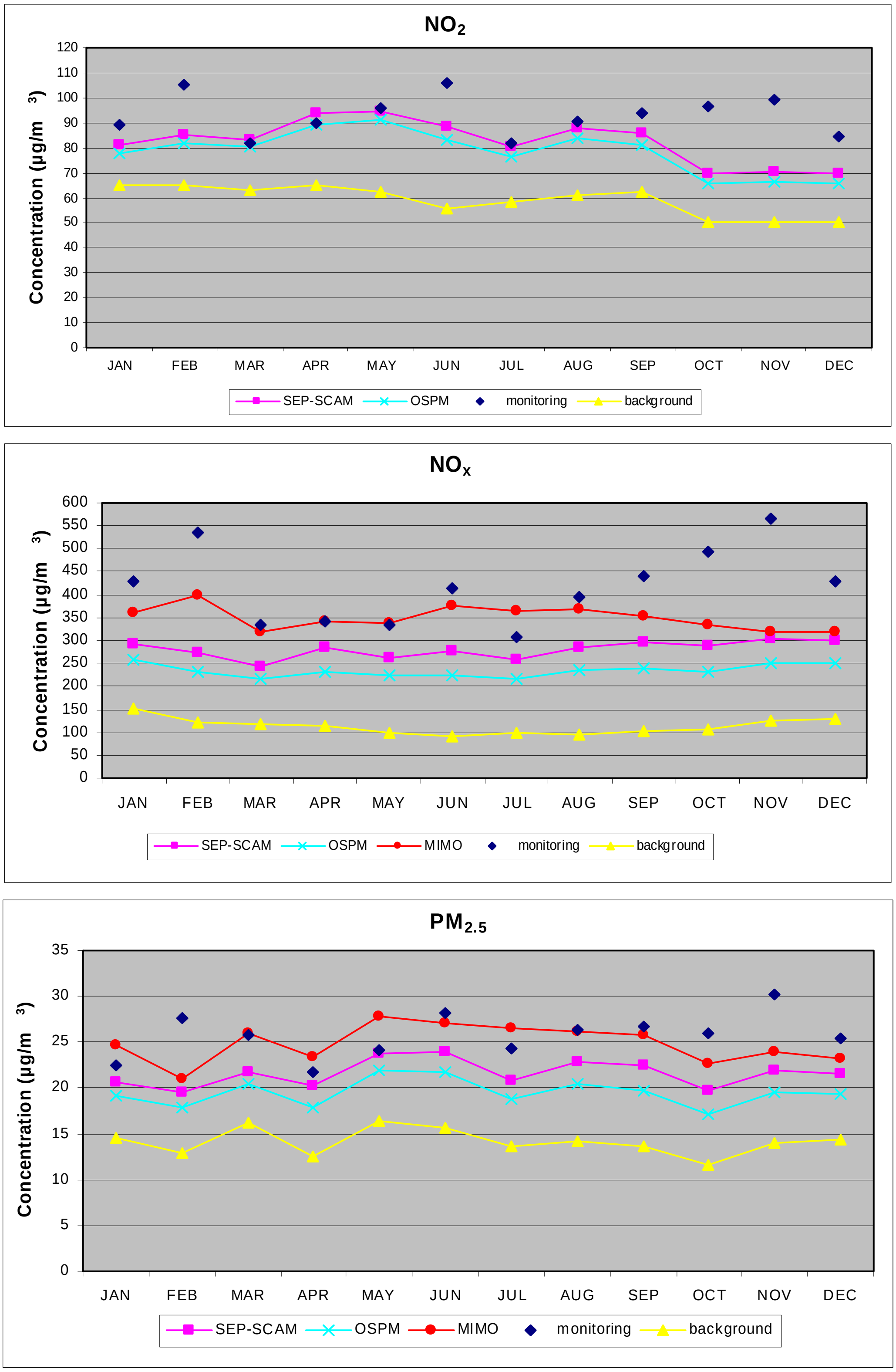


Figure 3.9. SEP-SCAM, OSPM and MIMO results for the monthly variation of NO_2, NO_x, $PM_{2.5}$ and CO concentrations at street level in Marylebone Rd. in 2000 compared with observations.

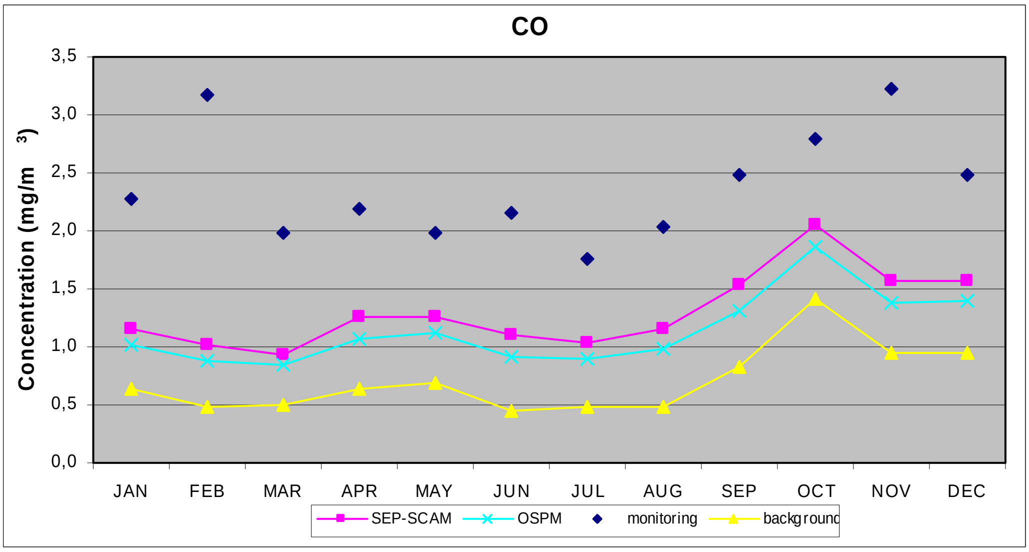


Figure 3.9 (continued).

In a qualitative sense, all three model results for Marylebone Rd. generally reproduce well the diurnal and monthly patterns observed in the monitoring data. MIMO presents better coincidence with NO_x $PM_{2.5}$ monitoring data. In particular the predicted concentrations by SEP-SCAM and OSPM are systematically much lower than both the ones predicted by MIMO and the observed ones. The underestimation of the street level concentrations by all models may be due to the high wind speeds observed, as it is likely that due to the distance of the meteorological station from Marylebone Rd. the wind speed is not representative and thus higher dispersion is assumed leading to lower concentrations. Similarly to the other cases, an underestimation in $PM_{2.5}$ is expected as emission sources other than diesel vehicles (e.g. contribution of gasoline vehicles) have not been considered in the calculations.

3.3 Conclusions

Results from the application of OSPM, SEP-SCAM and MIMO models for the three aforementioned case studies, show that the concentrations measured at street level can be satisfactorily reproduced. Moreover, these results show that the diurnal patterns of the observed concentrations are generally underestimated by all models, with the exception of the Berlin case where MIMO has demonstrated an overestimation of the street level NO_x and $PM_{2.5}$ concentrations. However, both MIMO and SEP-SCAM provide a better impression of the observations than OSPM. Overall, MIMO has demonstrated better agreement with the observed data than SEP-SCAM with the exception of the Berlin case.

Further steps of the SEC modelling work will include the application of the aforementioned models to the case study of Prague (data is currently being collected and assessed) and other cities, provided that data is made available.

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Berkowicz R., Hertel O., Larsen S.E., Sorensen N.N., Nielsen M. (1997). Modelling traffic pollution in streets. Ministry of Environment and Energy, National Environmental Research Institute.

Ehrhard J., Khatib I.A., Winkler C., Kunz R., Moussiopoulos N., Ernst G. (2000). The microscale model MIMO: development and assessment. J. of Wind Engineering and Industrial Aerodynamics 85, 163-176.

Ketzel M., Berkowicz R., Flassak T., Lohmeyer A., Kastner-Klein P. (2001). Adaption of Results from CFD-Models and Wind-Tunnels for Practical Traffic Pollution Modelling. 7th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Belgirate, Italy - 28-31 May 2001. Proceedings European Commission. Joint Research Centre. Environment Institute 261-265.

URL1: http://pandora.meng.auth.gr/mds/strquery.php?wholedb

Chapter 4: Model intercomparison report

4.1 Introduction

The model intercomparison exercise was planned in conjunction with the work performed within the Street Emission Ceilings (SEC) exercise of the ETC/ACC 2004 workprogramme, whose aim was to study specific hotspots and quantify the influence of local and urban emissions and other smaller scale effects on concentrations and exceedances. The intercomparison exercise was expected to provide an insight in the level of uncertainty that is inherent in the various model calculations and a first estimate of the uncertainty that enters from the street level, into a complete regional-urban-street scale model application. Moreover, the large number of models participating in the intercomparison and the variety of cases available enabled the evaluation of the model performance, bearing in mind the restrictions of the input data. The cases studied were: Hornsgatan (Stockholm), Frankfurter Allee (Berlin) and Marylebone Rd. (London). These are all busy streets, with available street level monitoring data (concentrations and traffic counts).

4.2 Procedure

The launch of the model intercomparison took place in March 2004, when various institutions were informed of the Hornsgatan data availability and the possibility to submit model results. The “call for participation” was open to all interested institutes and recipients of the information were encouraged to forward the call to other potential participants. Ten institutes took part in the Hornsgatan intercomparison and an additional eight were interested, but did not submit results. The interest of the participants led to the launch of the Frankfurter Allee and Marylebone Rd. cases, where additional institutes participated. Participation and presentation of model results was not anonymous.

The purpose of the model intercomparison was to assess the suitability of various models to describe the contribution of street level emissions to air quality levels in urban street canyons. The explicit comparison of the model results against the measured concentrations at street/road-side level (hotspot), as well as with the street/urban background level, led to interesting conclusions as regards the contribution of street emissions to the air quality inside street canyons. The detailed time schedule followed is summarised in Table 4.1.

Table 4.1. Analytic time schedule of the model intercomparison.

16/3/2004	E-mail informing the scientific community of the intension of launching the pilot model intercomparison for the Hornsgatan case study ("call for participation")
24/3/2004	Public availability of the Hornsgatan dataset
14/5/2004	Deadline for the receipt of model results
3/6/2004	Presentation of Hornsgatan intercomparison results in the SEC session during the 9^{th} Harmonisation Conference. Launch of the Marylebone Rd. and Frankfurter Allee cases
26/6/2004	Availability of Frankfurter Allee dataset
19/7/2004	Availability of Marylebone Rd. dataset
20/8/2004	Deadline for the receipt of Frankfurter Allee and Marylebone Rd. results

To ensure the comparability of model results, the participants were requested to follow a specific format and for this reason an excel worksheet was made available for the transfer of the results to the co-ordinator of the exercise.

The data requested included results for the full year (only average hourly and monthly values were required, not the complete hourly dataset), for a specific day (characterised by high concentration observations) and a specific hour of that day. This report concentrates on the models and results received for the full year, as these are the most relevant for the Street Emission Ceilings (SEC) task of the ETC/ACC 2004 workprogramme.

4.3 Input data

All input data were made available through http://aix.meng.auth.gr/sec using an excel file. Unless indicated otherwise, all data were collected by NILU[1] during the SEC Data analysis subtask of the ETC/ACC 2004 workprogramme and provided for the intercomparison. In all cases, the emission data were calculated by AUT/LAT[2].

4.3.1 Hornsgatan

4.3.1.1 Meteorological data

The meteorological data set included hourly data for wind speed, wind direction, temperature and global radiation for the period 1/1/2000-31/12/2000. Wind speed and direction were measured at a roof top monitoring station nearby Hornsgatan. Temperature and global radiation measurements were performed at Torkel monitoring station and downloaded from URL1.

4.3.1.2 Traffic data

The hourly traffic data included total number of vehicles, HDV percentage and vehicle speed for the period 1/1/2000-31/12/2000. Average hourly data for total number of vehicles, HDV percentage and vehicle speed were calculated by

[3] Norwegian Institute for Air Research

[2] Laboratory of Applied Thermodynamics, Aristotle University Thessaloniki.

AUT/LHTEE[3] and provided to the participants. The hourly traffic data were obtained from NILU.

4.3.1.3 Emission data

The average hourly emissions for NO_x and $PM_{2.5}$ were calculated using the COPERT 3 methodology. The length of the street canyon was set at 160 m. At the time of the calculation of the emissions, the road gradient (~2%) was not known and hence not considered in the calculations. Moreover, it was considered that all types of vehicles included in the TRENDS database are allowed to circulate in Hornsgatan street, including HDVs >16 tons.

4.3.1.4 Background concentrations

The hourly NO_x and $PM_{2.5}$ urban background concentrations were measured at a roof top nearby Hornsgatan and were available for the period 1/1/2000-31/12/2000. The hourly NO_2 background concentrations were measured at the urban background monitoring station Sodermalm and were downloaded from URL1.

4.3.1.5 Geometric characteristics

The street geometry was partly obtained from the data analysis report prepared by NILU and partly estimated from maps (Table 4.2).

Table 4.2. Geometric characteristics of Hornsgatan street canyon.

Buildings' height on the northern side of the street (m):	24
Buildings' height on the southern side of the street (m):	24
Width (m):	24
Road length (m):	160
Approximate angle the street axis makes with North (degrees):	66
Number of lanes:	4

Figure 4.1. Hornsgatan street canyon and location of the street monitoring station.

[3] Laboratory of Heat Transfer and Environmental Engineering, Aristotle University Thessaloniki.

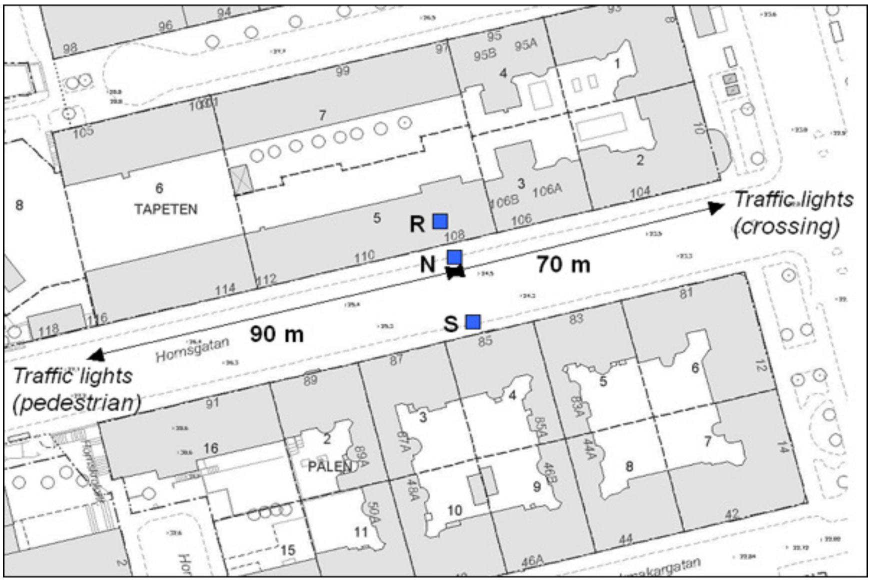

Figure 4.2. Street and roof top stations in Hornsgatan. The street monitoring station used for the intercomparison is indicated by N (North side of the street).

4.3.1.6 Position of the monitoring station

Hourly NO_x, NO_2 and $PM_{2.5}$ street level concentrations were monitored on both sides of the street during the period 1/1/2000-31/12/2000. However, the north side measurements were selected for the intercomparison, as the pollutant coverage was better (measurements included $PM_{2.5}$). The hourly NO_2 street concentrations were downloaded from URL1 (station name Hornsgatan, located on the north side of the street).

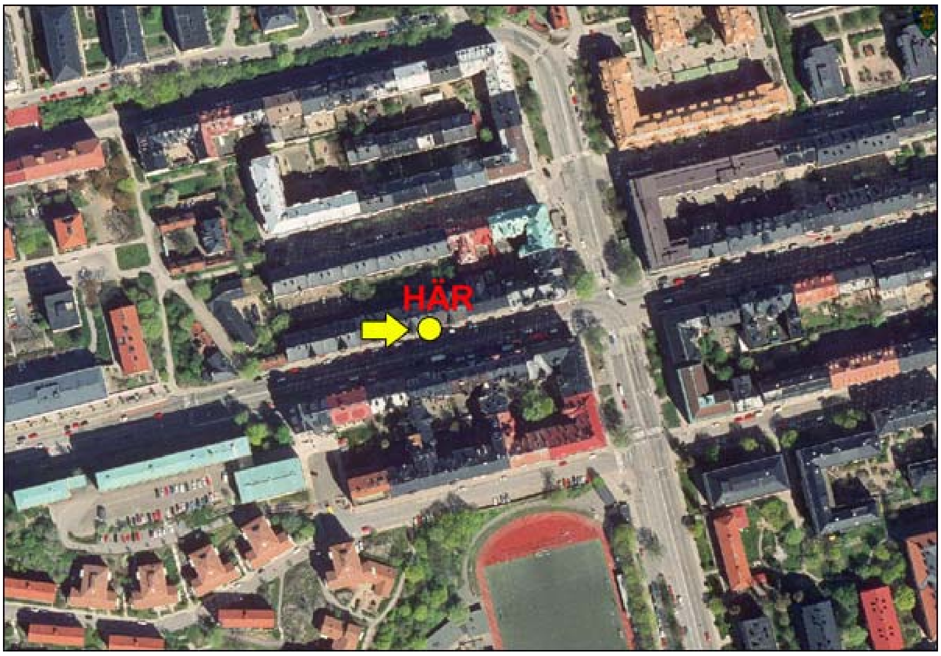

Figure 4.3. Overview of Hornsgatan and street station.

4.3.2 Frankfurter Allee

4.3.2.1 Meteorological data

The hourly meteorological data set included wind speed, wind direction, temperature and global radiation for the period 1/1/2002-31/12/2002. Wind speed and direction, as well as temperature, were measured at station DEBE043, located at roof level, 25 m above ground and 9 km away from Frankfurter Allee. The hourly global radiation measurements were from the Berlin-Dahlem WMO-station, 14 km SW-bound of Frankfurter Allee, but still representative. These were obtained from the Senate Department of Urban Development in Berlin.

4.3.2.2 Traffic data

The total number of vehicles per hour for the period 1/1/2002-31/12/2002 was available separately for the westbound and the eastbound traffic. From this data, the average number of vehicles per hour was calculated and provided to the participants. The average hourly vehicle speed and a fixed daily HDV percentage (4.8%) were also available and provided for the intercomparison.

4.3.2.3 Emission data

The average hourly emissions for CO, NO_x and $PM_{2.5}$ were calculated using the COPERT 3 methodology.

4.3.2.4 Background concentrations

The hourly CO, NO_x, NO_2, PM_{10} and O_3 urban background concentrations were measured at Neukölln, Nansenstrasse, 3.7 km away from Frankfurter Allee, as there was no other background station located closer.

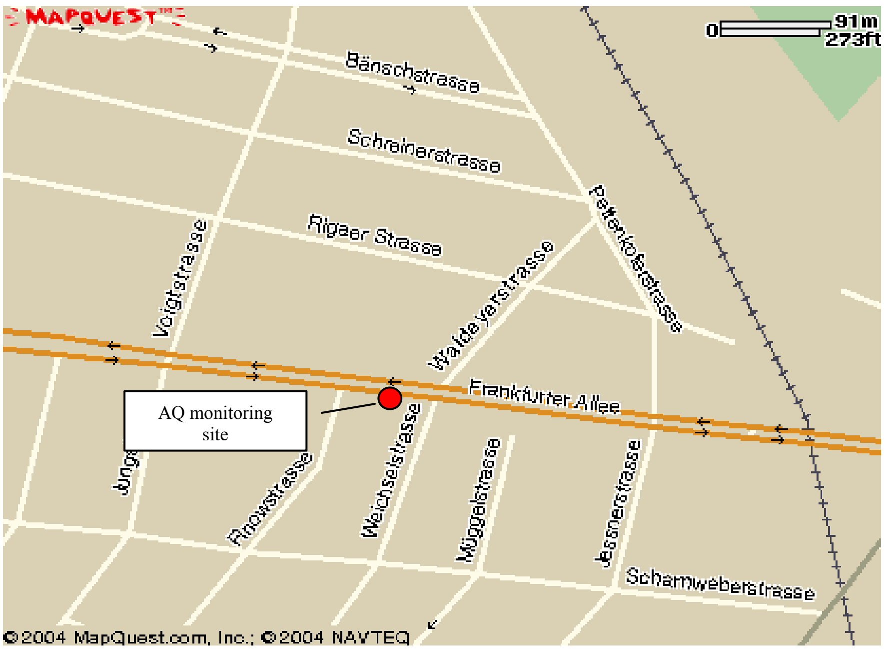

Figure 4.4. An overview of Frankfurter Allee.

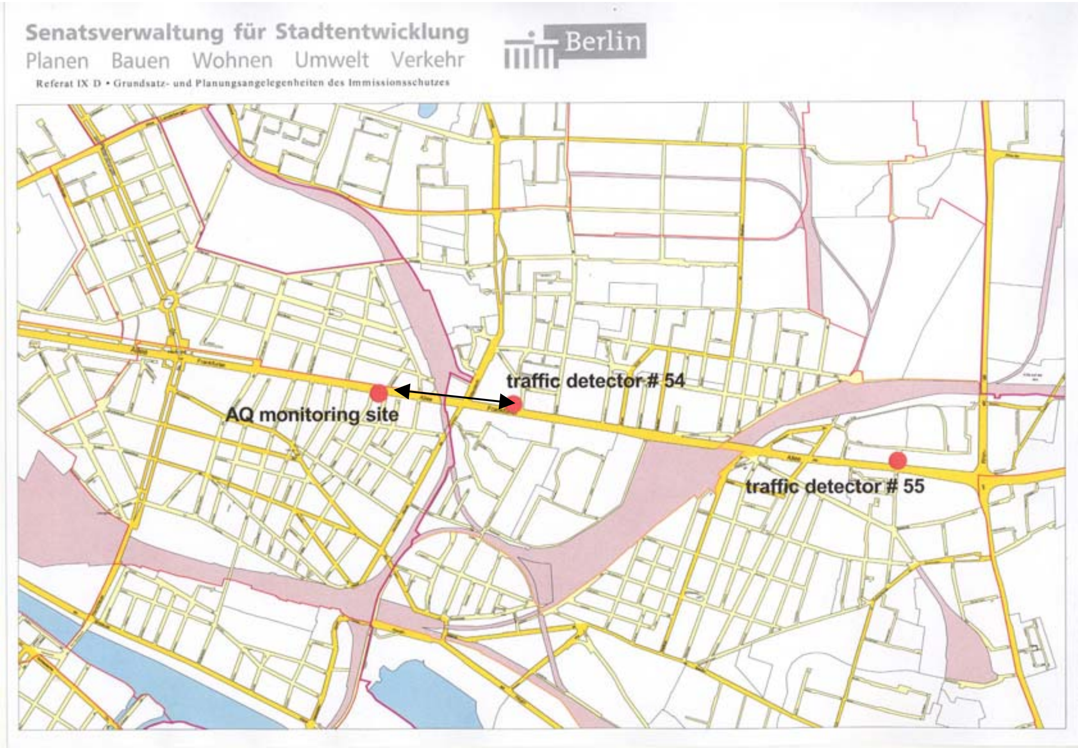

Figure 4.5. Location of the traffic detectors and the street level monitoring station.

4.3.2.5 Geometric characteristics

The height and width of street canyon as well as the number of lanes were obtained from the data analysis report prepared by NILU. The angle of the street with respect to north was estimated using maps of the area. The inlet height was provided by the Senate Department of Urban Development in Berlin.

Table 4.3. Geometric characteristics of Frankfurter Allee street canyon.

Buildings' height on the northern side of the street (m):	21
Buildings' height on the southern side of the street (m):	21
Width (m):	41.6
Approximate angle the street axis makes with North (degrees):	98
Number of lanes:	6
Height of inlet (m):	3.8

4.3.2.6 Position of the monitoring station

CO, NO_x, NO_2 and PM_{10} street level concentrations were monitored inside Frankfurter Allee.

4.3.3 Marylebone Rd.

4.3.3.1 Meteorological data

The hourly meteorological data set included wind speed, wind direction, temperature and global radiation for the period 1/1/2000-31/12/2000. Wind speed and direction, as well as temperature, were measured at the London Weather Centre, which is the only site with comprehensive meteorological data that can be obtained in Central London. This station is located 3 km away from Marylebone Rd. at 43 m above the ground. No other roof level meteorological station is located closer by. Another station that could be used was Heathrow Airport station, but this is located even farther away from the measurement site of Marylebone Rd.. The data analysis of the relevant wind speed data revealed an average yearly wind speed of 5.2 m/sec for 2000, which is higher than what one would expect to measure at roof level above a street canyon in central London. Moreover, the data is measured at 53 m above the ground (building height including mast), which is higher than the average building height close to Marylebone Rd.. The effect of this high wind speed is further analysed in section 4.5.3.1.

The hourly wind speed, wind direction, temperature data were obtained from the British Atmospheric Data Centre (URL 4) and provided by the Met Office (URL5). The solar radiation data were provided by the Environmental Research Group of King's College London.

4.3.3.2 Traffic data

The hourly traffic data included vehicle speed and number of vehicles for various classes that could be distinguished between LDVs and HDVs. The average traffic speed, the total number of vehicles and the percentage of HDVs per hour were calculated and provided to the participants.

4.3.3.3 Emission data

The average hourly emissions for CO, NO_x and $PM_{2.5}$ were calculated using the COPERT 3 methodology.

4.3.3.4 Background concentrations

CO, NO_x, NO_2, $PM_{2.5}$ and O_3 urban background concentrations were measured at Bloomsbury station located at a distance of 2 km east of Marylebone Rd. and was the only station that could be used for the analysis, as there was no other urban background station located closer.

4.3.3.5 Geometric characteristics

The street geometry was provided by the Environmental Research Group of King's College London and completed using maps of the area (http://www.maporama.com and http://streetmap.co.uk).

Table 4.4. Geometric characteristics of Marylebone Rd. street canyon.

Buildings' height on the northern side of the street (m):	22
Buildings' height on the southern side of the street (m):	22
Width (m):	35
Approximate angle the street axis makes with North (degrees):	76
Number of lanes:	6
Height of the receptor inlet (m):	3.5

Figure 4.6. An overview of Marylebone Rd.

Figure 4.7. Location of the street level monitoring station on Marylebone Rd..

4.3.3.6 Position of the monitoring station

CO, NO_x, NO_2 and $PM_{2.5}$ street level concentrations were measured on the south side of Marylebone Rd..

4.4 Participants and models used

Street level concentrations of specific pollutants for each test case were calculated as average daily variations for a whole year and/or specific day and/or specific hour using different models. The models, their type and the corresponding users during the intercomparison are presented in Table 4.5.

Table 4.5. Type of models and corresponding user.

Type of model	Model name	Applied by
Box model	BOXSTREET	CORIA (France)
Semi-empirical models	CPB3	Agenzia Milanese (Italy)
	SEP-SCAM	LHTEE (Greece)
	OSPM	NERI (Denmark), ESMG (Spain) and LHTEE (Greece)
Gaussian models	CALINE4	Pisa University (Italy)
	ADMS-Roads-Extra	ZAMG (Austria)
Lagrangian models	LASAT	ZAMG (Austria)
Eulerian models	MIMO	LHTEE (Greece)
	ADREA-HF	NCSR “Demokritos” (Greece)
	MISKAM	NERI (Denmark) and ZAMG (Austria)
Lagrangian and Eulerian combinations	VADIS	University of Aveiro (Portugal)
	FLUENT	CIEMAT (Spain)
	GRAL	Gratz University (Austria)

Every model had a unique user, apart from OSPM which was applied by NERI (Denmark), ESMG (Spain) and LHTEE (Greece). Therefore, in the case of OSPM a different “modeller” intercomparison using the same input data emerges, leading to interesting conclusions related to a user-oriented sensitivity analysis. The simulation character of each model, the consideration of chemical transformation of the pollutants and the corresponding computational time required for the simulations are shown in Tables 4.6 and 4.7 respectively. Additional model details can be found in EEA’s Model Documentation System (MDS) (URL 2).

It should be underlined that the flow and dispersion model MISKAM (version 4.2) was used in the framework of the model intercomparison to calculate normalised concentrations (also referred to as c* values) for 36 wind directions. The different scaling methods to calculate hourly concentration time series from c* values are described in detail in Ketzel et al. (2001). In the model intercomparison, the simple 1/u-scaling and the TPT (Traffic Produced Turbulence) scaling methods were used. Both MISKAM and MIMO results (average daily variation) that appear in this report were computed using the TPT scaling method, though the MIMO results were computed using 16 wind directions.

Table 4.6. The simulation character of the models.

Simulation character	Model name	Chemistry
Statistical (analysis of long-term AQ indicators)	CPB3	-
	MIMO	√
	SEP-SCAM	√
	BOXSTREET	√
Episodic (analysis of short-term AQ indicators)	SLP-2D	-
	VADIS	-
	ADMS-Roads-Extra	√
	CALINE4	√
	ADREA-HF	
Statistical/Episodic	GRAL	-
	OSPM	√
	MISKAM	-
	LASAT	√

Table 4.7. The simulation period and computational times.

Simulation period	Duration of the simulation	Model name
1 year results	Up to 10 minutes	BOXSTREET
	Up to 10 minutes	OSPM
	Up to 10 minutes	SEP-SCAM
	1 to 24 hours	ADMS-Roads-Extra
	1 to 24 hours	LASAT
	More than 24 hours	GRAL
	More than 24 hours	MISKAM
1 day results	Up to 10 minutes	CPB3
	1 to 24 hours	CALINE4
	1 to 24 hours	VADIS
	10 minutes to 1 hour + More than 24 hours	SLP-2D + Fluent
1 hour results	10 minutes to 1 hour	MIMO
	1 to 24 hours	ADREA-HF

4.5 Model results and intercomparison

4.5.1 Introduction

For all three cases studied, the models applied ranged from simple semi-empirical models to complex microscale models (Table 4.5). The former were applied for a full year, while the latter were used to simulate shorter time periods. In the analysis, four different comparisons can be distinguished (Table 4.8).

Table 4.8. Type of comparisons and reference year for the three test cases.

Type of comparison	Hornsgatan	Frankfurter Allee	Marylebone Rd.
Model results for the full year	2000	2002	2000
OSPM model results for the full year, applied by different users	2000	2002	2000
Model results for a single day	27.11.2000	3.7.2002	1.4.2000
Model results for a specific hour	Hour 10 of 27.11.2000	Hour 11 of 3.7.2002	Hour 11 of 1.4.2000

For the full year application, only the average hourly diurnal variation was requested and submitted by the participants for the intercomparison. The hourly values for the whole year were not available and hence not analysed. In this report, only a representative sample of the intercomparison results is presented. The complete presentation of the intercomparison results compared to measurements and the corresponding comparison of model Delta Concentration(s) (DeltaCs = Modelled – Background concentrations) with the observed Delta Concentration (DeltaC = Hotspot – Background measurements) are available through URL 3. The OSPM results that are included in the following paragraphs originate from the NERI application, using the dataset provided for the intercomparison.

The model results corresponding to Figures 4.8-4.25 (actual concentrations, not DeltaCs) are presented and compared to hotspot measurements in Annex D. The statistical DeltaC results (Average, Bias, NMSE and Correlation Coefficient (CC)) are depicted in Annex E.

4.5.2 The Stockholm case

The results of the Hornsgatan case were presented at the 9th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes held in Garmisch-Partenkirchen (Germany). Ten institutes provided model results and an additional eight participated in the dedicated session in Garmisch. The pollutants studied in the Hornsgatan case were NO_x, NO_2 and $PM_{2.5}$. Street level concentrations were calculated for the year 2000 using 12 of the 13 street scale models (Table 4.5). In Figures 4.8-4.10, model DeltaCs for the average daily concentration variation in the reference year are compared to the corresponding observed DeltaC.

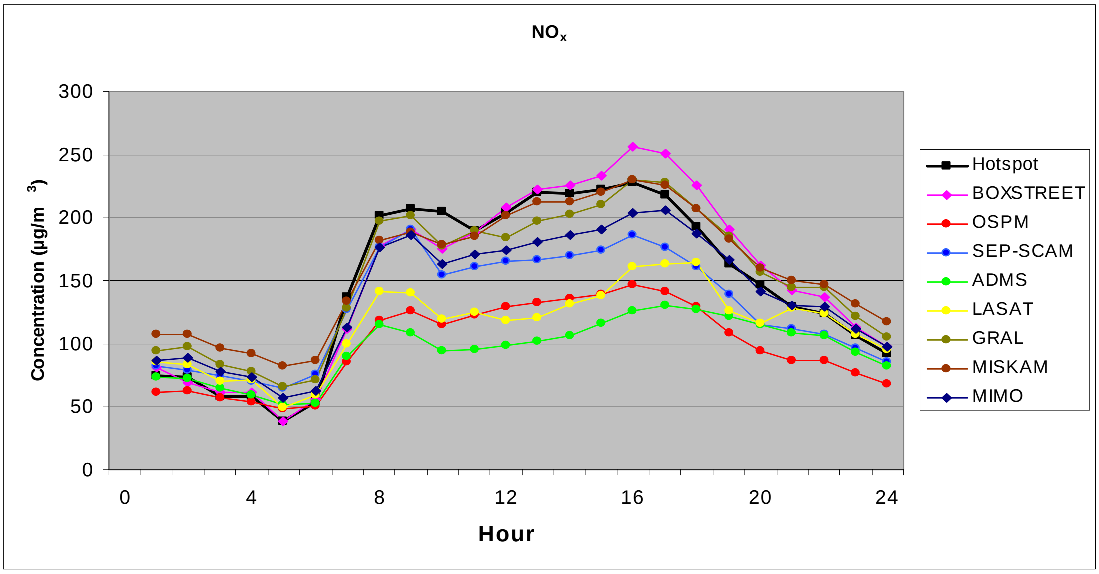

Figure 4.8. DeltaCs intercomparison for NO_x average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

In Figure 4.8, NO_x DeltaCs are presented. All models reproduce the diurnal contribution of traffic emissions to the background concentrations with a correlation coefficient above 0.85. BOXSTREET, GRAL and MIMO model results are closest to measurement with BIAS values of 4.7, 5.8 and -8.3 respectively. During the early morning hours, the deviation of all DeltaCs with respect to observed DeltaC is low, but the results are generally underestimated thereafter.

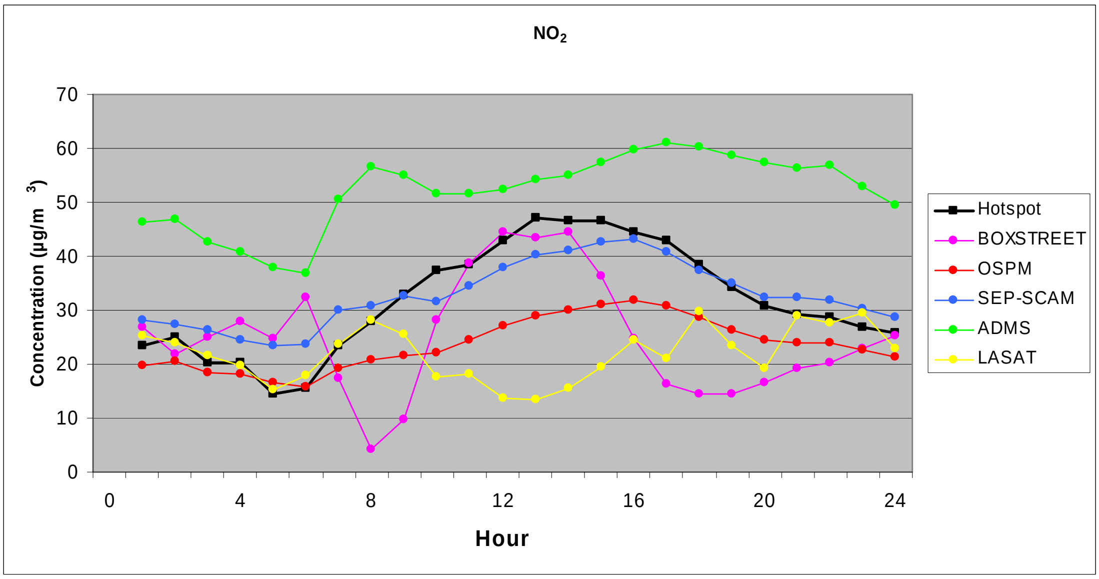

Figure 4.9. DeltaCs intercomparison for NO_2 average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

In Figure 4.9, OSPM and SEP-SCAM NO_2 DeltaCs are generally the closest to the observed, with OSPM achieving better comparison during early morning hours, but underestimating the concentrations from 7:00 onwards. SEP-SCAM results overestimate the concentrations observed during the early morning hours before 8:00 and are closer to measurements thereafter. LASAT model also achieves results close to the observed concentrations during the late evening and early morning hours, but underestimates the concentrations from 9:00 until 20:00. Although ADMS model reproduces the diurnal pattern observed in the monitoring data (the correlation coefficient is 0.76), the results overestimate the observed DeltaCs. BOXSTREET and LASAT ΔCs have a correlation coefficient less than 0.5.

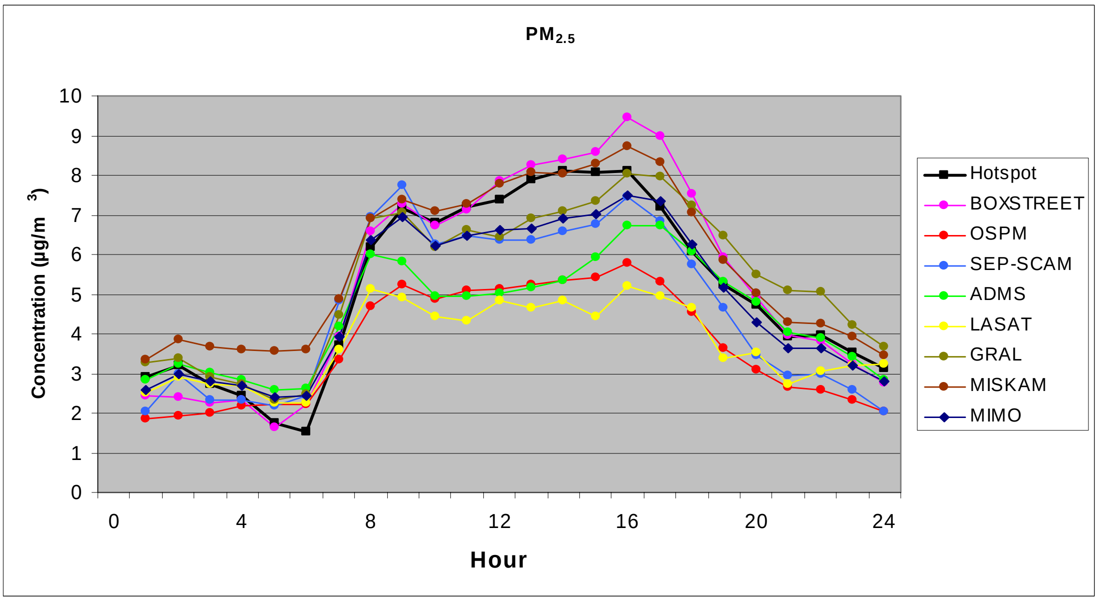

Figure 4.10. DeltaCs intercomparison for $PM_{2.5}$ average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

Similarly to NO_x, $PM_{2.5}$ DeltaCs correlation coefficient for all model results is high, above 0.9 (Figure 4.10). MIMO has the highest correlation coefficient 0.98. Most model results are close to the measured data, although OSPM, SEP-SCAM, LASAT and MIMO models slightly underestimate the observed concentrations between 10:00 and 24:00.

4.5.2.1 The OSPM model applications for the Hornsgatan case

In Figures 4.11-4.13, the OSPM model results (DeltaCs) obtained by various users are compared with observations. NERI performed additional runs using modified input data with slightly increased street emissions based on emission factors deviating from those used by the COPERT 3 methodology. These results are depicted as NERI* in the intercomparison charts.

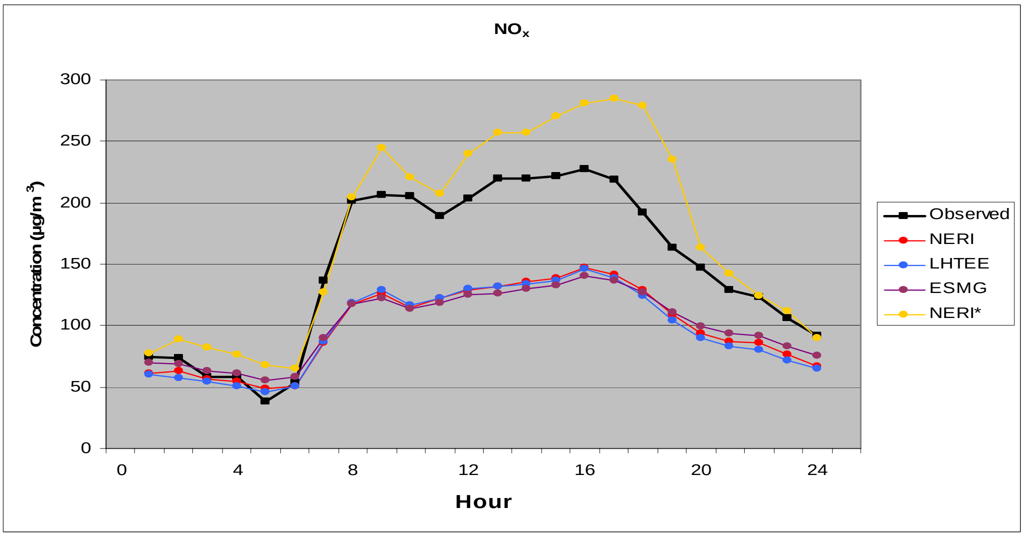

Figure 4.11. OSPM user DeltaCs intercomparison for NO_x average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

In Figure 4.11, NERI* application gives a DeltaC closest to the observed DeltaC, although for the period 9:00 – 20:00 the results are slightly overestimated. NERI, LHTEE and ESMG underestimate the traffic contribution, especially for the period 07:00 – 20:00 when road emissions are the highest. The correlation coefficients for all OSPM user DeltaCs contributions are close to 1.

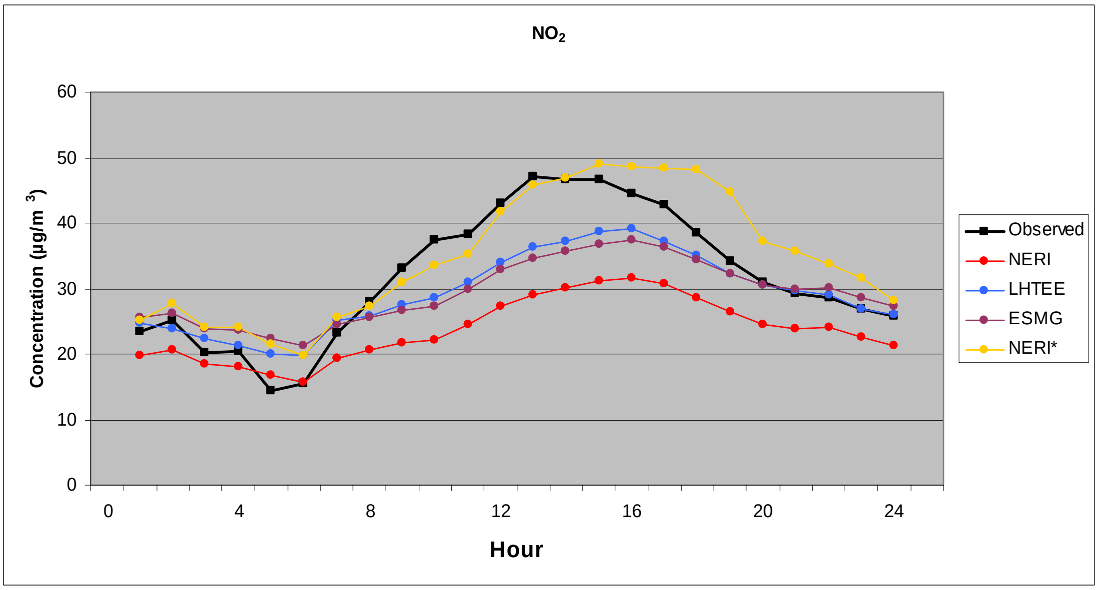

Figure 4.12. OSPM user DeltaCs intercomparison for NO_2 average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

In Figure 4.12, NERI DeltaCs are generally underestimated, while ESMG and LHTEE are close to the observed DeltaC between 19:00 and 2:00, they fluctuate between a slight overestimation and a slight underestimation between 3:00-7:00 and underestimated the concentrations thereafter. NERI* give the highest concentration estimates as expected, achieving good results between 7:00 and 15:00, but slightly over predict the concentrations between 16:00 and 6:00.

In Figure 4.13, NERI* application gives higher $PM_{2.5}$ street contributions for nearly the whole day, while NERI and LHTEE applications underestimate the observed DeltaCs between 8:00 and 24:00, when the traffic contribution is highest. All correlation coefficients are above 0.96.

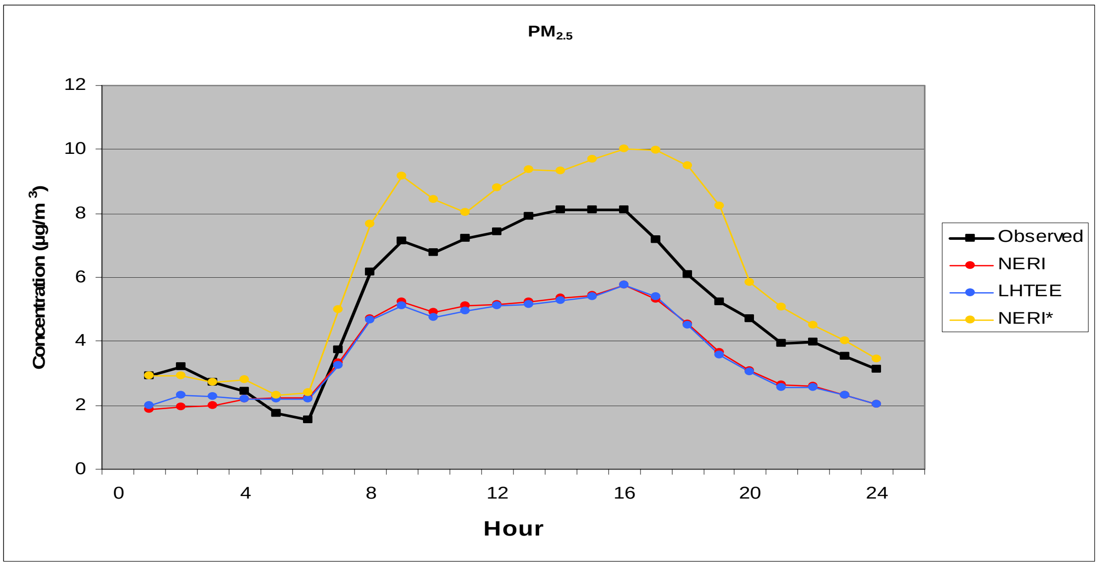

Figure 4.13. OSPM user DeltaCs intercomparison for $PM_{2.5}$ average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

4.5.3 The Berlin case

All models contributing to the Stockholm case study were also applied to the Frankfurter Allee case, and in addition the ADREA-HF model participated at this intercomparison. All 13 street scale models that appear in Table 4.5 were used to calculate street level concentrations. The pollutants studied were CO, NO_x, NO_2 and PM_{10}. In Figures 4.14-4.17, model DeltaCs for the average daily concentration variation in 2002 are compared to the corresponding observed DeltaC.

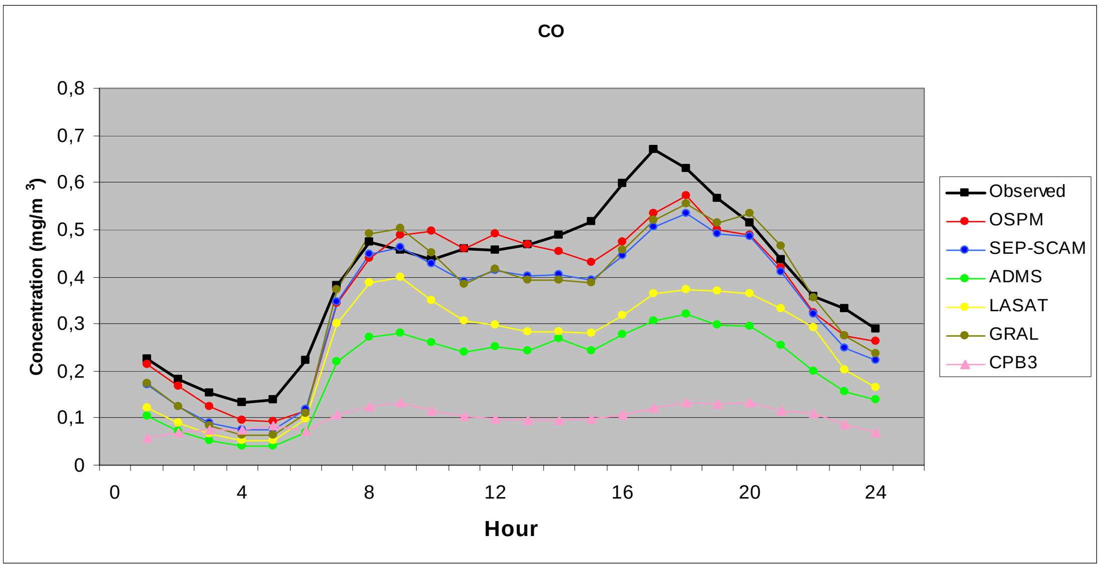

Figure 4.14. DeltaCs intercomparison for CO average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.14, the results for CO are presented. All models have high correlation coefficients, although they underestimate the actual concentrations. OSPM, SEP-SCAM and GRAL DeltaCs are the closest to the observed, with BIAS values of -0.04, -0.07 and -0.05 respectively. ADMS, LASAT and CPB3 models underestimate the observed DeltaCs throughout the day. This can be attributed to an underestimation of the CO emissions, as in all case studies only hot emissions were considered. However, in the case of Frankfurter Allee the cold start CO emissions appear significant since the monthly concentrations analysis reveals model results close to measurements for the summer months, but underestimated values are computed for the winter months.

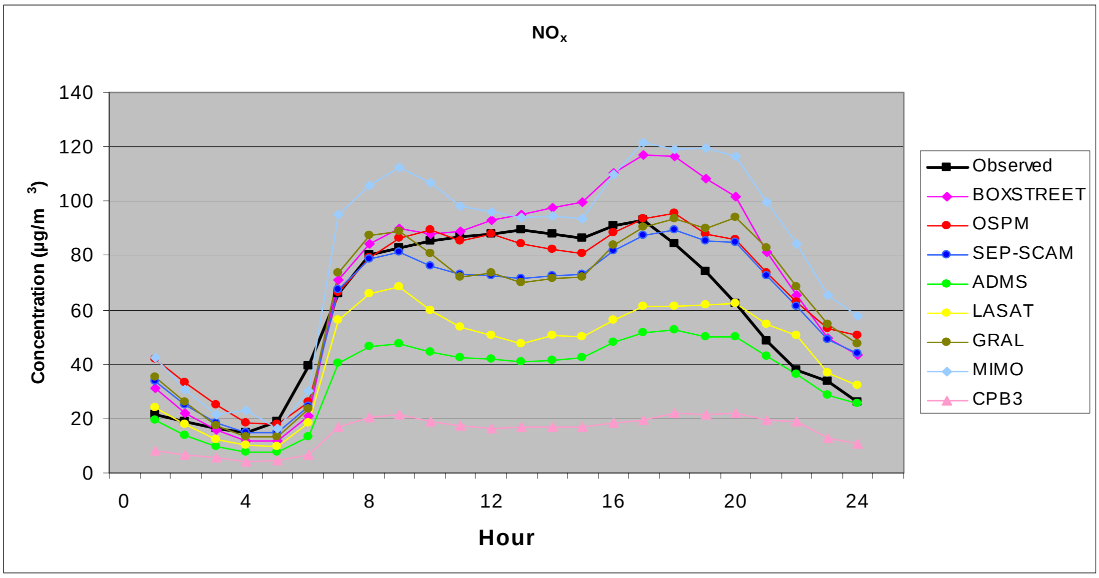

Figure 4.15. DeltaCs intercomparison for NO_x average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.15, all model DeltaCs have a high correlation coefficient. OSPM, SEP-SCAM and GRAL model results are the closest to the hotspot contribution. ADMS, LASAT and CPB3 model results reproduce the average diurnal variation of the concentrations and have correlation coefficients of 0.88, 0.85 and 0.81 respectively, although they underestimate the actual concentrations and have corresponding BIAS values of -24.42, -15.01 and -44.57. BOXSTREET model gives results close to the observed DeltaCs, although the concentrations are slightly overestimated from 12:00 onwards.

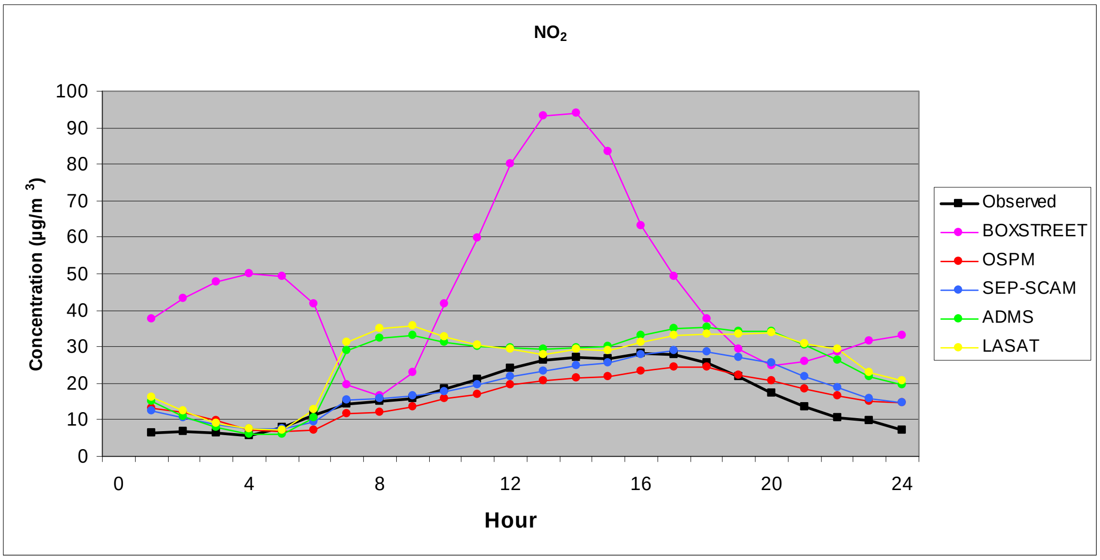

Figure 4.16. DeltaCs intercomparison for NO_2 average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.16, OSPM and SEP-SCAM model results prove to be the closest to the observed DeltaCs, with BIAS values of -0.28 and 2.03 respectively. ADMS and LASAT overestimate the concentrations at peak morning and afternoon hours. BOXSTREET model gives high NO_2 concentrations, while its diurnal pattern deviates from the observed, especially for the period 09:00 – 17:00.

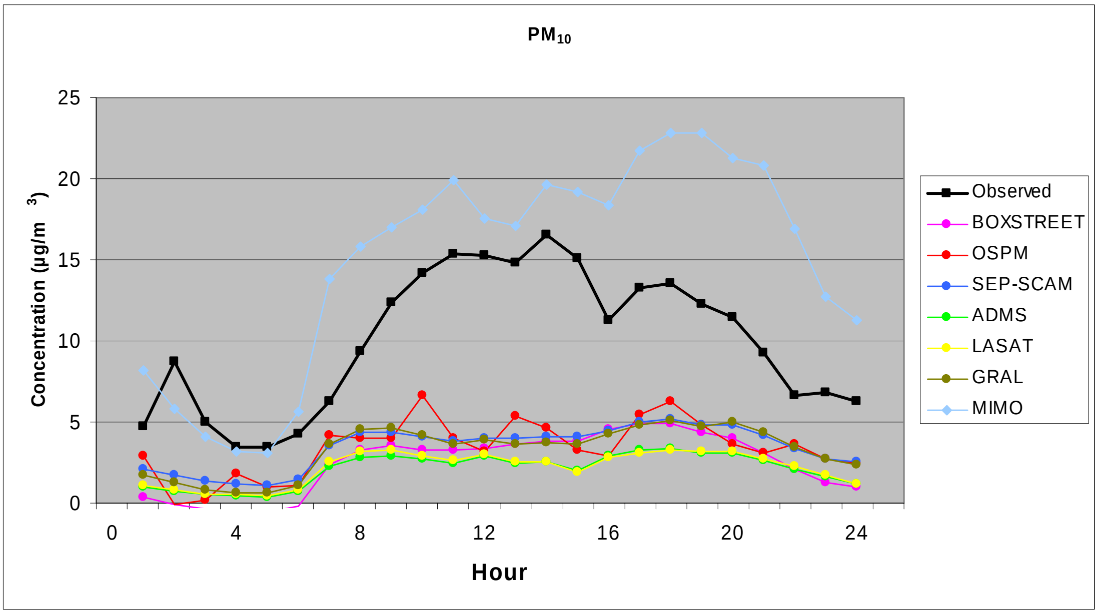

Figure 4.17: DeltaCs intercomparison for PM_{10} average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.17, the PM_{10} DeltaCs are presented. With the exception of MIMO, all models underpredict the measured concentrations, which is not surprising since only exhaust $PM_{2.5}$ emissions from diesel cars were calculated and used as input data for the models. Although MIMO generally overestimates the actual concentrations, it presents the lowest NMSE compared to all the other models (0.261). BOXSTREET and MIMO present the highest correlation coefficient 0.84 and 0.81 respectivelly.

Unfortunately, $PM_{2.5}$ street level and background concentrations were not available to compare with the model results. However, the underestimation of most of the model results in Figure 4.17 denotes the important contribution of non-exhaust $PM_{2.5}$ particles such as pavement erosion, break and tyre abrasion, but also the contribution of other emissions such as re-suspension particles, to the PM_{10} concentrations observed at street level.

4.5.3.1 The OSPM model applications for the Frankfurter Allee case

Figures 4.18-4.21 show OSPM DeltaCs for the average daily variations of the street level concentrations obtained by various users compared to corresponding observed DeltaC. As in the case of Stockholm, NERI performed additional runs not using the input data provided for the intercomparison, but a slightly different dataset. This was characterised by increased PM street emissions, in order to obtain an estimation of the PM_{10} emission data from the traffic observed in the street. The PM_{10} emissions were calculated as the $PM_{2.5}$ emissions given for the intercomparison (i.e. the exhaust contribution) plus non-exhaust emissions (30 mg/km for LDV and 300 mg/km for HDV) according to the emission factors suggested by Düring and Lohmeyer (2004). These results are depicted as NERI* in the intercomparison charts.

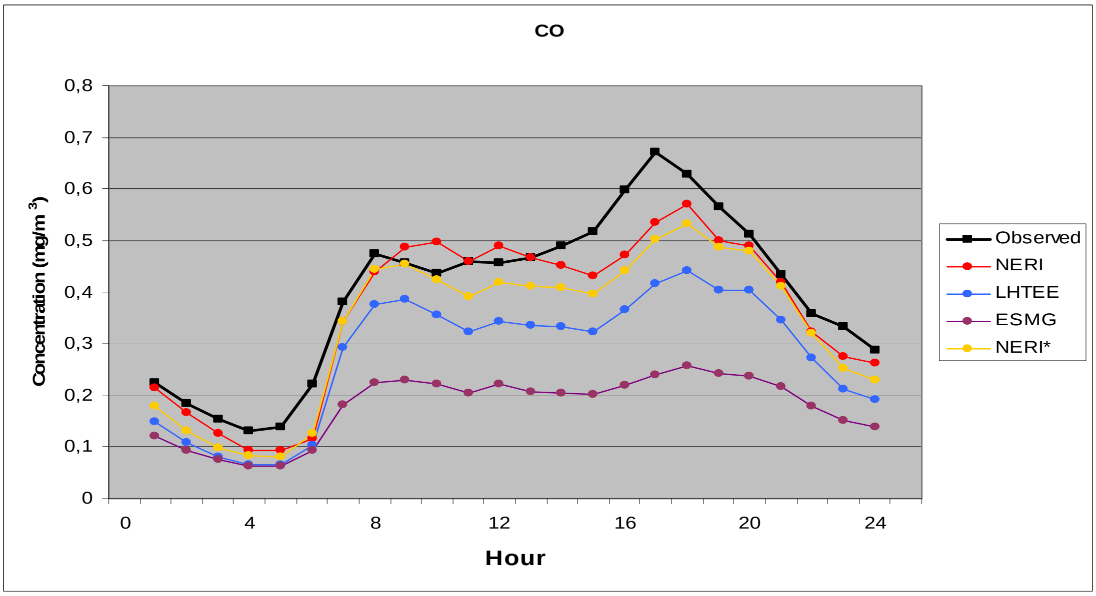

Figure 4.18. OSPM user DeltaCs intercomparison for CO average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.18, the diurnal variation is reproduced well by all models. LHTEE and ESMG results compare well to the observed DeltaC for the early morning hours (1:00-6:00), but underestimate the concentrations thereafter. NERI and NERI* applications are generally closer to the actual measurements, but with a slight underestimation of the second peak presented in the pattern and have BIAS values of -0.04 and -0.06 respectively.

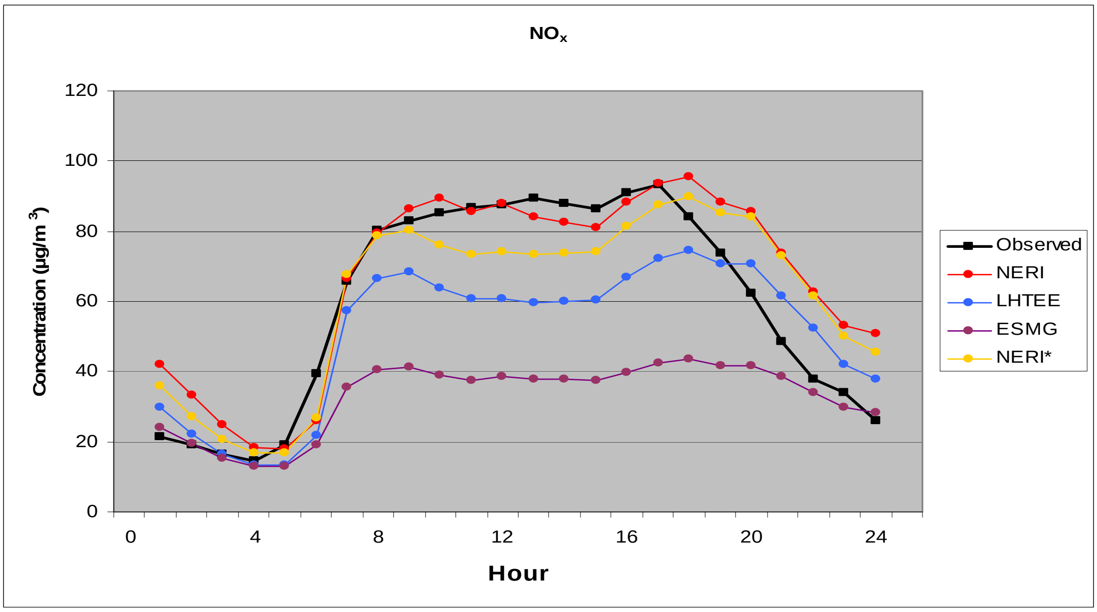

Figure 4.19. OSPM user DeltaCs intercomparison for NO_x average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.19, NERI and NERI* give results close to the measured data, while LHTEE and ESMG applications both underestimate the concentrations observed. All models have high correlation coefficients (all above 0.86).

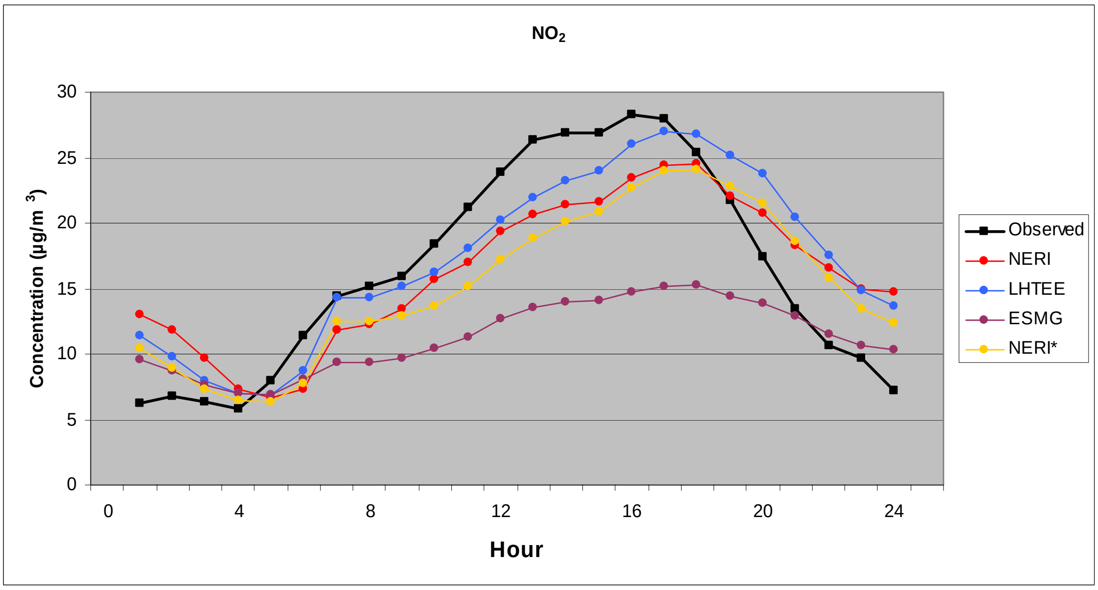

Figure 4.20. OSPM user DeltaCs intercomparison for NO_2 average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

In Figure 4.20, all applications reproduced the diurnal variation observed in the measured data, although the ESMG application generally underestimates the observed DeltaC and NERI, LHTEE and NERI* give higher concentration estimates between 18:00 and 3:00. LHTEE application presents the lowest NMSE (0.05) compared to the other three applications.

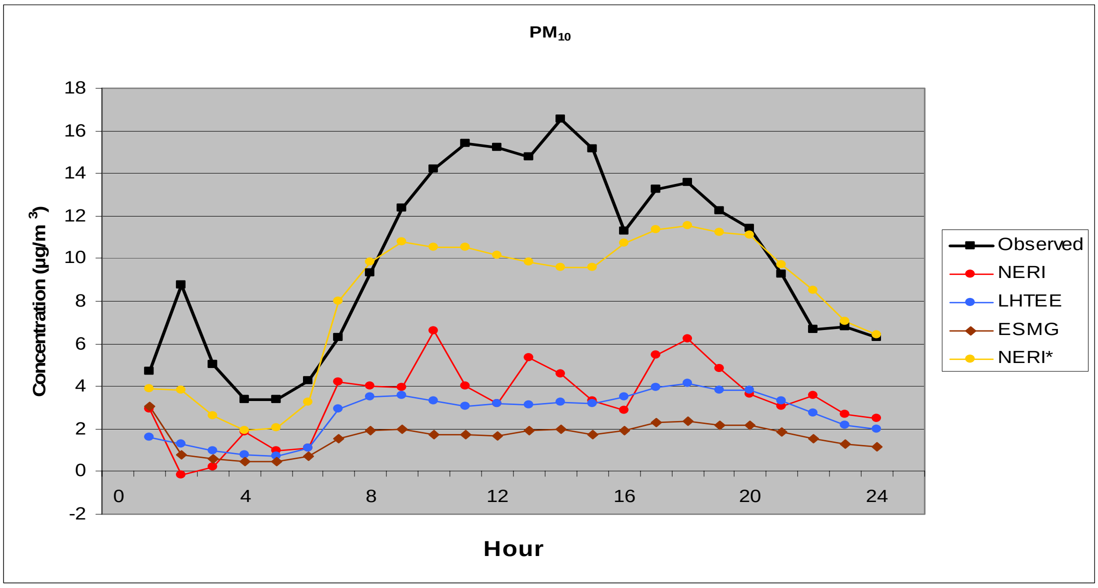

Figure 4.21. OSPM user DeltaCs intercomparison for PM_{10} average daily variation at street level in Frankfurter Allee for 2002 compared to measurements.

In Figure 4.21, all four OSPM users underestimate observed DeltaC, with the exception of NERI*, which computed slightly higher concentration estimates for periods 7:00 – 8:00 and 21:00 – 24:00. The NMSE for NERI* (0.11) is significantly lower than the one of the other three users. Additionally, NERI* has the highest correlation coefficient (0.83) and the lowest BIAS (-1.90) and hence describes best the hotspot contribution.

4.5.4 The London case

In Marylebone Rd. intercomparison case, the models that were applied and the pollutants under consideration were the same as those applied in the Frankfurter Allee case. In Figures 4.22-4.25, model DeltaCs for the average daily concentration variation in 2000 are compared to the corresponding observed DeltaC.

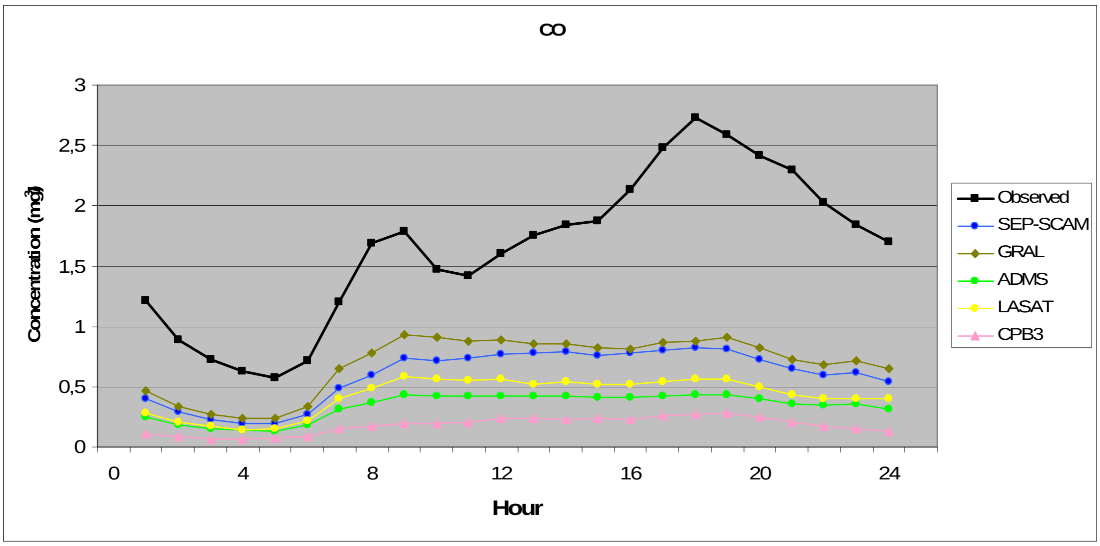

Figure 4.22. DeltaCs intercomparison for CO average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

In Figure 4.22, it is apparent that all model results are underestimated compared to DeltaC observed. All five applications present high negative BIAS values, which are -1.05, -0.96, -1.31, -1.22 and -1.47 for SEP-SCAM, GRAL, ADMS, LASAT and CPB3 respectively. However, the diurnal pattern is reproduced well and all models have a correlation coefficient above 0.8.

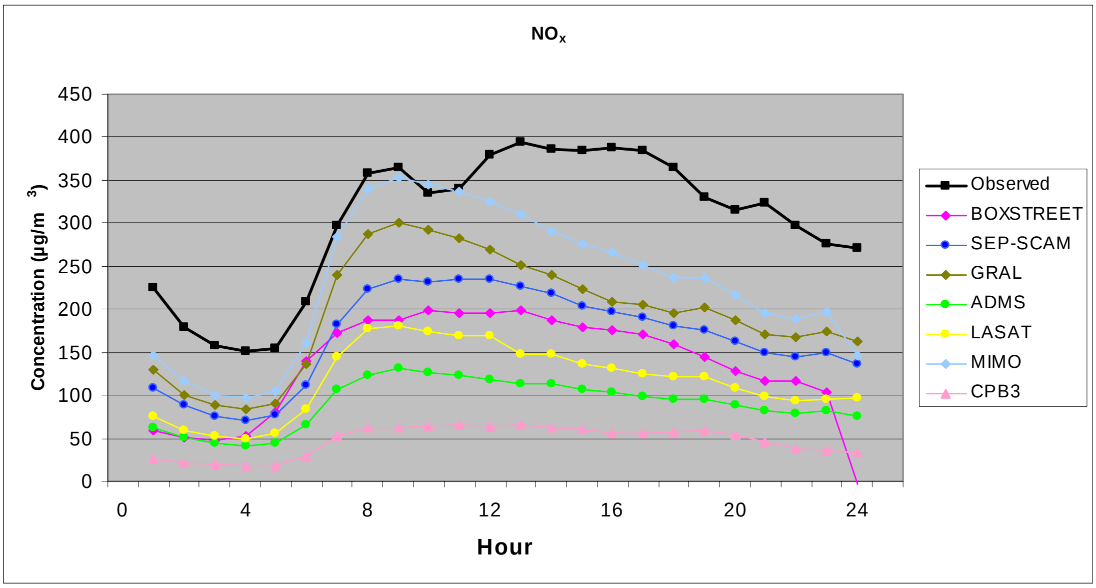

Figure 4.23. DeltaCs intercomparison for NO_x average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

As in the case of CO, in Figure 4.23, all models underestimate NO_x concentrations compared to DeltaC observed, although there is a reproduction of the diurnal variation by all models. The correlation coefficient for all models is again above 0.8. SEP-SCAM, GRAL and MIMO model DeltaCs results present the lowest NMSE (0.39, 0.23 and 0.10 respectively) values compared to the other four models.

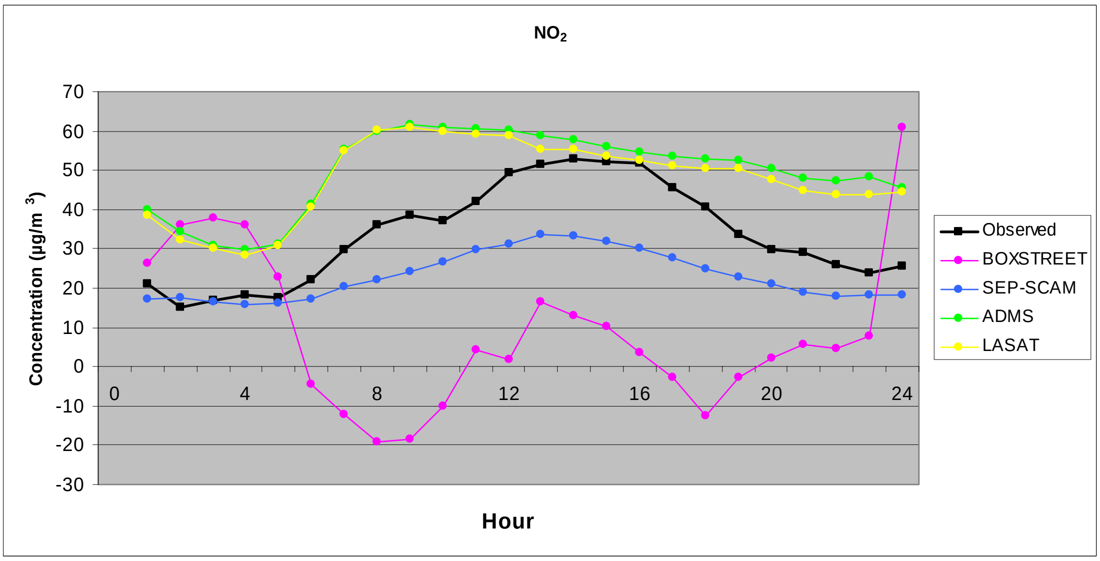

Figure 4.24. DeltaCs intercomparison results for NO_2 average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

In Figure 4.24, SEP-SCAM NO_2 DeltaCs are the closest to DeltaC observed, whereas ADMS and LASAT are overestimated, especially during the traffic peak hours. BOXSTREET DeltaCs are underestimated, especially for the period 6:00 – 23:00. In addition, BOXSTREET model does not reproduce the diurnal variation well (the correlation coefficient is -0.44). The highest correlation coefficient was achieved by SEP-SCAM (0.97).

As in the cases of CO and NO_x, all models underestimate ΔC observed for $PM_{2.5}$ (Figure 4.25). MIMO presents the lowest underestimation (BIAS: -0.93). SEP-SCAM, GRAL and MIMO models give results closest to the hotspot contribution (NMSE 0.20, 0.10 and 0.03 respectively) and all models have a correlation coefficient above 0.90.

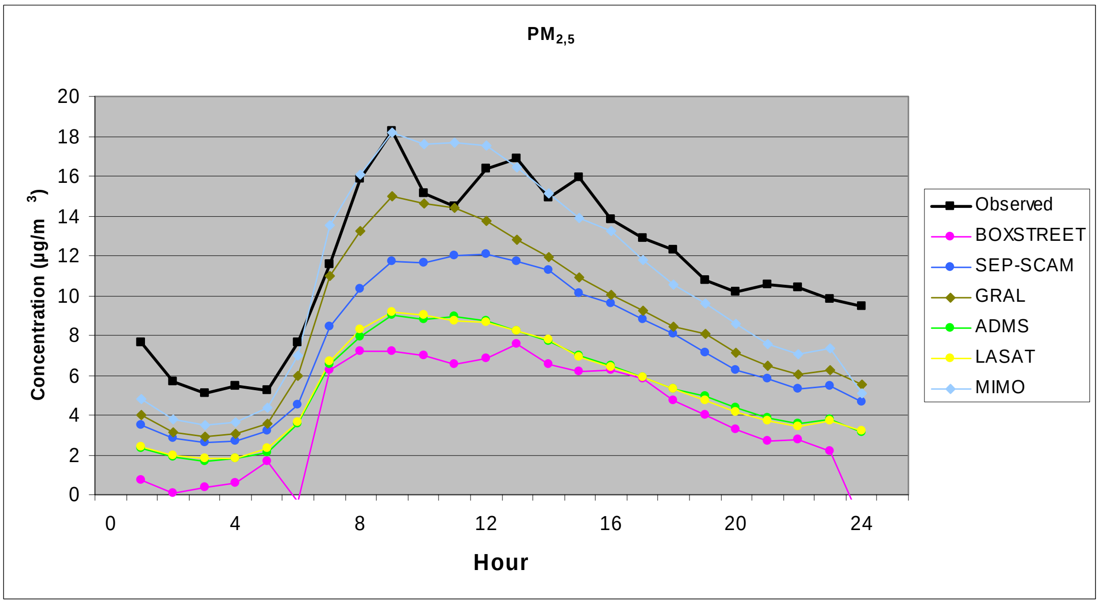

Figure 4.25. DeltaCs intercomparison results for $PM_{2.5}$ average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

It is apparent that the models applied cannot describe sufficiently the hotspot contribution for the Marylebone Rd. case. All models for all pollutants, with the exception of LASAT and ADMS for NO_2, give underestimated results compared to the measurements. The overall weak performance is attributed to the fact that the available meteorological data, which were used as input to the models, cannot be considered representative for the specific application (see section 4.3.3.1 for details).

4.5.3.1 The high wind speed effect on the Marylebone Rd. concentrations

The effect of the high wind speeds used in the Marylebone Rd. case study is apparent in Figure 4.26, where SEP-SCAM DeltaCs for the average daily variation at street level for each of the four pollutants, is compared with DeltaC observed and with indicative SEP-SCAM#2 results, which were performed using the same input data, but with reduced hourly wind speeds compared to the actual measurements. In particular the hourly wind speed values were halved for the following reason: the wind speed, u_{32}, hypothetically measured on a mast of 10 m located at the roof level of Marylebone canyon is given by the following equation (Stull, R.B., 1988):

$$u_{32} = u_{53} \frac{\ln\left(\frac{32-d_2}{z_{02}}\right)}{\ln\left(\frac{53-d_1}{z_{01}}\right)}$$

where,
u_{53}: wind speed measured on a 10 m mast located at the 43 m above ground roof level station approximately 1.88 miles away from Marylebone
z_{01}, z_{02}: roughness length scales for the area where the roof level station is located
d_1, d_2: scales of surface displacement above true surface for the area where the roof level station is located

Realistic values for z_{01}, z_{02}, d_1, d_2 lead to $u_{32} \approx 0{,}5 \cdot u_{53}$. As can be seen in Figure 4.26, the wind speed reduction gives results much closer to the actual measurements, with the exception of CO, where especially after hour 11:00, the concentrations are still severely underestimated.

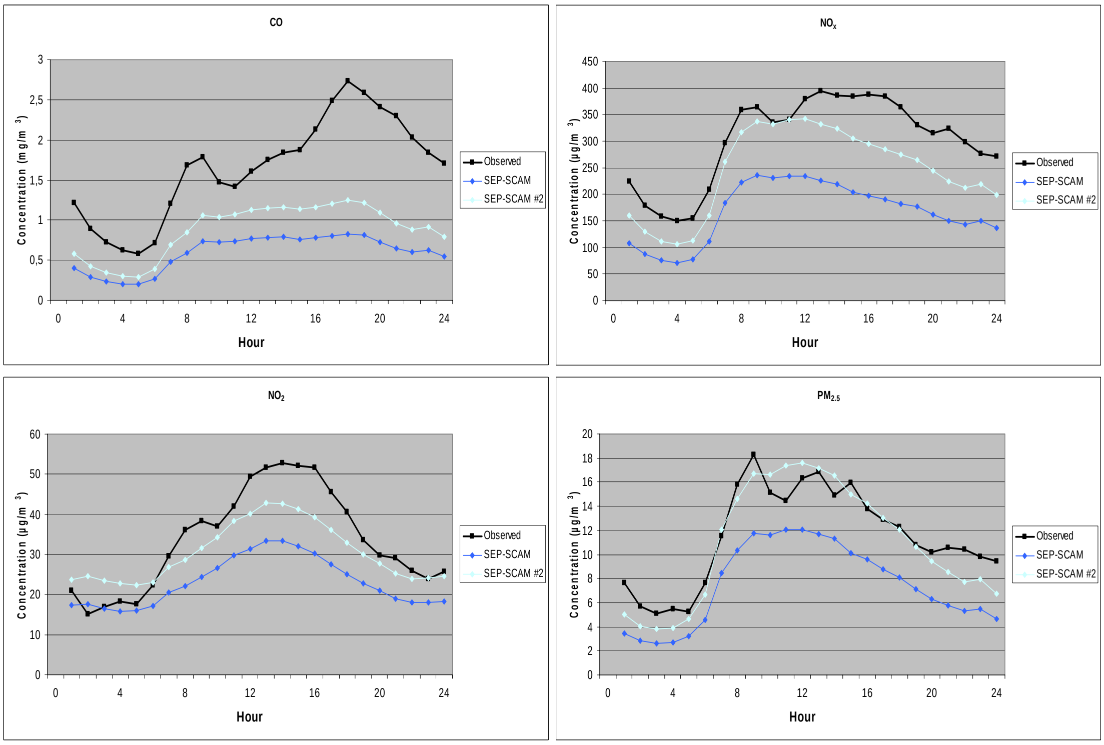

Figure 4.26. SEP-SCAM results for the average daily variation DeltaCs for all four pollutants at street level in Marylebone Rd. for 2000 compared to DeltaC observed and indicative SEP-SCAM DeltaCs results using halved hourly wind speeds intensity.

4.6 Conclusions

Overall, the model results for the Hornsgatan pilot case were close to the actual measurements, especially for $PM_{2.5}$ and NO_2. This can also be seen in the Annex D of this report where all the model results (actual concentrations, not DeltaCs) are presented and compared to hotspot measurements. Larger deviations were observed for NO_x. One reason for this is the dominance of the urban background level for NO_2 and $PM_{2.5}$, as opposed to NO_x, where the street contribution dominates (which can be easily seen in the corresponding DeltaCs). Thus, for NO_2 and $PM_{2.5}$, model deviations are to a large extent masked.

The intercomparison revealed that the models formulated specifically for describing pollutant dispersion in street canyons, yielded results closest to the actual measurements. OSPM results obtained by the three different modelling groups were in good agreement to each other. This result reveals that user introduced errors remain small for well documented modelling tools.

The models that participated in the Frankfurter Allee case generally underestimated the observed concentrations, especially in the case of $PM_{2.5}$ and NO_2. On the other hand MIMO seems to overestimate the street level concentrations. The OSPM NERI* approach, with adjusted PM emissions, in order to obtain a better estimate for PM_{10} emissions and hence a better comparison with the PM_{10} concentrations measured, proved successful in describing the hotspot contribution.

Overall, as it has already been previously mentioned, the effect of the high wind speeds used in the Marylebone Rd. case study has possibly resulted in the underestimation of the hotspot contribution by nearly all models. This underestimation can be attributed to the fact that the available meteorological data, which were used as input to the models, cannot be considered representative for the specific application.

The results of both the Frankfurter Allee and the Marylebone Rd. cases emphasise the importance of correct and representative input data and the need for a consequent sensitivity analysis. An important issue in this context is the availability of representative traffic data and corresponding traffic patterns which have a major influence on the hourly variation of the emissions calculated. In addition to the above, appropriate station pairs (urban background and street level) rarely exist and are often (as in the case of Marylebone Rd. and Frankfurter Allee) not located close to one another. This situation leads to uncertainties as regards the representativeness of the background concentrations occurring in the area where the street is located. An additional problem is the location of the street level monitoring stations close to junctions, which leads to difficulties in the estimation of the number of vehicles contributing to the pollutant concentrations observed. It is of vital importance that specific guidance on best practices for the combined use of monitoring methods and models to assess AQ in hotspot/street level are established. Moreover, the standardisation of the methods used to provide input for AQ assessment would lead to reliable and accurate data and would enhance quality assurance. Last but not least, the increase of station pairs is imperative in order to broaden hotspot assessment in European cities.

The model intercomparison results discussed in the present report show the feasibility of using a number of street scale models to study the contributions of street scale emissions to the air pollutant concentration levels at hotspots. For demonstrating the usefulness of the approach with regard to policy related applications it is necessary to extend such applications to more urban areas and additional street canyon situations in individual cities. It must be emphasised that in order to continue such model intercomparison activities in the future, it is important that valid datasets are prepared and made available and that a minimum set of requirements is specified for the submission of information on specific street canyons. In addition, a comprehensive Street Canyon Database should be established to include all essential information characterising major hotspots in European cities, so that street scale models can be applied using this data, thus providing the possibility of comparing results against a number of applications. Considering also the aim of the Street Emission Ceilings exercise (under which the intercomparison datasets where collected) to quantify the influence of local emissions on the concentrations and exceedances and acquire an estimate of the uncertainty that enters from the street level into a complete regional-urban-street scale model application, such intercomparison exercises would contribute significantly to this goal. Furthermore and considering the needs of non-expert model users, the intercomparison demonstrated that easy-to-use models can estimate the concentrations in hotspots and thus improve assessments and evaluations of measures to attain compliance with limit values.

Last but not least, the increase in the number of participants from one case to the next shows the interest of the scientific community to participate in such exercises and is promising in terms of continuing such work in the future, provided that complete and reliable datasets are available.

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URL3: http://aix.meng.auth.gr/sec/SEC_Page_2.htm

URL4: http://badc.nerc.ac.uk/

URL5: http://www.met-office.gov.uk/

Chapter 5: Street typology

5.1 Introduction

5.1.1 Background and purpose

This report builds on the report of Phase 1 of the Street Emission Ceilings (SEC) project (ETC/ACC, 2004). The SEC project has been set up as a three year project. Its aims are (1) to develop a simple model for city authorities for identifying streets with possibly high levels and (2) to make a simple tool for providing estimates of urban street levels to the integrated assessment modelling in CAFE. In view of the timetable of CAFE, the current Phase 2 focuses on the model development to serve CAFE.

Even though it is likely that the final result of the three year project will be more accurate than the Phase 2 version presented here for support in CAFE, we feel that the accuracy of the model is not the limiting issue. A rigorous treatment of streets in integrated assessment modelling would require a database of street properties throughout the EU, which is currently lacking and inclusion of a street module in the RAINS model, which is currently not feasible. The Phase 2 model proposed here should be applied with caution; in view of its limitations it should be regarded as nothing more than a tool for making estimates of street levels in the EU. Especially when one compares a calculated concentration with a limit value, one should be aware that the uncertainty in the *difference* between the two values can be very large.

Application in Integrated Assessment Modelling

An important goal of SEC is to provide a tool for integrated assessment, such as the work currently done in CAFE. The typology development work in Phase 2 has particularly focused on this. Application in integrated assessment at the European scale could be carried out along the following lines.

On the short term, integration of the SEC model with models for the urban and European scale cannot be foreseen. It is not yet clear what City-Delta will deliver and the optimisation system of RAINS cannot be simply applied to a system that includes hotspots. A more feasible approach is to use the SEC model for evaluation of the impact of given scenarios. After calculations by RAINS of the regional background and additional calculations of the urban background (preferably using the result of City-Delta, if that is not available using other approaches, e.g. the one of MERLIN), the SEC model can be used to produce a table of typical levels in the various street types under a given scenario. The typology described below would result in a table of twelve street types per European region.

Without further work, it will not be possible to quantify how many streets of each street type exists in Europe, because data on this do not exist. It is relevant to collect data on this. It does not seem possible to do this rigorously for the whole of Europe, but sufficient insight may be gained by collecting data from a limited number of cities across the EU. For e.g. 10 cities that have a database on their streets, the parameters needed in the street typology should then be collected. Cities with a traffic-orientated database would probably have these data readily available, except the two parameters characterising the street configuration (canyon or not; broad or narrow canyon – see below). For the determination of those two parameters, some inventory work needs to be done, but as the study would not be aiming at describing individual streets, the effort can be limited to the work needed to acquire a statistically representative database.

In the SEC Phase 1 report, we have proposed to develop a typology based on Table 5.3 *Possible key parameters* of that report. This table is repeated below as Table 5.1; it will be the starting point of the street typology development in Phase 2. On second consideration, we have changed a few entries; these are marked in the table.

Key parameters are candidate parameters for the model to be developed. These can either be *Classified parameters* (fixed in classes, representing ranges) or *Continuous parameters* (retained as explicit continuous parameters in the model formula(s)). The intention of the typology development is to keep the number of continuous parameters as low as possible, preferably to have only one continuous parameter. See the Phase 1 report.

Table 5.1. Possible key parameters (based on Table 3 of the Phase 1 report).

Parameter	a. Importance for air pollution [a]	b. Suitability for modelling	c. Data availability	
			On specific street for local authorities	Statistics at European level
Street parameters				
Emission of local traffic	+++	+++	++	+++
Average daily traffic intensity	+++	+++	+++	++
Mean percentage trucks	++	+++	++	++
Age of vehicle fleet	++	++	++ [b]	+++
Annual mean wind speed at nearby meteo station	++/+++ [b]	+++	+++	+++
Enclosure by buildings	++ [b]	++	+++	+
Traffic behaviour	+/++ [b]	+	+++	+
Street width	++	++	+++	-
Distance to locations with population exposure	++	+++ [b]	+++	-
Background parameters				
Distance from centre	+/++	++	+++	+++
City size	+/++	++	+++	+++
Region in EU or latitude	+/++	+++	+++	+++
Spatial isolation from other sources	+/++	+++	++	++
Presence of industry	+/++	+	++	+

[a] The importance for air pollution indicates how much the variability of the parameter in streets with considerable traffic influences the total annual concentration characteristics (annual mean, percentile) near the street:

+++ Order of magnitude for NO_x, CO, benzene; factor of two for NO_2 and PM_{10}
++ Factor of two for NO_x, CO, benzene; tens of percents for NO_2 and PM_{10}
+ Tens of percents for NO_x, CO, benzene; ten percent for NO_2 and PM_{10}

[b] Changed with respect to the corresponding Table 3 of the Phase 1 report.

Table 5.1 gives criteria for judging the relevance of a parameter. A further criterion, not indicated in the table, could be whether the parameter is likely to be changeable by measures. If it is, it is more interesting to distinguish than if it is not. A reason for distinguishing the percentage trucks as a separate parameter is that forthcoming emission reductions of trucks and private cars are quite considerable and follow different tracks in time.

In this report, we will develop the typology further for the street parameters. The characterisation of the urban background levels is left to the City-Delta project or an alternative approach. It should be noted that for the calculation of NO_2 concentrations the urban background level should be known not only for NO_2, but also for ozone.

An iterative procedure is envisaged, in which (a) a typology is proposed, which (b) is then applied in formulae or nomogrammes for each type. The result will then be reconsidered in terms of sensitivity for variations within a type, after which the typology and formulae may be improved as in steps (a) and (b). The first round, reported here, will be largely based on expert judgement, in the second round further substantiation by sensitivity analyses is envisaged.

The model will calculate annual statistics, in particular annual mean concentrations and numbers of exceedances of hourly or daily thresholds (or corresponding percentiles). As the typical user of the model will not have hourly input data available, the purpose will be to develop a model based on permanent or annual characteristics of the streets. This is particularly true for CAFE, where not specific streets but generic street types are of interest.

We will not attempt developing different typologies for different pollutants or for different concentration parameters (annual mean and percentiles). In principle, the optimum division in street type can be expected to depend on this. However, in view of the inherent uncertainties it is doubtful whether this complication would significantly increase the accuracy. Consequently we will not make this differentiation in the current phase.

5.1.2 Typology and model application

Below, we will first describe the development of the *typology*, i.e. the selection and quantification of street characteristics. After that, we will present an *application* of the typology using a street pollution model.

The calculation of statistics of the hourly and daily concentrations deserve special attention here. The typology only defines permanent and annual characteristics, so the calculation of hourly and daily statistics will need to be based on default assumptions. In the model application given below, the hourly and daily statistics are calculated from (fairly robust) empirical relations with the annual mean concentrations. Alternatively, it is also possible to construct hourly (or daily) time series of meteorological and traffic data, based on typical patterns and then calculate hourly and daily statistics by hourly (or daily) calculations. It is questionable, however, whether this will result in higher accuracy, given the fact that the typology, as defined below, does not provide input on how intra-annual variations deviate from normal conditions. It is therefore tempting to simplify the method and define the use of empirical relations between the annual mean and hourly or daily statistics as belonging to the typology. However, from a more basic point of view, we prefer to regard the calculation of hourly and daily statistics as a model application, thus leaving it up to the modeller how to arrange this.

5.2. Definition of the typology

5.2.1 Selection of key parameters

In the typology, a trade-off has to be made between model accuracy (requiring many explicit and continuous parameters) and simplicity (requiring a limited number of parameters, classified as much as reasonable). In this section, we will select the parameters that we need to distinguish explicitly because their variability in Europe is so large that it cannot be characterised by a single default value.

In Table 5.1, only one parameter is variable enough to cause (on an annual basis) the local contribution to air pollution to range over an order of magnitude:

- *the average daily traffic intensity.*

This parameter is proposed as continuous parameter.

Starting from Table 5.1, we will consider other parameters that may cause a large variation in the local contribution to air pollution; these are variable enough to cause (on annual basis) the local air contribution to range over about a factor of two between streets. We have renamed some parameters and have added four other parameters to consider: cold start, tunnel, trees and road slope. The evaluation of the variability below relies largely on expert judgement of the SEC team and occasional consultation of other experts; for most parameters it was hardly possible anyway to calculate the variability, but also the limited resources of the study made it necessary to resort to judgement.

- *Driving pattern*
  We will distinguish motorway and urban street traffic. Congested and free-flowing traffic may be considered for a second division, but as the differences for the total emissions on an annual basis are expected to be of the order of 30-50%, we will not make this distinction. For each of the two types, we hence choose a pattern intermediate between free-flowing and congested traffic.
- *Cold start*
  In the first minutes after departure, emissions of some pollutants are much higher than normal. For busy streets, however, it is considered unlikely that total emissions are much higher than normally due to cold start effects.
- *Obstacle geometry*
  The distinction in street configurations most commonly made is street canyon and non-canyon configuration. For canyons, it is customary to regard the aspect ratio (i.e. the ratio of street width and building height) as the most important variable, but in practice the concentrations are more sensitive to the street width than to the aspect ratio (for given street width). For non-canyon streets we will not take rural surroundings into account, because we are targeting the typology to urban environments. Motorways would therefore be limited to those in urban environment, which will be characterised by an urban roughness (z_0=1m). This results in two obstacle geometries: street canyons and urban non-street canyons (the latter including motorways, e.g. urban ring roads).[1]

[1] In wind tunnel experiments, the highest concentrations were found in roads with canyon-like buildings on one side and no buildings on the other side. This is due to the fact that in such a configuration the wind at street level

- *Street width*
  The street width is the most relevant geometric parameter for street canyons. For street canyons the distance of road traffic to the receptor point is in practice usually linked to the street width. For non-canyon streets, this distance sufficiently defines the geometry. Therefore the street width will be indirectly characterised by the distance to the receptor point (see below).
- *Tunnels*
  High concentrations are know to occur at tunnel exits. There are models for such situations, but the levels depend strongly on the configuration and surroundings. We will not attempt to develop a typology for tunnels, but we need to retain it as a highly relevant category, with probably the highest traffic related pollution levels that exist.
- *Trees*
  The presence of trees is known to affect dispersion in streets and may increase concentrations significantly [Hout et al, 1989]. Of the current standard models, only the CAR model has a provision for trees, a tree factor that increases levels by 25% or 50% depending on the tree density. Since this is not a generally accepted approach, we will not include trees in the models and hence consider it as a contributor to the variability within a street type.
- *Mean % trucks*
  As the major part of the local street contribution may be due to trucks and streets may have significantly different percentages of trucks, this parameter is considered important enough to distinguish.
- *Annual mean 'meteo' wind speed*
  For practical applications, it is not useful to have the wind speed in the street or at roof top as input parameter, as this is usually not available. Statistics of wind speed at meteorological stations is generally available. It varies across Europe by more than a factor of two, but less than an order of magnitude. It could be taken into account explicitly, but we will attempt to include it as a variable dependent on the EU region.
- *Other meteorological characteristics*
  Possibly the annual mean wind speed is not sufficient for characterising the local dispersion regime, e.g. the wind direction distribution may be very asymmetrical. Another relevant feature may be the topography of a city, which could e.g. lead to high episodic levels. It is not clear how strong deviations from the average behaviour can be brought about by these characteristics (apart from wind speed). For the current phase, we will not take other meteorological variables into account, at least not for the street level (the importance for the urban background levels is not considered here). This will be revisited when more specific information from the COST 715 action on Meteorology applied to Urban Air Pollution Problems will become available.
- *Orientation of the road*
  The orientation of the road with respect to wind direction is known to be important for the concentrations near streets. For usefully including the orientation of the road, it has also to be known whether relevant receptors are upwind or downwind of the (local street level) wind. Generally, the hourly concentrations are very dependent on whether the receptor location it is upwind or downwind of the

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virtually always blows from road to building (Den Tonkelaar et al., 1987). This geometry is represented as a street type in the CAR model, but because the phenomenon is not generally accepted, we will not include this street type here.

traffic, but the annual concentration statistics are not very dependent on the wind direction. The variability depends not only on frequency of wind directions relative to the street orientation, but also on wind speeds per wind sector. Model calculations with the TNO hourly traffic pollution model for the Netherlands (where southerly to westerly winds prevail to some extent) gave dependence of the order of 10-20%. As the dependence is, for the annual concentration statistics, expected to be considerable less than a factor of two in most situations and a simple characterisation could not be found, the road orientation was not included in the typology.

- *Road slope*
  The emission depends on whether cars ride on flat terrain, uphill or downhill. However, usually uphill and downhill traffic on the same road roughly compensate the differences with traffic on a flat road, but for unidirectional traffic this is not the case. Although it is not clear how much the concentrations can be increased in unfavourable cases, we will in this phase not distinguish unidirectional upslope traffic as a special type.
- *Composition of fleet*
  The composition of the fleet (diesels, age of cars, etc) is important for the total emission of street traffic. This composition is known to vary across the EU, but is largely country dependent. We will attempt to include it as a variable dependent on the EU region.
- *Base year*
  For the base year, i.e. the reference year for scenario variants, we are taking the current situation (e.g. 2004) or a scenario year (2010, 2020). The emission factors in the model should be available for each relevant year.
- *Distance to receptor point*
  A major question is whether the concentrations should be calculated at locations where human exposure occurs or also at shorter distances. From a health perspective, exposure would be the obvious choice, but the air quality directives may be read as defining the limit values irrespective of exposure. For street canyons this distinction is often not so important, because the distance of exposure, usually at the kerb not far from the building faces, is linked to the distance of the buildings, which is already characterised by a classified parameter (canyon width). For open roads on the other hand, especially motorways, the distance to exposure can vary strongly, largely independent of other parameters. As the distance to the nearest relevant location can be very important for the concentration, there is reason to define the distance from the traffic or the road axis as a continuous parameter. However, to avoid complicating the approach by introducing a second continuous parameter, we will make a division in classes. The class borders of motorways and urban non-canyons can be chosen to be different.

5.2.2 Variability within a street type: unfavourable cases

The Phase 1 report discusses the fundamental problem that in a typology based on classes the unfavourable cases within a type are not taken into account, because the most normal street for a type will be taken. Especially for evaluating the attainability of limit values in streets, these unfavourable cases are highly relevant. We will attempt to solve this by giving for each street type a ***typical case*** and an ***unfavourable case***, corresponding to:

- A ***typical case calculation***: for estimating the typical levels in the street type.
- A ***worst case calculation***: for identification purposes: in which types may problem situations occur?

This means that two model curves per street type are needed. In the Phase 1 report, it has been shown that the variability within a street type can only partly be modelled. The variability within a street type may in principle be derived from measurements, but then air quality data need to be available per street type, which is not the case. In this phase, we will estimate indicative factors for the concentration ratios between the unfavourable case and the typical case. It may be argued that quantifying this variability is belongs to the typology methodology, but it is more practical to estimate this while applying the methodology; hence the quantification of unfavourable cases will be addressed in Chapter 3.

5.2.3 Specification of street types

Based on the considerations above, Table 5.2 below lists the parameters that will be taken into account in the typology and indicates how the parameters will be dealt with.

Table 5.2. Street parameter taken into account in the typology and method of characterisation

Parameter	**Characterisation**
Traffic intensity [1]	Continuous parameter (mean total number of vehicles per day)
Driving pattern [1]	2 types related to obstacle geometry: typical for motorway; typical for urban streets
Geometry	2 geometries: urban non-canyon; canyon
Canyon width	Only for canyon: 2 types, with class border at 20m – this will be taken into account in the 'distance road axis to receptor' below
Distance road axis to receptor	2 types depending on geometry and driving pattern. Class border: for non-canyon motorway at 50m, for non-canyon urban traffic 30 m, for canyon ¾ of the canyon width
Wind at meteo station [1]	Link to EU region
% of trucks [1]	2 types; class border 10%
Age of fleet	Link to EU region
EU region	To be decided in relation to urban background model. If no useful combination can be made, the treatment of wind and fleet age should be reconsidered.
Base year	2004, 2010, 2020 (depending on the application)

[1] As annual characteristic

The table above leads to four combinations (2 distances (for canyons these are linked to canyon width, so canyon width is not an independent parameter), 2 percentages of trucks) in each of the three street geometry/driving pattern combinations, resulting in 4 x 3 = 12 street types for a given base year and a given EU region. Table 5.3 gives for each of these types input data on an annual basis for model calculations. For models based on hourly input data, hourly wind speed and traffic data should be taken from a realistic or idealised case and rescaled to the annual averages.

Table 5.3. Input parameters for the modal (typical) street of street types[1)]

Geometry/driving pattern	Geometry parameter	% trucks	Canyon width	Driving pattern [2)]	Wind speed	Fleet age	Distance [3)]
Urban motorway (4 combinations)	z_0=0.1m	7%/15%	-	80 km/h	Coupled to EU region	Coupled to EU region	25m; 100m
Urban non-canyon street (4 combinations)	z_0=1m	7%/15%	-	26km/h			10m; 40m
Canyon (4 combinations)	H=15m	7%/15%	15m	26km/h			5m
			40m				15m

[1)] In addition the age of the fleet and the average meteo wind speed has to be taken, dependent on the EU region. This needs to be defined later, consistent with the regions chosen in City-Delta.
[2)] The speeds in the table are a crude indication. If emission data allow, the emission should be based on a pattern intermediate between free-flowing and congested for the street types concerned.
[3)] The lower distance should not be combined with unrealistically high traffic intensities.

5.3 Application of the typology

In this chapter, we will apply the typology. We will use the CAR model (Hout and Baars, 1988; Eerens et al., 1993) as an example, as it has been developed along the same principles as the current SEC approach. We will use it for the annual average concentrations and use its approach for the exceedance statistics, but based on new empirical relations for statistics of the hourly and daily concentrations in Europe.

For a model for local authorities, resulting from a possible next phase, we will need to develop a full set of such curves, preferably in the form of formulas. For support to CAFE, this is not yet needed. The concentrations can then be calculated with existing models, as in the example based on CAR below.

5.3.1 Calculation of the annual mean concentration using the CAR model

Typical streets

Using the input parameters of Table 5.3, the curves as a function of distance to the road axis are presented in Figures 5.1 and 5.2 (annual mean DeltaCs, where Delta C= Street – Background concentrations). Table 5.4 lists the input parameters for each of the twelve street types. For the ‘EU region’ (as mentioned in Table 5.3) we have chosen an arbitrary location in Flandres (Belgium). The annual mean urban background concentration was 35 µg/m^3 for PM_{10}, 25 µg/m^3 for NO_2 and 40 µg/m^3 for O_3. The average wind speed at meteorological stations was 3.7 m/s, considerably higher than in many other EU regions. For application in CAFE, these calculations have to be done for all EU regions that are distinguished, but for this example only one EU region is sufficient.

It should be noted that all curves for canyon and non-canyon streets have been plotted for traffic intensities up to 100,000 vehicles per day – as this intensity is in practice not attainable in narrow street types, the highest values in the figures should be read as theoretical, which will not occur in practice.

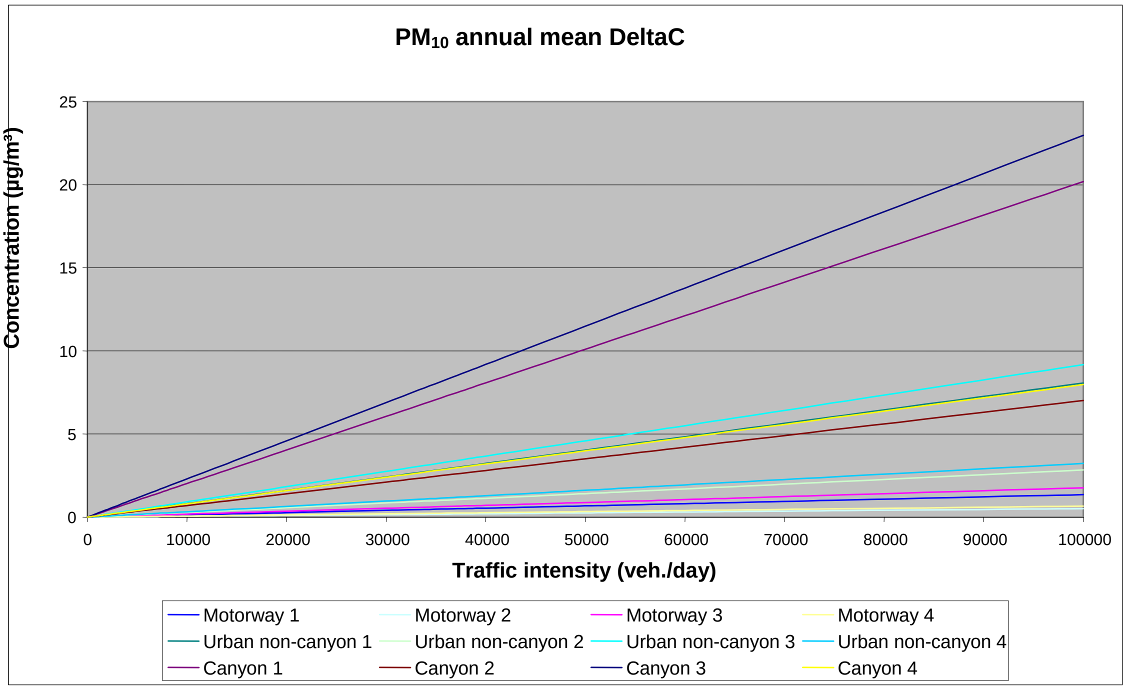

Figure 5.1. Annual mean PM_{10} DeltaC, as a function of street type and traffic intensity (based on conditions in Belgium).

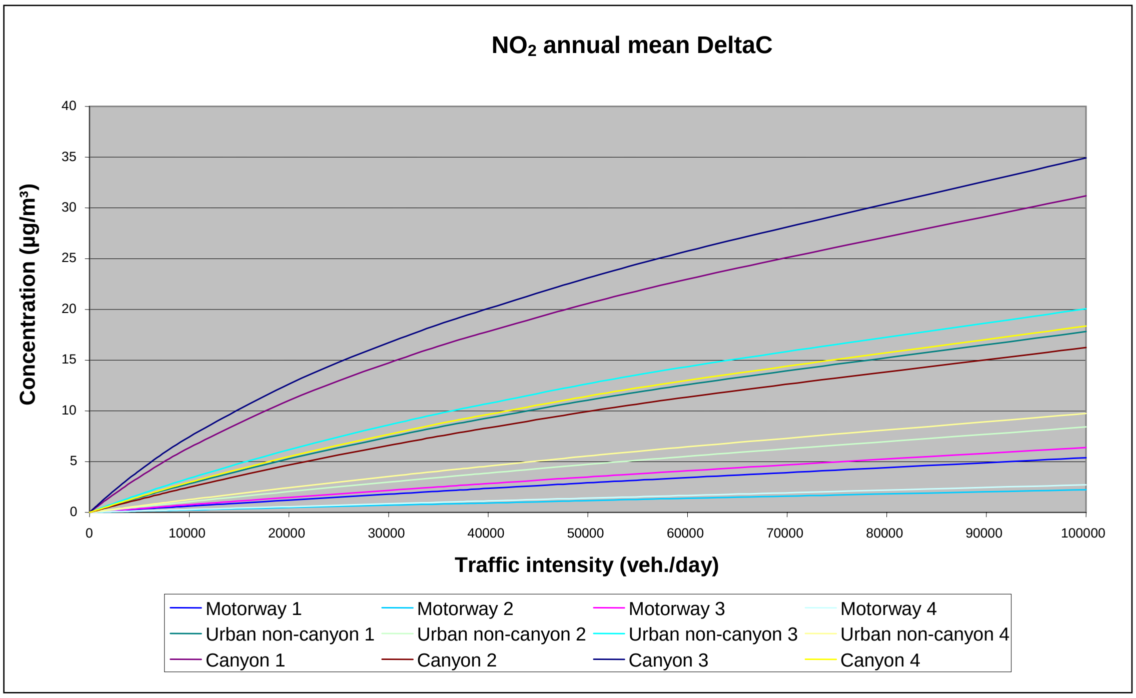

Figure 5.2. Annual mean NO_2 DeltaCs, as a function of street type and traffic intensity (based on conditions in Belgium).

Table 5.4. Street type parameters for *typical street cases* [1].

Street type	Geometry	Fraction of trucks (%)	Traffic behaviour	Distance receptor to road axis (m)
Motorway 1	Open z_0=0.1m	7	Typical motorway	25
Motorway 2	Open z_0=0.1m	7	Typical motorway	100
Motorway 3	Open z_0=0.1m	15	Typical motorway	25
Motorway 4	Open z_0=0.1m	15	Typical motorway	100
Urban non-canyon 1	Open, z_0=1m	7	Typical urban	10
Urban non-canyon 2	Open, z_0=1m	7	Typical urban	30
Urban non-canyon 3	Open, z_0=1m	15	Typical urban	10
Urban non-canyon 4	Open, z_0=1m	15	Typical urban	30
Canyon 1	Width/height = 1	7	Typical urban	5
Canyon 2	Width/height = 2.7	7	Typical urban	15
Canyon 3	Width/height = 1	15	Typical urban	5
Canyon 4	Width/height = 2.7	15	Typical urban	15

[1] Non-urban motorways and tunnels are not included.

Unfavourable streets

As discussed above, in unfavourable streets within a street type the levels can be higher for many reasons: lower distance or higher fraction of trucks than typical, unfavourable traffic behaviour, presence of trees, lower wind speed than typical for the region, higher background levels than typical for the city type. Tentatively, we estimate that the local contribution to the concentrations in unfavourable streets is a factor 2 higher for PM_{10} and (taking the non-linear relation with emissions into account) 1.5 for NO_2.

5.3.2 Calculation of exceedances of the hourly and daily limit values

5.3.2.1 Approach taken

For model calculations of the number of exceedances of the hourly limit value of NO_2 and the daily limit value for PM_{10}, one could ideally use hourly and daily input data. This is not feasible for the simple model envisaged here. One could also construct hourly/daily time series from annual statistics using default assumptions and then do hourly/daily calculations. This would give an impression of higher detail due to the hourly calculations, but it would in reality still rely fully on annual statistics as input. Another way of calculating number of exceedances is to use the modelled annual mean concentrations together with empirical relationships between the annual concentrations and numbers of exceedances. This approach is taken here. As AirBase provides data for hundreds of streets stations throughout the EU, this provides at the same time a good insight in the accuracy of the approach.

Instead of the number of exceedances (this is the parameter specified in the limit values), we will model the corresponding percentile. There are several reasons for this. For comparisons with the limit value, it does not matter whether number of exceedances or percentiles is used: if the percentile is higher / lower than the percentile corresponding with the limit value, the number of exceedances is higher / lower than allowed. Another reason is that for the number of exceedances the formula depends on the threshold, while for the percentile the formula is independent of the threshold. A very practical further reason, finally, is that percentiles could easily be extracted from available AirBase data, while calculating the numbers of exceedances would have required considerably more effort.

5.3.2.2 Empirical information

In Figures 5.3 and 5.4, the percentiles corresponding with the daily and hourly limit values are plotted against the annual average concentration. The figures present the street station data of 2001 and 2002 from AirBase. Stations with a data capture below 90% were not taken into account. For PM_{10} this resulted in 230 PM_{10} stations in 2001 and 339 in 2002. For NO_2, there were 447 such stations in 2001 and 427 in 2002.

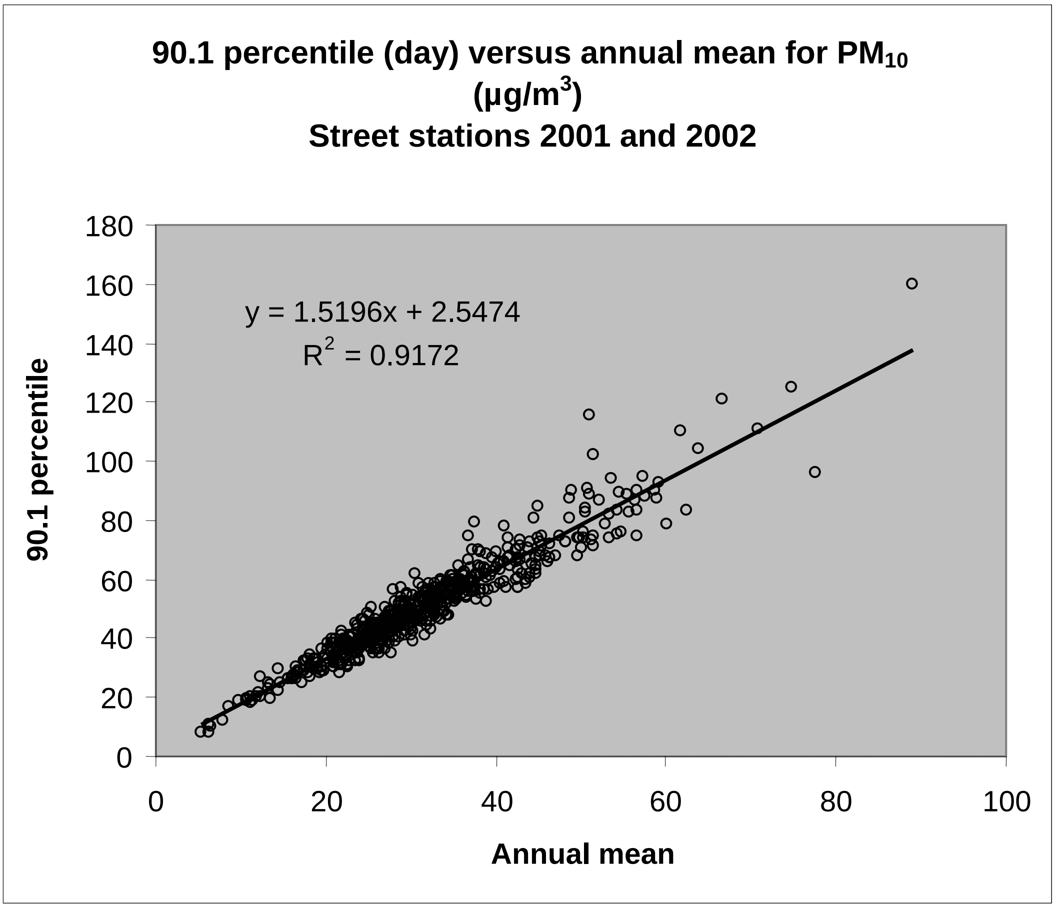

Figure 5.3. The 90.1 percentile of daily concentrations of PM_{10} (corresponding to the daily limit value) versus the annual mean concentration of PM_{10}, for European street stations in 2001 and 2002. Source: AirBase.

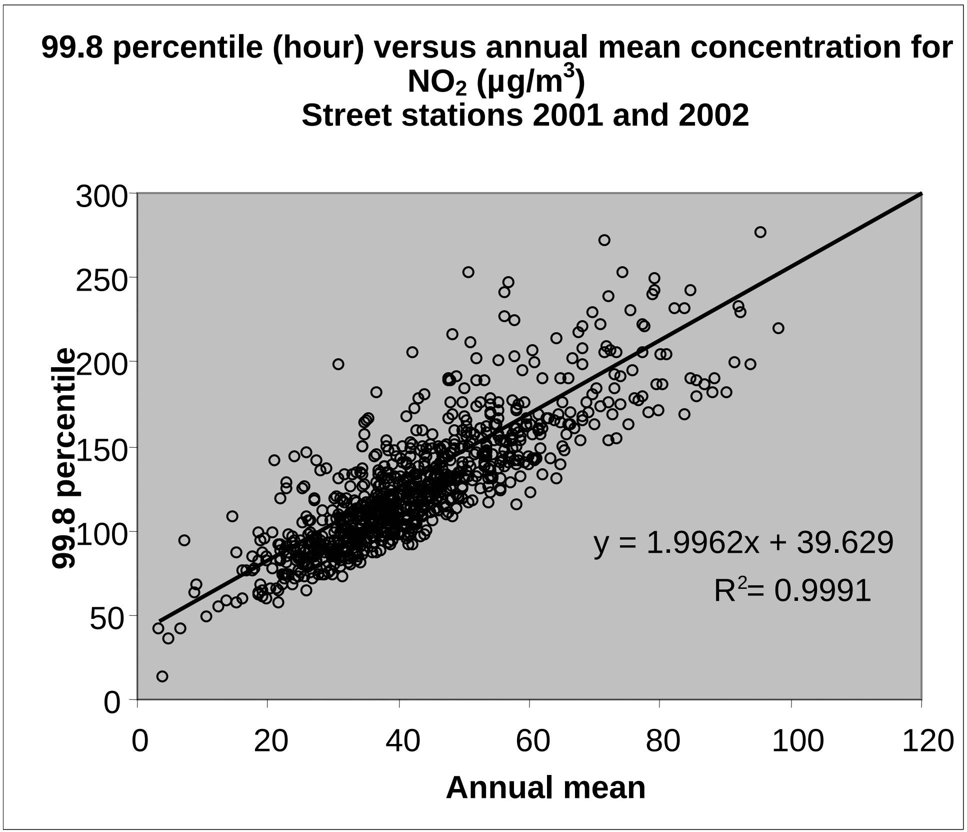

Figure 5.4. The 99.8 percentile of hourly concentrations of NO_2 (corresponding to the hourly limit value) versus the annual mean concentration of NO_2, for European street stations in 2001 and 2002. Source: AirBase

Figure 5.3 shows a distinct correlation of the 90.1 percentile for the daily mean (corresponding to the daily limit value) with the annual mean for PM_{10}, with R^2 = 0.92. The regression line shows a small intercept of +2.5 µg/m^3 on the 90.1 percentile axis.

A similar plot for NO_2 in Figure 5.4 of the 99.8 percentile of hourly concentrations (corresponding to the hourly limit value) against the annual mean, shows that the relation deviates significantly from linear (taking into account that the relationship has to go through the origin (0,0). As should be expected for a percentile as high as the 99.8 percentile, the scatter is considerable. For the model, the most relevant values are those around or above the 99.8 percentile 200 µg/m^3. When selecting only values >150 µg/m^3, there is no significant deviation from proportionality: we found a ratio of 2.8, with a standard deviation of the relative error of 18%.

One of the reasons for the non-linearity in Figure 5.4 for NO_2 is that the variability of the local contribution to hourly concentrations tends to be lower than the variability of the background concentrations. A more accurate approximation might perhaps be achieved when the contribution of the background to the total concentration would be known. As these data were not available and complications due to the non-additivity of contributions to percentiles are likely to arise, this would require more research than could be done in this work.

A difficulty for a percentile as high as the 99.8 percentile is that measuring errors are likely to play a significant role at some stations. Erroneous high values that have not been removed from the data set may directly contribute to the 99.8 percentile. As practitioners should be reluctant to remove without clear reasons high readings from measurements that are done for surveillance, one may speculate that the real ratio is lower than the regression formula found here. On the other hand one may argue that these errors are inherent to the current compliance checking practice and hence it can be justified to use the database of measuring results as the reference for the model.

5.3.2.3 Modelling the percentiles

Typical street cases

For PM_{10}, we have found a regression line with a small intercept. Physically, the curve should obviously go through the origin (0,0). We closely approximate the regression line found by neglecting the intercept:

[90.1 percentile] = 1.52 x [annual mean] for PM_{10}.

In the dataset used, the error in the prediction of the measured 90.1 percentile by this expression has a relative standard deviation of 10%.

For NO_2 the intercept is more significant, but also here the curve should go through the origin. By excluding streets with low concentrations (annual mean < 30 $\mu g/m^3$), which are not relevant for the SEC purposes, we can use the regression line as a simple approximation:

[99.8 percentile] = 2.0 x [mean] + 40 $\mu g/m^3$ for NO_2 (for [mean] > 30$\mu g/m^3$).

In the dataset used, the error in the prediction of the measured 99.8 percentile by this expression has relative standard deviation of 17%.

Unfavourable street cases

The above formulas are for calculating the percentiles of *typical cases* of streets types. For *unfavourable cases*, most of the variability between streets within a type may already been comprised in the assumed factor for the annual mean (2 for PM_{10} and 1.5 for NO_2), but one may argue that the variability between streets is in principle larger for the percentiles. However, the uncertainty in the factors for the annual mean concentrations is so large that we will also use the indicative factors for the annual means as indicator for the percentiles. Hence we will apply the relations between the percentile and the annual mean given above both for typical cases and unfavourable cases.

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Chapter 6: Recommendation on the treatment of the street scale in ETC’s own IA methodology
- current possibilities and future perspectives

6.1 Current possibilities in the existing context

In the developments of EU AQ legislation prior to CAFE, as well as projections of AQ across Europe accounting for existing and new policies and measures (EEA and DGEnv work), Integrated Assessment Modelling has been carried out with the RAINS model. The approach focuses on the regional scale concentrations in Europe, in line with the analyses needed for the CLTRAP, and dealt primarily with long-range transport and the impact on vegetation and ecosystems. However, air quality is still poor in numerous densely populated areas and population exposure is in some cases alarmingly high despite the adopted policies and measures. In addition, as health effect studies are continuously providing new evidence rendering air quality one of the most important parameters to the European citizen’s well being, compliance with limit values is of prime importance. Exceedances of limit values are in their vast majority observed in urban areas and particularly hotspots, which should therefore be included in the assessment.

To support this need, the JRC has set up the City-Delta study, targeted at modelling the urban background levels in Europe in order to provide an urban module for use in IAM. In a further straightforward step, the hotspot levels can be modelled.

SEC proposes to make use of urban scale model results, either via the City-Delta methodology (see City-Delta final report) or any suitable urban scale AQ model, which will be driven by the regional scale model, in order to provide the urban background conditions for a street scale model and thus consider hotspots. This approach can be applied to the street/traffic configurations that have now been defined in the SEC project (see chapter 5). The approach allows for base year and scenario projections as the impact of particular policies and measures to be accounted for at the regional, urban and street scales providing information that can then be used to calculate population exposure.

The tools available to the ETC/ACC (urban and street scale models) are currently being applied and tested in this context and have led to encouraging results as they have been proved (at an acceptable level of accuracy) capable of reproducing the concentrations observed at street level.

For the immediate needs of the State-of-the-Environment 2005 report (according to the IP2004) the urban scale air quality model OFIS will be applied to the ensemble of the cities considered in the MERLIN project. These cities have been chosen, as MERLIN will supply the detailed emission inventories required by the urban scale model. The boundary concentrations and meteorological data required by OFIS for base year and scenarios will be obtained from EMEP model results. Emission reduction factors (per sector) derived from the emission reductions calculated by RAINS (see Technical report on Scenario test run results for Climate Change and Air Pollution SoEOR2005 Part 1) will be applied to the urban emission inventories leading to air quality projections at city level. These model results will then be used by the street scale model, in conjunction with reasonable assumptions to account for the street emissions and emission changes per scenario.

6.2 Future needs and possibilities*:* the ultra fine particles

Information on PM_{10} and to a lesser extent on $PM_{2.5}$ levels has greatly improved following implementation of the Council Decision on Exchange of Information 97/101/EC and the First Daughter Directive. Compared with the PM_{10} limit values of the First Daughter Directive to be met in 2005 (Stage 1), PM_{10} concentrations in parts of Europe are rather high. According to the CAFE Second Position Paper on Particulate Matter[2]:

- Exceedances in PM_{10} concentrations are more frequent at traffic exposed and industrial sites than in the urban background.
- Similar is the situation for $PM_{2.5}$; there are indications that the additional burden of $PM_{2.5}$ at traffic exposed sites is comparable to the additional PM_{10} burden at the same sites.
- For the less “conventional metrics”, it seems that traffic sites tend to show somewhat higher levels of $PM_{1.0}$ than urban background sites and considerably higher number concentrations of ultrafine particles. There is evidence that the number concentration of ultrafine particles varies much stronger spatially, with a range of an order of magnitude going from rural to hotspot levels (compare also Figures 6.1-6.3 and the references given in the figure legends).

It becomes obvious that in the near future the ultrafine particles should be included in the assessment and their hotspot levels modeled. Indeed, this task may be urgently needed, as scientific evidence on the adverse health effects of ultrafine particles grows.

So far the SEC modeling exercise for the local scale has only focused on PM_{10} and $PM_{2.5}$ approximated at that scale as inert. The exercise has so far shown that there is an underestimation of the concentrations, due to missing sources or to low estimates of the emissions.

In a second step, SEC should also focus on the ultrafine particles emitted from vehicles. It should be recalled that these particles comprise two families: the larger ones from the formation of soot during combustion process and the smaller ones (nanoparticles) from gas-to-particle conversion processes during dilution of exhaust gases. Control of dilution can influence the relative proportions of the two families of particles. By control of the fuel sulphur content it appears possible to suppress the formation of nanoparticles and to manipulate particle number emitted through vehicle design and fuel composition. This potential should be taken into account in number based hotspot models and should be tested against available and future databases.

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2 Final Draft, CAFE Working Group on Particulate $_2$Matter, April 6th, 2004

To this aim, a future SEC activity focused on ultrafine particles could be based on and benefit from:

- Existing methods and codes that are being modified to deal with nanoparticle aerosols. In particular in the nanoparticle size range, collision and coagulation processes should be accounted for to determine the particle size distribution and chemical composition as a function of particle size. Moreover, the microphysical processes, such as nucleation of gas-phase species or coagulation of primary exhaust particles, are also attempted to be modeled on spatial scales as small as a few meters.
- The new version of COPERT (4) which is currently under preparation. This emission database will also include emission factors on nanoparticle number counts, size distributions (number and mass based) specific area and size resolved chemical composition of particles emitted by all types of vehicles.

Evidently such a modelling exercise will need to be thoroughly evaluated against sets of comprehensive measurements. There is considerable evidence that suitable measurements are being conducted currently at European scale and can be used for this evaluation.

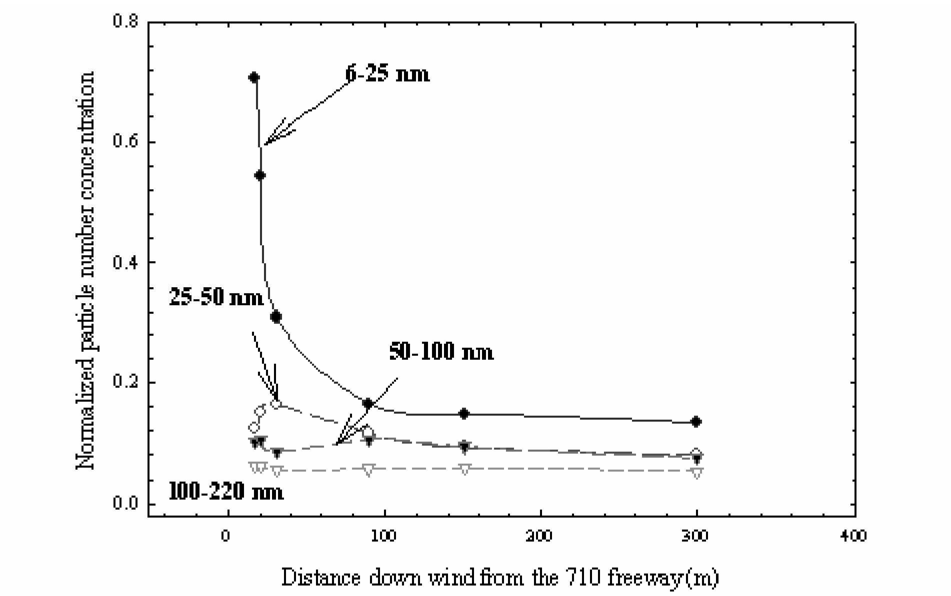

Figure 6.1. PM number concentration decrease with distance for various particle size ranges. (Zhu et al., Atmospheric Environment, 2002).

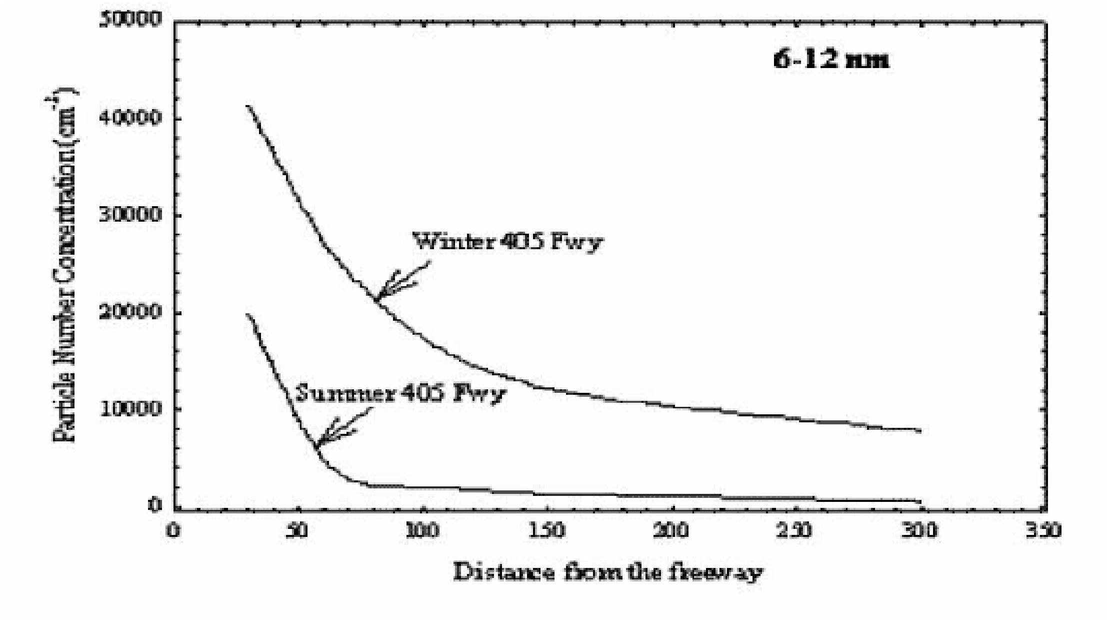

Figure 6.2. Effect of ambient temperature on particle number concentration and decay rates (Zhu et al., Aerosol Science and Technology, 2004).

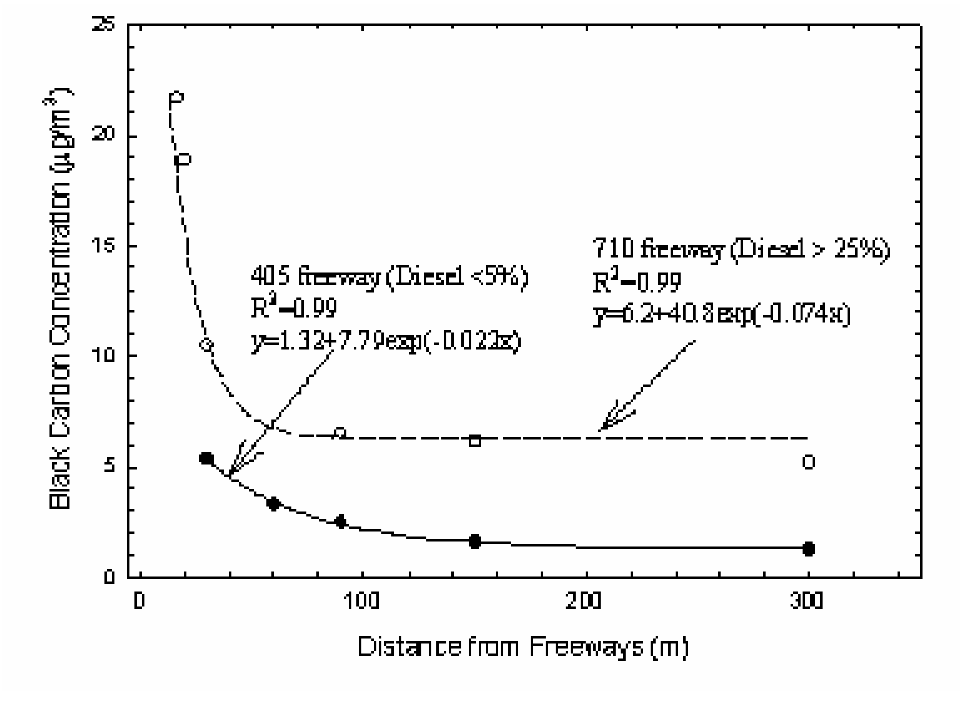

Figure 6.3. Black carbon concentration decrease with distance for two cases with different vehicle fleet compositions (Zhu et al., Atmospheric Environment, 2002).

ANNEX A

Table A.1. Monthly vehicle distribution in Hornsgatan, Stockholm**.**

Type	Class	Legislation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/02	378	353	409	368	425	368	312	388	398	392	395	374
		ECE 15/03	11434	10680	12376	11140	12853	11136	9442	11736	12027	11843	11958	11302
		ECE 15/04	38002	35497	41135	37025	42718	37013	31381	39007	39974	39363	39746	37564
		Improved Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Open Loop	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	44030	41128	47660	42898	49495	42884	36359	45195	46315	45607	46050	43522
		Euro II - 94/12/EC	51382	47995	55618	50061	57759	50045	42430	52741	54049	53223	53740	50790
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/02	511	477	553	498	574	498	422	524	537	529	534	505
		ECE 15/03	15450	14431	16723	15052	17367	15047	12758	15858	16251	16003	16158	15271
		ECE 15/04	51349	47964	55582	50029	57721	50012	42402	52707	54014	53188	53705	50757
		Improved Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Open Loop	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	59494	55572	64399	57965	66877	57946	49128	61067	62581	61625	62224	58808
		Euro II - 94/12/EC	69428	64851	75152	67643	78044	67621	57331	71264	73031	71915	72613	68627
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Gasoline >2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/02	125	116	135	121	140	121	103	128	131	129	130	123
		ECE 15/03	3770	3522	4081	3673	4238	3672	3113	3870	3966	3905	3943	3727
		ECE 15/04	12532	11705	13565	12209	14087	12205	10348	12863	13182	12980	13107	12387
		Euro I - 91/441/EEC	14519	13562	15716	14146	16321	14141	11990	14903	15273	15039	15186	14352
		Euro II - 94/12/EC	16944	15827	18341	16508	19047	16503	13992	17392	17823	17551	17721	16748
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <2,0 l	Conventional	4007	3742	4337	3904	4504	3902	3309	4113	4215	4150	4190	3960
		Euro I - 91/441/EEC	2224	2077	2407	2166	2500	2166	1836	2282	2339	2303	2326	2198
		Euro II - 94/12/EC	4448	4155	4815	4334	5000	4333	3673	4566	4679	4608	4652	4397
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel >2,0 l	Conventional	2671	2495	2891	2602	3003	2602	2206	2742	2810	2767	2794	2640
		Euro I - 91/441/EEC	1482	1385	1605	1444	1666	1444	1224	1522	1559	1535	1550	1465
		Euro II - 94/12/EC	2966	2770	3210	2889	3334	2888	2449	3044	3119	3072	3102	2931
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	LPG	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 94/12/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	2-Stroke	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
Light Duty Vehicles	Gasoline <3,5t	Conventional	15762	14723	17062	15357	17719	15352	13016	16179	16580	16327	16486	15581
		Euro I - 93/59/EEC	1178	1101	1276	1148	1325	1148	973	1210	1240	1221	1232	1165
		Euro II - 96/69/EC	41	39	45	40	46	40	34	42	43	43	43	41
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <3,5 t	Conventional	2718	2539	2942	2648	3055	2647	2244	2790	2859	2815	2843	2687
		Euro I - 93/59/EEC	2020	1887	2187	1968	2271	1968	1668	2074	2125	2093	2113	1997
		Euro II - 96/69/EC	6415	5992	6944	6250	7211	6248	5297	6585	6748	6645	6709	6341
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 3,5 - 7,5 t	Conventional	6203	6195	6066	5296	6806	6172	5810	7717	6453	6062	6041	5576
		Euro I - 91/542/EEC Stage I	1441	1439	1409	1230	1581	1434	1350	1793	1499	1408	1403	1295
		Euro II - 91/542/EEC Stage II	2063	2060	2017	1761	2264	2053	1932	2566	2146	2016	2009	1854
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 7,5 - 16 t	Conventional	6815	6807	6664	5818	7478	6782	6383	8478	7090	6661	6637	6127
		Euro I - 91/542/EEC Stage I	1583	1581	1548	1352	1737	1575	1483	1970	1647	1547	1542	1423
		Euro II - 91/542/EEC Stage II	2266	2264	2216	1935	2487	2255	2123	2820	2358	2215	2207	2037
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 16 - 32 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/542/EEC Stage I	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 91/542/EEC Stage II	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel >32t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/542/EEC Stage I	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 91/542/EEC Stage II	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
Buses - Coaches	Urban Buses	Conventional	3231	3227	3159	2758	3545	3215	3026	4019	3361	3157	3146	2904
		Euro I - 91/542/EEC Stage I	315	315	308	269	346	314	295	392	328	308	307	283
		Euro II - 91/542/EEC Stage II	409	409	400	350	449	407	384	509	426	400	399	368
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Coaches	Conventional	808	807	790	690	886	804	756	1005	840	789	787	726
		Euro I - 91/542/EEC Stage I	79	79	77	67	86	78	74	98	82	77	77	71
		Euro II - 91/542/EEC Stage II	102	102	100	87	112	102	96	127	107	100	100	92
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
Mopeds	<50 cm³	Conventional	11631	10864	12589	11332	13074	11328	9604	11938	12234	12047	12164	11496
		97/24/EC Stage I	1866	1743	2019	1818	2097	1817	1541	1915	1962	1932	1951	1844
		97/24/EC Stage II	1895	1770	2051	1846	2130	1845	1565	1945	1993	1962	1982	1873
Motorcycles	2-stroke >50 cm³	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		97/24/EC	0	0	0	0	0	0	0	0	0	0	0	0
	4-stroke <250 cm³	Conventional	3211	2999	3475	3128	3609	3127	2651	3296	3377	3326	3358	3174
		97/24/EC	1038	970	1124	1011	1167	1011	857	1065	1092	1075	1086	1026
	4-stroke 250 - 750 cm³	Conventional	3211	2999	3475	3128	3609	3127	2651	3296	3377	3326	3358	3174
		97/24/EC	1038	970	1124	1011	1167	1011	857	1065	1092	1075	1086	1026
	4-stroke >750 cm³	Conventional	3211	2999	3475	3128	3609	3127	2651	3296	3377	3326	3358	3174
		97/24/EC	1038	970	1124	1011	1167	1011	857	1065	1092	1075	1086	1026

Table A.2. Hourly vehicle distribution in Hornsgatan, Stockholm, 01:00 – 12:00.

Type	Class	Legislation	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	0.5	0.5	0.4	0.3	0.2	0.3	0.7	1.3	1.4	1.2	1.4	1.5
		ECE 15/03	16.5	14.6	11.5	10.2	7.1	8.1	22.6	38.3	41.2	37.2	41.4	45.9
		ECE 15/04	54.9	48.6	38.4	34.0	23.7	26.9	75.1	127.3	136.9	123.7	137.5	152.4
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	63.7	56.3	44.4	39.4	27.4	31.2	87.0	147.4	158.6	143.3	159.3	176.6
		Euro II - 94/12/EC	74.3	65.7	51.9	46.0	32.0	36.4	101.5	172.1	185.1	167.3	185.9	206.1
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline 1,4 - 2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	0.7	0.7	0.5	0.5	0.3	0.4	1.0	1.7	1.8	1.7	1.8	2.0
		ECE 15/03	22.3	19.8	15.6	13.8	9.6	10.9	30.5	51.7	55.6	50.3	55.9	62.0
		ECE 15/04	74.2	65.7	51.8	46.0	32.0	36.3	101.4	172.0	184.9	167.2	185.8	206.0
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	86.0	76.1	60.0	53.3	37.0	42.1	117.5	199.2	214.3	193.7	215.3	238.7
		Euro II - 94/12/EC	100.4	88.8	70.1	62.2	43.2	49.1	137.1	232.5	250.0	226.0	251.2	278.5
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline >2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.4	0.5	0.5
		ECE 15/03	5.5	4.8	3.8	3.4	2.3	2.7	7.4	12.6	13.6	12.3	13.6	15.1
		ECE 15/04	18.1	16.0	12.6	11.2	7.8	8.9	24.8	42.0	45.1	40.8	45.3	50.3
		Euro I - 91/441/EEC	21.0	18.6	14.7	13.0	9.0	10.3	28.7	48.6	52.3	47.3	52.5	58.2
		Euro II - 94/12/EC	24.5	21.7	17.1	15.2	10.5	12.0	33.5	56.7	61.0	55.2	61.3	68.0
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <2,0 l	Conventional	5.8	5.1	4.0	3.6	2.5	2.8	7.9	13.4	14.4	13.0	14.5	16.1
		Euro I - 91/441/EEC	3.2	2.8	2.2	2.0	1.4	1.6	4.4	7.4	8.0	7.2	8.0	8.9
		Euro II - 94/12/EC	6.4	5.7	4.5	4.0	2.8	3.1	8.8	14.9	16.0	14.5	16.1	17.8
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >2,0 l	Conventional	3.9	3.4	2.7	2.4	1.7	1.9	5.3	8.9	9.6	8.7	9.7	10.7
		Euro I - 91/441/EEC	2.1	1.9	1.5	1.3	0.9	1.0	2.9	5.0	5.3	4.8	5.4	5.9
		Euro II - 94/12/EC	4.3	3.8	3.0	2.7	1.8	2.1	5.9	9.9	10.7	9.7	10.7	11.9
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	LPG	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2-Stroke	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Duty Vehicles	Gasoline <3,5t	Conventional	22.8	20.2	15.9	14.1	9.8	11.2	31.1	52.8	56.8	51.3	57.0	63.2
		Euro I - 93/59/EEC	1.7	1.5	1.2	1.1	0.7	0.8	2.3	3.9	4.2	3.8	4.3	4.7
		Euro II - 96/69/EC	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <3,5 t	Conventional	3.9	3.5	2.7	2.4	1.7	1.9	5.4	9.1	9.8	8.8	9.8	10.9
		Euro I - 93/59/EEC	2.9	2.6	2.0	1.8	1.3	1.4	4.0	6.8	7.3	6.6	7.3	8.1
		Euro II - 96/69/EC	9.3	8.2	6.5	5.7	4.0	4.5	12.7	21.5	23.1	20.9	23.2	25.7
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 3,5 - 7,5 t	Conventional	6.1	8.0	7.4	6.8	6.0	6.4	12.7	21.5	24.3	23.6	25.5	27.0
		Euro I - 91/542/EEC Stage I	1.4	1.9	1.7	1.6	1.4	1.5	2.9	5.0	5.6	5.5	5.9	6.3
		Euro II - 91/542/EEC Stage II	2.0	2.7	2.5	2.3	2.0	2.1	4.2	7.1	8.1	7.8	8.5	9.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 7,5 - 16 t	Conventional	6.7	8.8	8.1	7.5	6.6	7.0	13.9	23.6	26.7	25.9	28.0	29.7
		Euro I - 91/542/EEC Stage I	1.6	2.1	1.9	1.7	1.5	1.6	3.2	5.5	6.2	6.0	6.5	6.9
		Euro II - 91/542/EEC Stage II	2.2	2.9	2.7	2.5	2.2	2.3	4.6	7.9	8.9	8.6	9.3	9.9
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 16 - 32 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >32t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Buses - Coaches	Urban Buses	Conventional	3.2	4.2	3.8	3.6	3.1	3.3	6.6	11.2	12.6	12.3	13.3	14.1
		Euro I - 91/542/EEC Stage I	0.3	0.4	0.4	0.3	0.3	0.3	0.6	1.1	1.2	1.2	1.3	1.4
		Euro II - 91/542/EEC Stage II	0.4	0.5	0.5	0.5	0.4	0.4	0.8	1.4	1.6	1.6	1.7	1.8
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coaches	Conventional	0.8	1.0	1.0	0.9	0.8	0.8	1.7	2.8	3.2	3.1	3.3	3.5
		Euro I - 91/542/EEC Stage I	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3
		Euro II - 91/542/EEC Stage II	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.4	0.4	0.4	0.4
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mopeds	<50 cm^3	Conventional	16.8	14.9	11.7	10.4	7.2	8.2	23.0	38.9	41.9	37.9	42.1	46.7
		97/24/EC Stage I	2.7	2.4	1.9	1.7	1.2	1.3	3.7	6.2	6.7	6.1	6.8	7.5
		97/24/EC Stage II	2.7	2.4	1.9	1.7	1.2	1.3	3.7	6.3	6.8	6.2	6.9	7.6
Motorcycles	2-stroke >50 cm^3	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		97/24/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4-stroke <250 cm^3	Conventional	4.6	4.1	3.2	2.9	2.0	2.3	6.3	10.8	11.6	10.5	11.6	12.9
		97/24/EC	1.5	1.3	1.0	0.9	0.6	0.7	2.1	3.5	3.7	3.4	3.8	4.2
	4-stroke 250 - 750 cm^3	Conventional	4.6	4.1	3.2	2.9	2.0	2.3	6.3	10.8	11.6	10.5	11.6	12.9
		97/24/EC	1.5	1.3	1.0	0.9	0.6	0.7	2.1	3.5	3.7	3.4	3.8	4.2
	4-stroke >750 cm^3	Conventional	4.6	4.1	3.2	2.9	2.0	2.3	6.3	10.8	11.6	10.5	11.6	12.9
		97/24/EC	1.5	1.3	1.0	0.9	0.6	0.7	2.1	3.5	3.7	3.4	3.8	4.2

Table A.3. Hourly vehicle distribution in Hornsgatan, Stockholm, 13:00 – 24:00.

Type	Class	Legislation	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	1.7	1.7	1.8	1.9	1.9	1.8	1.5	1.3	1.1	1.0	0.8	0.7
		ECE 15/03	50.3	51.4	53.6	57.7	58.7	53.3	46.0	37.9	33.5	31.5	25.1	21.3
		ECE 15/04	167.0	171.0	178.1	191.8	195.2	177.1	153.0	126.1	111.5	104.7	83.3	70.7
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	193.5	198.1	206.3	222.3	226.2	205.2	177.3	146.1	129.2	121.4	96.5	81.9
		Euro II - 94/12/EC	225.8	231.2	240.7	259.4	263.9	239.4	206.9	170.5	150.8	141.6	112.6	95.6
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline 1,4 - 2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	2.2	2.3	2.4	2.6	2.6	2.4	2.1	1.7	1.5	1.4	1.1	1.0
		ECE 15/03	67.9	69.5	72.4	78.0	79.4	72.0	62.2	51.3	45.3	42.6	33.8	28.7
		ECE 15/04	225.7	231.0	240.6	259.2	263.8	239.3	206.7	170.4	150.7	141.5	112.5	95.5
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	261.5	267.7	278.8	300.3	305.6	277.2	239.5	197.4	174.6	164.0	130.3	110.7
		Euro II - 94/12/EC	305.1	312.4	325.3	350.5	356.6	323.5	279.5	230.4	203.7	191.4	152.1	129.2
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline >2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/02	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.4	0.3	0.3	0.2
		ECE 15/03	16.6	17.0	17.7	19.0	19.4	17.6	15.2	12.5	11.1	10.4	8.3	7.0
		ECE 15/04	55.1	56.4	58.7	63.3	64.4	58.4	50.5	41.6	36.8	34.5	27.5	23.3
		Euro I - 91/441/EEC	63.8	65.3	68.0	73.3	74.6	67.7	58.5	48.2	42.6	40.0	31.8	27.0
		Euro II - 94/12/EC	74.5	76.2	79.4	85.5	87.0	79.0	68.2	56.2	49.7	46.7	37.1	31.5
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <2,0 l	Conventional	17.6	18.0	18.8	20.2	20.6	18.7	16.1	13.3	11.8	11.0	8.8	7.5
		Euro I - 91/441/EEC	9.8	10.0	10.4	11.2	11.4	10.4	9.0	7.4	6.5	6.1	4.9	4.1
		Euro II - 94/12/EC	19.6	20.0	20.8	22.5	22.9	20.7	17.9	14.8	13.1	12.3	9.7	8.3
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >2,0 l	Conventional	11.7	12.0	12.5	13.5	13.7	12.4	10.8	8.9	7.8	7.4	5.9	5.0
		Euro I - 91/441/EEC	6.5	6.7	6.9	7.5	7.6	6.9	6.0	4.9	4.3	4.1	3.2	2.8
		Euro II - 94/12/EC	13.0	13.3	13.9	15.0	15.2	13.8	11.9	9.8	8.7	8.2	6.5	5.5
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	LPG	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2-Stroke	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Duty Vehicles	Gasoline <3,5t	Conventional	69.3	70.9	73.9	79.6	81.0	73.5	63.5	52.3	46.3	43.4	34.5	29.3
		Euro I - 93/59/EEC	5.2	5.3	5.5	5.9	6.1	5.5	4.7	3.9	3.5	3.2	2.6	2.2
		Euro II - 96/69/EC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <3,5 t	Conventional	11.9	12.2	12.7	13.7	14.0	12.7	10.9	9.0	8.0	7.5	6.0	5.1
		Euro I - 93/59/EEC	8.9	9.1	9.5	10.2	10.4	9.4	8.1	6.7	5.9	5.6	4.4	3.8
		Euro II - 96/69/EC	28.2	28.9	30.1	32.4	33.0	29.9	25.8	21.3	18.8	17.7	14.1	11.9
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 3,5 - 7,5 t	Conventional	27.9	28.6	29.2	31.1	29.1	23.5	18.1	14.7	10.8	10.2	8.4	7.0
		Euro I - 91/542/EEC Stage I	6.5	6.6	6.8	7.2	6.8	5.5	4.2	3.4	2.5	2.4	1.9	1.6
		Euro II - 91/542/EEC Stage II	9.3	9.5	9.7	10.4	9.7	7.8	6.0	4.9	3.6	3.4	2.8	2.3
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 7,5 - 16 t	Conventional	30.7	31.4	32.1	34.2	32.0	25.8	19.8	16.1	11.9	11.2	9.2	7.7
		Euro I - 91/542/EEC Stage I	7.1	7.3	7.4	7.9	7.4	6.0	4.6	3.7	2.8	2.6	2.1	1.8
		Euro II - 91/542/EEC Stage II	10.2	10.4	10.7	11.4	10.6	8.6	6.6	5.4	4.0	3.7	3.1	2.6
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 16 - 32 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >32t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Buses - Coaches	Urban Buses	Conventional	14.5	14.9	15.2	16.2	15.1	12.2	9.4	7.6	5.6	5.3	4.4	3.6
		Euro I - 91/542/EEC Stage I	1.4	1.5	1.5	1.6	1.5	1.2	0.9	0.7	0.6	0.5	0.4	0.4
		Euro II - 91/542/EEC Stage II	1.8	1.9	1.9	2.1	1.9	1.6	1.2	1.0	0.7	0.7	0.6	0.5
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coaches	Conventional	3.6	3.7	3.8	4.1	3.8	3.1	2.4	1.9	1.4	1.3	1.1	0.9
		Euro I - 91/542/EEC Stage I	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1
		Euro II - 91/542/EEC Stage II	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.2	0.2	0.2	0.1	0.1
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mopeds	<50 cm³	Conventional	51.1	52.3	54.5	58.7	59.7	54.2	46.8	38.6	34.1	32.1	25.5	21.6
		97/24/EC Stage I	8.2	8.4	8.7	9.4	9.6	8.7	7.5	6.2	5.5	5.1	4.1	3.5
		97/24/EC Stage II	8.3	8.5	8.9	9.6	9.7	8.8	7.6	6.3	5.6	5.2	4.2	3.5
Motorcycles	2-stroke >50 cm³	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		97/24/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4-stroke <250 cm³	Conventional	14.1	14.4	15.0	16.2	16.5	15.0	12.9	10.7	9.4	8.8	7.0	6.0
		97/24/EC	4.6	4.7	4.9	5.2	5.3	4.8	4.2	3.4	3.0	2.9	2.3	1.9
	4-stroke 250 - 750 cm³	Conventional	14.1	14.4	15.0	16.2	16.5	15.0	12.9	10.7	9.4	8.8	7.0	6.0
		97/24/EC	4.6	4.7	4.9	5.2	5.3	4.8	4.2	3.4	3.0	2.9	2.3	1.9
	4-stroke >750 cm³	Conventional	14.1	14.4	15.0	16.2	16.5	15.0	12.9	10.7	9.4	8.8	7.0	6.0
		97/24/EC	4.6	4.7	4.9	5.2	5.3	4.8	4.2	3.4	3.0	2.9	2.3	1.9

ANNEX B

Table B.1. Monthly vehicle distribution in Marylebone Rd., London.

Type	Class	Legislation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	259	258	275	258	275	263	276	269	257	256	256	259
		ECE 15/02	2109	2103	2241	2101	2238	2142	2250	2192	2091	2089	2082	2108
		ECE 15/03	18586	18536	19752	18515	19721	18874	19831	19318	18432	18410	18352	18580
		ECE 15/04	250489	249811	266197	249536	265783	254368	267268	260350	248408	248110	247329	250409
		Improved Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Open Loop	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	193002	192479	205105	192267	204786	195990	205930	200599	191398	191168	190566	192940
		Euro II - 94/12/EC	396789	395715	421671	395279	421016	402934	423368	412408	393492	393020	391783	396662
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	263	262	279	262	279	267	281	273	261	260	260	263
		ECE 15/02	2141	2136	2276	2133	2272	2175	2285	2226	2124	2121	2114	2141
		ECE 15/03	18873	18822	20056	18801	20025	19165	20137	19616	18716	18693	18635	18867
		ECE 15/04	254351	253663	270301	253384	269881	258290	271389	264364	252238	251935	251142	254270
		Improved Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Open Loop	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	195977	195447	208267	195232	207943	199012	209105	203692	194349	194116	193505	195914
		Euro II - 94/12/EC	402907	401816	428173	401374	427507	409146	429896	418767	399559	399080	397823	402778
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Gasoline >2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	48	48	52	48	51	49	52	50	48	48	48	48
		ECE 15/02	395	394	420	393	419	401	421	410	392	391	390	395
		ECE 15/03	3480	3470	3698	3467	3692	3534	3713	3617	3451	3447	3436	3479
		ECE 15/04	20539	20484	21827	20461	21793	20857	21915	21348	20369	20344	20280	20533
		Euro I - 91/441/EEC	62493	62324	66412	62255	66309	63461	66679	64953	61974	61899	61705	62473
		Euro II - 94/12/EC	74289	74088	78947	74006	78825	75439	79265	77213	73671	73583	73351	74265
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <2,0 l	Conventional	29464	29385	31312	29352	31263	29921	31438	30624	29220	29184	29093	29455
		Euro I - 91/441/EEC	20950	20893	22263	20870	22229	21274	22353	21774	20776	20751	20685	20943
		Euro II - 94/12/EC	43070	42954	45771	42906	45700	43737	45955	44766	42712	42661	42527	43057
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel >2,0 l	Conventional	19643	19590	20875	19568	20842	19947	20959	20416	19480	19456	19395	19637
		Euro I - 91/441/EEC	13966	13929	14842	13913	14819	14183	14902	14516	13850	13834	13790	13962
		Euro II - 94/12/EC	28714	28636	30514	28604	30467	29158	30637	29844	28475	28441	28351	28704
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	LPG	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 94/12/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	2-Stroke	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
Light Duty Vehicles	Gasoline <3,5t	Conventional	44927	44805	47744	44756	47670	45623	47937	46696	44554	44500	44360	44913
		Euro I - 93/59/EEC	16809	16763	17863	16745	17835	17069	17934	17470	16669	16649	16596	16803
		Euro II - 96/69/EC	35489	35393	37715	35354	37656	36039	37867	36886	35194	35152	35041	35478
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <3,5 t	Conventional	40651	40541	43200	40496	43133	41281	43374	42251	40313	40265	40138	40638
		Euro I - 93/59/EEC	15209	15168	16163	15151	16137	15444	16228	15807	15082	15064	15017	15204
		Euro II - 96/69/EC	32112	32025	34125	31989	34072	32609	34263	33376	31845	31807	31706	32101
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 3,5 - 7,5 t	Conventional	24181	25794	27376	23778	27428	26410	27182	26338	25947	26479	27228	23842
		Euro I - 91/542/EEC Stage I	16201	17282	18342	15932	18377	17695	18212	17647	17385	17741	18243	15975
		Euro II - 91/542/EEC Stage II	23214	24763	26281	22828	26331	25354	26096	25285	24909	25420	26140	22889
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 7,5 - 16 t	Conventional	49944	53277	56544	49113	56651	54549	56144	54400	53592	54691	56239	49246
		Euro I - 91/542/EEC Stage I	33463	35696	37885	32907	37957	36548	37617	36449	35907	36644	37681	32995
		Euro II - 91/542/EEC Stage II	47947	51147	54283	47150	54386	52368	53899	52225	51449	52505	53991	47277
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 16 - 32 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/542/EEC Stage I	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 91/542/EEC Stage II	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel >32t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/542/EEC Stage I	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 91/542/EEC Stage II	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
Buses - Coaches	Urban Buses	Conventional	18072	19278	20460	17771	20499	19738	20315	19684	19392	19790	20350	17819
		Euro I - 91/542/EEC Stage I	10709	11424	12124	10531	12148	11697	12039	11665	11492	11727	12059	10560
		Euro II - 91/542/EEC Stage II	13593	14500	15389	13367	15418	14846	15280	14806	14586	14885	15306	13403
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Coaches	Conventional	4518	4819	5115	4443	5125	4935	5079	4921	4848	4947	5087	4455
		Euro I - 91/542/EEC Stage I	2677	2856	3031	2633	3037	2924	3010	2916	2873	2932	3015	2640
		Euro II - 91/542/EEC Stage II	3398	3625	3847	3342	3855	3712	3820	3701	3646	3721	3827	3351
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
Mopeds	<50 cm^3	Conventional	5450	5435	5792	5429	5783	5535	5815	5665	5405	5398	5381	5448
		97/24/EC Stage I	2383	2377	2533	2374	2529	2420	2543	2477	2363	2361	2353	2382
		97/24/EC Stage II	2489	2482	2645	2480	2641	2528	2656	2587	2469	2466	2458	2488
Motorcycles	2-stroke >50 cm^3	Conventional	2928	2920	3112	2917	3107	2973	3124	3043	2904	2900	2891	2927
		97/24/EC	2618	2611	2782	2608	2777	2658	2793	2721	2596	2593	2585	2617
	4-stroke <250 cm^3	Conventional	6871	6852	7301	6844	7290	6977	7331	7141	6814	6805	6784	6868
		97/24/EC	6142	6126	6527	6119	6517	6237	6554	6384	6091	6084	6065	6140
	4-stroke 250 - 750 cm^3	Conventional	6871	6852	7301	6844	7290	6977	7331	7141	6814	6805	6784	6868
		97/24/EC	6142	6126	6527	6119	6517	6237	6554	6384	6091	6084	6065	6140
	4-stroke >750 cm^3	Conventional	6871	6852	7301	6844	7290	6977	7331	7141	6814	6805	6784	6868
		97/24/EC	6142	6126	6527	6119	6517	6237	6554	6384	6091	6084	6065	6140

Table B.2. Hourly vehicle distribution in Marylebone Rd., London, 01:00 -12:00.

Type	Class	Legislation	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.2	0.2	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4
		ECE 15/02	1.7	1.4	1.2	1.1	1.6	2.6	3.2	3.3	3.3	3.4	3.5	3.6
		ECE 15/03	15.1	11.9	10.3	10.0	13.8	23.1	28.5	29.0	29.3	30.1	30.7	31.5
		ECE 15/04	203.1	160.5	139.5	134.9	186.3	310.9	384.4	391.4	394.9	405.5	413.5	424.1
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	156.5	123.7	107.5	103.9	143.5	239.5	296.2	301.6	304.3	312.4	318.6	326.7
		Euro II - 94/12/EC	321.8	254.3	220.9	213.7	295.1	492.4	608.9	620.0	625.6	642.3	655.0	671.7
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline 1,4 - 2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.2	0.2	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4
		ECE 15/02	1.7	1.4	1.2	1.2	1.6	2.7	3.3	3.3	3.4	3.5	3.5	3.6
		ECE 15/03	15.3	12.1	10.5	10.2	14.0	23.4	29.0	29.5	29.8	30.6	31.2	32.0
		ECE 15/04	206.3	163.0	141.6	137.0	189.2	315.7	390.3	397.4	401.0	411.7	419.9	430.6
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	158.9	125.6	109.1	105.5	145.7	243.2	300.8	306.2	309.0	317.2	323.5	331.8
		Euro II - 94/12/EC	326.8	258.2	224.3	217.0	299.6	500.0	618.3	629.6	635.2	652.2	665.1	682.1
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline >2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		ECE 15/02	0.3	0.3	0.2	0.2	0.3	0.5	0.6	0.6	0.6	0.6	0.7	0.7
		ECE 15/03	2.8	2.2	1.9	1.9	2.6	4.3	5.3	5.4	5.5	5.6	5.7	5.9
		ECE 15/04	16.7	13.2	11.4	11.1	15.3	25.5	31.5	32.1	32.4	33.2	33.9	34.8
		Euro I - 91/441/EEC	50.7	40.0	34.8	33.7	46.5	77.6	95.9	97.6	98.5	101.2	103.2	105.8
		Euro II - 94/12/EC	60.2	47.6	41.4	40.0	55.2	92.2	114.0	116.1	117.1	120.3	122.6	125.8
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <2,0 l	Conventional	23.9	18.9	16.4	15.9	21.9	36.6	45.2	46.0	46.5	47.7	48.6	49.9
		Euro I - 91/441/EEC	17.0	13.4	11.7	11.3	15.6	26.0	32.2	32.7	33.0	33.9	34.6	35.5
		Euro II - 94/12/EC	34.9	27.6	24.0	23.2	32.0	53.5	66.1	67.3	67.9	69.7	71.1	72.9
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >2,0 l	Conventional	15.9	12.6	10.9	10.6	14.6	24.4	30.1	30.7	31.0	31.8	32.4	33.3
		Euro I - 91/441/EEC	11.3	9.0	7.8	7.5	10.4	17.3	21.4	21.8	22.0	22.6	23.1	23.6
		Euro II - 94/12/EC	23.3	18.4	16.0	15.5	21.4	35.6	44.1	44.9	45.3	46.5	47.4	48.6
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	LPG	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2-Stroke	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Duty Vehicles	Gasoline <3,5t	Conventional	36.4	28.8	25.0	24.2	33.4	55.8	68.9	70.2	70.8	72.7	74.2	76.1
		Euro I - 93/59/EEC	13.6	10.8	9.4	9.1	12.5	20.9	25.8	26.3	26.5	27.2	27.7	28.5
		Euro II - 96/69/EC	28.8	22.7	19.8	19.1	26.4	44.0	54.5	55.5	56.0	57.5	58.6	60.1
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <3,5 t	Conventional	33.0	26.1	22.6	21.9	30.2	50.5	62.4	63.5	64.1	65.8	67.1	68.8
		Euro I - 93/59/EEC	12.3	9.7	8.5	8.2	11.3	18.9	23.3	23.8	24.0	24.6	25.1	25.7
		Euro II - 96/69/EC	26.0	20.6	17.9	17.3	23.9	39.9	49.3	50.2	50.6	52.0	53.0	54.4
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 3,5 - 7,5 t	Conventional	10.9	10.7	11.9	15.3	26.1	44.6	55.0	56.7	57.2	60.4	60.9	59.3
		Euro I - 91/542/EEC Stage I	7.3	7.2	8.0	10.2	17.5	29.9	36.8	38.0	38.4	40.4	40.8	39.7
		Euro II - 91/542/EEC Stage II	10.4	10.3	11.4	14.7	25.1	42.8	52.8	54.4	55.0	58.0	58.4	56.9
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 7,5 - 16 t	Conventional	22.4	22.1	24.5	31.6	54.0	92.2	113.6	117.1	118.2	124.7	125.7	122.5
		Euro I - 91/542/EEC Stage I	15.0	14.8	16.4	21.1	36.2	61.8	76.1	78.4	79.2	83.5	84.2	82.1
		Euro II - 91/542/EEC Stage II	21.5	21.2	23.5	30.3	51.8	88.5	109.1	112.4	113.5	119.7	120.7	117.6
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 16 - 32 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >32t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Buses - Coaches	Urban Buses	Conventional	8.1	8.0	8.9	11.4	19.5	33.4	41.1	42.4	42.8	45.1	45.5	44.3
		Euro I - 91/542/EEC Stage I	4.8	4.7	5.3	6.8	11.6	19.8	24.4	25.1	25.4	26.7	27.0	26.3
		Euro II - 91/542/EEC Stage II	6.1	6.0	6.7	8.6	14.7	25.1	30.9	31.9	32.2	33.9	34.2	33.3
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coaches	Conventional	2.0	2.0	2.2	2.9	4.9	8.3	10.3	10.6	10.7	11.3	11.4	11.1
		Euro I - 91/542/EEC Stage I	1.2	1.2	1.3	1.7	2.9	4.9	6.1	6.3	6.3	6.7	6.7	6.6
		Euro II - 91/542/EEC Stage II	1.5	1.5	1.7	2.1	3.7	6.3	7.7	8.0	8.0	8.5	8.6	8.3
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mopeds	<50 cm³	Conventional	4.4	3.5	3.0	2.9	4.1	6.8	8.4	8.5	8.6	8.8	9.0	9.2
		97/24/EC Stage I	1.9	1.5	1.3	1.3	1.8	3.0	3.7	3.7	3.8	3.9	3.9	4.0
		97/24/EC Stage II	2.0	1.6	1.4	1.3	1.9	3.1	3.8	3.9	3.9	4.0	4.1	4.2
Motorcycles	2-stroke >50 cm³	Conventional	2.4	1.9	1.6	1.6	2.2	3.6	4.5	4.6	4.6	4.7	4.8	5.0
		97/24/EC	2.1	1.7	1.5	1.4	1.9	3.2	4.0	4.1	4.1	4.2	4.3	4.4
	4-stroke <250 cm³	Conventional	5.6	4.4	3.8	3.7	5.1	8.5	10.5	10.7	10.8	11.1	11.3	11.6
		97/24/EC	5.0	3.9	3.4	3.3	4.6	7.6	9.4	9.6	9.7	9.9	10.1	10.4
	4-stroke 250 - 750 cm³	Conventional	5.6	4.4	3.8	3.7	5.1	8.5	10.5	10.7	10.8	11.1	11.3	11.6
		97/24/EC	5.0	3.9	3.4	3.3	4.6	7.6	9.4	9.6	9.7	9.9	10.1	10.4
	4-stroke >750 cm³	Conventional	5.6	4.4	3.8	3.7	5.1	8.5	10.5	10.7	10.8	11.1	11.3	11.6
		97/24/EC	5.0	3.9	3.4	3.3	4.6	7.6	9.4	9.6	9.7	9.9	10.1	10.4

Table B.3. Hourly vehicle distribution in Marylebone Rd., London, 13:00 -24:00.

Type	Class	Legislation	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	00:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3
		ECE 15/02	3.6	3.7	3.7	3.8	3.9	4.0	3.7	3.3	3.1	3.0	2.8	2.3
		ECE 15/03	32.0	32.2	32.6	33.4	34.4	35.0	32.5	28.9	27.0	26.2	25.0	19.9
		ECE 15/04	431.3	434.1	439.4	449.9	463.2	472.2	438.3	390.1	363.3	353.3	336.4	268.8
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	332.3	334.4	338.6	346.6	356.9	363.8	337.7	300.5	279.9	272.2	259.2	207.1
		Euro II - 94/12/EC	683.3	687.6	696.1	712.6	733.8	748.0	694.4	617.9	575.5	559.6	532.8	425.8
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline 1,4 - 2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3
		ECE 15/02	3.7	3.7	3.8	3.8	4.0	4.0	3.7	3.3	3.1	3.0	2.9	2.3
		ECE 15/03	32.5	32.7	33.1	33.9	34.9	35.6	33.0	29.4	27.4	26.6	25.3	20.3
		ECE 15/04	438.0	440.8	446.2	456.8	470.4	479.5	445.1	396.1	368.9	358.7	341.6	273.0
		Improved Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Open Loop	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	337.5	339.6	343.8	352.0	362.4	369.5	343.0	305.2	284.2	276.4	263.2	210.3
		Euro II - 94/12/EC	693.8	698.2	706.8	723.6	745.1	759.6	705.1	627.4	584.3	568.3	541.1	432.4
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Gasoline >2,0 l	PRE ECE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		ECE 15/00-01	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		ECE 15/02	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4
		ECE 15/03	6.0	6.0	6.1	6.2	6.4	6.6	6.1	5.4	5.0	4.9	4.7	3.7
		ECE 15/04	35.4	35.6	36.0	36.9	38.0	38.7	35.9	32.0	29.8	29.0	27.6	22.0
		Euro I - 91/441/EEC	107.6	108.3	109.6	112.2	115.6	117.8	109.4	97.3	90.6	88.1	83.9	67.1
		Euro II - 94/12/EC	127.9	128.7	130.3	133.4	137.4	140.0	130.0	115.7	107.7	104.8	99.8	79.7
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <2,0 l	Conventional	50.7	51.1	51.7	52.9	54.5	55.5	51.6	45.9	42.7	41.6	39.6	31.6
		Euro I - 91/441/EEC	36.1	36.3	36.8	37.6	38.7	39.5	36.7	32.6	30.4	29.5	28.1	22.5
		Euro II - 94/12/EC	74.2	74.6	75.6	77.4	79.7	81.2	75.4	67.1	62.5	60.7	57.8	46.2
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >2,0 l	Conventional	33.8	34.0	34.5	35.3	36.3	37.0	34.4	30.6	28.5	27.7	26.4	21.1
		Euro I - 91/441/EEC	24.0	24.2	24.5	25.1	25.8	26.3	24.4	21.7	20.3	19.7	18.8	15.0
		Euro II - 94/12/EC	49.4	49.8	50.4	51.6	53.1	54.1	50.2	44.7	41.6	40.5	38.6	30.8
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	LPG	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/441/EEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 94/12/EC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2-Stroke	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Duty Vehicles	Gasoline <3,5t	Conventional	77.4	77.9	78.8	80.7	83.1	84.7	78.6	70.0	65.2	63.4	60.3	48.2
		Euro I - 93/59/EEC	28.9	29.1	29.5	30.2	31.1	31.7	29.4	26.2	24.4	23.7	22.6	18.0
		Euro II - 96/69/EC	61.1	61.5	62.3	63.7	65.6	66.9	62.1	55.3	51.5	50.1	47.7	38.1
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel <3,5 t	Conventional	70.0	70.4	71.3	73.0	75.2	76.6	71.1	63.3	59.0	57.3	54.6	43.6
		Euro I - 93/59/EEC	26.2	26.4	26.7	27.3	28.1	28.7	26.6	23.7	22.1	21.5	20.4	16.3
		Euro II - 96/69/EC	55.3	55.6	56.3	57.7	59.4	60.5	56.2	50.0	46.6	45.3	43.1	34.5
		Euro III - 98/69/EC Stage2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 3,5 - 7,5 t	Conventional	56.2	52.1	47.4	41.2	36.1	30.6	27.1	24.4	21.3	19.7	17.7	13.2
		Euro I - 91/542/EEC Stage I	37.7	34.9	31.8	27.6	24.2	20.5	18.1	16.3	14.3	13.2	11.8	8.8
		Euro II - 91/542/EEC Stage II	54.0	50.0	45.5	39.6	34.6	29.4	26.0	23.4	20.5	18.9	17.0	12.6
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 7,5 - 16 t	Conventional	116.1	107.6	97.9	85.2	74.5	63.2	55.9	50.4	44.1	40.7	36.5	27.2
		Euro I - 91/542/EEC Stage I	77.8	72.1	65.6	57.1	49.9	42.3	37.4	33.8	29.5	27.3	24.5	18.2
		Euro II - 91/542/EEC Stage II	111.5	103.3	94.0	81.8	71.5	60.7	53.7	48.4	42.3	39.1	35.0	26.1
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel 16 - 32 t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diesel >32t	Conventional	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro I - 91/542/EEC Stage I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro II - 91/542/EEC Stage II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Buses - Coaches	Urban Buses	Conventional	42.0	38.9	35.4	30.8	27.0	22.9	20.2	18.2	15.9	14.7	13.2	9.8
		Euro I - 91/542/EEC Stage I	24.9	23.1	21.0	18.3	16.0	13.6	12.0	10.8	9.4	8.7	7.8	5.8
		Euro II - 91/542/EEC Stage II	31.6	29.3	26.6	23.2	20.3	17.2	15.2	13.7	12.0	11.1	9.9	7.4
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coaches	Conventional	10.5	9.7	8.9	7.7	6.7	5.7	5.1	4.6	4.0	3.7	3.3	2.5
		Euro I - 91/542/EEC Stage I	6.2	5.8	5.2	4.6	4.0	3.4	3.0	2.7	2.4	2.2	2.0	1.5
		Euro II - 91/542/EEC Stage II	7.9	7.3	6.7	5.8	5.1	4.3	3.8	3.4	3.0	2.8	2.5	1.9
		Euro III - 2000 Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mopeds	<50 cm^3	Conventional	9.4	9.4	9.6	9.8	10.1	10.3	9.5	8.5	7.9	7.7	7.3	5.8
		97/24/EC Stage I	4.1	4.1	4.2	4.3	4.4	4.5	4.2	3.7	3.5	3.4	3.2	2.6
		97/24/EC Stage II	4.3	4.3	4.4	4.5	4.6	4.7	4.4	3.9	3.6	3.5	3.3	2.7
Motorcycles	2-stroke >50 cm^3	Conventional	5.0	5.1	5.1	5.3	5.4	5.5	5.1	4.6	4.2	4.1	3.9	3.1
		97/24/EC	4.5	4.5	4.6	4.7	4.8	4.9	4.6	4.1	3.8	3.7	3.5	2.8
	4-stroke <250 cm^3	Conventional	11.8	11.9	12.1	12.3	12.7	13.0	12.0	10.7	10.0	9.7	9.2	7.4
		97/24/EC	10.6	10.6	10.8	11.0	11.4	11.6	10.7	9.6	8.9	8.7	8.2	6.6
	4-stroke 250 - 750 cm^3	Conventional	11.8	11.9	12.1	12.3	12.7	13.0	12.0	10.7	10.0	9.7	9.2	7.4
		97/24/EC	10.6	10.6	10.8	11.0	11.4	11.6	10.7	9.6	8.9	8.7	8.2	6.6
	4-stroke >750 cm^3	Conventional	11.8	11.9	12.1	12.3	12.7	13.0	12.0	10.7	10.0	9.7	9.2	7.4
		97/24/EC	10.6	10.6	10.8	11.0	11.4	11.6	10.7	9.6	8.9	8.7	8.2	6.6

ANNEX C

Table C.1. Monthly vehicle distribution in Frankfurter Allee, Berlin.

Type	Class	Legislation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	2241	1934	1825	1917	2181	1934	1769	1834	2197	2257	2274	2136
		ECE 15/02	5529	4772	4502	4731	5381	4771	4366	4524	5420	5568	5611	5271
		ECE 15/03	19471	16808	15857	16662	18950	16802	15376	15933	19087	19610	19761	18564
		ECE 15/04	19917	17192	16220	17043	19384	17187	15728	16298	19524	20058	20214	18989
		Improved Conventional	31936	27567	26008	27328	31082	27559	25219	26133	31307	32163	32412	30448
		Open Loop	12306	10622	10021	10530	11977	10619	9718	10070	12063	12393	12489	11732
		Euro I - 91/441/EEC	153999	132931	125411	131778	149879	132891	121610	126014	150963	155093	156293	146825
		Euro II - 94/12/EC	174989	151050	142505	149739	170308	151005	138185	143190	171539	176232	177596	166837
		Euro III - 98/69/EC Stage2000	76772	66269	62520	65694	74718	66249	60625	62821	75258	77317	77916	73195
	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	3028	2614	2466	2591	2947	2613	2391	2478	2968	3049	3073	2887
		ECE 15/02	7470	6448	6083	6392	7270	6446	5899	6113	7323	7523	7582	7122
		ECE 15/03	26310	22710	21426	22513	25606	22704	20776	21529	25791	26497	26702	25084
		ECE 15/04	30053	25942	24474	25717	29249	25934	23733	24592	29461	30267	30501	28653
		Improved Conventional	13081	11291	10653	11193	12731	11288	10330	10704	12823	13174	13276	12472
		Open Loop	5057	4365	4118	4327	4921	4364	3993	4138	4957	5093	5132	4821
		Euro I - 91/441/EEC	246586	212852	200811	211004	239989	212788	194724	201776	241724	248337	250260	235098
		Euro II - 94/12/EC	236447	204100	192554	202328	230121	204038	186717	193479	231785	238125	239969	225431
		Euro III - 98/69/EC Stage2000	103735	89543	84478	88766	100959	89516	81917	84884	101689	104471	105280	98902
	Gasoline >2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	739	638	602	632	719	638	584	605	724	744	750	704
		ECE 15/02	1823	1574	1485	1560	1774	1573	1440	1492	1787	1836	1850	1738
		ECE 15/03	6421	5542	5229	5494	6249	5541	5070	5254	6294	6466	6516	6122
		ECE 15/04	7155	6177	5827	6123	6964	6175	5651	5855	7014	7206	7262	6822
		Euro I - 91/441/EEC	64784	55921	52758	55436	63051	55905	51159	53012	63507	65244	65749	61766
		Euro II - 94/12/EC	57704	49810	46992	49378	56161	49795	45568	47218	56567	58114	58564	55016
		Euro III - 98/69/EC Stage2000	25316	21853	20617	21663	24639	21846	19992	20716	24817	25496	25693	24137
	Diesel <2,0 l	Conventional	40456	34921	32946	34618	39374	34911	31947	33104	39658	40743	41059	38571
		Euro I - 91/441/EEC	23867	20602	19437	20423	23229	20596	18847	19530	23397	24037	24223	22755
		Euro II - 94/12/EC	50692	43757	41281	43377	49335	43744	40030	41480	49692	51051	51447	48330
		Euro III - 98/69/EC Stage2000	22939	19801	18680	19629	22325	19795	18114	18770	22486	23102	23280	21870
	Diesel >2,0 l	Conventional	26971	23281	21964	23079	26249	23274	21298	22069	26439	27162	27372	25714
		Euro I - 91/441/EEC	15912	13735	12958	13616	15486	13731	12565	13020	15598	16024	16149	15170
		Euro II - 94/12/EC	33794	29171	27521	28918	32890	29162	26687	27653	33128	34034	34298	32220
		Euro III - 98/69/EC Stage2000	15293	13200	12454	13086	14883	13196	12076	12514	14991	15401	15520	14580
	LPG	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 94/12/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	2-Stroke	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
Light Duty Vehicles	Gasoline <3,5t	Conventional	7519	6490	6123	6434	7318	6488	5937	6152	7370	7572	7631	7168
		Euro I - 93/59/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 96/69/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <3,5 t	Conventional	28042	24205	22836	23995	27292	24198	22144	22946	27489	28241	28459	26735
		Euro I - 93/59/EEC	6205	5356	5053	5309	6039	5354	4900	5077	6082	6249	6297	5916
		Euro II - 96/69/EC	17428	15044	14193	14913	16962	15039	13762	14261	17084	17551	17687	16616
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 3,5 - 7,5 t	Conventional	24070	20777	19601	20596	23426	20771	19007	19696	23595	24241	24428	22948
		Euro I - 91/542/EEC Stage I	5638	4867	4591	4825	5487	4865	4452	4614	5527	5678	5722	5375
		Euro II - 91/542/EEC Stage II	9005	7773	7334	7706	8764	7771	7111	7369	8828	9069	9139	8586
		Euro III - 2000 Standards	1913	1652	1558	1637	1862	1651	1511	1566	1876	1927	1942	1824
	Diesel 7,5 - 16 t	Conventional	14279	12326	11628	12219	13897	12322	11276	11684	13997	14380	14492	13614
		Euro I - 91/542/EEC Stage I	3345	2887	2724	2862	3255	2886	2641	2737	3279	3368	3395	3189
		Euro II - 91/542/EEC Stage II	5342	4611	4351	4571	5199	4610	4219	4371	5237	5380	5422	5093
		Euro III - 2000 Standards	1135	980	924	971	1105	979	896	929	1113	1143	1152	1082
	Diesel 16 - 32 t	Conventional	10891	9401	8869	9319	10600	9398	8600	8912	10676	10968	11053	10384
		Euro I - 91/542/EEC Stage I	2551	2202	2078	2183	2483	2201	2015	2088	2501	2569	2589	2432
		Euro II - 91/542/EEC Stage II	4075	3517	3318	3487	3966	3516	3218	3334	3994	4104	4135	3885
		Euro III - 2000 Standards	866	747	705	741	843	747	684	708	849	872	879	825
	Diesel >32t	Conventional	596	514	485	510	580	514	471	488	584	600	605	568
		Euro I - 91/542/EEC Stage I	140	120	114	119	136	120	110	114	137	141	142	133
		Euro II - 91/542/EEC Stage II	223	192	182	191	217	192	176	182	219	225	226	213
		Euro III - 2000 Standards	47	41	39	41	46	41	37	39	46	48	48	45
Buses - Coaches	Urban Buses	Conventional	3190	2754	2598	2730	3105	2753	2519	2611	3128	3213	3238	3042
		Euro I - 91/542/EEC Stage I	584	504	475	499	568	504	461	478	572	588	592	556
		Euro II - 91/542/EEC Stage II	580	500	472	496	564	500	458	474	568	584	588	553
		Euro III - 2000 Standards	113	97	92	97	110	97	89	92	111	114	115	108
	Coaches	Conventional	798	688	650	683	776	688	630	653	782	803	809	760
		Euro I - 91/542/EEC Stage I	146	126	119	125	142	126	115	119	143	147	148	139
		Euro II - 91/542/EEC Stage II	145	125	118	124	141	125	114	119	142	146	147	138
		Euro III - 2000 Standards	28	24	23	24	27	24	22	23	28	28	29	27
Mopeds	<50 cm^3	Conventional	61714	53271	50258	52809	60063	53255	48734	50499	60497	62152	62633	58839
		97/24/EC Stage I	4618	3986	3761	3952	4495	3985	3647	3779	4527	4651	4687	4403
		97/24/EC Stage II	253	219	206	217	247	219	200	207	248	255	257	241
Motorcycles	2-stroke >50 cm^3	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		97/24/EC	0	0	0	0	0	0	0	0	0	0	0	0
	4-stroke <250 cm^3	Conventional	27946	24123	22758	23913	27198	24116	22068	22868	27395	28144	28362	26644
		97/24/EC	2206	1904	1796	1888	2147	1904	1742	1805	2162	2222	2239	2103
	4-stroke 250 - 750 cm^3	Conventional	27946	24123	22758	23913	27198	24116	22068	22868	27395	28144	28362	26644
		97/24/EC	2206	1904	1796	1888	2147	1904	1742	1805	2162	2222	2239	2103
	4-stroke >750 cm^3	Conventional	27946	24123	22758	23913	27198	24116	22068	22868	27395	28144	28362	26644
		97/24/EC	2206	1904	1796	1888	2147	1904	1742	1805	2162	2222	2239	2103

Table C.2. Hourly vehicle distribution in Frankfurter Allee, Berlin, 01:00 – 12:00.

Type	Class	Legislation	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	330	235	176	176	310	1009	1172	1266	1238	1300	1349	1369
		ECE 15/02	814	579	434	434	765	2490	2892	3125	3055	3208	3328	3377
		ECE 15/03	2866	2038	1527	1527	2694	8771	10184	11005	10760	11298	11723	11894
		ECE 15/04	2931	2085	1562	1562	2755	8972	10418	11257	11007	11557	11991	12166
		Improved Conventional	4700	3343	2505	2505	4418	14386	16704	18050	17649	18531	19227	19508
		Open Loop	1811	1288	965	965	1702	5543	6437	6955	6800	7141	7409	7517
		Euro I - 91/441/EEC	22664	16122	12079	12079	21303	69372	80549	87040	85103	89359	92714	94068
		Euro II - 94/12/EC	25753	18319	13725	13726	24207	78827	91528	98903	96702	101539	105351	106889
		Euro III - 98/69/EC Stage2000	11298	8037	6022	6022	10620	34583	40155	43391	42426	44548	46220	46895
	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	446	317	237	237	419	1364	1584	1711	1673	1757	1823	1849
		ECE 15/02	1099	782	586	586	1033	3365	3907	4222	4128	4335	4497	4563
		ECE 15/03	3872	2754	2064	2064	3640	11852	13761	14870	14539	15266	15840	16071
		ECE 15/04	4423	3146	2357	2357	4157	13538	15719	16986	16608	17439	18093	18358
		Improved Conventional	1925	1369	1026	1026	1810	5893	6842	7393	7229	7590	7875	7990
		Open Loop	744	529	397	397	700	2278	2645	2858	2794	2934	3044	3089
		Euro I - 91/441/EEC	36289	25815	19341	19342	34111	111079	128977	139369	136268	143084	148455	150623
		Euro II - 94/12/EC	34797	24753	18546	18546	32708	106511	123673	133639	130665	137200	142350	144429
		Euro III - 98/69/EC Stage2000	15266	10860	8136	8137	14350	46729	54258	58630	57326	60193	62452	63364
	Gasoline >2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	109	77	58	58	102	333	386	418	408	429	445	451
		ECE 15/02	268	191	143	143	252	821	954	1030	1007	1058	1098	1114
		ECE 15/03	945	672	504	504	888	2892	3358	3629	3548	3726	3866	3922
		ECE 15/04	1053	749	561	561	990	3223	3743	4044	3954	4152	4308	4371
		Euro I - 91/441/EEC	9534	6782	5081	5082	8962	29183	33885	36616	35801	37592	39003	39572
		Euro II - 94/12/EC	8492	6041	4526	4526	7982	25994	30182	32614	31888	33483	34740	35248
		Euro III - 98/69/EC Stage2000	3726	2650	1986	1986	3502	11404	13242	14309	13990	14690	15241	15464
	Diesel <2,0 l	Conventional	5954	4235	3173	3173	5596	18224	21160	22865	22357	23475	24356	24712
		Euro I - 91/441/EEC	3512	2499	1872	1872	3302	10751	12484	13490	13189	13849	14369	14579
		Euro II - 94/12/EC	7460	5307	3976	3976	7012	22835	26514	28651	28013	29414	30518	30964
		Euro III - 98/69/EC Stage2000	3376	2401	1799	1799	3173	10333	11998	12965	12676	13310	13810	14012
	Diesel >2,0 l	Conventional	3969	2824	2115	2116	3731	12149	14107	15244	14904	15650	16237	16475
		Euro I - 91/441/EEC	2342	1666	1248	1248	2201	7168	8322	8993	8793	9233	9579	9719
		Euro II - 94/12/EC	4973	3538	2651	2651	4675	15223	17676	19100	18675	19609	20346	20643
		Euro III - 98/69/EC Stage2000	2251	1601	1199	1200	2115	6889	7999	8643	8451	8874	9207	9341
	LPG	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 94/12/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	2-Stroke	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
Light Duty Vehicles	Gasoline <3,5t	Conventional	1107	787	590	590	1040	3387	3933	4250	4155	4363	4527	4593
		Euro I - 93/59/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 96/69/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <3,5 t	Conventional	4127	2936	2199	2200	3879	12632	14667	15849	15496	16271	16882	17129
		Euro I - 93/59/EEC	913	650	487	487	858	2795	3245	3507	3429	3600	3736	3790
		Euro II - 96/69/EC	2565	1824	1367	1367	2411	7851	9116	9850	9631	10113	10492	10645
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 3,5 - 7,5 t	Conventional	3542	2520	1888	1888	3330	10843	12590	13604	13301	13967	14491	14703
		Euro I - 91/542/EEC Stage I	830	590	442	442	780	2540	2949	3187	3116	3272	3394	3444
		Euro II - 91/542/EEC Stage II	1325	943	706	706	1246	4057	4710	5090	4976	5225	5422	5501
		Euro III - 2000 Standards	282	200	150	150	265	862	1001	1081	1057	1110	1152	1169
	Diesel 7,5 - 16 t	Conventional	2101	1495	1120	1120	1975	6432	7469	8070	7891	8285	8597	8722
		Euro I - 91/542/EEC Stage I	492	350	262	262	463	1507	1749	1890	1848	1941	2014	2043
		Euro II - 91/542/EEC Stage II	786	559	419	419	739	2406	2794	3019	2952	3100	3216	3263
		Euro III - 2000 Standards	167	119	89	89	157	511	594	642	627	659	683	693
	Diesel 16 - 32 t	Conventional	1603	1140	854	854	1507	4906	5697	6156	6019	6320	6557	6653
		Euro I - 91/542/EEC Stage I	375	267	200	200	353	1149	1334	1442	1410	1480	1536	1558
		Euro II - 91/542/EEC Stage II	600	427	320	320	564	1836	2131	2303	2252	2364	2453	2489
		Euro III - 2000 Standards	127	91	68	68	120	390	453	489	478	502	521	529
	Diesel >32t	Conventional	88	62	47	47	82	268	312	337	329	346	359	364
		Euro I - 91/542/EEC Stage I	21	15	11	11	19	63	73	79	77	81	84	85
		Euro II - 91/542/EEC Stage II	33	23	17	17	31	100	117	126	123	129	134	136
		Euro III - 2000 Standards	7	5	4	4	7	21	25	27	26	27	29	29
Buses - Coaches	Urban Buses	Conventional	470	334	250	250	441	1437	1669	1803	1763	1851	1921	1949
		Euro I - 91/542/EEC Stage I	86	61	46	46	81	263	305	330	323	339	351	356
		Euro II - 91/542/EEC Stage II	85	61	45	45	80	261	303	328	320	336	349	354
		Euro III - 2000 Standards	17	12	9	9	16	51	59	64	62	66	68	69
	Coaches	Conventional	117	84	63	63	110	359	417	451	441	463	480	487
		Euro I - 91/542/EEC Stage I	21	15	11	11	20	66	76	82	81	85	88	89
		Euro II - 91/542/EEC Stage II	21	15	11	11	20	65	76	82	80	84	87	88
		Euro III - 2000 Standards	4	3	2	2	4	13	15	16	16	16	17	17
Mopeds	<50 cm³	Conventional	9082	6461	4841	4841	8537	27800	32280	34881	34104	35810	37154	37697
		97/24/EC Stage I	680	483	362	362	639	2080	2416	2610	2552	2680	2780	2821
		97/24/EC Stage II	37	27	20	20	35	114	132	143	140	147	152	155
Motorcycles	2-stroke >50 cm³	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		97/24/EC	0	0	0	0	0	0	0	0	0	0	0	0
	4-stroke <250 cm³	Conventional	4113	2926	2192	2192	3866	12589	14617	15795	15444	16216	16825	17070
		97/24/EC	325	231	173	173	305	994	1154	1247	1219	1280	1328	1347
	4-stroke 250 - 750 cm³	Conventional	4113	2926	2192	2192	3866	12589	14617	15795	15444	16216	16825	17070
		97/24/EC	325	231	173	173	305	994	1154	1247	1219	1280	1328	1347
	4-stroke >750 cm³	Conventional	4113	2926	2192	2192	3866	12589	14617	15795	15444	16216	16825	17070
		97/24/EC	325	231	173	173	305	994	1154	1247	1219	1280	1328	1347

Table C.3. Hourly vehicle distribution in Frankfurter Allee, Berlin, 13:00 – 24:00.

Type	Class	Legislation	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	1414	1449	1602	1658	1612	1510	1415	1138	939	725	639	467
		ECE 15/02	3489	3575	3953	4090	3977	3727	3491	2809	2316	1790	1576	1152
		ECE 15/03	12287	12592	13921	14405	14008	13126	12294	9893	8158	6303	5552	4057
		ECE 15/04	12568	12880	14239	14735	14328	13426	12575	10119	8345	6448	5679	4150
		Improved Conventional	20152	20652	22832	23627	22975	21528	20164	16226	13380	10339	9107	6654
		Open Loop	7765	7958	8798	9104	8853	8295	7770	6252	5156	3984	3509	2564
		Euro I - 91/441/EEC	97175	99587	110098	113932	110787	103811	97232	78241	64521	49853	43914	32085
		Euro II - 94/12/EC	110420	113161	125105	129461	125888	117960	110485	88905	73315	56648	49899	36458
		Euro III - 98/69/EC Stage2000	48444	49646	54886	56798	55230	51752	48472	39005	32165	24853	21892	15995
	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	1911	1958	2165	2240	2178	2041	1912	1538	1269	980	863	631
		ECE 15/02	4714	4831	5341	5527	5374	5036	4717	3795	3130	2418	2130	1556
		ECE 15/03	16602	17014	18810	19465	18927	17735	16612	13367	11023	8517	7502	5481
		ECE 15/04	18964	19435	21486	22234	21621	20259	18975	15269	12592	9729	8570	6261
		Improved Conventional	8254	8459	9352	9678	9410	8818	8259	6646	5481	4235	3730	2725
		Open Loop	3191	3270	3615	3741	3638	3409	3193	2569	2119	1637	1442	1054
		Euro I - 91/441/EEC	155598	159461	176291	182430	177395	166224	155690	125281	103312	79826	70315	51375
		Euro II - 94/12/EC	149199	152904	169042	174929	170100	159389	149288	120129	99064	76543	67424	49262
		Euro III - 98/69/EC Stage2000	65457	67083	74163	76745	74627	69927	65496	52703	43462	33581	29580	21613
	Gasoline >2,0 l	PRE ECE	0	0	0	0	0	0	0	0	0	0	0	0
		ECE 15/00-01	466	478	528	547	532	498	467	375	310	239	211	154
		ECE 15/02	1150	1179	1303	1349	1312	1229	1151	926	764	590	520	380
		ECE 15/03	4052	4152	4590	4750	4619	4328	4054	3262	2690	2079	1831	1338
		ECE 15/04	4515	4627	5116	5294	5148	4824	4518	3635	2998	2316	2040	1491
		Euro I - 91/441/EEC	40879	41894	46316	47929	46606	43671	40904	32914	27143	20972	18473	13497
		Euro II - 94/12/EC	36412	37316	41254	42691	41513	38898	36433	29317	24176	18680	16455	12022
		Euro III - 98/69/EC Stage2000	15975	16371	18099	18729	18213	17066	15984	12862	10607	8195	7219	5274
	Diesel <2,0 l	Conventional	25528	26162	28923	29930	29104	27271	25543	20554	16950	13097	11536	8429
		Euro I - 91/441/EEC	15060	15434	17063	17658	17170	16089	15069	12126	10000	7726	6806	4973
		Euro II - 94/12/EC	31987	32781	36241	37503	36468	34171	32006	25754	21238	16410	14455	10561
		Euro III - 98/69/EC Stage2000	14475	14834	16400	16971	16502	15463	14483	11654	9611	7426	6541	4779
	Diesel >2,0 l	Conventional	17019	17441	19282	19953	19403	18181	17029	13703	11300	8731	7691	5619
		Euro I - 91/441/EEC	10040	10290	11376	11772	11447	10726	10046	8084	6666	5151	4537	3315
		Euro II - 94/12/EC	21324	21854	24161	25002	24312	22781	21337	17170	14159	10940	9637	7041
		Euro III - 98/69/EC Stage2000	9650	9889	10933	11314	11001	10309	9655	7770	6407	4951	4361	3186
	LPG	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		Euro I - 91/441/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 94/12/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	2-Stroke	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
Light Duty Vehicles	Gasoline <3,5t	Conventional	4744	4862	5375	5562	5409	5068	4747	3820	3150	2434	2144	1566
		Euro I - 93/59/EEC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro II - 96/69/EC	0	0	0	0	0	0	0	0	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <3,5 t	Conventional	17695	18134	20048	20746	20173	18903	17705	14247	11749	9078	7996	5842
		Euro I - 93/59/EEC	3915	4012	4436	4590	4464	4183	3918	3152	2600	2009	1769	1293
		Euro II - 96/69/EC	10997	11270	12460	12893	12538	11748	11004	8854	7302	5642	4970	3631
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 3,5 - 7,5 t	Conventional	15188	15565	17208	17807	17316	16225	15197	12229	10084	7792	6864	5015
		Euro I - 91/542/EEC Stage I	3558	3646	4031	4171	4056	3801	3560	2865	2362	1825	1608	1175
		Euro II - 91/542/EEC Stage II	5682	5823	6438	6662	6478	6070	5686	4575	3773	2915	2568	1876
		Euro III - 2000 Standards	1207	1237	1368	1416	1376	1290	1208	972	802	619	546	399
	Diesel 7,5 - 16 t	Conventional	9010	9234	10208	10564	10272	9625	9015	7255	5982	4622	4072	2975
		Euro I - 91/542/EEC Stage I	2111	2163	2391	2475	2406	2255	2112	1699	1401	1083	954	697
		Euro II - 91/542/EEC Stage II	3371	3455	3819	3952	3843	3601	3373	2714	2238	1729	1523	1113
		Euro III - 2000 Standards	716	734	811	840	817	765	717	577	476	367	324	236
	Diesel 16 - 32 t	Conventional	6872	7043	7786	8057	7835	7342	6876	5533	4563	3526	3106	2269
		Euro I - 91/542/EEC Stage I	1610	1650	1824	1887	1835	1720	1611	1296	1069	826	727	532
		Euro II - 91/542/EEC Stage II	2571	2635	2913	3015	2931	2747	2573	2070	1707	1319	1162	849
		Euro III - 2000 Standards	546	560	619	640	623	584	547	440	363	280	247	180
	Diesel >32t	Conventional	376	385	426	441	429	402	376	303	250	193	170	124
		Euro I - 91/542/EEC Stage I	88	90	100	103	100	94	88	71	58	45	40	29
		Euro II - 91/542/EEC Stage II	141	144	159	165	160	150	141	113	93	72	64	46
		Euro III - 2000 Standards	30	31	34	35	34	32	30	24	20	15	14	10
Buses - Coaches	Urban Buses	Conventional	2013	2063	2281	2360	2295	2151	2014	1621	1337	1033	910	665
		Euro I - 91/542/EEC Stage I	368	377	417	432	420	393	368	297	245	189	166	122
		Euro II - 91/542/EEC Stage II	366	375	414	429	417	391	366	294	243	188	165	121
		Euro III - 2000 Standards	71	73	81	84	81	76	71	57	47	37	32	24
	Coaches	Conventional	503	516	570	590	574	538	504	405	334	258	227	166
		Euro I - 91/542/EEC Stage I	92	94	104	108	105	98	92	74	61	47	42	30
		Euro II - 91/542/EEC Stage II	91	94	104	107	104	98	91	74	61	47	41	30
		Euro III - 2000 Standards	18	18	20	21	20	19	18	14	12	9	8	6
Mopeds	<50 cm³	Conventional	38942	39909	44121	45657	44397	41601	38965	31355	25856	19978	17598	12858
		97/24/EC Stage I	2914	2986	3302	3417	3322	3113	2916	2346	1935	1495	1317	962
		97/24/EC Stage II	160	164	181	187	182	171	160	129	106	82	72	53
Motorcycles	2-stroke >50 cm³	Conventional	0	0	0	0	0	0	0	0	0	0	0	0
		97/24/EC	0	0	0	0	0	0	0	0	0	0	0	0
	4-stroke <250 cm³	Conventional	17634	18072	19979	20675	20104	18838	17645	14198	11709	9047	7969	5822
		97/24/EC	1392	1427	1577	1632	1587	1487	1393	1121	924	714	629	460
	4-stroke 250 - 750 cm³	Conventional	17634	18072	19979	20675	20104	18838	17645	14198	11709	9047	7969	5822
		97/24/EC	1392	1427	1577	1632	1587	1487	1393	1121	924	714	629	460
	4-stroke >750 cm³	Conventional	17634	18072	19979	20675	20104	18838	17645	14198	11709	9047	7969	5822
		97/24/EC	1392	1427	1577	1632	1587	1487	1393	1121	924	714	629	460

ANNEX D

Hornsgatan case

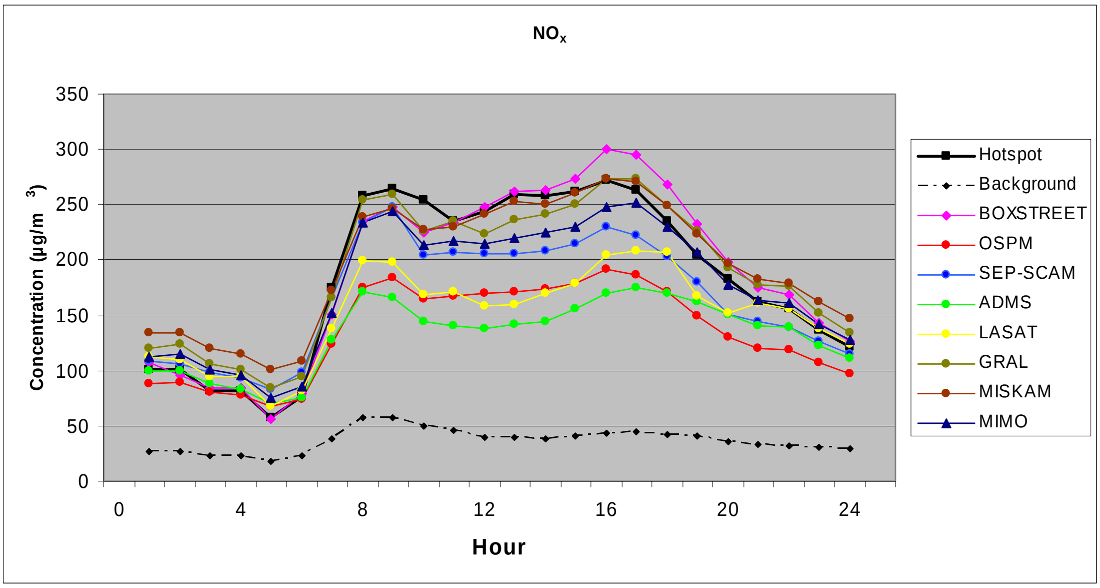

Figure D.1. Model intercomparison results for NO_x average daily variation at street level in Hornsgatan in 2000 compared to hotspot measurements.

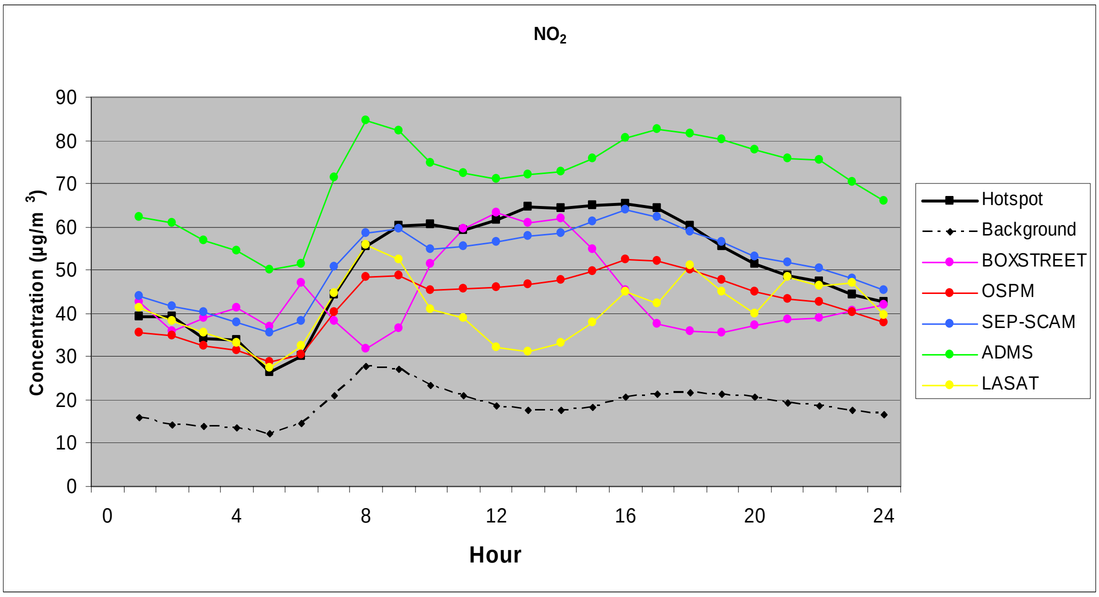

Figure D.2. Model intercomparison results for NO_2 average daily variation at street level in Hornsgatan in 2000 compared to hotspot measurements.

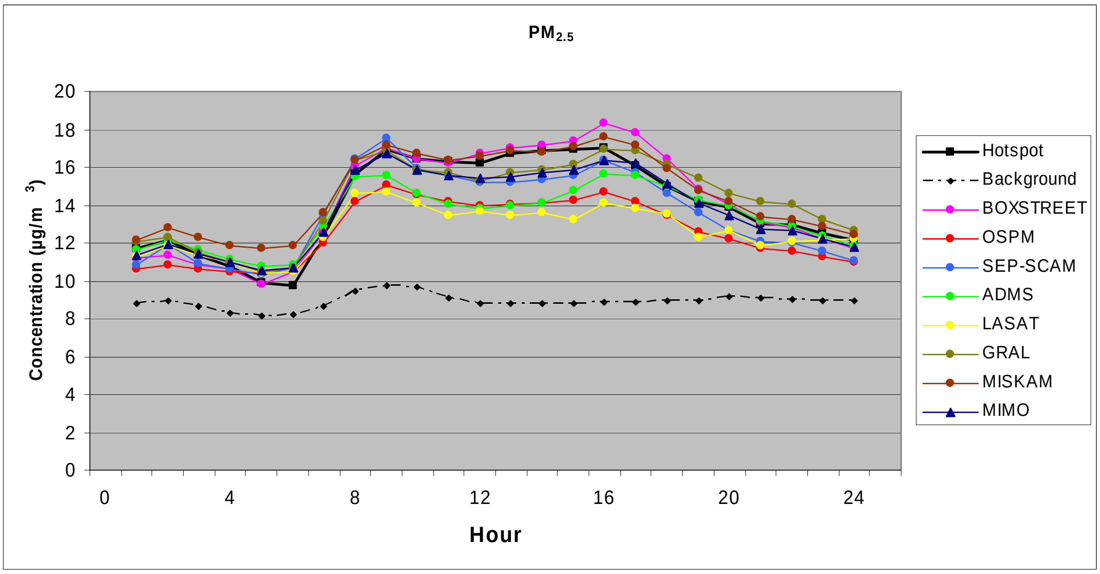

Figure D.3. Model intercomparison results for $PM_{2.5}$ average daily variation at street level in Hornsgatan in 2000 compared to hotspot measurements.

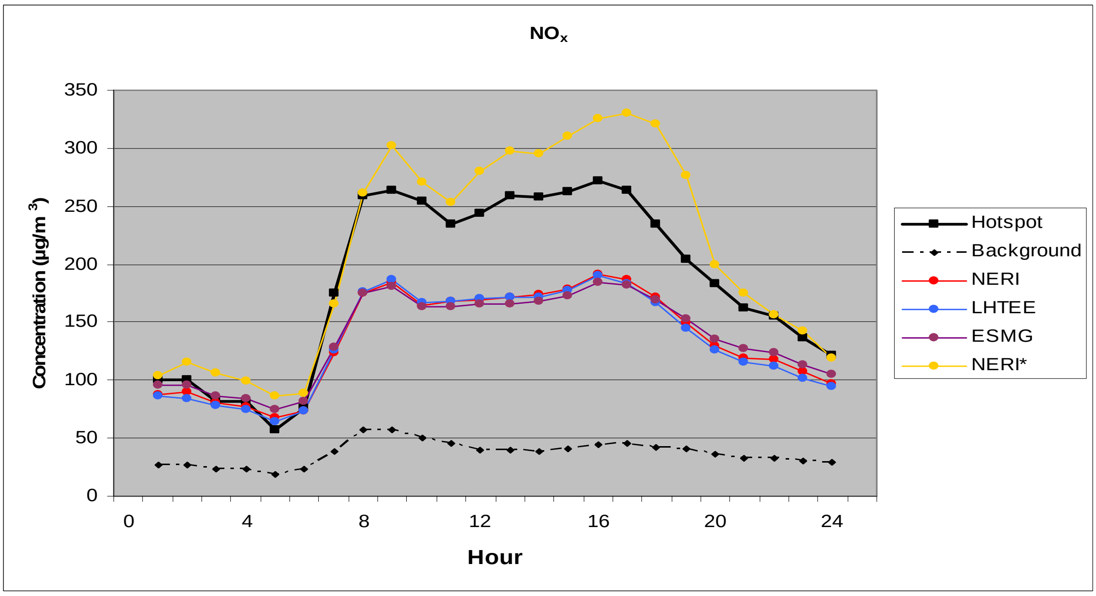

Figure D.4. OSPM model, user intercomparison results for NO_x average daily variation at street level in Hornsgatan in 2000 compared to measurements.

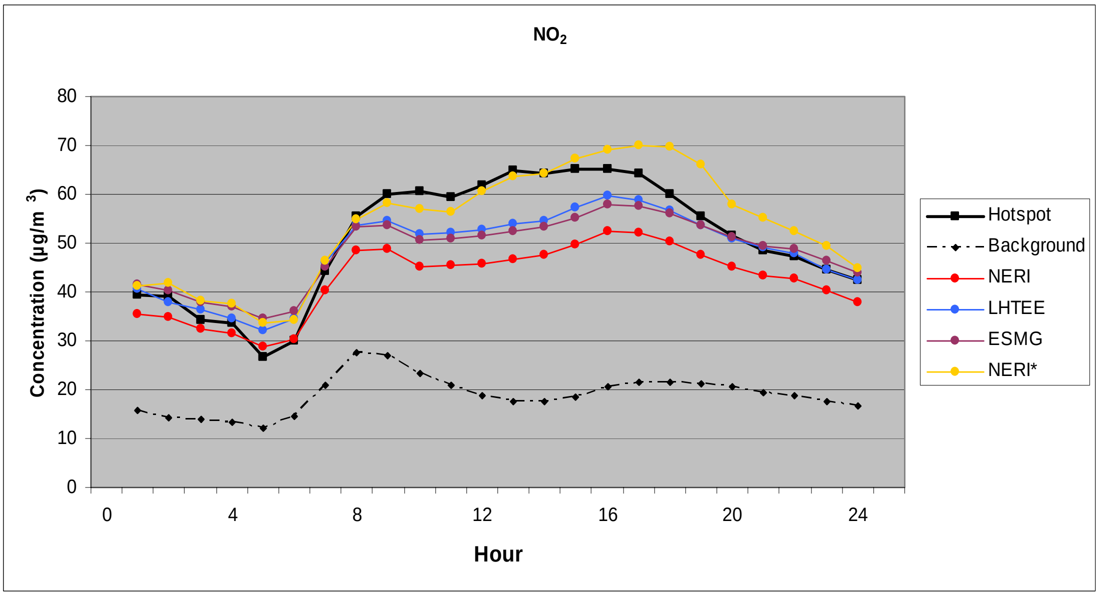

Figure D.5. OSPM model, user intercomparison results for NO_2 average daily variation at street level in Hornsgatan in 2000 compared to measurements.

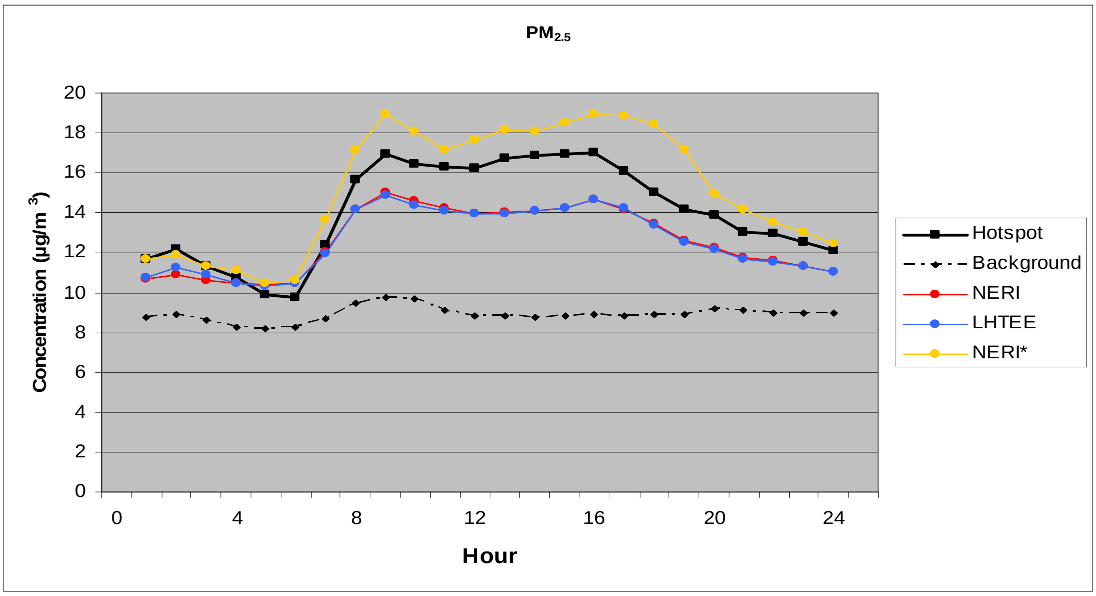

Figure D.6. OSPM model, user intercomparison results for $PM_{2.5}$ average daily variation at street level in Hornsgatan in 2000 compared with measurements.

Frankfurter Allee case

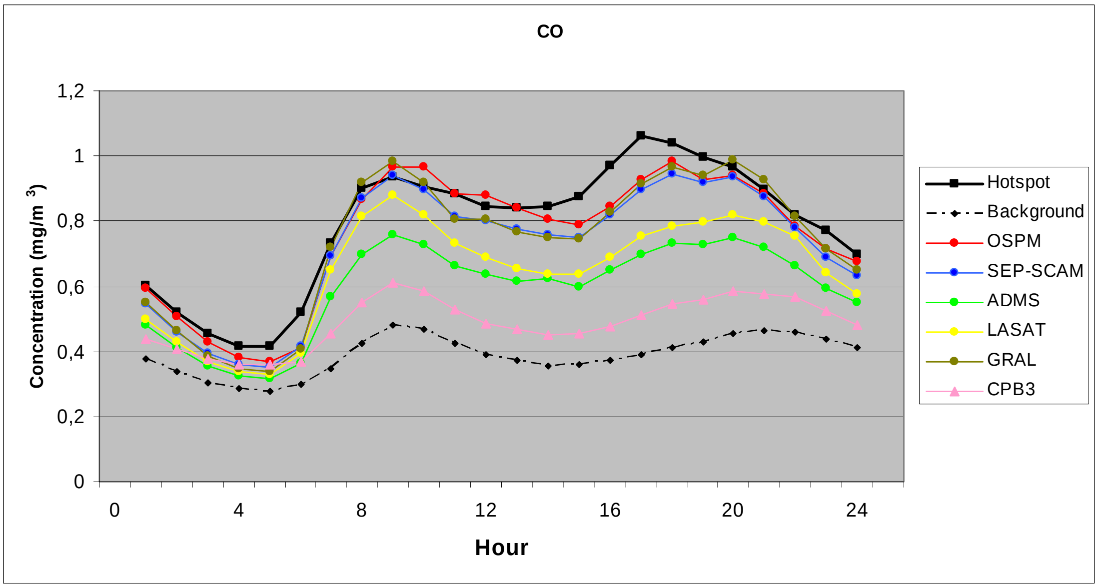

Figure D.7. Model intercomparison results for CO average daily variation at street level in Frankfurter Allee in 2002 compared to hotspot measurements.

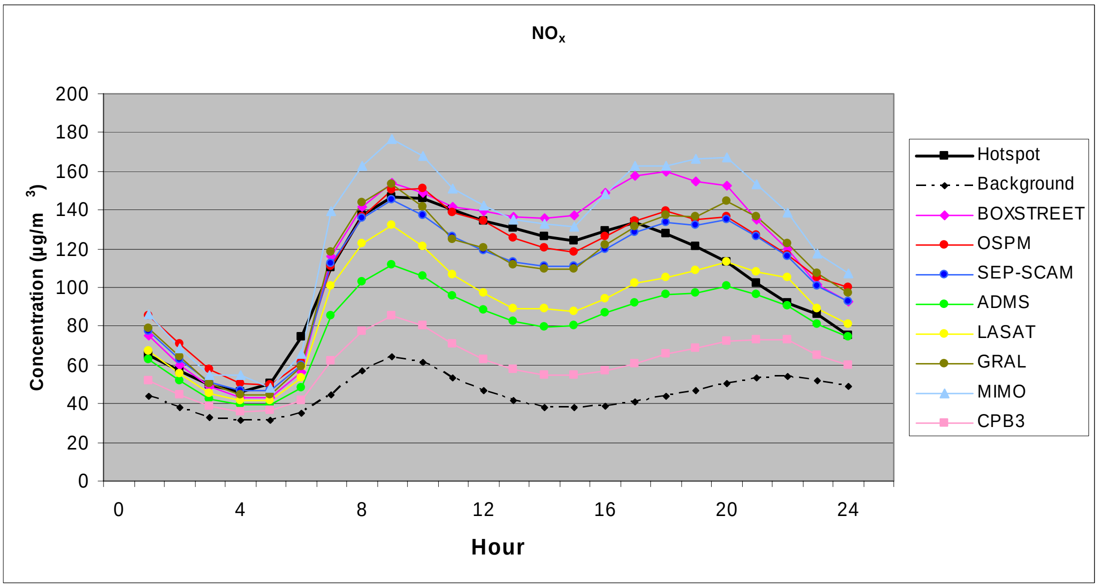

Figure D.8. Model intercomparison results for NO_x average daily variation at street level in Frankfurter Allee in 2002 compared to hotspot measurements.

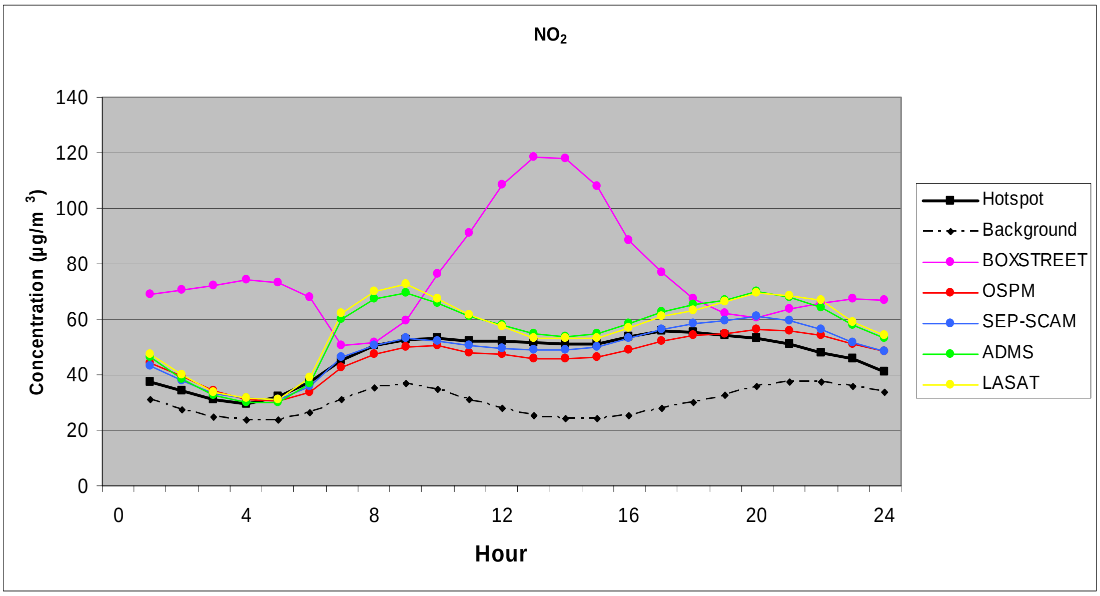

Figure D.9. Model intercomparison results for NO_2 average daily variation at street level in Frankfurter Allee in 2002 compared to hotspot measurements.

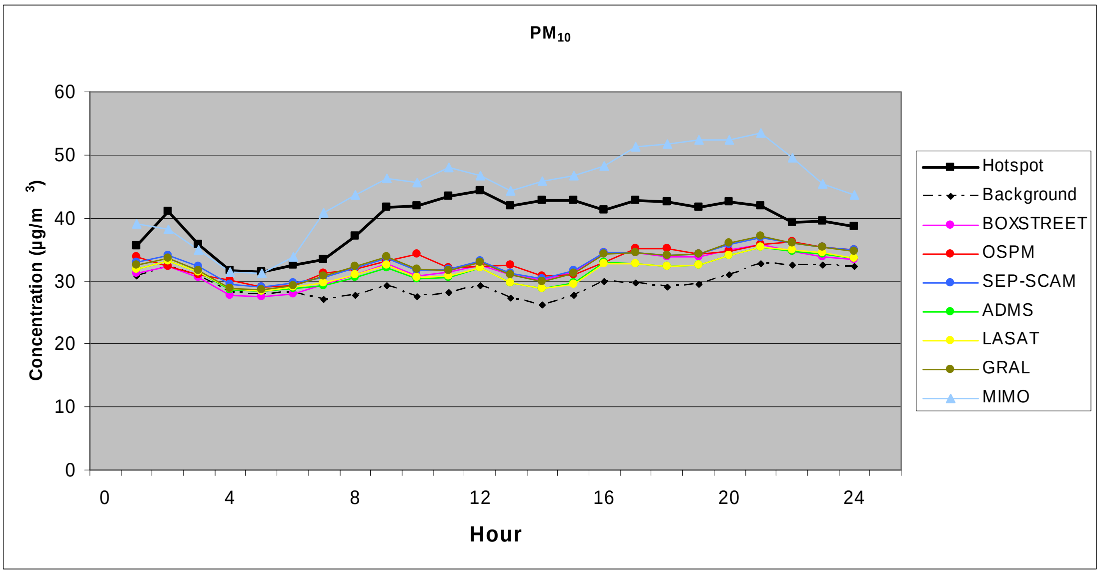

Figure D.10. Model intercomparison results for PM_{10} average daily variation at street level in Frankfurter Allee in 2002 compared to hotspot measurements.

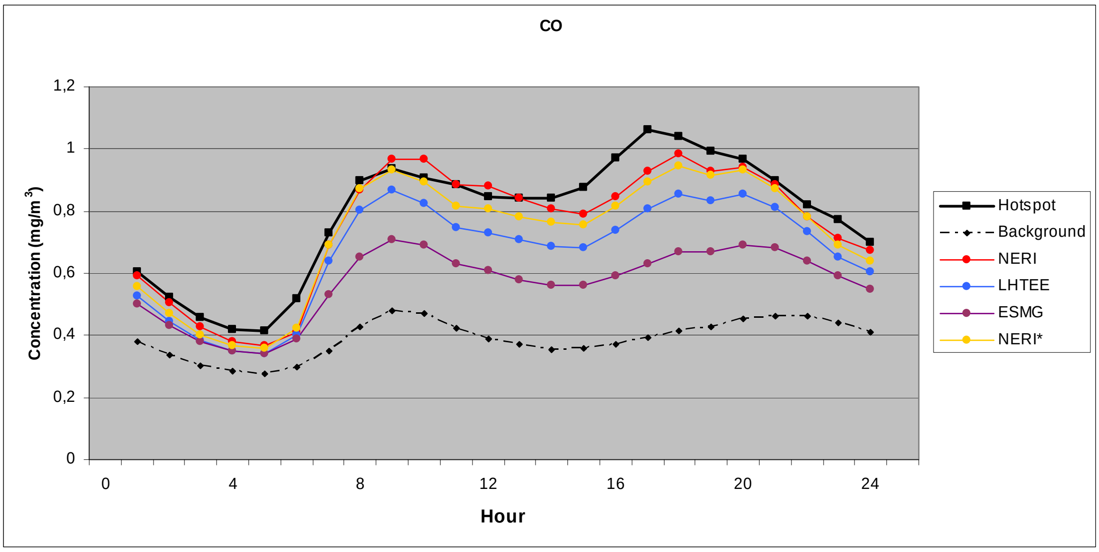

Figure D.11. OSPM model, user intercomparison results for CO average daily variation at street level in Frankfurter Allee in 2002 compared to measurements.

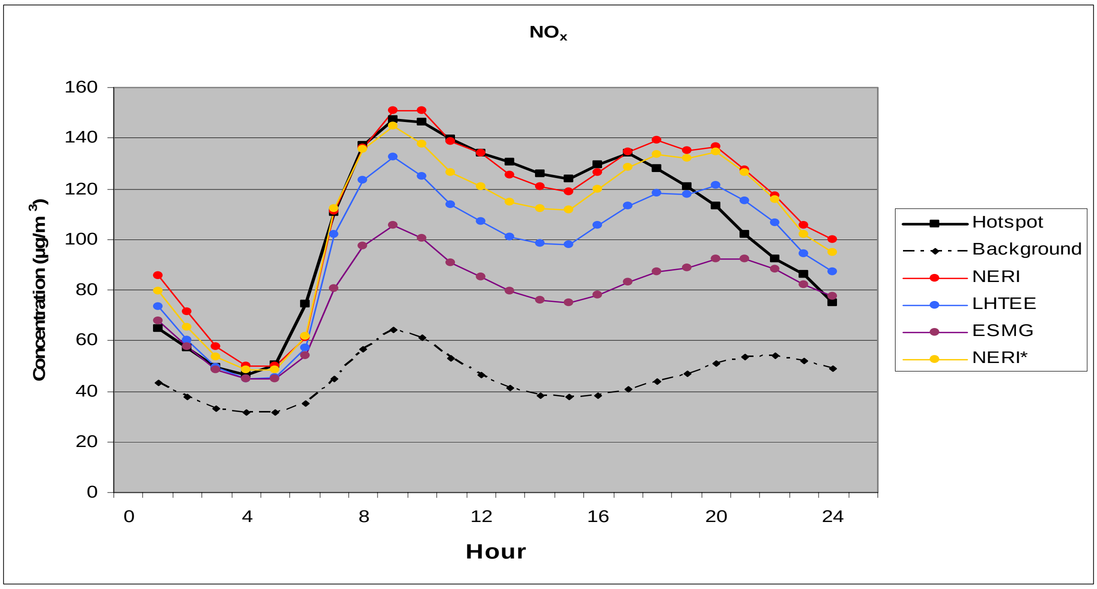

Figure D.12. OSPM model, user intercomparison results for NO_x average daily variation at street level in Frankfurter Allee in 2002 compared to measurements.

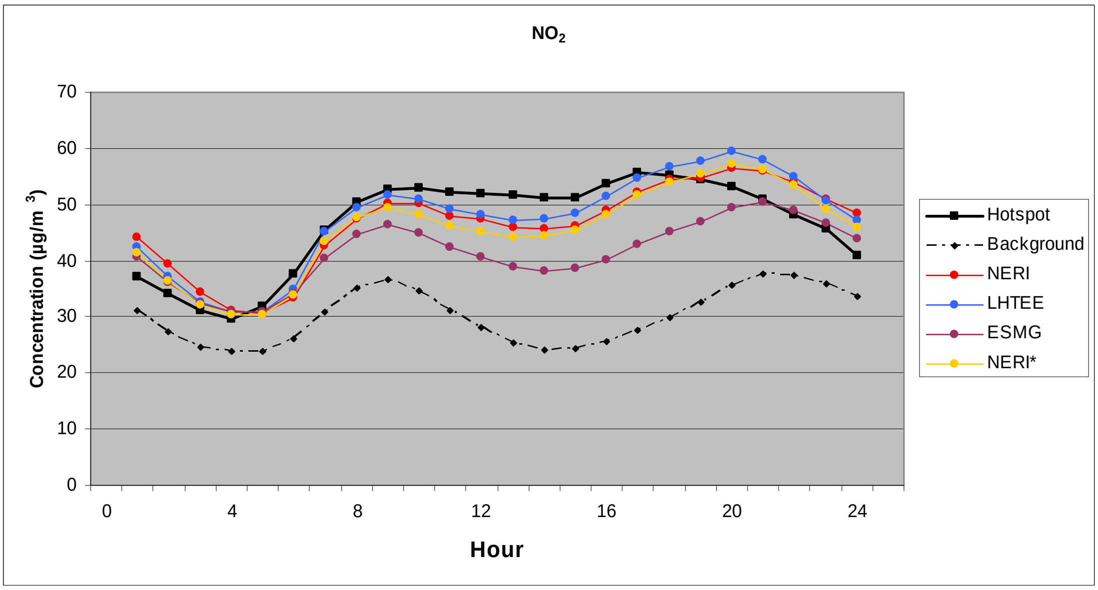

Figure D.13. OSPM model, user intercomparison results for NO_2 average daily variation at street level in Frankfurter Allee in 2002 compared to measurements

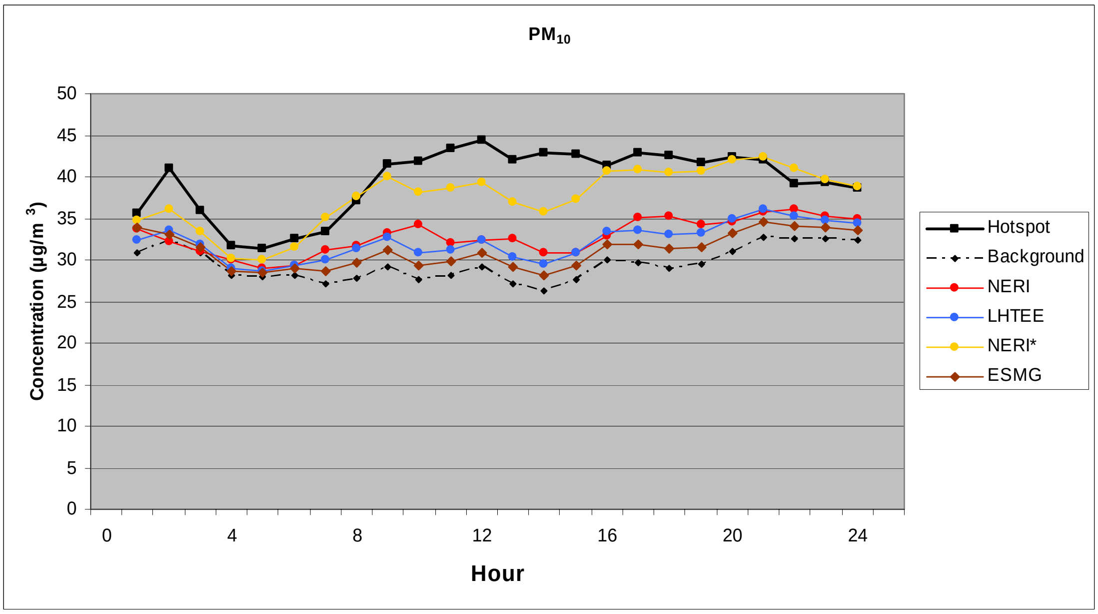

Figure D.14. OSPM model, user intercomparison results for PM_{10} average daily variation at street level in Frankfurter Allee in 2002 compared to measurements.

Marylebone Rd. case

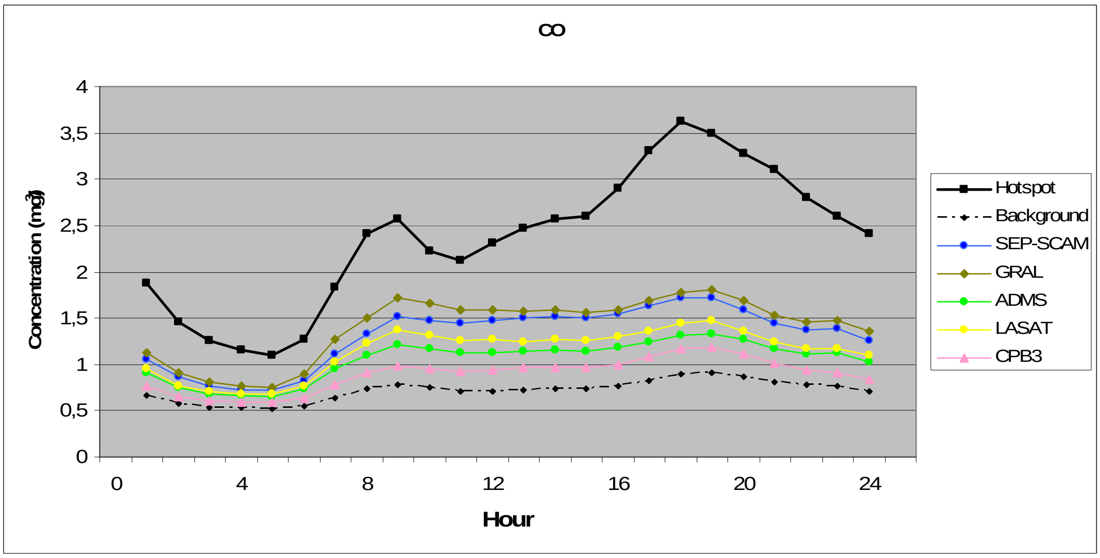

Figure D.15. Model intercomparison results for CO average daily variation at street level in Marylebone Rd. in 2000 compared to hotspot measurements.

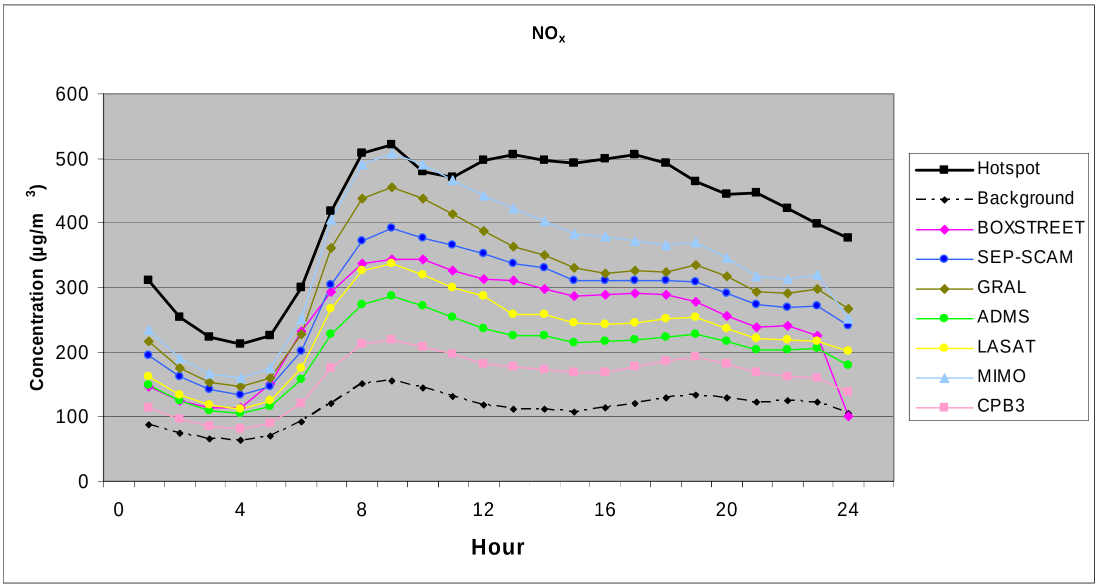

Figure D.16. Model intercomparison results for NO_x average daily variation at street level in Marylebone Rd. in 2000 compared with hotspot.

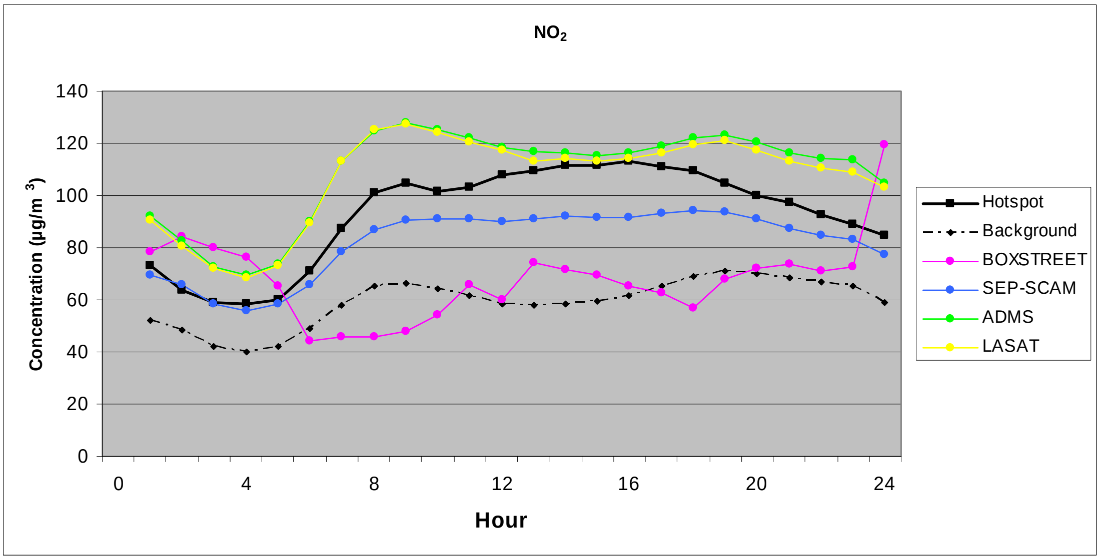

Figure D.17. Model intercomparison results for NO_2 average daily variation at street level in Marylebone Rd. in 2000 compared with hotspot measurements.

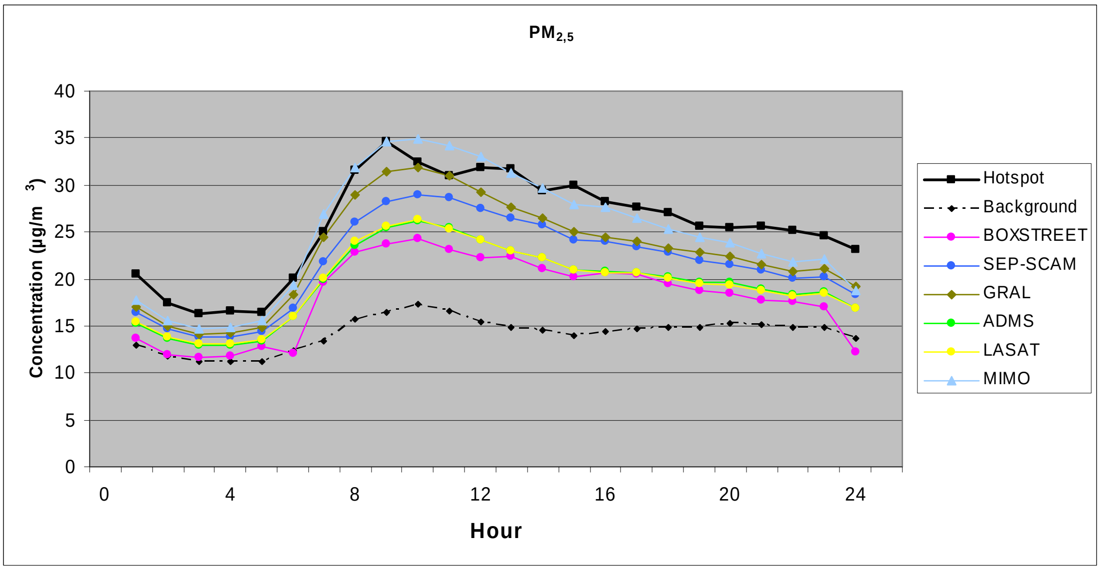

Figure D.18. Model intercomparison results for the $PM_{2.5}$ average daily variation at street level Marylebone Rd. in 2000 compared to hotspot measurements.

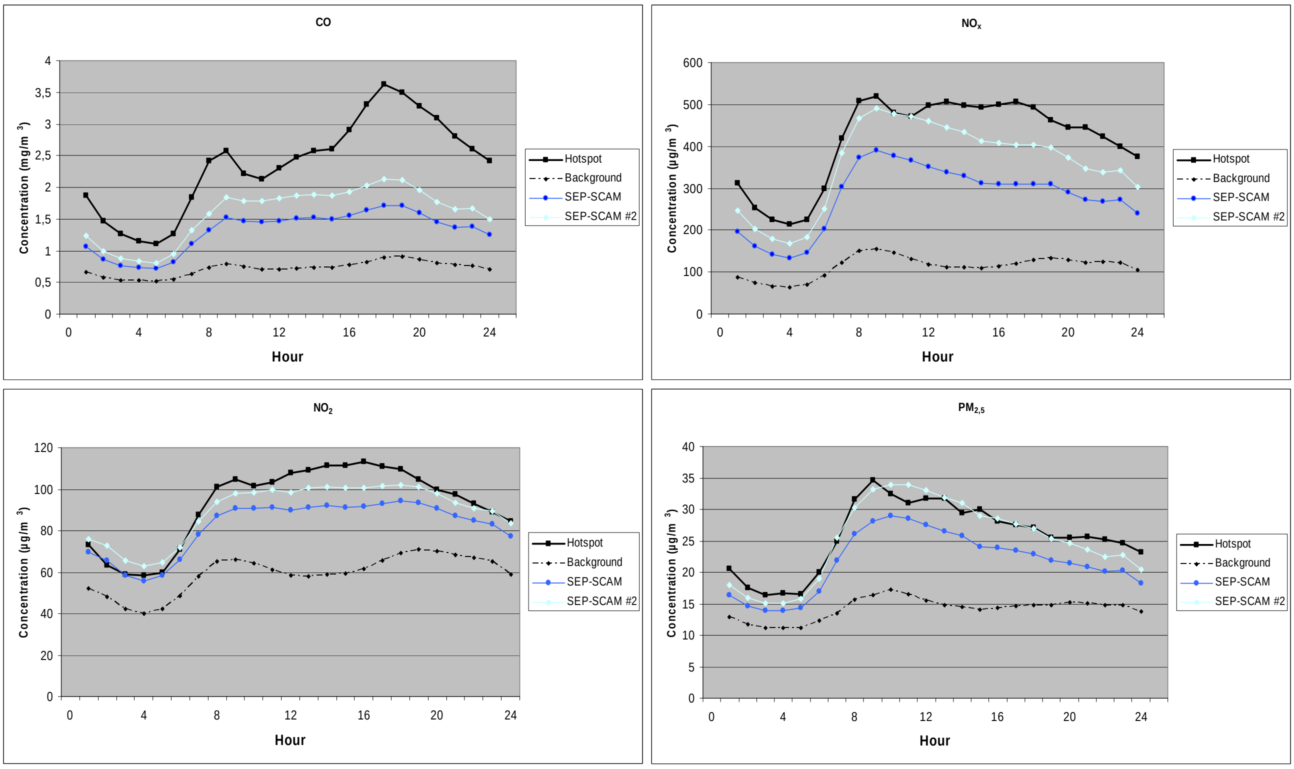

Figure D.19. SEP-SCAM model results, average daily variation for all four pollutants at street level in Marylebone Rd. in 2000 is compared to street measurement and indicative SEP-SCAM results using half the hourly wind speed intensity.

ANNEX E

Table E.1. DeltaCs statistical intercomparison for NO_x average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

	BOXSTREET	OSPM	SEP-SCAM	ADMS	LASAT	GRAL	MISKAM	MIMO
AVERAGE	152.96	98.90	129.52	96.01	113.85	154.08	159.91	139.99
BIAS	4.67	-49.38	-18.77	-52.28	-34.43	5.80	11.62	-8.29
NMSE	0.013	0.236	0.048	0.340	0.159	0.013	0.022	0.021
CC	0.970	0.989	0.983	0.844	0.890	0.980	0.980	0.983

Table E.2. DeltaCs statistical intercomparison for NO_2 average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

	BOXSTREET	OSPM	SEP-SCAM	ADMS	LASAT
AVERAGE	24.96	23.69	32.80	52.02	21.92
BIAS	-6.87	-8.13	0.98	20.20	-9.90
NMSE	0.227	0.130	0.020	0.271	0.346
CC	0.360	0.941	0.966	0.759	-0.235

Table E.3. DeltaCs statistical intercomparison for $PM_{2.5}$ average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

	BOXSTREET	OSPM	SEP-SCAM	ADMS	LASAT	GRAL	MISKAM	MIMO
AVERAGE	5.36	3.70	4.64	4.51	3.77	5.39	5.76	4.87
BIAS	0.24	-1.43	-0.49	-0.61	-1.36	0.27	0.64	-0.25
NMSE	0.016	0.149	0.033	0.073	0.183	0.022	0.023	0.014
CC	0.979	0.967	0.940	0.901	0.939	0.950	0.976	0.979

Table E.4. OSPM user DeltaCs statistical intercomparison for NO_x average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

	NERI	LHTEE	ESMG	NERI*
AVERAGE	98.90	96.97	100.50	174.82
BIAS	-49.38	-51.32	-47.79	26.54
NMSE	0.236	0.250	0.244	0.050
CC	0.989	0.991	0.989	0.965

Table E.5. OSPM user DeltaCs statistical intercomparison for NO_2 average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

	NERI	LHTEE	ESMG	NERI*
AVERAGE	23.69	29.25	29.33	34.81
BIAS	-8.13	-2.57	-2.50	2.98
NMSE	0.130	0.029	0.042	0.020
CC	0.941	0.960	0.924	0.928

Table E.6. OSPM user DeltaCs statistical intercomparison for $PM_{2.5}$ average daily variation at street level in Hornsgatan in 2000 compared to DeltaC observed.

	NERI	LHTEE	NERI*
AVERAGE	3.70	3.69	6.34
BIAS	-1.43	-1.44	1.21
NMSE	0.149	0.154	0.072
CC	0.967	0.970	0.966

Table E.7. DeltaCs statistical intercomparison for CO average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	OSPM	SEP-SCAM	ADMS	LASAT	GRAL	CPB3
AVERAGE	0.36	0.33	0.20	0.26	0.35	0.10
BIAS	-0.04	-0.07	-0.20	-0.14	-0.05	-0.30
NMSE	0.023	0.045	0.529	0.248	0.040	2.712
CC	0.956	0.966	0.965	0.910	0.944	0.810

Table E.8. DeltaCs statistical intercomparison for NO_x average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	BOXSTREET	OSPM	SEP-SCAM	ADMS	LASAT	GRAL	MIMO	CPB3
AVERAGE	71.42	66.54	60.59	35.25	44.66	63.47	81.44	15.10
BIAS	11.75	6.87	0.92	-24.42	-15.01	3.80	21.77	-44.57
NMSE	0.079	0.043	0.047	0.424	0.184	0.070	0.156	2.860
CC	0.922	0.922	0.892	0.883	0.848	0.841	0.877	0.812

Table E.9. DeltaCs statistical intercomparison for NO_2 average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	BOXSTREET	OSPM	SEP-SCAM	ADMS	LASAT
AVERAGE	46.03	16.19	18.51	25.08	25.57
BIAS	29.56	-0.28	2.03	8.60	9.10
NMSE	1.628	0.070	0.057	0.269	0.301
CC	0.543	0.848	0.886	0.785	0.711

Table E.10. DeltaCs statistical intercomparison for PM_{10} average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	BOXSTREET	OSPM	SEP-SCAM	ADMS	LASAT	GRAL	MIMO
AVERAGE	2.46	3.38	3.43	2.09	2.17	3.27	14.87
BIAS	-7.53	-6.60	-6.56	-7.90	-7.81	-6.72	4.89
NMSE	2.646	1.615	1.571	3.580	3.397	1.713	0.261
CC	0.843	0.681	0.798	0.774	0.747	0.744	0.811

Table E.11. OSPM user DeltaCs statistical intercomparison for CO average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	NERI	LHTEE	ESMG	NERI*
AVERAGE	0.36	0.28	0.18	0.34
BIAS	-0.04	-0.12	-0.22	-0.06
NMSE	0.023	0.154	0.820	0.042
CC	0.956	0.961	0.952	0.967

Table E.12. OSPM user DeltaCs statistical intercomparison for NO_x average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	NERI	LHTEE	ESMG	NERI*
AVERAGE	66.54	50.99	32.88	61.37
BIAS	6.87	-8.69	-26.79	1.70
NMSE	0.043	0.093	0.586	0.046
CC	0.922	0.885	0.872	0.897

Table E.13. OSPM user DeltaCs intercomparison for NO_2 average daily variation at street level in Frankfurter Allee for 2002 compared to DeltaC observed.

	NERI	LHTEE	ESMG	NERI*
AVERAGE	16.19	17.26	11.30	15.26
BIAS	-0.28	0.79	-5.17	-1.22
NMSE	0.070	0.050	0.322	0.077
CC	0.848	0.885	0.850	0.853

Table E.14. OSPM user DeltaCs statistical intercomparison for PM_{10} average daily variation at street level in Frankfurter Allee for 2002 compared to measurements.

	NERI	LHTEE	ESMG	NERI*
AVERAGE	3.38	2.71	1.63	8.08
BIAS	-6.60	-7.28	-8.36	-1.90
NMSE	1.615	2.397	5.240	0.114
CC	0.681	0.788	0.539	0.831

Table E.15. DeltaCs statistical intercomparison for CO average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

	SEP-SCAM	GRAL	ADMS	LASAT	CPB3
AVERAGE	0.60	0.69	0.34	0.43	0.18
BIAS	-1.05	-0.96	-1.31	-1.22	-1.47
NMSE	1.334	0.992	3.573	2.511	8.384
CC	0.862	0.813	0.826	0.793	0.886

Table E.16. DeltaCs statistical intercomparison for NO_x average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

	BOXSTREET	SEP-SCAM	GRAL	ADMS	LASAT	MIMO	CPB3
AVERAGE	135.11	166.98	195.29	90.52	117.20	230.07	47.18
BIAS	-167.67	-135.79	-107.48	-212.25	-185.58	-72.70	-255.59
NMSE	0.743	0.390	0.225	1.762	1.041	0.102	4.864
CC	0.807	0.928	0.852	0.900	0.855	0.864	0.945

Table E.17. DeltaCs statistical intercomparison results for NO_2 average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

	BOXSTREET	SEP-SCAM	ADMS	LASAT
AVERAGE	8.63	23.07	49.66	47.82
BIAS	-24.96	-10.52	16.07	14.23
NMSE	4.681	0.199	0.183	0.158
CC	-0.442	0.971	0.831	0.813

Table E.18. DeltaCs statistical intercomparison results for $PM_{2.5}$ average daily variation at street level in Marylebone Rd. for 2000 compared to DeltaC observed.

	BOXSTREET	SEP-SCAM	ADMS	LASAT	MIMO	GRAL
AVERAGE	3.94	7.49	5.32	5.34	10.58	8.65
BIAS	-7.57	-4.03	-6.19	-6.17	-0.93	-2.86
NMSE	1.334	0.202	0.671	0.669	0.034	0.098
CC	0.905	0.967	0.957	0.952	0.951	0.950