Street Emission Ceiling exercise

Phase 1 report

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European Topic Centre on Air and Climate Change

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ETC-ACC Street Emission Ceiling (SEC) exercise

Phase 1 report

Final Report, August 2004

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Foreword

This report has been prepared by the task team of the Street Emissions 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 (AUTh), 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 1 final report.

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Introduction

1 Primary Objectives

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 Modelling (IAM) for the Clean Air For Europe (CAFE) programme.

1.1 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.

1.2 Purpose 2: Use in Integrated Assessment Modelling for CAFE

In the developments of EU legislation prior to CAFE, integrated assessment modelling has been carried out with the RAINS model. It focused on the regional scale concentrations in Europe, in line with the analyses needed for the Convention on Long Range Transboundary Air Pollution (CLRTAP), 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, and hence urban levels and hotspots should somehow be included in the assessment. Because of this, the Joint Research Centre (JRC) of the European Commission 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.

2 Similarities and differences in model requirements in view of the two purposes

The two purposes of SEC do not necessarily lead to the same street model, but it seems likely that a single model can be largely suitable for both. In both cases a simple street model is needed that can be applied to a multitude of streets, either in single cities anywhere in Europe (Purpose 1) or (at least in principle) in all cities of Europe (Purpose 2). For both purposes it is common practice to use a model cascade[1]:

1. Regional model, giving the regional background levels (e.g. EMEP/RAINS model)
2. Urban model, giving the contribution of a city to its own urban background levels
3. Street model, giving the contribution of a street to the levels in this street.

There are, however, also significant differences between the purposes:

1. Urban authorities are likely to calculate air quality in known individual streets, with known parameters, while in IAM at the European level the streets cannot be dealt with individually, but rather as a statistical ensemble.

[1] Urban background levels can in principle also be described based on observations, but this is obviously not an option in case of IAM or for any forecast for a given city.

2. Urban authorities are likely to be interested in overviews of air pollution levels in their streets, (now and in future years), requiring straightforward model calculations, while in the IAM for CAFE a cost optimisation for given air quality (or deposition) targets is needed, which requires a special model design and brings along important restraints for the model.
3. When evaluating the results of street scale calculations, city authorities can per individual case consider special measures, while CAFE's IAM can in practice only assume generic measures, without taking the special situation of individual streets into account.

3 Use of the results and findings of the SEC project by local authorities

For local authorities, the intended application of the methodology developed in the SEC project is as follows. Externally the regional background levels have to be provided. This can be made available as part of the SEC methodology. For the urban background, the authorities can either use, if it becomes available, a City-Delta model, another model already developed and used for the city or, by way of default, an easy-to-use city type model to be provided by the SEC project. On top of this, the city authority will then use a street model. In most cities, detailed input data will not be available for all streets; consequently a simple model is called for, requiring only the most essential input, preferably in a simple form. This model is planned to be a simple model differentiating between street types. City authorities may follow alternatively the ceiling approach and use the gap between the limit value and the urban background to calculate the critical traffic characteristics (e.g., maximum load or speed, composition etc.) for each street type.

In some cities, detailed urban/street level pollution concentrations have been modelled using state-of-the-art models. Results from the application of the simple SEC model can be compared with such detailed model results already available.

4 Integration of the results and findings of the SEC project into RAINS

Integrated assessment in CAFE should as far as possible integrate the regional, urban and hotspot scale. However, at present the urban scale is not as yet integrated in the RAINS approach including the cost optimisation modelling and it is most unlikely that the local level will be included soon. If the optimisation would include street concentration levels, it would be driven by a few of the most polluted streets in Europe, as the levels there are always higher than the background levels (except for ozone). Similar problems arose in the past in the case of moving from a 150 km grid to 50 km grid cells; a redistribution of environmental targets was needed to achieve an acceptable solution. For streets, however, the inherent uncertainties are considerably larger than for 50 km grid cells. Furthermore, the generic measures that can be included in RAINS may be not adequate for such problem streets. However, it is possible to calculate for each (regional scale) optimised result of RAINS the remaining exceedances at urban and street scale using results from City-Delta and SEC.

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Chapter 1: Street/background typology

1.1 Introduction

The aim of this report is to describe the development of a typology for urban background and streets in the ETC/ACC's Urban Hotspot Air Quality Analysis project. The primary objective of this project is to develop a method for determining the levels of emissions[1] – depending on street type and city type – in streets for which certain air quality thresholds, e.g. limit values, are reached. This method will help in making it more feasible to take the street level into account in CAFE's integrated assessment modelling. Moreover, it will help local authorities in identifying streets where certain air quality thresholds are likely to be exceeded.

During the reporting period (Phase 1), the project has focused on a review of already available information and results from model calculations for a set of well-documented streets. As the typology aims to generalise the results of Phase 1, it is expected that this will be more relevant after the completion of this first phase. However, it is important to define the generalisation framework already now at the outset of the project.

1.2 General approach

1.2.1 Typology

A large number of models exist for the calculation of air pollution in streets and particularly for street canyons (see also the Model Documentation System of the ETC/ACC (MDS, 2004). These models usually require input data for the traffic and/or emission rates, the meteorology and the building configuration and also for the urban background concentration level. The urban background concentration levels used at local scale are usually taken from calculations made with other models which use input data for sources of emissions and their rates, the meteorology and sometimes topography, as well as input on the regional background level. The development of a typology for streets is closely linked with the development of a simple model for calculations at a local scale able to produce results for the same quantities as those produced by the street and urban background models described above.

A street type consists of a collection of similar streets. It is defined by a set of parameters or characteristics and their ranges. For example, a parameter like that is the average speed of the traffic which for a specific street type can vary between 30 – 70 Km/hr and is classified as a "continuous" parameter. On the other hand an example of a characteristic is the "motorway", which although it has no range, it has associated parameters with possibly implicit ranges, such as the one mentioned above, the average speed of the traffic. From this point forward, the term "parameter" will be broadened to include the term "characteristic", for convenience purposes.

The concentration of pollutants in streets depends on many parameters. In air quality models, these parameters are often continuous parameters that may have any value. In the street typology, it will be attempted to divide (classify) all streets into types whose definition will be based on ranges of the most relevant parameters. However, one or a few parameter(s) will be excluded from this classification: these continuous parameters will be retained as parameters that can be given any chosen value. The variable by which policy measures are quantified should be a continuous variable with the most powerful candidate continuous parameter being

[1] In the course of the project, it may turn out that it is better to take a more basic traffic parameter, e.g. the average traffic intensity instead of the emission. This will be investigated later, as part of the optimisation work.

the street emissions. A limitation of the street typology is that the other parameters cannot be available as continuous parameters and hence they cannot be given an arbitrary value. Following this approach, several types of parameters need to be distinguished for modelling the concentrations in various street types:

a) Key parameters: parameters explicitly taken into account. This group comprises two sorts of parameters:

  1. Classified parameters, which are to be fixed in classes by the street typology, i.e. for which a certain range (e.g. width between 10 and 20 m) or a certain value (tunnel) is defined for street types.
  2. Continuous parameters, which are retained as explicit continuous parameters, being input parameters for the formula (or simple model) by which the concentration in the street types is to be calculated (e.g. the traffic emission, if it has not been chosen as a classified parameter).

b) All other parameters: these are not taken into account and hence cause a remaining variability of concentrations within a street type.

So, only for the continuous parameter(s) an accurate response of the concentrations to changes can be expected. The classified parameters can only jump from one range to the next when going from one street type to another (possibly with other parameters jumping simultaneously). The other parameters are not taken into account at all.

The optimum way of dividing the parameters among the three groups mentioned above, depends on the simplicity required for the anticipated use and on the accuracy needed. Obviously, these two criteria are competing: a single continuous parameter makes the system simple to use, but brings along a crude treatment of all other parameters. A small set of street types is simpler but coarser than a large and detailed set. The choice will be based on trial model calculations to quantify how the concentration depends on candidate parameters and to find options for minimising the variability within street types.

The most obvious way of structuring the typology is to use the usual division based on scales: regional background, urban background, and local hotspot. This matches the available models well and fits with the way calculations various scenarios are made.

Once a method has been established to calculate the concentration for given types of streets (in a given type of city in a given region of Europe), the method can be converted into a method of calculating emission ceilings for those types of streets. This is achieved by inverting the calculation, a process which is easy to complete when it is applied to simple formulas. In addition, the uncertainties (see below) must then be taken into account.

1.2.2 Uncertainty due to typification

Before selecting the key parameters, it is useful to investigate the inherent uncertainties in the concentrations associated with street typology approach. Tables 1.1 & 1.2 illustrate the approach. The parameters, on which the concentrations near a street depend, are divided in:

- Key parameters, which can be dealt with in a model and to which the concentration is sensitive. These key parameters are to be taken explicitly into account, either as

  a) Classified parameter.

or

b) Continuous parameter.

- All other parameters, which are here subdivided in:

a) Parameters that can be dealt with in a model, but do not affect the concentration, like the number of cyclists. These parameters are not to be included in the definition of a street type, and their variability causes a remaining range in the concentrations, which should be fairly small.

b) Parameters that cannot be dealt with in a model like the presence of unknown nearby sources other than traffic. These parameters cannot be included in the definition of a street type, and their variability also causes a remaining range in the concentrations.

Table 1.1: Concentration range in all streets

Parameter type	**Effect on concentrations range**
Key parameters:	
a1. Classified	⟷
a2. Continuous	⟷
Other parameters:	
b1. Low sensitivity	↔
b2. Cannot be modelled	**?**
All parameters	⟷

Table 1.2: Concentration range in a single street type

Parameter type	**Effect on concentrations range**
Key parameters:	
a1. Classified	↔
a2. Continuous	|
Other parameters:	
b1. Low sensitivity	↔
b2. Cannot be modelled	**?**
All parameters	←?→

Comparison between Tables 1.1 & 1.2 shows that the typology has the potential to reduce the variability. It also shows that there will always be a remaining non-zero concentration range. This range is partly due to the range of the classified parameters, which could of course be reduced by refining the classification or by changing classified parameters into continuous parameters, thus making the typology function more like a common simulation model. Also, the "other parameters" that cannot be modelled, give rise to a range which is an uncertainty range. The remaining concentration range is particularly important when estimating whether streets of a particular type will have concentrations above a limit value or not. Figure 1.1 illustrates that even when the average, "typical" streets of all street types do not exceed the limit value, there can in reality still be streets with exceedance. This is why not only the typical concentration for a street type has to be known but also its range, e.g. approximated by a standard deviation.

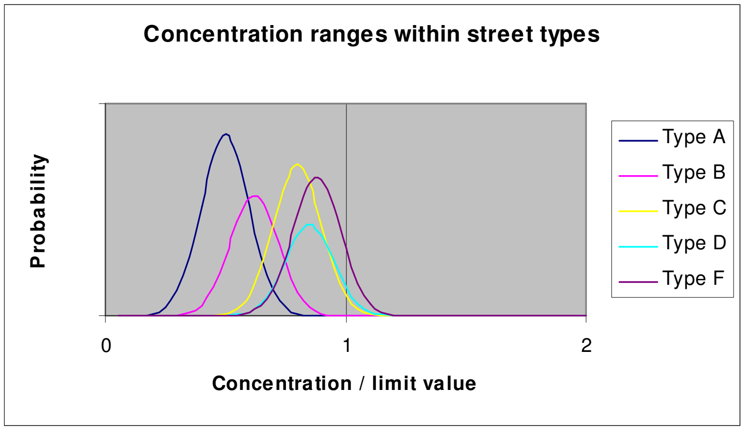

Figure 1.1: Concentration ranges of a set of street types compared with a limit value: the limit value can be exceeded even when all typical streets have no exceedance

1.2.3 Candidate key parameters

To establish a typology the model parameters which the concentrations are sensitive to, referred to as key parameters, must be selected. The selection process is based on the following criteria:

- **(a)** Importance for air pollution, particularly high levels of air pollution, taking the sensitivity of the concentration to the parameter and the range of the parameter into account.
- **(b)** Suitability for use in model calculations.
- **(c)** Availability of data: for local authorities for a particular street under consideration and for European level authorities in terms of statistics

The criteria described above are listed based on their importance, with the first one being the most important and the third one being the less existing mainly for informative purposes. Table 1.3 is a list of possible key parameters, including a judgement of the criteria. This list should be regarded as a first iteration of the selection process.

Table 1.3: Possible key parameters

Parameter	a. Importance for air pollution[1]	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 heavy duty vehicles	++	+++	++	++
Age of vehicle fleet	++	++	+++	+++
Annual mean wind speed at nearby meteo station	++	+++	+++	+++
Enclosure by buildings	++/+++	++	+++	+
Congestion parameters	+/++	+	+++	+
Street width	++	++	+++	-
Distance population#?	++		+++	-
Traffic velocity profile	++	++	++	++
Background parameters				
Distance from centre	+/++	++	+++	+++
City size	+/++	++	+++	+++
Region in EU or latitude	+/++	+++	+++	+++
Spatial isolation from other sources	+/++	+++	++	++
Presence of industry	+/++	+	++	+

Later on in the project in model calculations, the importance for air pollution and the suitability for modelling can be evaluated more precisely. A principal decision has to be taken regarding the role of population exposure. Even if a complete set of data regarding the street configuration is available, it is still not clear at which distance from the traffic lanes the concentrations should be calculated. Under the "Guidance on assessment under the EU air quality directives"[2] it has been recommended to assume that the limit values apply

[1] The importance for air pollution is indicates how much the variability of the parameter in streets with considerable traffic influences the total annual concentration level (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}

[2] http://www.europa.eu.int/comm/environment/air/pdf/guidanceunderairquality.pdf

everywhere even if there is no exposure. However, at the same time the working group that wrote the guidance has recommended aim abatement actions at situations where population exposure does occur. In order to accurately and correctly identify the hot spots, this is a major decision that needs to be taken in consultation with EEA and DG Environment of the European Commission: high concentrations of NO_2 are known to exist near motorways, but population exposure there is, at most locations along motorways virtually zero.

1.3 Definition of street types

1.3.1 General considerations

Apart from the street characteristics themselves, background concentration levels may significantly affect concentrations in a specific street and they should therefore be part of the street typology. The contribution of the background level concentrations is distinguished in the regional background contribution and depending on whether the street is within or near a city the urban contribution. With respect to the regional contribution the background concentration levels could be treated as the key parameter. However, regarding the urban contribution a city typology needs to be developed. It should be noted at this point, that the various key parameters are not fully independent between each other. For example, high traffic density is not possible in a narrow street. Also, city parameters may be correlated with the street parameters. To avoid too much complexity, it is not attempted to define street types per pollutant (e.g. for PM_{10} and CO separately) or per limit value parameter (e.g. for annual means and percentiles separately).

Before a selection of street types can be made, a decision as to whether the SEC study should focus only on streets with the highest expected concentration levels or whether it should be applied to all streets in Europe, has to be taken. In practice, however, this is not a clear distinction, since the dependence of concentrations on street parameters itself depends on the kind of pollutant and on the limit value. At the same time, it is not intended to develop a pollutant or limit value dependent typology. Although the first approach will be emphasised, it will be possible to consider 'average' streets as well, without however any further subdivision in street types.

The selection process of street types is made as follows. First, a tentative selection is made (see below), in order to focus on street typology. Then, model calculations are made for the various street types, using for example the CAR model *(Eerens et al., 1993)* for streets and the GEA model (EEA-ETC/AQ, 2001) for cities, possibly also with models that are more detailed. This will result in a quantitative insight with respect to the dependence of the sensitivity of the concentrations on the various candidate key parameters. Then the occurrence of combinations of candidate key parameters has to be investigated (e.g. based on statistics for cities that have these data, followed by – subjective – generalisation) and finally various street types are defined by selecting combinations of key parameter ranges.

1.3.2 First division in street types

In order to facilitate the development at a later stage, an initial tentative street typification is given below. It is based on three contributions to the concentration levels in the street:

- Quantification of the contribution of the traffic in the street considered: For streets, the key parameters chosen are the emission of the local traffic which will be treated as

continuous parameter, the configuration of the street and buildings, the average wind speed and the type of city (Table 1.4).

Table 1.4: Contribution to the concentration by the traffic in the street considered

Configuration	**Average wind speed at nearby meteo station (10m high)**	
	=<3.5 m/s	**>3.5 m/s**
Open rural terrain	Type S1a	Type S1b
Non-canyon streets in built-up areas	Type S2a	Type S2b
Wide street canyon (W/H>1.5)	Type S3a	Type S3b
Narrow street canyon (W/H=<1.5)	Type S4a	Type S4b
Continuous parameter (variable): annual mean street emission (g/m/s)		

- Quantification of the contribution by the other sources in the city: For cities, the key parameters chosen are the size of the city, its European region and type of predominant sources (Table 1.5).

Table 1.5 The contribution by the other sources in the city

Region and local climate	**Type of predominant sources**	
	Major industrial sources	**No major industrial sources**
Southern Europe, enclosed	Type C1a	Type C1b
Southern Europe, open setting	Type C2a	Type C2b
Central Europe, enclosed	Type C3a	Type C3b
Central Europe, open setting	Type C4a	Type C4b
W and N Europe, enclosed	Type C5a	Type C5b
W and N Europe, open setting	Type C6a	Type C6b
Continuous parameter (variable): city population (number of inhabitants)		

- Quantification of the regional background concentration: For the regional background, no typification is needed. Model results (from the integrated assessment model RAINS (IIASA, 2001) or a regional air pollution model such as EMEP (EMEP, 2002)) will be directly used.

This leads to the following procedure for calculating concentrations in a street of type S in the city C in the European region R (Figure 1.2):

1. Look up for the pollutant and the year concerned the annual mean concentration in the output of the regional model (e.g. EMEP, RAINS) C_{region},
2. Calculate the urban background concentration as follows:
   $$C_{urban} = C_{region} + f_{City\ type\ C}\ (city\ population).$$
3. Calculate the concentration in the street as follows:
   $$C_{street} = C_{urban} + f_{Street\ type\ S}\ (street\ emission).$$

The concentrations C_{urban} and C_{street} are annual mean concentrations or percentiles. For percentiles, empirical relations between the annual mean and the percentiles are used. The calculation of street emissions ceilings $E_{ceiling}$ for a given limit value C_{LV} is then carried out as follows:

1. Calculate the urban background concentration C_{urban} as indicated above.
2. Calculate the emission ceiling as follows:

$$E_{Ceiling} = F_{Street\ type\ S}\ (C_{LV} - C_{urban},)\ \textit{with}\ F_{Street\ type}\ \textit{deriving from}\ f_{Street\ type}.$$

In the illustrative Figure 1.2, C_{street} has been indicated as a function $f_{Street\ type\ S}$ that is proportional to the street emission. This is appropriate for most of the relevant pollutants, but it should be noted that for NO_2 the relation with the emission of the precursor NO_x is certainly not linear. Hence, the inversion of function $f_{Street\ type\ S}$ into $F_{Street\ type\ S}$ may be less simple than for proportional function. However, it is to be expected that a realistic inverse equation can be established for the relation between the local contribution to the NO_2 concentration and the emission in the street, once $f_{Street\ type\ S}$ is known. Figure 1.3 illustrates this qualitatively. The figure also illustrates that the NO_x emission ceiling is sensitive to uncertainties in the NO_2 concentration. This dependence is not due to the method employed, but it reflects the reality that at elevated NO_x levels NO_2 is considerably less than proportionally dependent of NO_x.

The above scheme can be improved at a later stage, when results from exploratory calculations will provide us with a detailed insight. Examples of improvements to be investigated are:

- Linking of the annual mean wind speed to the local climate in the city type.
- Adding the distance to the centre of the road or nearest traffic lane as a classifying (or continuous parameter).
- Replacing the continuous parameter city population by city area.
- Replacing the industrial source dependence by distance from the city centre.

It should be noted that the continuous parameter "street emission" can be regarded as the result of several underlying continuous parameters (traffic intensity, composition and speed profile). A formula for calculating the emission from these underlying parameters can be included as part of the method.

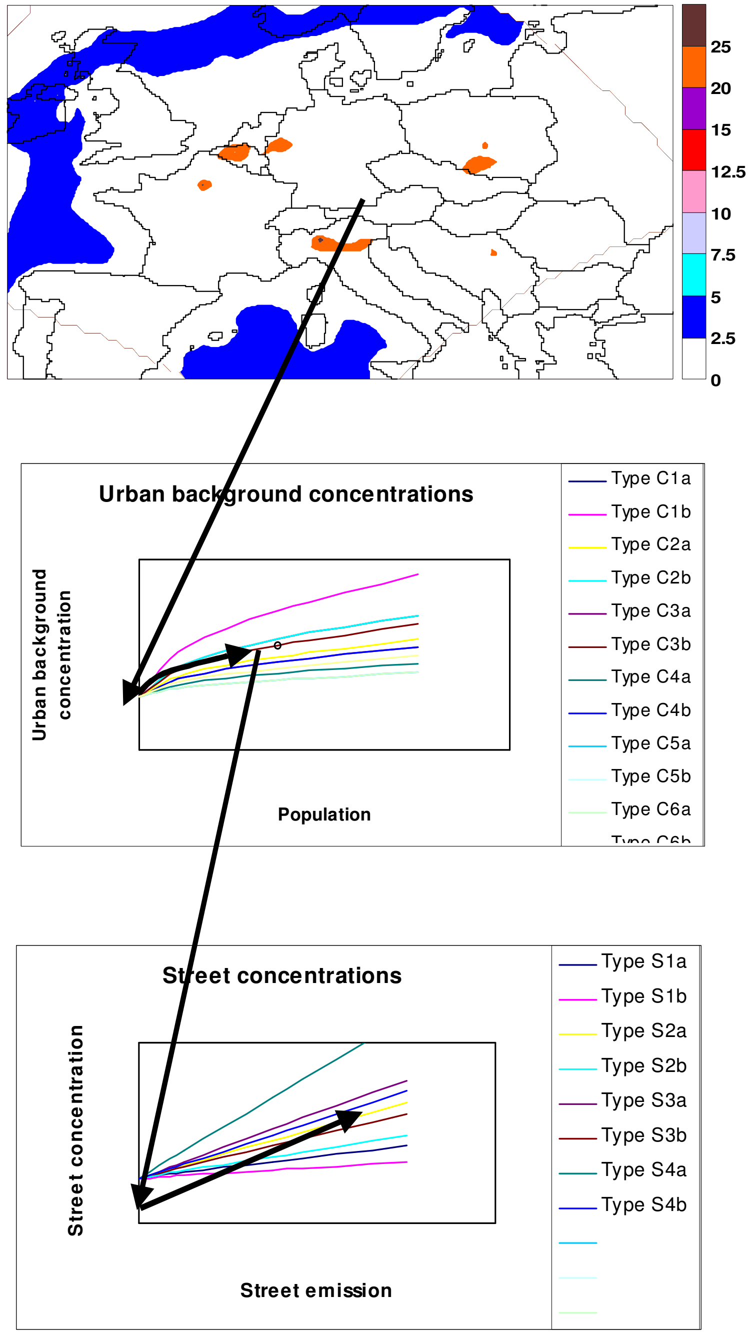

Figure 1.2: Illustration of the street typology method

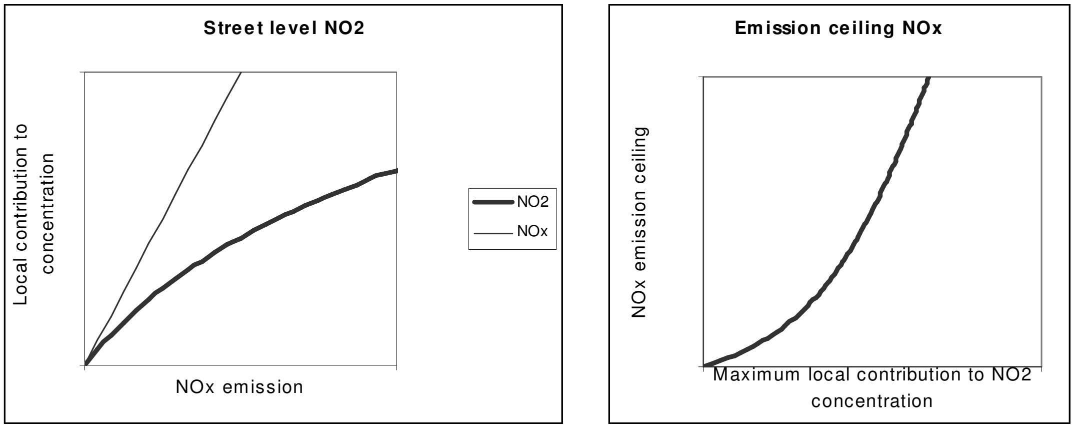

Figure 1.3: Illustration of $f_{Street\ type\ S}$ (left) for NO_2 in comparison with NOx and of $F_{Street\ type\ S}$ (right) for NO_2

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ETC-ACC Street Emission Ceiling (SEC) exercise

Phase 1 Report

Chapter 2: Review of relevent studies and projects

2.1 Introduction

Within the remit of the SEC exercise it is necessary to:

1. Develop a methodology for quantifying the influence of urban emissions and other small scale effects on concentrations (emphasising PM_{10} and NO_2) at urban hotspots with reference to human health

2. Develop a pilot application to estimate street emission ceilings (SECs) for different street types

The purpose of the literature review summarised in this report is to highlight key contributions which form the bedrock of the methodology to be applied. There are 5 identified strands with relevance to the overall exercise:

a) Field campaigns related to source apportionment
b) Monitoring data analysis associated with the characteristics of hot spots
c) Re-suspension studies
d) Modelling studies related to urban air quality and source-receptor relationships
e) Emission patterns in busy streets and associated key parameters

The report is structured as follows:
- The state of the art is briefly reviewed in each strand.
- At the end of the chapter, a table is provided showing which project contributes to which strand (s).
- The details of the individual case studies and projects are described in more detail in alphabetical order in Annex A, where relevant websites are also provided.

2.2 Review of field campaigns related to source apportionment

Following the development of factor analysis with desktop statistical packages such as SPSS, field measurements separating particulate matter (PM) using filters could identify with some certainty the sources and apportion their origins, as was performed in Thessaloniki in 1994 *(Manoli et al., 2002)*. These initial results suggested that the fine fractions dominated, but were shifted to larger size fractions in the cooler winter months. Traffic dominated the source of fine particles, while resuspension off road surfaces was seen to dominate the coarse particle fractions. In Helsinki two different 6-month campaigns were carried out with a difference of 2 years, to measure and apportion urban ambient $PM_{2.5}$ *(Vallius et al., 2003)*. Long-range transboundary air pollution was found to be the main contributing factor accounting for half of the particles with traffic accounting for a further 30%. A 1999 study in Copenhagen to apportion fine and ultrafine particles in a street canyon found significant correlation between CO, NO_x and ultrafine particles indicating that traffic is the major source of pollution, but diurnal variations in the volume of diesel and petrol engine vehicles caused a measure of uncertainty *(Palmgren et al., 1999, 2003, Ketzel et al. 2003)*. However, data supporting this work came from a local scale campaign in London conducted in 1999 which aimed to monitor human exposure to fine $PM_{2.5}$ investigating a variety of road users along different routes *(Adams et al. 2001a, 2001b, 2001c, 2002)*. Car drivers were found to have double the exposure than other road users, again adding weight to the Copenhagen findings where traffic was found

to be the main contributing factor. Further source apportionment work is planned in London, it began in 2002 and will continue until 2006 combining field measurements of $PM_{2.5}$ in conjunction with dispersion modelling using ADMS-Urban *(Adams et al. 2001b, 2002)*. These local site campaigns have provided impetus for broader studies such as the project URBAN AEROSOL which ran from 2001 and will end in 2003 and which aims to chemically characterise the PM associated with actual human exposure in 6 residential European urban areas (Athens, Oslo, Milan, London, Hanover and Prague). To date, a detailed chemical analysis and bioaerosol contribution study has taken place and the factors affecting the indoor/outdoor PM characteristics (mass/number/chemical composition/size distribution) have been characterised (*Rezacova et al. 2002, Domasova et al. 2002, Brozova and Blazek 2002)*. The draft of the Second Position Paper on PM, prepared by the CAFE Working Group *(CAFE Working Group on Particulate Matter, 2003)* summarises the findings of source apportionment analysis performed in Germany, Spain, the United Kingdom, the Netherlands and Sweden and focuses on PM_{10} and $PM_{2.5}$ source contributions in urban areas in the EU and on the differences observed among the above EU regions. The report concluded that the results obtained for traffic hot spots may apply to most of EU urban areas due to the similarity of the emission sources. Most of the differences observed among traffic hot spots may be attributable to traffic intensity but differences may also be due to climatic patterns such as frequency of rain (due to both scavenging and road dust wash out capacity) or dispersive conditions.

Finally, the new project SAPPHIRE which began last winter and will run until 2005, aims to develop and validate a transferable pan-European approach to the source apportionment of PM and Polycyclic Aromatic Hydrocarbons (PAH) for use by city authorities. SAPPHIRE is monitoring at two different urban locations in Athens, Birmingham, Copenhagen, Helsinki and Porto the ambient urban air plus samples of pollutant emissions from many sources including petrol and diesel fuelled vehicles and a universal software package providing pollution source profiles is under development *(Harrad S., et al. 2003).*

2.3 Review of monitoring data analysis associated with the characteristics of hotspots

A major contemporary street measurement campaign of hourly CO, O_3, NO and NO_2 concentrations associated with urban hotspots was performed in Finland in Elimaki (1995) *(Kukkonen et al. 2001b, Ottl et al. 2001)* and Helsinki (1997) *(Kukkonen et al., 2003, 2000, 2001a, Granberg et al. 2000, Väkevä et al., 1999)* at both street and rooftop levels. In the case of Helsinki, the data was compared with the results of the street dispersion model OSPM and it was found that there was good agreement with respect to CO and NO but that NO_2 concentrations were over-predicted with the model. In the case of Elimaki, the data was compared with the results of a street scale Gaussian finite line source dispersion model (CAR-FMI) and a Lagrangian dispersion model (GRAL). The dispersion of NO, NO_2 and O_3 was found to be dependent upon traffic densities and relevant meteorological parameters. Furthermore, at wind speeds lower than approximately 2 m/s, excessively high predicted concentrations were obtained compared with the measured data, possibly due to plume meandering. Due to this disparity, a more extensive and elaborate street monitoring campaign in terms of the duration and breadth of measurements started in Nantes in the summer of 1999 *(Vachon 2001, Vachon et al. 2000a, 2000b, 2002; Berkowicz et al. 2002, Louka et al. 2002)*. The aim was to investigate also the effects of traffic-induced turbulence and

surface heating in a carefully selected street canyon with regular geometry, to try to account for the model over-predictions found in Finland. It was found that the surface albedo effect was being under-predicted in sunny periods and that the thermal boundary layer of canyon walls was much thinner than expected, leading to an over-estimation of heat transfer to canyon flow. Furthermore, traffic turbulence was shown to be very important in low wind conditions. In an attempt to verify the findings of the Nantes study, the VALIUM project which ran from 2000 to 2002 used a detailed concentrations dataset for two streets in Hanover, which 24 modellers from 21 institutions used as a common input set to model the air quality and flow in these street canyons *(Lohmeyer et al. 2002, Kuhlwein and Friedrich, 2001).* In particular it was revealed that the advection and turbulence due to traffic fleets affected the migration of pollutants significantly in the direction of traffic flow. Furthermore, it was found that small difference in the set-up of model runs resulted in very varied outcomes, suggesting that a more universal and standardised approach is needed when modelling using field data. In recent years, the EU-funded project APPETISE is data mining pollution hotspots to measure and analyse the daily, monthly and yearly concentration levels for O_3, NO_x, SO_2 and PM in most European cities. Through the use of inter-model comparisons of statistical and deterministic methods, linear/nonlinear dispersion models, neural networks and cluster analysis, are used for compiling weekly, monthly and yearly data for pollution concentrations and for ambient meteorological parameters across the continent for future use in predictive runs. Finally, this year saw the production of an extensive European study on aerosol phenomenology, conducted by JRC from 34 sites across Europe to study aerosol sources, their effects on human health, their role in atmospheric energetics and their use in model validation *(Putaud et al., 2003).* The key findings are that background annual PM_{10} and $PM_{2.5}$ mass concentrations for Europe are 7.0 ± 4.1 and 4.8 ± 2.4 $\mu g/m^3$ respectively and result from natural and long range transport of anthropogenic particles. The EU 2005 annual average PM_{10} standard of 40 $\mu g/m^3$ is exceeded at a few sites and the EU 2010 annual average PM_{10} standard of 20 $\mu g/m^3$ and the $PM_{2.5}$ standard of 15 $\mu g/m^3$ is exceeded at ALL near-city, urban and street sites monitored. It was found that there is no universal ratio between PM_{10} and $PM_{2.5}$ mass sizes nor any correlation between PM values and total particle values or chemical composition. This study found that traffic is responsible for the high concentrations of PM_{10} and $PM_{2.5}$ concentrations in urban areas either from resuspended coarse fraction dust at street level or by contributing VOCs and nitrates in the fine and coarse fractions of the aerosols in the urban background. These levels were found to be even higher in winter due to reduced mixed boundary layer height and due to greater condensation in the particle phase. Sulphates and organic matter were found to be the two main contributors to PM, while black carbon was found to contribute only 5-10% to $PM_{2.5}$ and 15-20% to PM_{10}. Future work will be conducted by the FUMAPEX project which began in 2002 and will run through to 2004 and aims to map emissions and quantify the urban air pollution using suitable models as well as to improve meteorological forecasts for urban areas *(Baklanov et al., 2002).* It is expected to forecast and prevent the worst air pollution episodes in large cities according to air quality directives. Running in parallel with FUMAPEX is the project OSCAR whose overall aim is to assess the environmental impact of road traffic in terms of traffic flows, emissions and air pollution, integrated with the capability of identifying suitable impact reduction options for the end user. The work in this project focuses mainly on the comparison and analysis of current urban datasets, an assessment of traffic parameters and emission factors relevant to congested flows, the measurement of

NO_x, PM_{10}, $PM_{2.5}$ and meteorological parameters and the improvement and evaluation of predictive air pollution models for urban streets. Finally, a PM_{10} and NO_2 data analysis was performed for stations across Europe using AirBase data and shows that increased concentrations are observed at traffic stations, compared to urban background and rural stations *(EEA, 2003)*. The annual and daily concentrations averaged across European stations for each of the three station types showed a decreasing tendency in PM_{10} until 1999, but a slight increase between 1999 and 2000 (and preliminary 2001 data indicate a continuing slight upward tendency). For NO_2, a downward tendency is observed for both the annual mean and the daily values. The PM_{10} daily limit value is widely exceeded whereas exceedances are not observed for the annual limit value and for NO_2 the annual average is exceeded but not the daily limit value. It should be noted that the AirBase station coverage is limited and in the report the differences across the different European regions is not studied. Furthermore the influence of meteorological conditions on the observed concentrations has not yet been analysed.

2.4 Review of re-suspension studies

The principal work in this area in recent years is the TRAKER system study in 1998 in Las Vegas which made pivotal measurements of the effects of traffic motion on PM re-suspension using a novel system that is suspended above the road on a moving vehicle *(Kuhns et al. 2000, Mollinger et al. 1993)*. The moving device was linked to a Global Positioning System (GPS) to survey the changes in PM along 500 km of paved roads. The study found that dust emissions are exponentially related to vehicle speed and also that large size fractions of PM were re-suspended by faster moving vehicles. In parallel with this ground-breaking work, the vertical distribution of Total Suspended Particulates (TSP), PM_{10} and $PM_{2.5}$ was measured over four months and at four morphologically different building locations in Hong Kong to investigate dispersion and re-suspension effects (. It was found that PM dispersion is strongly affected by prevailing wind direction, local vertical mixing effects and the aspect ratio of street canyons. The latest attempt to understand re-suspension of PM was the "PM and Health" study performed from 1998 to 2000 in Stockholm in Sweden *(Johansson 1999a, Kristensson et al. 2000, Gridhagen et al. 2002)*. The project included both emission and air quality measurement campaigns, as well as dispersion and source-receptor modelling to generate detailed emission databases that include NO_x, CO, PM, benzene and PAH. The aerosol and gas measurements that were performed were: aerosol size distributions, PM mass, coarse and fine fraction elemental composition, organic and elemental carbon CO, NO, NO, and VOC at hourly time resolution. Furthermore, traffic flows and speeds were recorded as well as the wind velocity, temperature and relative humidity in a street canyon. Most of the particles were found to be in the size range from 10 to 60 nm diameter and the total numbers of particles in the size range from 3 to 7 nm tended to decrease significantly during morning rush hours due to coagulation and deposition. The results suggest that local traffic is the main source of ultra-fine particles. However, it was found that the size distribution changed markedly as a function of vertical distance from the traffic. At the rooftop location, the size distribution shifted towards larger sizes, compared with the corresponding results at the street level location. Local vehicle exhaust particles had a dominant contribution to the number concentration of particles less than 200 nm, whereas long-range transport dominated the sizes between 200 and 600 nm. For the large particles (> 600 nm), local vehicles were again the main source, but these

particles mainly originate from the wear of roads, tyres, brakes etc. Principal component analysis was performed to aerosol and gas phase data from measurements. NO_x, CO, CO_2, VOC's and copper were mainly associated with gasoline exhaust, whereas particulate organic carbon and NO_2 show high loadings on both the gasoline and diesel factor. Particle number concentration was dominated by particles with a diameter around 20 nm and was associated with diesel exhausts. Furthermore, it was also concluded that the modelling of the re-suspension of particles in street canyon models was unsatisfactory and new projects are expected to address this important question. Finally, the draft of the Second Position Paper on PM, prepared by the CAFE Working Group highlights the importance of re-suspension on the PM concentrations observed *(CAFE Working Group on Particulate Matter, 2003)*. The results from the many studies and models on re-suspension of PM from roads show a large spread in the results in terms of emission factors for various PM fractions, as well as in terms of calculated total national emissions. The uncertainty is very large. Estimates of the ratio of re-suspension to tail pipe PM_{10} emissions differ largely from a factor of 0.5 to 10. This ratio is considerably lower for $PM_{2.5}$, since all tail pipe emissions are in this size fraction, while the main part of re-suspension falls under the coarse mode.

2.5 Review of modelling studies of urban air quality and of source-receptor relationships

The most intensive European study of source-receptor relationship modelling was conducted within the SATURN project *(Moussiopoulos (ed.) et al., 2003)*, a EUROTRAC sub-project within the EUREKA framework. Field measurements began in Budapest in 1997 and continued over a 5 year period to provide a dataset against which the pollution predictions using the dispersion model ADMS could be compared *(Bozó et al.)*. The model results were compared with data from two roadside stations. It was found that the presence of lead from petrol fuelled vehicles is still the most important contributor to air pollution episodes, but that its concentration has declined during the period of investigation. The ADMS model was also used in the M25 study in a comparison exercise with the model CALINE4 in 1997, to incorporate the effects of mechanical and thermal turbulence to model traffic emission patterns of PM_{10} at a heavy traffic motorway section and to compare with field measurements *(Benson 1984, Sokhi et al. 1998)*. Regarding PM_{10}, both models showed good agreement with measured data and suggested that the running mean standard of 50 $\mu m/m^3$ would be exceeded. In Singapore in 1998, the street canyon module EPA Mobile 5 and a Gaussian line source module were used to simulate ambient CO concentrations arising from traffic flow and good agreement was found *(Mukherjee and Viswanathan, 2001)*. In 1997 in Helsinki, the OSPM model together with an ambient model for urban meteorology was used to compare field data taken from Runeberg Street which included on-site traffic measurements and hourly street concentrations *(Kukkonen et al., 2003, 2000, 2001a, Granberg et al. 2000)*. The aim was to establish whether or not street canyon dispersion models could be accurate predictors without roof level data fore-knowledge. It was found that measured and predicted urban background concentrations were in good agreement and that street dispersion models such as OSPM perform well when urban background and meteorological parameters are modelled and used as input data. This study was followed by one performed in Brno in the Czech Republic in March 2001, to quantify the effect of traffic flow and meteorology on calculations of pollutant dispersion using a Eulerian-Lagrangian

model, originally developed for road tunnels in 1998 and 1999 *(Jicha et al., 2000).* Together with detailed modelling of a traffic fleet (car queuing statistics, fleet composition and velocity components), the model was also applied to street canyon intersections. The traffic dynamics at low wind speeds significantly affected the flow field, especially at the ground level. In parallel to the Brno study, tracer balloons were followed in a central London street in 1999 together with measurements in a reduced-scale version of the flow in a wind tunnel model of the street *(Scaperdas et al., 1999, 2000*). The measured flow profiles were compared with the output of StarCD, a CFD code. The model succeeded in reproducing the flow characteristic directions and speeds and modelled tracer concentrations were within 10% of the wind tunnel measurements. While model predictions of pollutant concentrations were good overall, the model failed to predict accurately decay rates away from the intersections. In 2000, the newly developed microscale photochemistry model MICRO-CALGRID, which included traffic induced turbulence, was applied to 1995 field measurement data for a busy street in central Berlin *(Stern and Yamartino, 2001).* The model incorporated flow fields calculated with MISKAM and traffic emissions estimated with MOBILEV. Concentration profiles over a 5 day winter episode were very well reproduced, especially for NO_2. Traffic-induced turbulence was found to lead to improved statistical measures. With growing awareness of the effect of traffic on flow characteristics and emissions, the model TREMOVE was developed and has been evolving since 1996 (*Commission of the EC, 2000).* The TREMOVE model covers 9 different European countries and is able to calculate traffic fleet composition data, to estimate emissions and is able to distinguish between urban, rural and local scale data. TREMOVE calculates the effects of vehicle speeds, ambient temperature and road particle resuspension. It is expected that TREMOVE will provide baseline scenarios for future dispersion modelling that can draw on its data. The newest project is ATREUS which will focus on modelling source-receptor relationships through microclimatic flow modelling in street canyons and will contribute to the EU-funded Cluster of European Air Quality Research (CLEAR). As well as studying boundary layer effects at building surfaces and the street canopy level, ATREUS will also model energy fluxes in street canyons. It is expected that ATREUS will provide new field and wind tunnel measurements, will define and simulate synoptical scenarios at the mesoscale, evaluate the wind-field around buildings and thermal convection around buildings as well as the impact on ventilation and heating of the buildings.

2.6 Review of studies identifying emission patterns in busy streets and associated key parameters

Completed and on going activities clearly show that there are both the tools and the necessary empirical knowledge to link traffic emissions and air quality in urban environments. This applies basically to gaseous pollutants and mass based PM emissions. In particular, emission estimates and air concentrations are found to be well correlated. On the basis of this remark the Auto-Oil Programme I (*Commission of the EC, 1996)* identified the need for further reductions in vehicle emissions if air quality targets are to be achieved, while the Auto-Oil Programme II (*Commission of the EC, 2000)* suggested that exceedances of the PM objective would be more widespread in more than half of the Auto-Oil cities. In an attempt to estimate average car fleet emission factors typical of urban conditions from urban air quality measurements and street pollution models, two measurement campaigns were conducted in Copenhagen in 1997 *(Palmgren et al. 1999)* and in 2001 *(Ketzel et al.,*

2003). Significant correlations of particle number concentration with NO_x as well as between VOCs and CO concentrations were documented. The expected increase in the relative contribution from heavy duty trucks and buses to NO_x emissions with increasing percentage of passenger cars equipped with catalytic converters and a shift to smaller sizes in the emitted particle size distribution during night hours were confirmed. With regard to the spatial and temporal distribution of particles, a number of individual case studies have provided satisfactory insight. One of the main goals of the YOGAM programme *(Bukowiecki et al., 2002)* was the spatially and temporally resolved mapping of aerosol parameters by performing pollutant level measurements both near traffic and at rural locations. The large diurnal and regional variation of ultra nanoparticles for both urban and rural areas was confirmed, however, diurnal variations showed that neither the ultra nanoparticle fraction nor the total particle number concentration is an exclusive indicator of primary traffic emissions. A four-year project on particle studies aiming, among others, at characterising the temporal and spatial variability in particle composition and size distribution and determining particle emission factors for various vehicle categories used measurements performed in a street canyon in Copenhagen *(Palmgren et al., 2003)*. A clear diurnal variation of all measured concentrations was again observed. Traffic was the dominating source of ultrafine particles in busy streets, but contribution to PM_{10} was also significant. Emission factors of particles from diesel and petrol vehicles were determined by means of averaged PM data application, routine monitoring data and manually counted traffic rates. The vertical changes in concentrations of pollutants were investigated at a study conducted in an urban street canyon in Helsinki *(Väkevä et al., 1999)*. The concentrations of all pollutants had clear diurnal patterns that can be correlated to road traffic emissions. The dilution factor between street and rooftop levels was observed to be on average 5 for gas and particle concentrations. The emerging knowledge however clearly indicates that the next challenge is the introduction of number based particle concentrations. In this direction, experience gained from projects such as PARTICULATES *(LAT, 2003)* and ARTEMIS *(TRL, 2003)* will be of particular relevance. Road tunnel studies performed within ARTEMIS aim at validating fleet weighted emission factors derived from chassis dynamometer tests while PARTICULATES aim at improving the understanding and measurement of automotive particulates and emission models. Moreover, the AIRESUND project is expected to provide an improved understanding of the dynamic links between population distribution, traffic, air quality, health impacts and societal responses related to air pollution by investigating the relationships between traffic volume and driving patterns and the effect this relationship has on emission and fuel consumption factors.

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Project	Field campaigns related to source apportionment	Monitoring data analysis associated with the characteristics of hotspots	Resuspension studies	Modelling studies related to urban air quality and source-receptor relationships	Emission patterns and associated key parameters
Air Pollution in Europe report 1990-2000		*			
AIResund: A Multidisciplinary Research School on Travel Patterns – Traffic – Air Quality – Health Impact in the Öresund Region (2001), Denmark					*
AOPI: AUTO-OIL PROGRAMME I (1994 - 1997)				*	*
AOPII: AUTO-OIL PROGRAMME II (Spring 1997 - 2000)				*	*
APPETISE: Air Pollution Episodes: Modelling Tools for Improved Smog Management (2000 - 2003)		*			
ARTEMIS: Assessment and Reliability of Transport Emission Models and Inventory Systems (Winter 2000 – Summer 2003)					*
ATREUS – Advanced Tools for Rational Energy Use towards Sustainability (August 2002 – August 2005)				*	
Berlin, Germany: Application of the urban scale photochemistry model MICRO-CALGRID(MCG) (1995 data)				*	
Bern, Czech Republic: A modeling study to investigate the influence of traffic and meteorology on pollutant dispersion (March 2001)				*	
Budapest, Hungary: A source-receptor modeling study using ADMS (since 1997)				*	
City-Delta Project (2002 - 2004)				*	
CLEAR: Cluster of European Air Quality Research (2002 – 2005)		*		*	*
Copenhagen, Denmark: Source apportionment of fine and ultrafine particles (winter/spring 1999)	*				

Project	Field campaigns related to source apportionment	Monitoring data analysis associated with the characteristics of hotspots	Resuspension studies	Modelling studies related to urban air quality and source-receptor relationships	Emission patterns and associated key parameters
Copenhagen, Denmark: Characterisation of particle emissions from the driving car fleet and the contribution to ambient and indoor particle concentrations (2000-2003)					*
Copenhagen, Denmark: Particle and trace gas emission factors under urban driving conditions based on street and roof-level observations (2001)					*
Copenhagen, Denmark: Actual car fleet emissions estimated from urban air quality measurements and street pollution models (1997)					*
EC Joint Research Centre Study: A European aerosol phenomenology	*	*			*
Elimäki, Finland: A local scale field campaign (1995)		*			
ENV-e-CITY: ENvironmentally Viable electronic CITY (2002 - 2003)				*	*
FUMAPEX: Integrated systems for forecasting urban meteorology, air pollution and population exposure (2002-2004)		*			*
Helsinki, Finland: Source apportionment of urban ambient $PM_{2.5}$ in two successive measurement campaigns(1996-7 and 1998-9)	*				
Helsinki, Finland: Evaluation of the OSPM model combined with an urban background model against the data measured in Runeberg Street (1997)		*		*	
Helsinki, Finland: Street level versus rooftop concentrations of submicron aerosol particles and gaseous pollutants in an urban street canyon					*

Project	**Field campaigns related to source apportionment**	**Monitoring data analysis associated with the characteristics of hotspots**	**Resuspension studies**	**Modelling studies related to urban air quality and source-receptor relationships**	**Emission patterns and associated key parameters**
Hong Kong: Suspended Particle Study (November 1998 – January 1999)			*		
ISHTAR: Integrated Software for Health, Transport Efficiency and Artistic Heritage Recovery				*	
Leipzig, Germany: Particle number size distributions in a street canyon and their transformation into the urban-air background: measurements and a simple model study	*				*
London, UK: Source Apportionment of fine $PM_{2.5}$ (Summer 1999, Winter 2000)	*				
London, UK: Source apportionment of $PM_{2.5}$ (2002 – 2006)	*			*	
London, UK: Tracer – model validation study (1998 - 2000)	*				
London, UK: M25 Motorway study				*	
Lyon, France: A traffic emission model application using the model TREMOVE (since 1996)				*	*
Nantes campaign, France (June – July 1999)		*		*	
OSCAR: Optimised Expert System for Conducting Environmental Assessment of Urban Road Traffic (2002-2004)		*			*
PARTICULATES: Characterisation of Exhaust Particulate Emissions from Road Vehicles					*
SAPPHIRE: Source Apportionment of Urban Airborne Particles and Polycyclic Aromatic Hydrocarbons in Europe (October 2002-September 2005)	*				

Project	Field campaigns related to source apportionment	Monitoring data analysis associated with the characteristics of hotspots	Resuspension studies	Modelling studies related to urban air quality and source-receptor relationships	Emission patterns and associated key parameters
SATURN: Studying Atmospheric Pollution in Urban Areas (1997 – 2002)	*	*		*	
Second Position Paper on Particulate Matter (draft of August 2003)		*	*		
Singapore: CO modelling from transportation sources using street canyon and Gaussian line source modules				*	*
Stockholm PM and Health Study, Sweden: (1998 - 2000)	*	*		*	*
SUTRA: Sustainable Urban Transportation (1999 - 2003)				*	*
Thessaloniki, Greece: Source apportionment of fine and coarse air particles (1994-1995)	*				
TRAKER system study: Testing Re-entrained Aerosol Kinetic Emissions from Roads (1998 - 1999)			*		
UK: Studies of the coarse particle (2.5-10 µm) component in urban atmospheres	*				
URBAN AEROSOL: Characterisation of Urban Air Quality Indoor/Outdoor Particulate Matter Chemical Characteristics and Source-to-Inhaled Dose Relationships (2001 - 2003)	*			*	
VALIUM: Development and Validation of Tools for the Implementation of European Air Quality Policy in Germany (2000 - 2002): A field campaign in Hanover, Germany		*		*	*
YOGAM: Year of Gas phase and Aerosol Measurements (February 2001 – May 2002), Switzerland		*			*

ETC-ACC Street Emission Ceiling (SEC) exercise

Phase 1 Report

Chapter 3: Analysis of excess concentrations

3.1 Introduction

The primary objective of the Street Emission Ceilings (SEC) project is to develop a method for determining at which emissions in streets certain air quality thresholds, e.g. limit values, are reached.

The primary objective of subtask 3 is to study excess concentrations at street/road-side stations over and above the urban background concentrations in the area where the hot-spot 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 hot-spot 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. It would be important to include as many of the CITY-DELTA cities as possible.

The results of the analysis in this subtask should:

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

3.2 Selection of station pairs

3.2.1 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 3.1 shows a summary of PM_{10} data for 2001 reported to AIRBASE from 25 countries, totally 818 stations. The figure shows the importance of the regional and urban background (UB) contributions to the concentrations close to streets. On the 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} (and also, and even to a larger extent, for $PM_{2.5}$ and other smaller particle fractions). For NO_2, the importance of the background is much smaller (see Figure 3.2).

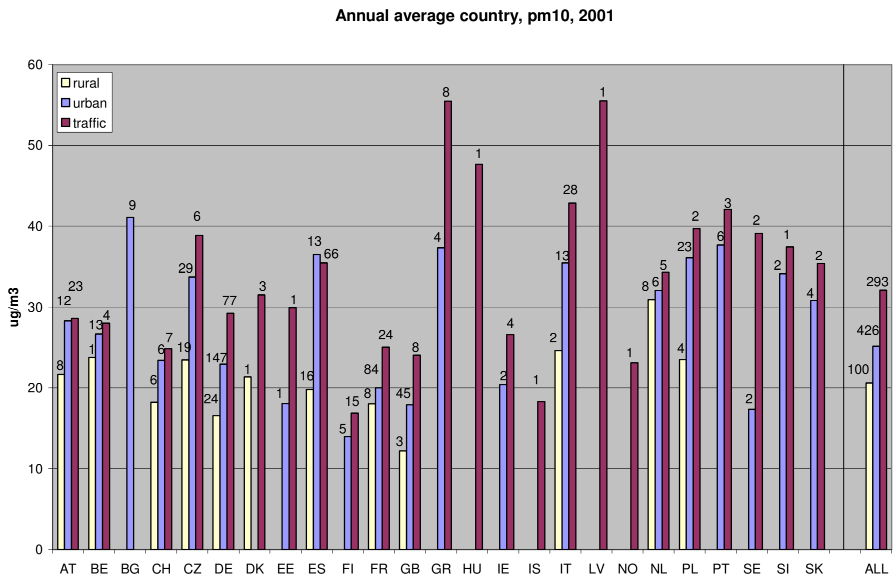


Figure 3.1: Country- average PM_{10} concentrations (annual average) for rural, urban background and traffic stations, 2001 AirBase data (number of sites on top of bars)

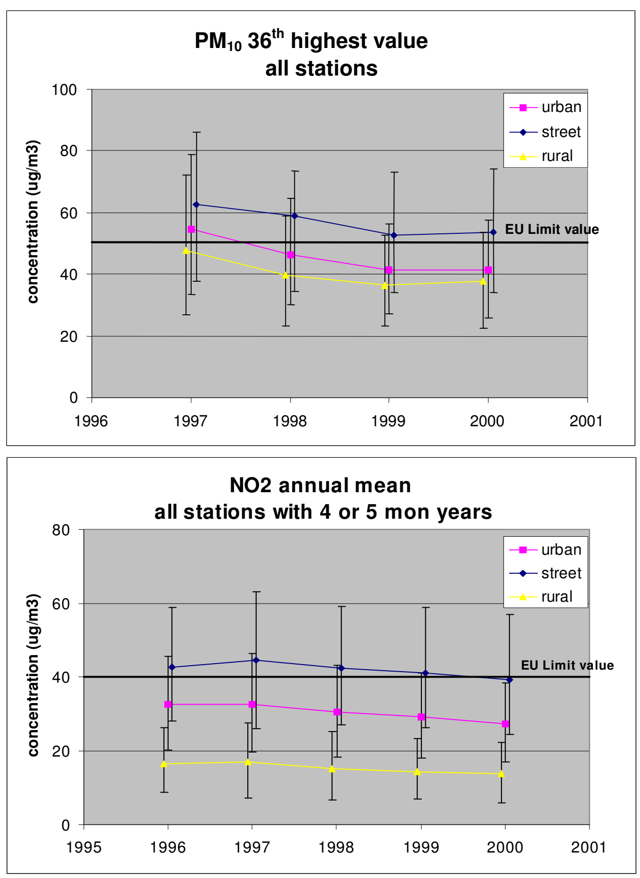


Figure 3.2: Concentrations of PM_{10} (Max 36^{th} day) and NO_2 (annual average) at stations in AIRBASE 1995-2000, averaged over each station type (rural, urban, traffic).

AIRBASE contains data from a fair number of cities where PM_{10} is measured continuously at least one traffic and one UB station. These are listed in Table 3.1. 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 is being prepared by the CAFE PM Working Group, a selection of these, plus some other data (Table 3.2), were studied (Bruckmann, Hout and Larssen), in order to identify more clearly the additional PM_{10} burden at traffic exposed sites from AIRBASE and to remove the ambiguity of comparing hot spot data from one city with background 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. Specific information on distance between the two stations in each pair has not been looked for these pairs. They may be in the same area, and they may be fairly widely apart, so they may not all we "good" station pairs.

A frequency distribution of the ratios is presented in Figure 3.3. The ratios of the annual means span a considerable range from 1.9 to 0.7, and the majority of the ratios are considerably 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 that some station pairs are indeed not "good" ones.

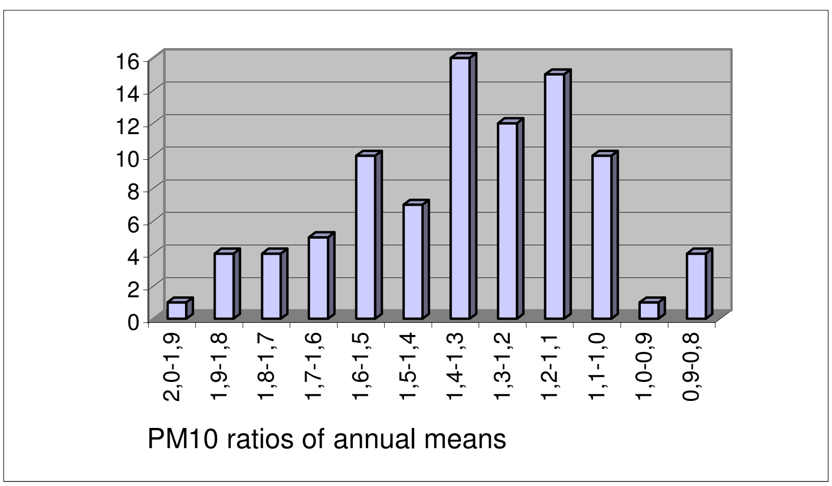


Figure 3.3: Frequency distribution of ratios of PM10 levels (annual means, µg/m³) at traffic exposed sites and in the urban background. Data from Air Base, 2001. Only pairs of data from the same city were taken into account. N = 89

In the majority of cases, the number of "exceedance days" at traffic exposed sites is also considerably higher compared with the urban background Figure 3.4). On average, there were 11.6 extra exceedance days (range up to 43 days).

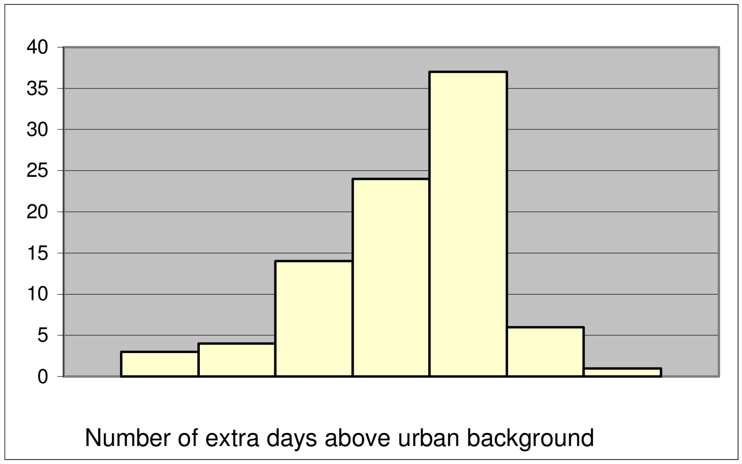


Figure 3.4: Extra days of PM_{10} daily means > 50 µg/m³ at traffic exposed sites compared with the urban background. Data from Air Base, 2001. Only pairs of data from the same city were taken into account. N = 89

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 3.5, for traffic stations. The figure shows that the spread around the regression line is fairly limited, but that there are stations were 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 re-suspension of road dust, from a large road dust depot 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 will are above the regression line are Spanish stations, where the problem of re-suspended dust is also pronounced, although from a very different source.

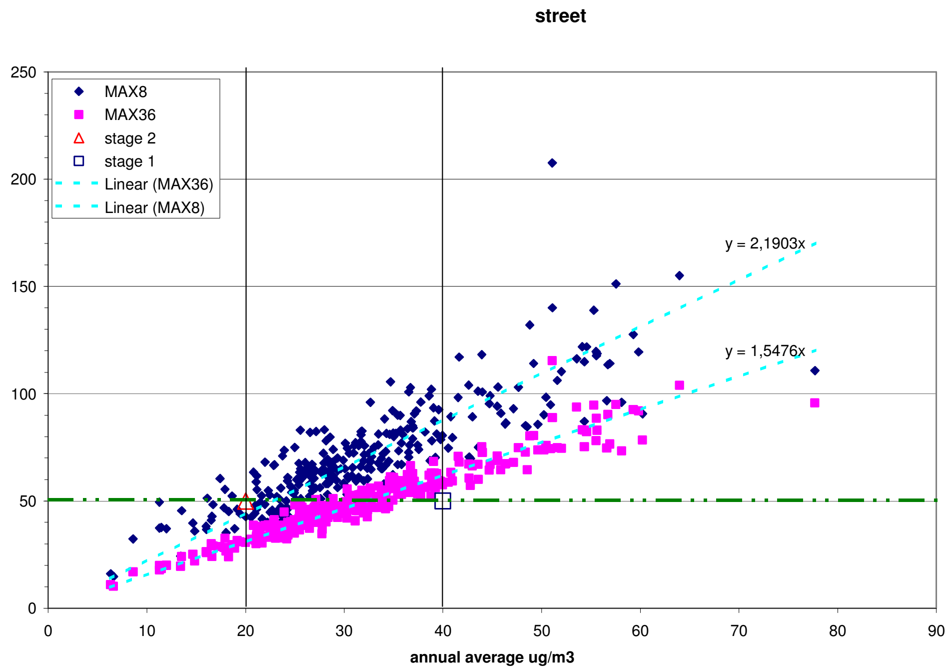


Figure 3.5: Exceedances of annual and short term limit values (stage 1, squares, and indicative values of stage 2, rhombus) at European street stations monitoring stations for the year 2001. Plotted is the position of each monitoring station on a surface which is spanned by the annual mean (right axis) and the 90.4 and 97.8 percentile, respect. (left axis)

Table 3.1: Cities in AIRBASE with PM10 data from both traffic hot-spot and urban background stations.

	NN_CODE_ISO2	SN_EU_CODE	LAT	LON	TYPE	Average_ hour	EXC_DAY	MAX36	MAX8	SP_NAME	CITY
pm	DE	DE0773A	52,519	13,284	street	32,235	39	52,083	70,875	DEBE014:Charlottenbur g-Lerschpfad""	BERLIN
pm	DE	DE1169A	52,465	13,32	street	35,65	56	54,5	69,958	DEBE061:Steglitz Schildhornstr.""	BERLIN
pm	DE	DE0946A	52,518	13,411	urban	31,493	35	49,792	61,333	DEBE044:Mitte-Parochialstr.""	BERLIN
pm	DE	DE0742A	52,489	13,436	urban	28,607	21	45,042	60,292	DEBE034:Neukölln-Nansenstraße""	BERLIN
pm	DE	DE1115A	52,515	13,471	street	37,141	67	57,708	78,083	DEBE065:Frankfurter Allee""	BERLIN
pm	DE	DE1091A	52,638	13,497	urban	22,827	16	39	53,625	DEBE051:Buch""	BERLIN
pm	SK	SK0002A	48,15	17,12	street	39,239	84	61,542	84,125	Trnavske myto""	BRATISLAVA
pm	SK	SK0004A	48,146	17,117	urban	28,376	27	45,708	66,417	Kamenne Namestie""	BRATISLAVA
pm	DE	DE0256A	53,089	8,811	urban	22,426	9	33,542	51,667	DEHB001:Bremen-Mitte""	BREMEN
pm	DE	DE1143A	53,068	8,784	street	31,583	27	47,375	60,125	DEHB007:Bremen Verkehr 2""	BREMEN
pm	BE	BE0237A	50,409	4,397	urban		22	45	63	45R512 - MARCHIENNE""	CHARLEROI
pm	BE	BE0235A	50,41	4,453	street		5	37	50	45R501 - CHARLEROI""	CHARLEROI

	NN_CODE_ISO2	SN_EU_CODE	LAT	LON	TYPE	Average_ hour	EXC_DAY	MAX36	MAX8	SP_NAME	CITY
pm	BE	BE0245A	50,43	4,46	urban		14	41	60	45R502 - LODELINSART""	CHARLEROI
pm	BE	BE0236A	50,417	4,522	urban		12	40	56	45R510 - CHATELINEAU""	CHARLEROI
pm	DE	DE0483A	49,873	8,665	urban	22,987	7	35,762	48,208	DEHE001:Darmstadt""	DARMSTADT
pm	DE	DE1073A	49,87	8,654	street	33,02	41	51,625	70	DEHE040:Darmstadt-Hügelstraße""	DARMSTADT
pm	GB	GB0641A	55,86	-4,784	urban	21,549	9	35,917	56,739	GLASGOW CENTRE""	GLASGOW
pm	GB	GB0657A	55,859	-4,256	street	20,482	2	34,083	43,167	GLASGOW KERBSIDE""	GLASGOW
pm	FI	FI0004A	60,194	24,967	street	19,24	7	31,167	42,792	Vallila 1""	HELSINKI
pm	FI	FI0018A	60,185	24,92	street	22,296	10	37,292	51,125	Töölö""	HELSINKI
pm	FI	FI0124A	60,187	24,954	urban	14,689	1	24,667	40	Kallio 2""	HELSINKI
pm	PT	PT0087A	38,77	-9,107	urban	30,183	42	51,917	76,174	Olivais""	LISBOA
pm	PT	PT0088A	38,749	-9,149	street	36,513	61	61,875	94,792	Entrecampos""	LISBOA
pm	PT	PT0093A	38,721	-9,146	street	61,327				Avenida da Liberdade""	LISBOA
pm	GB	GB0642A	51,513	-0,447	urban	19,503	1	30,792	40	LONDON HILLINGDON""	LONDON
pm	GB	GB0659A	51,374	-0,287	street	20,073	0	30,833	41,542	LONDON A3 ROADSIDE""	LONDON
pm	GB	GB0616A	51,541	-0,271	urban	17,475	1	27,042	35,958	LONDON BRENT""	LONDON
pm	GB	GB0620A	51,52	-0,209	urban	19,625	1	31,042	41,542	LONDON N. KENSINGTON""	LONDON
pm	GB	GB0608A	51,465	-0,2	urban	18,039	3	29,542	41,292	LONDON BEXLEY""	LONDON

	NN_CODE_ISO2	SN_EU_CODE	LAT	LON	TYPE	Average_ hour	EXC_DAY	MAX36	MAX8	SP_NAME	CITY
pm	GB	GB0623A	51,366	-0,181	street	19,235	0	28,292	38,917	SUTTON ROADSIDE""	LONDON
pm	GB	GB0636A	51,543	-0,173	street	25,859	4	37,826	47,25	CAMDEN KERBSIDE""	LONDON
pm	GB	GB0682A	51,522	-0,154	street	37,053	43	51,458	67,458	LONDON MARYLEBONE ROAD""	LONDON
pm	GB	GB0566A	51,521	-0,125	urban	21,315	0	32,875	40,958	LONDON BLOOMSBURY""	LONDON
pm	GB	GB0637A	51,598	-0,067	street	20,43	3	29,043	40,708	HARINGEY ROADSIDE""	LONDON
pm	GB	GB0586A	51,452	0,07	urban	15,655	0	22,789	32,583	LONDON ELTHAM""	LONDON
pm	ES	ES1193A	40,422	-3,749	other	28,915	35	49,25	71,75	CASA DE CAMPO""	MADRID
pm	ES	ES0125A	40,347	-3,705	street	47,262	136	80,31	96,94	VILLAVERDE""	MADRID
pm	ES	ES0116A	40,443	-3,689	street	42,759	116	75,62	92,84	MARAÑÓN""	MADRID
pm	ES	ES0123A	40,468	-3,688	street	37,17	69	59,13	74,87	PLAZA DE CASTILLA""	MADRID
pm	ES	ES0117A	40,431	-3,679	street	34,757	59	56,9	79,71	MARQUÉS DE SALAMANCA""	MADRID
pm	ES	ES1426A	40,407	-3,65	street	32,174	47	54,86	72,24	MORATALAZ""	MADRID
pm	ES	ES1192A	40,449	-3,608	street	32,364	59	58,29	72,02	ALCALÁ FINAL""	MADRID
pm	DE	DE0533A	48,153	11,462	street	31,015	25	44,75	58	DEBY040:München-Pasing""	MÏNCHEN
pm	DE	DE0535A	48,135	11,516	street	27,525	20	43,625	56,75	DEBY045:München-Westendstraße""	MÏNCHEN
pm	DE	DE1005A	48,114	11,519	street	33,858	33	49,625	59,75	DEBY085:München (Luise-Kiesselbach-Platz)""	MÏNCHEN
pm	DE	DE0532A	48,156	11,556	street	29,409	28	48	63,125	DEBY039:München-Lothstr.""	MÏNCHEN
pm	DE	DE0534A	48,153	11,61	street	32,356	34	48,875	64	DEBY038:München-Effnerplatz""	MÏNCHEN

	NN_CODE_ISO2	SN_EU_CODE	LAT	LON	TYPE	Average_ hour	EXC_DAY	MAX36	MAX8	SP_NAME	CITY
pm	DE	DE1107A	48,174	11,65	urban	25,514				DEBY089:München-Johanneskirchen""	MÏNCHEN
pm	IT	IT1264A	42,466	14,213	street	46,117	138	77,467	105,294	VIA FIRENZE""	PESCARA
pm	IT	IT1423A	42,456	14,25	urban	55,413	204	86,662	107,969	TEATRO DI ANNUNZIO""	PESCARA
pm	CZ	CZ0009A	50	14	urban		16	40	60	Pha8-Kobylisy""	PRAHA
pm	CZ	CZ0015A	50,09	14,35	urban		20	45	61	Pha6-Veleslavin""	PRAHA
pm	CZ	CZ0011A	50,07	14,38	street		70	64	94	Pha5-Mlynarka""	PRAHA
pm	CZ	CZ0021A	50,107	14,39	urban		33	50	75	Pha6-Santinka""	PRAHA
pm	CZ	CZ0065A	50,073	14,399	street		64	63	85	Pha5-Smichov""	PRAHA
pm	CZ	CZ0014A	50,043	14,414	street		38	51	84	Pha4-Branik""	PRAHA
pm	CZ	CZ0008A	50,088	14,429	street		80	73	110	Pha1-nam. Republiky""	PRAHA
pm	CZ	CZ0010A	50,08	14,44	urban		42	53	77	Pha2-Riegrovy sady""	PRAHA
pm	CZ	CZ0013A	50,067	14,447	street		96	98	141	Pha10-Vrsovice""	PRAHA
pm	CZ	CZ0020A	50,008	14,449	urban		44	54	82	Pha4-Libus""	PRAHA
pm	CZ	CZ0012A	50,079	14,487	street		137	75	122	Pha10-Pocernicka""	PRAHA
pm	CZ	CZ0016A	50,11	14,5	other		60	64	102	Pha9-Vysocany""	PRAHA
pm	CH	CH0021A	47,359	8,525	street		44	53	66	Zürich Bahnhof Wiedikon""	ZÜRICH
pm	CH	CH0010A	47,366	8,531	urban		12	40,1	54,1	Zürich""	ZÜRICH
pm	CH	CH0013A	47,375	8,541	street	26,764	24	45,096	61,971	Zürich Stampfenbachstrasse""	ZÜRICH
pm	CH	CH0001A	47,409	8,607	urban		2	29,7	39	Wallisellen""	ZÜRICH
pm	CH	CH0005A	47,391	8,614	urban		11	35,1	53,2	Dübendorf""	ZÜRICH

Table 3.2: Examples of simultaneously measured pairs of PM10 data from well characterized traffic sites and urban background sites in the same conurbation

Station, type	Year	measurement method	PM_{10}, ann. mean (µg/m³)	ratios for ann. means	PM_{10}, No. of days > 50 µg/m³	Ref.
Düsseldorf, street canyon, 1 m from kerbside, 45.000 veh./day	2001	grav.	43	2	98	(1)
Düsseldorf (urban background)	2001	grav.	21		13	(5)
Berlin, street canyon, near kerbside, 64.000 veh./day	2001	grav.	42	1.4	51 (β-att.)	(2)
Berlin (urban background)	2001	grav.	29		20 (β-att.)	(2)
London, street canyon, 1 m from kerbside, 80.000 veh./day	2000	TEOM (corrected by 1.3)	48	1.7	43	(3)
London (urban background)	2000	TEOM (corrected by 1.3)	28		0	(3)
Zürich street canyon, 3 m from kerbside, 31.0000 vehicles/day	2000	grav.	42	1.8	38	
Zürich urban background	2000	grav.	24 ($PM_{2.5}$ = 20.5)		12	
Bern street canyon, 2m from kerbside, 32.000 vehicles/day	2000	grav.	39.5 ($PM_{2.5}$ = 24)	1.6	51	
Bern urban background	2000	grav.	25		19	
Basel street canyon 4m from kerbside 19.000 vehicles/day	2000	grav.	30	1.2		
Basel urban background	2000	grav.	25		12	

[5] Landesumweltamt Essen, 2002
[2] Lutz, 2002
[3] Laxen and al., 2002

3.2.2 Selection of station pairs for this study

At stations 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 stations are located, and not situated within the street area.

Table 3.3 gives an overview of station pairs which have been selected as candidates for data collection and further analysis.

Table 3.3: Selected station pairs and data years

City	Street station	UB station	Type	AADT	Data available	Comments
Stockholm 2000	Hornsgatan	Roof-top	canyon	Ca. 35,000	PM_{10}, $PM_{2.5}$, NO_x, Traffic vol, speed, composition meteo Modelling available	Data available and analysed
Helsinki	to be determined					
Oslo 1996	Helsfyr	OK	"open"	Ca. 40,000	PM_{10}, NO_x, NO_2, O_3 Traffic vol, speed, comp. meteo	Data available
Oslo 2002	Skårer	OK	"open"	Ca. 25,000	PM_{10}, NO_x, NO_2, Traffic vol, speed, comp. meteo Modelling to be done	Data available and analysed
Hannover	Goettinger strasse	OK	canyon	Ca. 30,000	PM_{10}, $PM_{2.5}$ (some), NO_x, NO_2 Traffic meteo Modelling available	Data not yet available for the project
Berlin	Frankfurter Allee	OK	canyon	ca. 65,000	PM_{10}, NO_x, NO_2 Traffic Meteo Modelling??	Data available and analysed
Madrid	Pontones	UB (Case de Campo)	canyon	?	PM_{10}, NO_x,??? Traffic?? Meteo??	Data not yet available for the project
Thessaloniki	Ermou street	UB	close to street crossing	Ca. 13,500 ++	PM_{10}, NO_x, NO_2 Traffic Meteo	Data available and analysed
Milano						Station pair not yet decided

City	Street station	UB station	Type	AADT	Data available	Comments
London	Marylebone road	UB (Bloomsbury)	canyon	Ca. 85,000		Data available and analysed
Copenhagen	Jagtvej	Roof-top	canyon	Ca. 26,000	PM_{10}, NO_x, NO_2, CO Traffic Meteo	Data to be included
	HC Andersen Boulevard	Roof-top	"open"	Ca. 67,000	PM_{10}, NO_x, NO_2, CO	Data to be included
Praha	Vrsovice	UB	"open"	Data to be made available	PM_{10}, NO_x, NO_2, O_3	Data available and analysed

3.3 Data analysis

The basic objectives of subtask 3 are to study the excess concentrations at street hot-spot stations (street concentration minus UB concentration) calculated from carefully selected station pairs, to provide the basis for:

– validation of vehicle class emission factors, such as from COPERT
– validation of dispersion/calculation models for street/road (line) configurations.

For validation of vehicle 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 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 separation enables to look at emission factors for light and heavy duty vehicles separately, and also to elucidate the effect of the re-suspension 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 sparately (e.g. $PM_{2.5}$ at the street station and background station separately);
- "Delta" concentrations ("deltaC": street – background);
- "Delta ratios": ratio between the deltas, form each component compared to the NO_x delta.

In terms of providing the background for validation of emission factors, the "delta ratios" provide the main basis for comparison between the emission factors from various data bases and the key results provided by the measurements.

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 *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 data base collected under this project includes data from a number of carefully selected station pairs from various cities. The streets canyons have different dimensions, the traffic amount varies over a large range, and the climate/meteorological conditions also vary over a large range. This data base thus enables comparison of DeltaC for various compounds ($PM_{2.5}$, PM_{10}, NO_x, NO_2, CO) for differing street, traffic and

dispersion conditions characterised by parameters such as e.g. height/width ratio, traffic speed, average wind and dispersion parameters.

3.4 Synthesis of results from the selected station pair data analysis

The details of each station pair, and of the analysis of the data, are given in Annex B (one section per city/station pair). The purpose of this synthesis chapter is to:

- present extracted summarised data from each station pair suitable for comparison of the station pairs.
- The selected extracted data should be suitable and sufficient for the further subtasks of the project.

3.4.1 Station meta data

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 3.4 summarises the essential station metadata.

Pictures and sketches of stations are included under each station pair section in the Annex.

Specific comments to each station pairs will be elaborated in the final version of the chapter.

Table 3.4: Overview of stations pair meta data

City/year	**Stations**	**Street topography**			**Traffic**			**Meteorology (annual aver.)**	
		Width m	***Building height (m)***	***No. of tr.lanes***	***AADT veh/day***	***Aver.speed km/h***	***HD fraction %***	***Wind speed m/s***	***Temp °C***
Stockholm 2000	Hornsgatan	22	20	4	34 800	47	10.0		
	Hornsgatan, roof							3.5	10.7
London 2000	Marylebone Rd			6	85 500	40	10.3	0.7	13.4
	Bloomsbury								
Oslo 2002	Skårersletta	19.4	0	4	35 900	91	6.0	1.85	0.1
	Nordby								
Thessaloniki 2001	Ermou	40	25		22 650	19	9.6		
	-							2.1	17.3
Berlin	Frankfurter Allee	42	21	6	56 000	40	4.8	2.9	9.8
Praha	Vrsovice		0					1.3	

3.4.2 Summarised meteorological characteristics

Here will be shown, in the final version of the chapter, figures with monthly average wind speed (WS) and temperature, as well as wind direction distribution ("wind rose", and including the geographical street direction) for each station pair.

3.4.2.1 Summarised traffic characteristics

This section will be included in the final version of the chapter.

3.4.3 Synthesis of air pollution concentrations

Table 3.5 gives summarised long term averaged data (annual averages), for DeltaC and Delta-ratios, for the station pairs with such data available so far.

Table 3.6 gives summarised short-term averaged data for DeltaC and Delta-ratios for the Stockholm, London and Berlin station pairs.

These tables will be completed as data become available /have been processed.

In Figures 3.6-3.8, DeltaC and Delta-ratio data, relative to NO_x, are shown for Hornsgatan Stockholm, Marylebone Road, London and Frankfurter Allee, Berlin. Data are presented in terms of average numbers per hour-of-day, for winter and summer conditions and workdays and weekend days separately.

In Figure 3.9 data from these plots are extracted further, to give the average of the Delta-ratios for the middle 6 hours of the day, for each of the season/part-of-the-week combinations. This is shown for Hornsgatan and Marylebone Road. The 6 middle-of-the-day hours have been selected to exclude the rush-time hours as well as with a view to the variation of the ratios over the day, so that a period with as small variation in the ratio 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 Delta-ratios will then be representative for emission and atmospheric conditions which can be reasonably well characterised, again enabling a better comparison with emission factor based ratios.

At first sight, there are significant differences between the two station pairs:

- The summer $PM_{2.5}$ ratios is much higher at Marylebone than at Hornsgatan, while the winter rtios are quite similar. This is surprising, considering that the re-suspension source should be much larger in the studded tyre city of Stockholm than in London.

- For PM_{10}, however, the summer ratios are not so different in the two cities, while, as expected, the winter ratio is much higher in Stockholm, again due to the re-suspension source.

- For NO_2, surprisingly, the summer ratios are higher in Stockholm than in the more southerly London, while during winter workday conditions, they are quite similar. Another dissimilarity is that in Stockholm the winter weekend NO_2 ratio is a bit higher that the workday ratio, while in London it is lower.

It will be necessary to quality assure these calculations, before going further in the evaluation. It will also be useful to make first comparisons with ratios calculated from emission factors (from subtask 4), made for the vehicle fleet compositions in these two countries/cities. Also, similar results from the other cities in the study will broaden the understanding of similarities and differences.

Table 3.5: Synthesis of long-term average data

	AADT	WS	Delta (Street-roof)				Delta ratios		
			NO_x	NO_2	PM2,5	PM_{10}	$PM_{2,5}/NO_x$	PM_{10}/NO_x	NO_2/NO_x
Hornsgatan ~ 45 km/h 10% HD									
Year (2000)	35,000		155	29.8	5.2	24.5	0.033	0.151	0.192
Skårersletta 90 km/h 6% HD									
Winter (2002)	35,900		104[1] 144[2]	14.3[1] 19.7[2]		31.3[2]		0.24	0.15 0.15
Marylebone Road									
Year (2000)	85,480		305	33.7	11.7	20.5	0.039	0.069	0.11
Frankfurter Allee	55,000		59	16,5		9,6		0,16	0,28

[1] 24 hours
[2] 12 hours (daytime only)

Table 3.6: Synthesis of short-term average data (hour, day)

	AADT	WS	Delta				Delta ratios			Limit value indicators			
			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*	*PM_{10}-35*	*PM2,5-35*	*PM_{10}-7*
Hornsgatan ~ 45 km/h 10% HD													
Year (2000)											88	21	
Summer													
- Workdays			*237.1*	*48.0*	*7.2*	*23.3*	*0.030*	*0.098*	*0.202*				
- Weekends			*138.3*	*34.4*	*3.1*	*10.7*	*0.023*	*0.078*	*0.249*				
Winter													
- Workdays			*271.1*	*40.9*	*10.9*	*67.8*	*0.040*	*0.251*	*0.151*				
- Weekends			*180.3*	*29.5*	*7.9*	*55.1*	*0.044*	*0.306*	*0.165*				
Skårersletta 90 km/h 6% HD													
Winter (2002)										84[1]	41[1]		

[1]Only 4 winter months

	AADT	WS	Delta				Delta ratios			Limit value indicators			
			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	PM_{10}-35	PM2,5-35	PM_{10}-7
Marylebone Road													
Year (2001)													
Summer													
- Workdays			*353.4*	*56.5*	*21.8*	*25.8*	*0.62*	*0.73*	*1.59*				
- Weekends			*193.0*	*35.1*	*11.5*	*9.6*	*0.60*	*0.50*	*1.83*				
Winter													
- Workdays			*276.6*	*39.1*	*10.7*	*21.7*	*0.39*	*0.79*	*1.41*				
- Weekends			*136.9*	*16.0*	*6.6*	*10.1*	*0.48*	*0.74*	*1.17*				
Frankfurter Allee													
Year (2002)										127.4	161.7		226.9
Summer													
- Workdays			*97.9*	*34.1*		*15.9*		*0.16*	*0.35*				
- Weekends			*45.6*	*20.5*		*8.4*		*0.19*	*0.45*				
Winter													
- Workdays			*107.4*	*21.3*		*19.7*		*0.18*	*0.20*				
- Weekends			*50.6*	*11.9*		*8.9*		*0.18*	*0.23*				
Ermou													
Year (2001)										173	106		

Hornsgatan, Stockholm

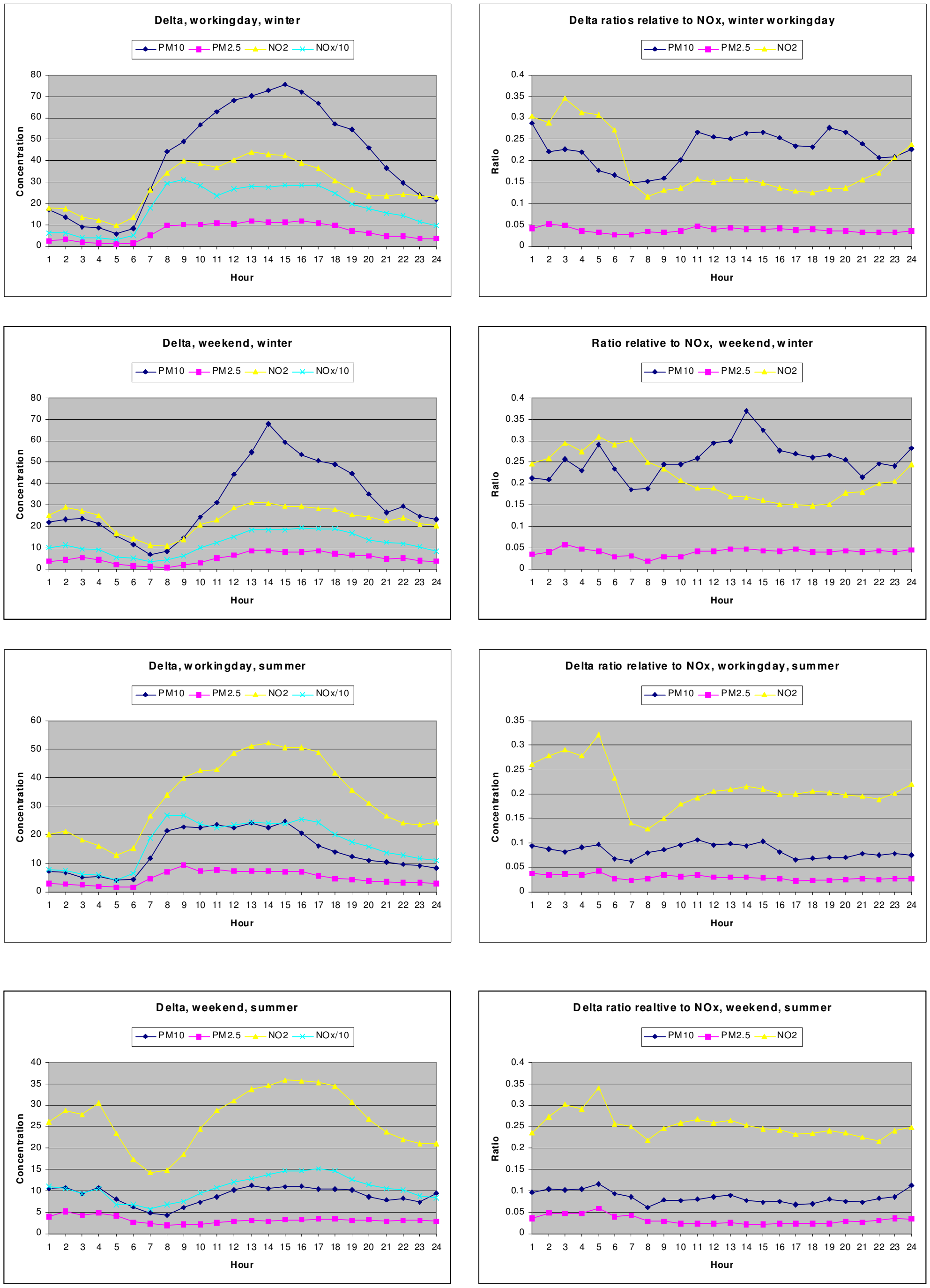


Figure 3.6: Average concentration variation over the day, Hornsgatan, Stockholm, DeltaC and Delta-ratio relative to NO_x

Marylebone Road, London

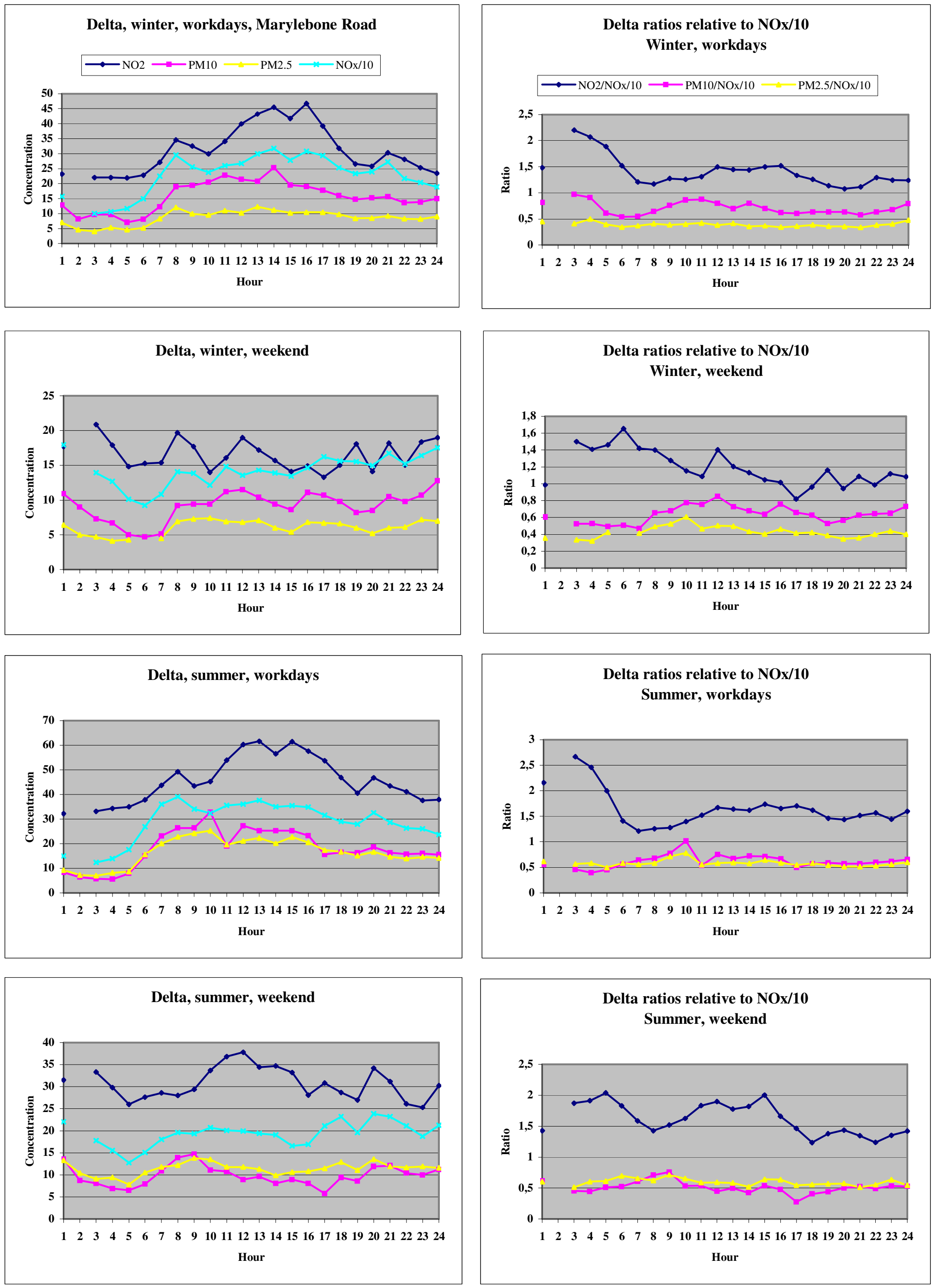


Figure 3.7: Average concentration variation over the day, Marylebone Road, London, DeltaC and Delta-ratio relative to NO_x

Frankfurter Allee, Berlin

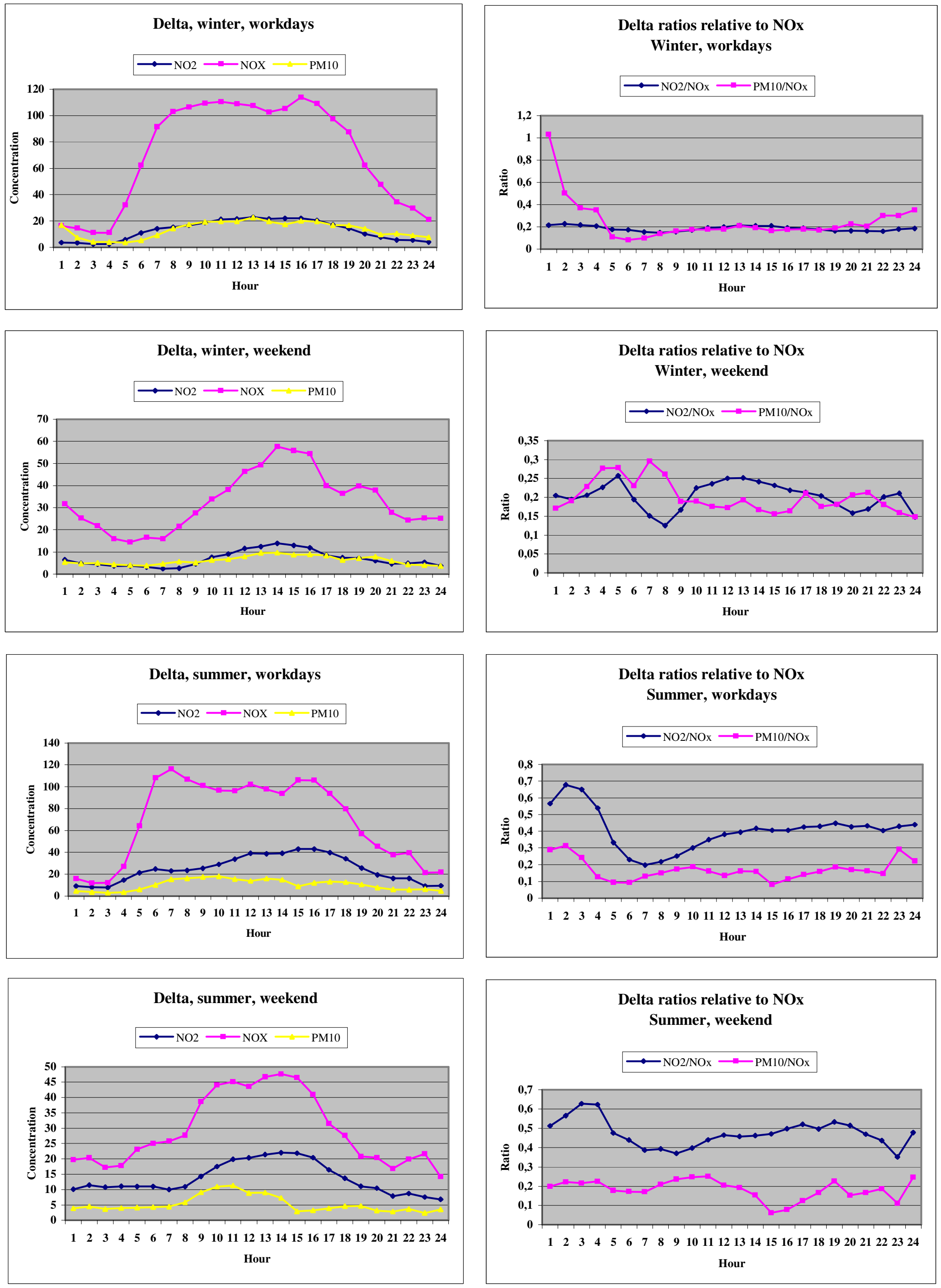
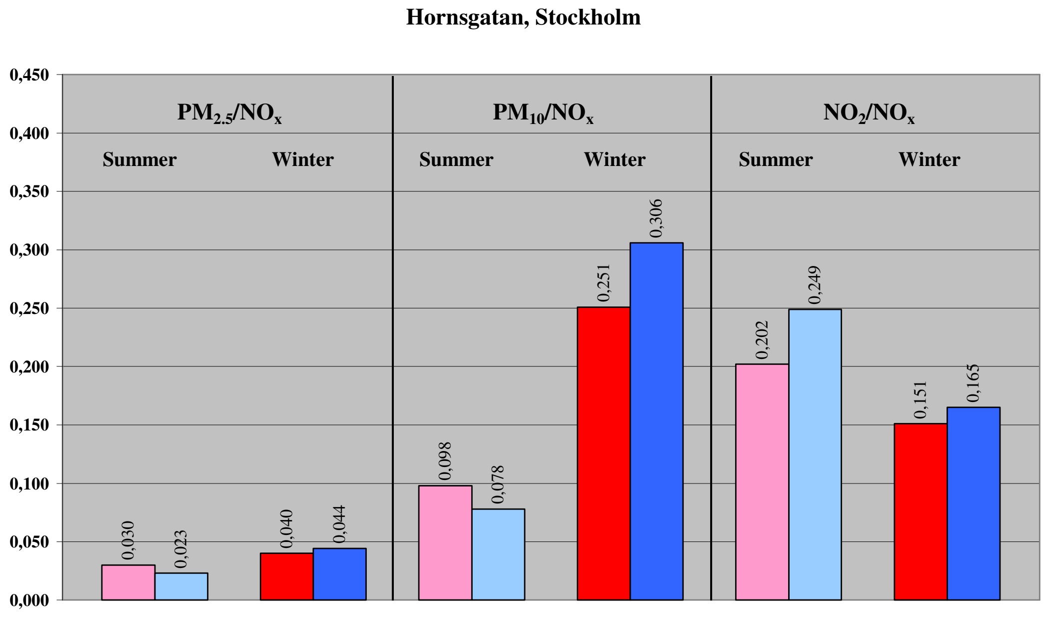


Figure 3.8: Average concentration variation over the day, Frankfurter Allee, Berlin, DeltaC and Delta-ratio relative to NO_x



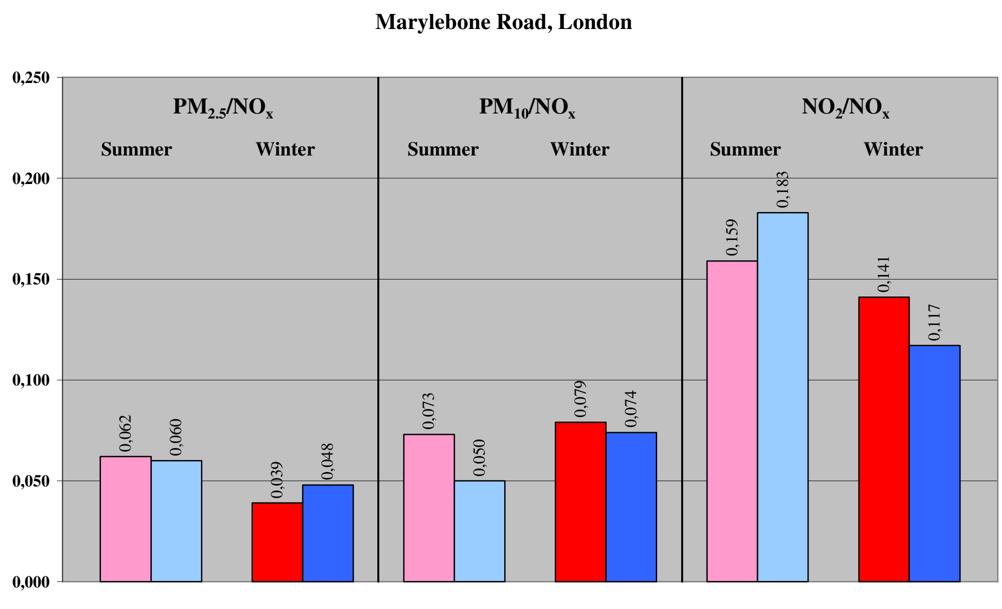


Figure 3.9: Delta-ratios for $PM_{2.5}$, PM_{10} and NO_2 relative to NO_x, for Winte and Summer conditions.
Red columns: workdays
Blue columns: weekend days

ETC-ACC Street Emission Ceiling (SEC) exercise

Phase 1 Report

Chapter 4: Local emission estimates

4.1 Introduction

The present subtask aims at contributing to analysis of excess concentrations by providing data deriving 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 III methodology for the estimation of urban emissions from road transport has been used. For this purpose a local scale calculation module was derived based on the COPERT model, 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.

4.2 Hornsgatan, Stockholm

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 C.1) and hourly (Tables C.2 & C.3) distribution of traffic into the various vehicle categories is presented in Annex C.

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.
Two sets of runs were performed with COPERT, for the hourly and monthly distribution of traffic emissions. From the traffic data monitored, 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). It should be noted that due to an error in the data available, the emissions were calculated using only half the number of vehicles and no road gradient. In order to correct for this error, a first estimate was to double the emissions. The correct emissions (accounting for double the vehicle fleet and road gradient) were calculated and included in the SEC 2004 update of the report.

As practically all PM emitted by road vehicles are in the fine fraction, the entire PM emissions are considered as $PM_{2.5}$ emissions and thus the PM_{10} concentrations are not examined in the present study. From the above emissions and delta concentrations, $PM_{2.5}$ emission factors relative to NO_x are derived, on an hourly and on a monthly basis and are also presented in the Tables below. It has to be noted that the emissions calculated include hot emissions only as it is assumed that the cold start effect is negligible in the specific street canyon.

The composition of the HDV fleet in January is presented in Table 4.1. Also, Table 4.2 & 4.3 show the calculated hourly and monthly traffic emissions and the atmospheric concentration deltas of NO_x and $PM_{2.5}$ respectively.

Table 4.1: Heavy Duty Vehicles composition in January in Hornsgatan, Stockholm

Type	Class	Legislation	Jan
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0
	Diesel 3,5 - 7,5 t	Conventional	24812
		Euro I - 91/542/EEC Stage I	5764
		Euro II - 91/542/EEC Stage II	8251
		Euro III - 2000 Standards	0
	Diesel 7,5 - 16 t	Conventional	27260
		Euro I - 91/542/EEC Stage I	6333
		Euro II - 91/542/EEC Stage II	9066
		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	12922
		Euro I - 91/542/EEC Stage I	1261
		Euro II - 91/542/EEC Stage II	1638
		Euro III - 2000 Standards	0
	Coaches	Conventional	3231
		Euro I - 91/542/EEC Stage I	315
		Euro II - 91/542/EEC Stage II	409
		Euro III - 2000 Standards	0

Table 4.2: Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Hornsgatan, Stockholm

	Emissions (kg)					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	712,1	216,6	7,5	0,035	3,288	168,6	4,1	0,024
February	688,0	208,3	7,6	0,036	3,302	179,2	6,2	0,035
March	746,7	225,3	7,4	0,033	3,314	181,6	10,8	0,059
April	662,6	200,5	6,4	0,032	3,305	180,6	6,8	0,038
May	785,2	240,8	8,2	0,034	3,260	152,6	5,6	0,037
June	668,3	211,9	7,3	0,035	3,154	141,7	3,5	0,025
July	544,7	185,8	6,6	0,036	2,932	150,1	4,6	0,031
August	725,3	239,6	9,1	0,038	3,027	167,5	4,7	0,028
September	736,8	226,5	7,8	0,034	3,253	194,5	5,6	0,029
October	725,4	219,2	7,4	0,034	3,308	110,4	3,2	0,029
November	743,1	220,6	7,4	0,034	3,368	104,4	3,7	0,035
December	693,9	206,5	6,8	0,033	3,359	132,2	3,4	0,026

Table 4.3: Calculated hourly average traffic emissions versus monitored hourly average delta concentrations in Hornsgatan, Stockholm

	Emissions (g)					Concentrations (µg/m³)		
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	394,8	133,6	3,5	0,026	2,956	77,8	3,0	0,039
02:00	342,0	132,0	4,3	0,032	2,590	78,6	3,4	0,043
03:00	264,8	109,5	3,8	0,035	2,418	62,4	2,9	0,046
04:00	232,8	98,7	3,5	0,035	2,359	63,4	2,6	0,041
05:00	164,2	75,0	3,0	0,040	2,190	42,1	1,9	0,045
06:00	189,0	83,1	3,2	0,039	2,273	57,6	1,7	0,030
07:00	559,6	205,6	6,9	0,034	2,721	141,9	3,9	0,027
08:00	1082,7	353,1	12,6	0,036	3,067	208,7	6,3	0,030
09:00	1194,6	387,5	14,3	0,037	3,083	215,0	7,2	0,033
10:00	1058,7	359,3	13,7	0,038	2,946	209,7	6,8	0,032
11:00	1190,1	395,9	14,9	0,038	3,006	195,3	7,4	0,038
12:00	1373,1	433,3	16,2	0,037	3,169	208,7	7,4	0,035
13:00	1539,7	465,9	17,2	0,037	3,305	223,6	8,0	0,036
14:00	1576,2	476,9	17,6	0,037	3,305	223,2	8,2	0,037
15:00	1650,9	493,4	18,0	0,037	3,346	225,7	8,0	0,035
16:00	1810,0	530,8	19,5	0,037	3,410	232,2	8,2	0,035
17:00	1858,2	524,4	18,5	0,035	3,543	224,5	7,3	0,033
18:00	1632,4	456,1	14,9	0,033	3,579	196,2	6,2	0,032
19:00	1330,9	379,0	11,4	0,030	3,512	167,4	5,4	0,032
20:00	1045,0	310,6	9,0	0,029	3,365	150,0	4,8	0,032
21:00	903,2	261,7	6,8	0,026	3,451	131,8	4,0	0,030
22:00	848,3	245,8	6,4	0,026	3,451	126,0	4,0	0,032
23:00	655,8	196,9	5,1	0,026	3,330	109,1	3,6	0,033
24:00	533,0	166,8	4,2	0,025	3,196	95,9	3,3	0,034

In Figure 4.1 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. When comparing the above $PM_{2.5}/NO_x$ ratio with the calculated one, a good agreement is observed as regards the average value. For the concentration ratio a seasonal variation is observed (quite stable during summer and almost double in the winter months), which can be attributed to the re-suspension of road dust during the winter months, particularly in March-April. On the contrary, the calculated $PM_{2.5}/NO_x$ ratio varies only with the traffic variations and thus the seasonal variations due to meteorological conditions can not be reproduced.

Figure 4.2 shows the hourly variation over the day of the $PM_{2.5}$ over NO_x concentration ratio against the respective calculated emission ratio. Again, the calculated ratios are in good agreement with ratios derived from the data analysis.

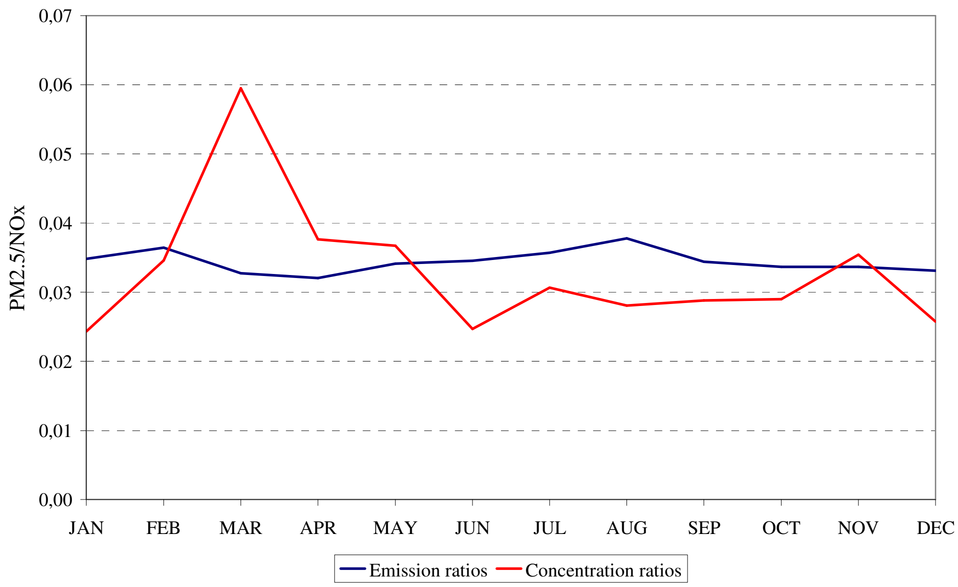


Figure 4.1: Monthly variation of the average traffic emissions and delta concentrations in Hornsgatan, Stockholm

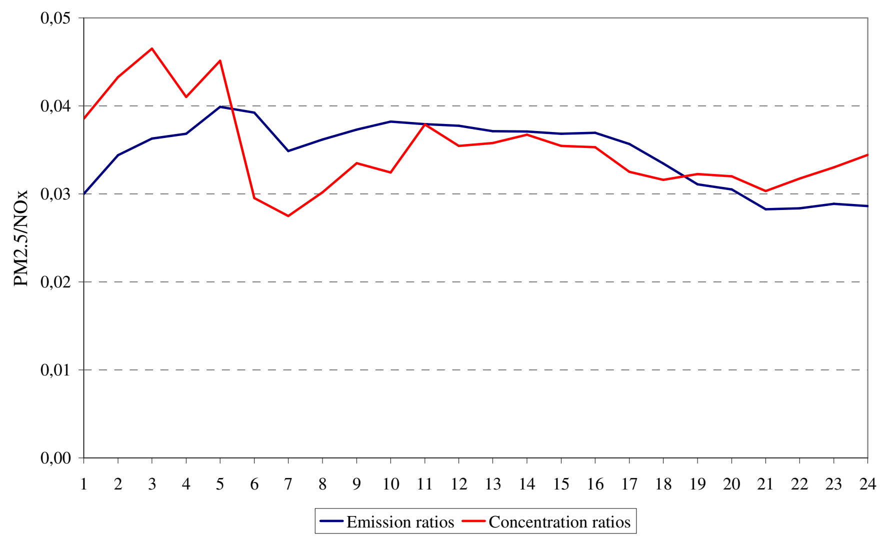


Figure 4.2: Diurnal variation of the average traffic emissions and delta concentrations in Hornsgatan, Stockholm

4.3 Skårersletta, Oslo

As no data for Norway are included in the TRENDS database, the Swedish vehicle fleet for the year 2002 was considered again, assuming that the composition of the Norwegian fleet is similar to that of Sweden. The detailed monthly (Table 4.4) and hourly (Tables 4.5 & 4.6) distribution of traffic into the various vehicle categories is presented in Annex C. As the traffic station is located near a highway outside the urban area of Oslo, all vehicle categories are taken into account for the calculations. The average monthly distribution of passenger cars in the various categories at 08:00 is presented in Table 4.4 below.

Table 4.4: Passenger Cars distribution at 08:00, Skårersletta, Oslo

Type	Class	Legislation	8:00
Passenger Cars	Gasoline <1,4 l	PRE ECE	0,0
		ECE 15/00-01	0,0
		ECE 15/02	2,7
		ECE 15/03	2248,5
		ECE 15/04	21522,9
		Improved Conventional	0,0
		Open Loop	0,0
		Euro I - 91/441/EEC	30204,3
		Euro II - 94/12/EC	35612,3
		Euro III - 98/69/EC Stage2000	13114,6
	Gasoline 1,4 - 2,0 l	PRE ECE	0,0
		ECE 15/00-01	0,0
		ECE 15/02	3,6
		ECE 15/03	3038,1
		ECE 15/04	29081,8
		Improved Conventional	0,0
		Open Loop	0,0
		Euro I - 91/441/EEC	40812,3
		Euro II - 94/12/EC	48119,6
		Euro III - 98/69/EC Stage2000	17720,6
	Gasoline >2,0 l	PRE ECE	0,0
		ECE 15/00-01	0,0
		ECE 15/02	0,9
		ECE 15/03	741,4
		ECE 15/04	7097,4
		Euro I - 91/441/EEC	9960,1
		Euro II - 94/12/EC	11743,5
		Euro III - 98/69/EC Stage2000	4324,7
	Diesel <2,0 l	Conventional	2304,6
		Euro I - 91/441/EEC	1534,0
		Euro II - 94/12/EC	3083,2
		Euro III - 98/69/EC Stage2000	1443,7
	Diesel >2,0 l	Conventional	1536,4
		Euro I - 91/441/EEC	1022,7
		Euro II - 94/12/EC	2055,5
		Euro III - 98/69/EC Stage2000	962,4
	LPG	Conventional	0,0
		Euro I - 91/441/EEC	0,0
		Euro II - 94/12/EC	0,0
		Euro III - 98/69/EC Stage2000	0,0
	2-Stroke	Conventional	0,0

The traffic volume was grouped into three traffic lanes in total, with different vehicle volumes, and thus three sets of runs were performed with COPERT. From the traffic data monitored for each group of traffic lanes, average hourly and monthly data were derived for the number of passenger cars, the heavy duty fraction and the average vehicle speed. As the exact length of the road is unknown, traffic emissions were calculated for a mileage of 1000 m.

The calculated hourly and monthly traffic emissions and the atmospheric delta concentrations of NO_x and PM are presented in Table 4.5 and Table 4.6 respectively. As for the specific traffic station no data for $PM_{2.5}$ concentration were available, only PM_{10} data are presented below. As explained above, the entire PM emissions from vehicles exhaust are actually $PM_{2.5}$ emissions. From the above emissions and delta concentrations,

PM_{10} and $PM_{2.5}$ emission factors relative to NO_x are derived, on an hourly and on a monthly basis and are also presented in the Tables below.

Table 4.5: Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Skårersletta, Oslo

	Emissions (kg)					Concentrations (µg/m³)		
Month	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**PM_{10}**	**PM_{10}/NO_x**
January	2,884	1,209	0,023	0,019	2,386	136,9	5,8	0,043
February	2,821	1,135	0,021	0,019	2,486	104,7	9,5	0,090
March	3,054	1,179	0,021	0,018	2,591	84,4	39,0	0,463
April	3,484	1,367	0,026	0,019	2,548	89,0	70,8	0,795

Table 4.6: Calculated monthly average traffic emissions versus monitored monthly average delta concentrations in Skårersletta, Oslo

	Emissions (g)					Concentrations (µg/m³)		
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	97,3	34,9	0,5	0,014	2,790	41,6	n.a.	n.a.
02:00	62,1	22,6	0,3	0,015	2,753	31,1	n.a.	n.a.
03:00	47,2	17,5	0,3	0,016	2,696	23,2	n.a.	n.a.
04:00	41,4	17,2	0,4	0,021	2,407	22,9	n.a.	n.a.
05:00	44,2	20,6	0,5	0,024	2,148	35,8	n.a.	n.a.
06:00	119,3	57,0	1,4	0,025	2,093	80,8	n.a.	n.a.
07:00	588,3	243,0	4,8	0,020	2,421	184,3	n.a.	n.a.
08:00	909,1	364,2	6,6	0,018	2,497	207,4	n.a.	n.a.
09:00	737,4	309,7	6,4	0,021	2,381	183,1	n.a.	n.a.
10:00	527,9	249,3	6,2	0,025	2,118	153,5	n.a.	n.a.
11:00	511,8	246,8	6,2	0,025	2,073	127,8	n.a.	n.a.
12:00	586,9	267,4	6,2	0,023	2,195	110,3	n.a.	n.a.
13:00	653,6	293,3	6,7	0,023	2,229	116,1	n.a.	n.a.
14:00	735,8	317,2	6,8	0,022	2,320	109,1	n.a.	n.a.
15:00	845,1	347,9	7,0	0,020	2,429	121,1	n.a.	n.a.
16:00	1116,7	428,4	7,3	0,017	2,607	128,8	n.a.	n.a.
17:00	1113,8	414,8	6,4	0,015	2,685	123,4	n.a.	n.a.
18:00	864,3	316,0	4,8	0,015	2,735	123,2	n.a.	n.a.
19:00	708,9	253,2	3,6	0,014	2,800	129,1	n.a.	n.a.
20:00	577,7	204,3	2,9	0,014	2,827	124,7	n.a.	n.a.
21:00	471,7	164,6	2,2	0,013	2,865	110,6	n.a.	n.a.
22:00	374,4	131,5	1,7	0,013	2,847	97,2	n.a.	n.a.
23:00	288,8	99,9	1,3	0,013	2,890	82,1	n.a.	n.a.
24:00	192,6	66,3	0,8	0,013	2,905	65,6	n.a.	n.a.

In Figure 4.3 the variation in monthly averages over the January-April 2002 period of the delta concentration ratio of PM_{10} over NO_x is plotted against the calculated emission ratio of $PM_{2.5}$ over NO_x. A complete assessment based on the above ratios can not be realised since no concentration data on $PM_{2.5}$ are available for the specific pair of stations. Due to the lack of hourly PM concentration data, a comparison with the calculated emission ratio is not available.

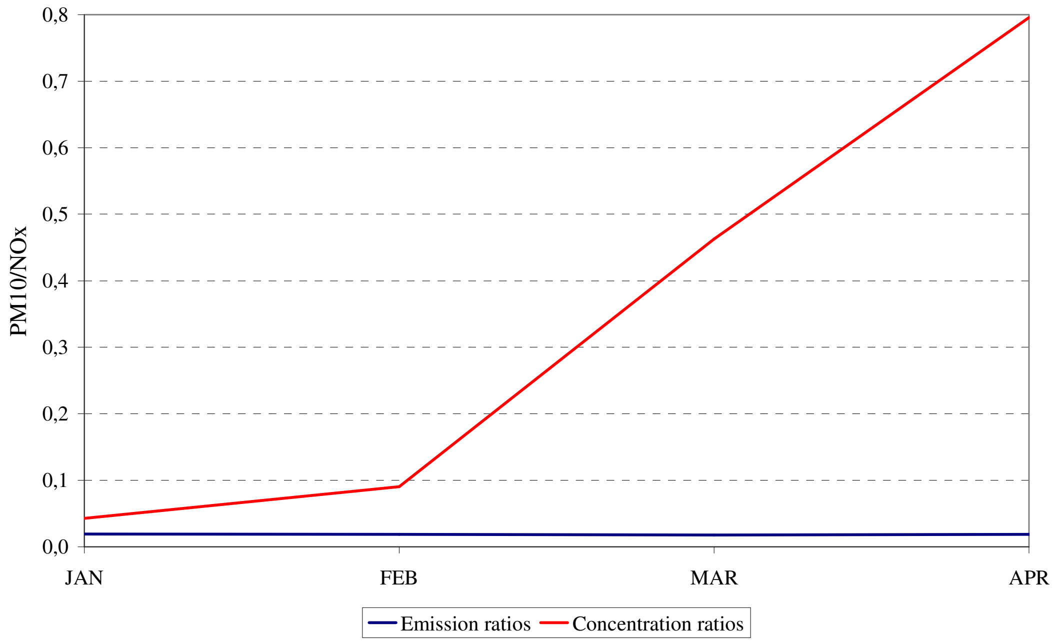


Figure 4.3: Monthly variation of the average traffic emissions and delta concentrations in Skårersletta, Oslo

4.4 Ermou St., Thessaloniki

Using the composition of the Greek vehicle fleet for the year 1999 extracted from the TRENDS database, the share of each vehicle category is derived. The detailed hourly distribution of traffic into the various vehicle categories is presented in Annex C (Tables C.7 & C.8). A monthly distribution could not be determined due to the lack of average monthly traffic data.

The traffic station is located in the centre of Thessaloniki 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. As the station is located on the corner of two streets having five traffic lanes in total, with different vehicle volumes, five sets of runs were performed with COPERT. From the traffic data monitored for each traffic lane, average hourly 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 two streets (approximately 200 m).

The calculated hourly vehicle emissions and the measured delta concentrations of NO_x and PM are presented in Table 4.7. As for the specific traffic station no data for $PM_{2.5}$ concentration were available, only PM_{10} data are presented below. From the above emissions and delta concentrations, PM_{10} and $PM_{2.5}$ over NO_x ratios are derived, on an hourly basis and are also presented in the Table below.

Table 4.7: Calculated hourly traffic emissions versus monitored average delta concentrations in Ermou St., Thessaloniki

	Emissions (g)					Concentrations (µg/m³)		
Hour	**CO**	**NO_x**	**$PM_{2.5}$**	**$PM_{2.5}/NO_x$**	**CO/NO_x**	**NO_x**	**PM_{10}**	**PM_{10}/NO_x**
01:00	307,2	34,1	1,6	0,046	9,017	46,4	34,3	0,739
02:00	203,8	22,6	1,0	0,046	9,017	40,7	33,7	0,828
03:00	140,9	15,6	0,7	0,046	9,017	41,0	30,7	0,748
04:00	140,8	15,6	0,7	0,046	9,017	36,5	24,9	0,681
05:00	383,6	42,5	2,0	0,046	9,017	30,3	23,2	0,765
06:00	1775,0	177,6	8,9	0,050	9,995	22,3	20,3	0,908
07:00	4101,9	410,4	20,6	0,050	9,995	22,8	21,8	0,954
08:00	5610,0	734,8	47,2	0,064	7,635	29,9	27,8	0,930
09:00	3235,3	316,0	18,5	0,058	10,237	34,8	37,6	1,081
10:00	3629,8	309,1	21,4	0,069	11,745	41,2	45,1	1,093
11:00	2790,1	234,0	16,5	0,070	11,925	37,5	47,3	1,262
12:00	2823,8	240,3	13,9	0,058	11,750	33,8	42,4	1,253
13:00	4419,2	376,1	21,7	0,058	11,750	38,5	32,0	0,832
14:00	5414,8	460,8	26,6	0,058	11,750	41,6	23,2	0,558
15:00	3925,3	334,1	19,3	0,058	11,750	43,0	19,1	0,443
16:00	3775,8	323,7	17,1	0,053	11,666	44,6	16,0	0,357
17:00	3647,1	296,0	15,8	0,053	12,320	42,5	17,6	0,414
18:00	2849,4	217,7	13,5	0,062	13,091	39,3	12,5	0,317
19:00	2714,3	203,7	11,1	0,055	13,323	44,2	8,8	0,199
20:00	2865,8	243,9	14,1	0,058	11,750	43,2	15,1	0,349
21:00	1858,0	158,1	9,1	0,058	11,750	47,3	18,9	0,399
22:00	1168,9	117,0	5,9	0,050	9,995	54,1	24,3	0,449
23:00	831,1	83,2	4,2	0,050	9,995	51,8	30,3	0,586
24:00	451,3	45,2	2,3	0,050	9,995	45,1	32,4	0,717

In Figure 4.4 the hourly variation over the day of the delta concentration ratio of PM_{10} over NO_x is plotted against the calculated emission ratio of $PM_{2.5}$ over NO_x. A complete assessment based on the above ratios can not be realised since no concentration data on $PM_{2.5}$ are available. When compared with the respective emission ratios of Stockholm and Oslo as calculated in the previous sections, the $PM_{2.5}/NO_x$ ratio is considerably higher.

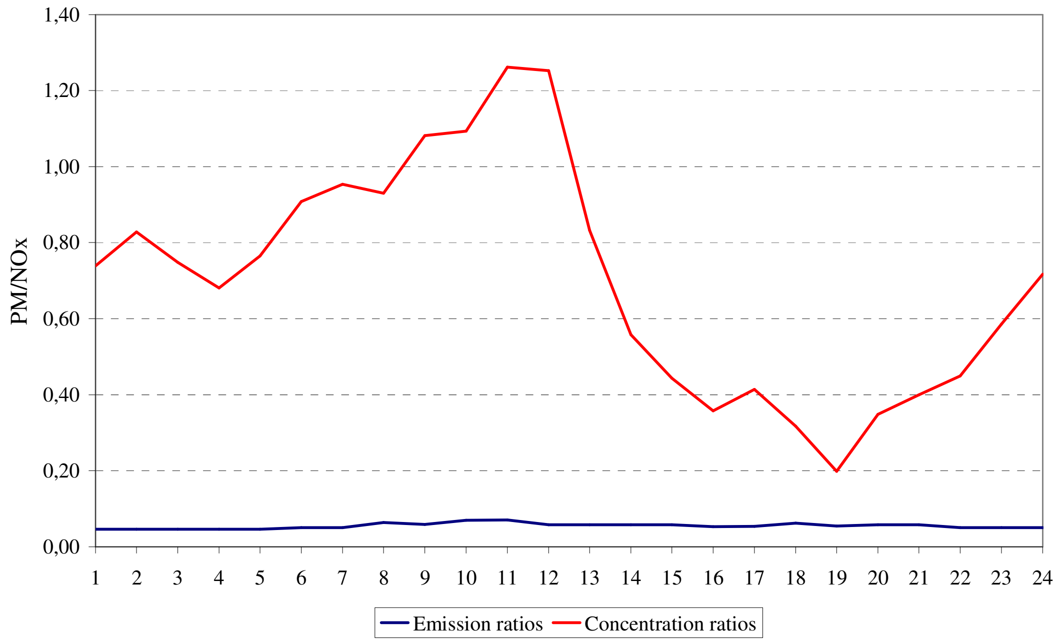


Figure 4.4: Diurnal variation of the average traffic emissions and delta concentrations in Ermou St., Thessaloniki

ETC-ACC Street Emission Ceiling (SEC) exercise

Phase 1 Report

Chapter 5: Review of urban models relevant to the Street Emisison Ceiling Exercise

5.1 Introduction

This chapter aims at reviewing existing dispersion models for application within the SEC-exercise. A large number of models exist for the calculation of air pollution in urban background and hot-spot (in particular street canyon) situations. In this chapter a review of urban and street models as far as relevant for the current project will be given. Considering the main objective of the SEC-project ("what local emisison reduction is needed in an ensemble of streets to reach certain air quality standards in a street") and considering that the health related air quality standards more and more refer to a long-term (annual) period, typical episodic models and models designed for very specific situations will not be discussed.

In general terms, an air quality model can be defined as "any mathematical operation to obtained a desired (air quality) quantity". In this sense models may range from *complex* to *simple*. Complex models are very CPU time demanding models but with increasing computer power they become more popular tools for assessment. Typical examples of complex models at an urban background levels are the 3D- chemical tracer models used within the City Delta project (JRC, 2004). A dynamic link between regional background and urban background is obtained in the so called zooming models. This type of models has the option to have a higher spatial resolution in the urban areas. Especially the models able to have a 2-way nesting are promising for future work. With 2-way nesting, the urban plume in the fine scale nest could be transmitted back into the coarse model domain; in this way impact of photochemical non-linearities in the urban plume on the regional background can be estimated.

A second approach to simulate traffic induced air pollution, is based on the use of different types of models for different scales. Such a modelling system might therefore consist of different models at the regional, urban and street scale. In general terms, the modelling of concentrations at street levels is made in three separate steps. First the regional background concentrations are modelled. These are used as input to a more detailed model covering the urban region. The urban background concentration calculated in this way is used as input for the local, hot spot models. Advantage of this approach is that at each scale a model can be chosen which adequately reproduce the dominant physical processes at that particular scale. Depending on the requirements, models of different complexity can be selected at the various scales. Disadvantage of this approach is that the interface between the models might become complex. A second disadvantage is that the coupling is only one way, from regional to street scale.

The second approach will be followed within the SEC-study. From a scientific point of view the 2-way zooming approach is to prefer as in this case one consistent model is applied at all three scale. However, computer resources are high especially when fine scale nests are used for a number of cities simultaneously. The second approach is more flexible. It offers the possibility to link the regional scale model to specific urban or local scale models depending on the local sitaution. Sensitivity studies, e.g. exploring the impact of abatement measures at urban or street level can be made without re-running the regional scale model.

5.2 Urban background models

In preparing a pan-European assessment of urban air quality, it will be necessary to make comparative assessments for a large selection of cities. It will be impracticable to make a very detailed assessment of the situation in each European city. In this light,

a number of requirements can be formulated for an urban air quality assessment model:

- Computing time per city should be small. This makes it possible to analyse air quality in a broad selection of cities (e.g. all European cities with more than 100,000) allowing for a generalised assessment of European urban air quality. Short computing time is also important for making a more statistical evaluation of exceedances of threshold value using meteorological conditions over a period of 3 to 5 years.
- It is expected that available urban environmental data, both at present and in the foreseeable future, will be limited, especially when considering smaller cities. To be able to run the model for as many cities as possible, the input required for the model should be limited to the most basic data available for most cities, or data which can be generated from national census data. Preferably, input data should be limited to urban emissions, city area, regional background concentrations and meteorological observations.
- The structure of the model should be transparent i.e. simple parameterisations simulating the most important phenomena.

Existing urban air quality models broadly satisfying the restrictions defined above can be subdivided in the following classes:

- Complex, Eulerian 3D-models frequently including a detailed photochemical mechanism;
- Gaussian plume models or numerical chemical plume models;
- statistical and (photochemical) box models.

An example of the application of different type of urban models in a pan-European assessment is given in the AutoOil-2 study. Here the ETC/ACC has applied three easy-to-use models varying from an empirical approach, a Gaussian/Box model and a photochemical model (*de Leeuw et al., 2001*). This experience will be used as guidance for the selection of the urban background model.

5.3 Street models

Over a period of more than 30 years - see e.g. the pioneering work of Johnson et al. (1973) and Nicholson (1975) - models of widely varying complexity have been developed at the local, street level scale. Typical examples of complex models are the 3D Computational Fluid Dynamic models (see e.g. *Ketzel et al., 2002; Sahm et al., 2002*). In this approach the entire flow and concentrations fields within urban canyons of any configuration can be reproduced if the necessary input data is available. CFD models have high requirements regarding computer resources. The Gaussian plume models form an other class of models. In various application a plume model for the direct contribution of traffic emission is combined with a box model to account for the re-circulation within the street canyon (Yamartino and Wiegand, 1986). Based on field experiments, wind tunnel measurements or simulation with complex models, simple empirical models have been developed. This type of models is frequently used for regulatory purposed (see e.g. the CAR-model, *Eerens et al. 1993).*

A recent review of street models has been prepared by Vardoulakis et al. (2003). In this review almost 50 operational street models are listed. A collection of operational street model is available from the Model Documentation System developed by the ETC/ACC (2004). It allows the selection of models according to selection criteria. Restricting the search to models able to calculate concentrations from traffic

emissions (unstructured search on one of the words *street, traffic* or *roadside*) results in a selection of about 30 models. Clearly there is an overwhelming choice in models which all might be applicable with the SEC-project. For a further selection of the models a intercomparison study has been proposed. At one hand such an intercomparison may demonstrate that various models are operational in Europe that can reflect the reality at street hotspots. Using the results of the intercomparison study, it can be evaluated whether a robust and reliable easy-to-use model exists for the general application with SEC. If a suitable model is not yet available, the intercomparison wil provide valuable information for constructing such a model from the more complex models.

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ETC-ACC Street Emission Ceiling (SEC) exercise

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Chapter 6: Air Quality Modelling

6.1 Introduction

In order to estimate the concentrations at a street level, urban background concentrations and the street contribution (traffic data) are required. The object of this subtask is twofold. Firstly to apply simple street scale models and demonstrate their applicability across a number of cases using the same sets of data collected within the framework of this task and secondarily to demonstrate the applicability of the regional-urban-street scale model cascade approach which will enable the street scale to be considered in the overall IA modelling. The data available in 2003 allowed for two case studies. For the Thessaloniki case study the complete model cascade was applied, as an urban emission inventory was available. For the Stockholm case study, the urban background concentrations were obtained from an appropriate monitoring station which provided the necessary input for the street scale models. In both cases, the street scale modelling was performed using the Operational Street Pollution Model (OSPM) model (*Berkowicz et al., 1997*) and the CAR model (*Wesseling J. et al., 2002*), whereas the urban scale modelling was performed with the Ozone Fine Structure (OFIS) model (Moussiopoulos and Sahm, 2001, Sahm and Moussiopoulos, 1999) using EMEP model results (URL1) for the boundary concentrations. The street emissions were calculated using COPERT III methodology and local traffic data (see chapters 3 and 4).

6.2 The OSPM and OFIS model application

6.2.1 Thessaloniki, Greece

Street level concentrations of NO_2, NO_x, CO and O_3 in Ermou street, Thessaloniki were calculated for 2001 using the OSPM model. The urban background concentrations required by the street scale model were obtained through the application of the OFIS urban scale model. EMEP model results for the year 2000 were used as boundary concentrations and the meteorological data were derived from a representative station in the Thessaloniki area (Kalamaria station). The urban scale emission inventory does not currently include PM_{10} emissions and thus the concentrations for this pollutant were not computed. The local contribution to emissions was estimated using COPERT III methodology and the local traffic data (diurnal variation, fleet composition, average vehicle speed, etc.).

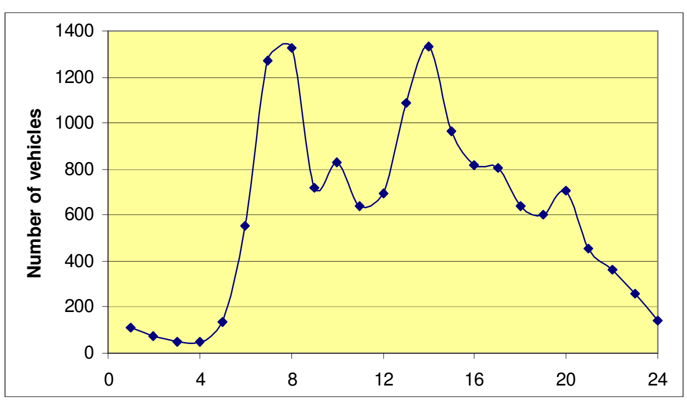

Figure 6.1: Diurnal variation of the traffic data in Thessaloniki

In Figure 6.1, the diurnal variation of the traffic data for Ermou street is presented. In Figure 6.2 the model results for NO_2, NO_x CO and O_3 (OFIS and OSPM) are compared with corresponding values from the traffic (street level) monitoring station.

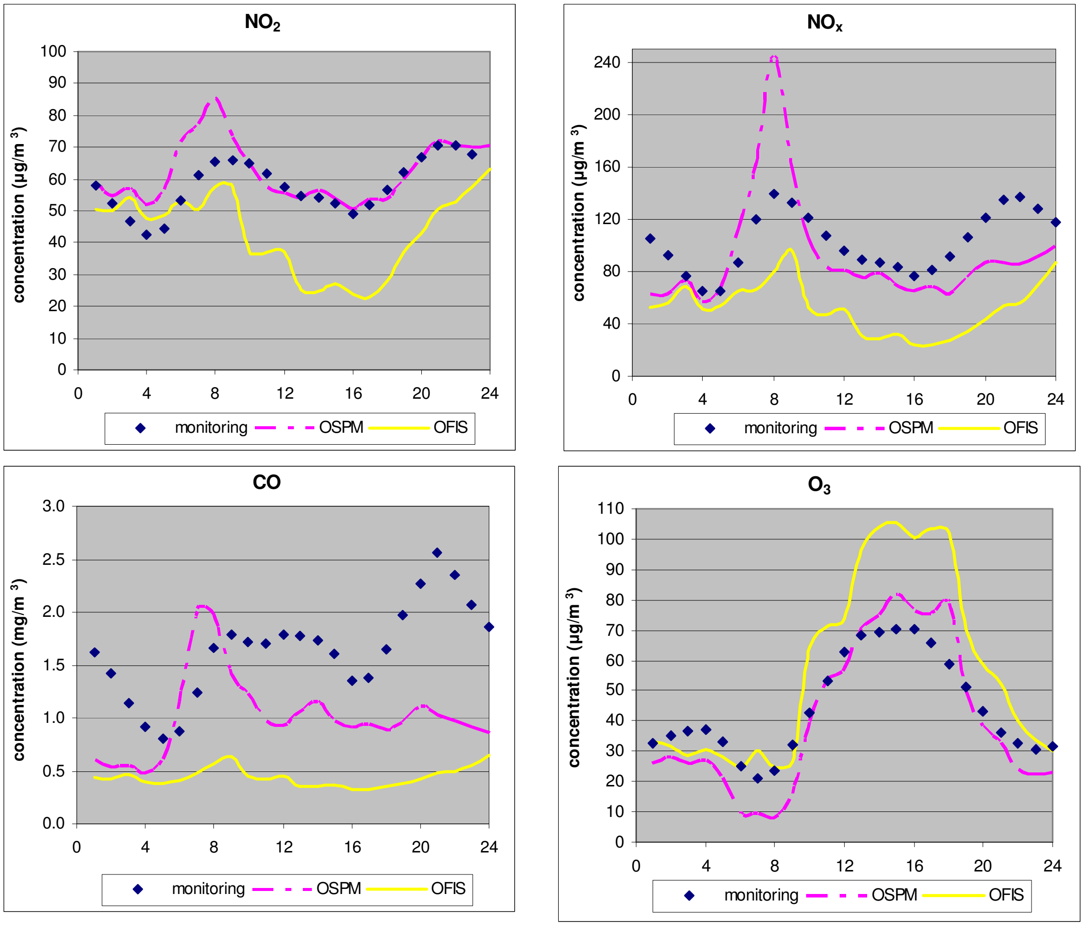

Figure 6.2: Results of OSPM for the mean hourly NO_2, NO_x CO and O_3 concentrations at street level in Ermou in 2001 compared with observations

In Figure 6.3 the monthly variation of the model results for NO_2, NO_x, CO and O_3 (OFIS and OSPM) are compared with corresponding values from the traffic (street level) monitoring station.

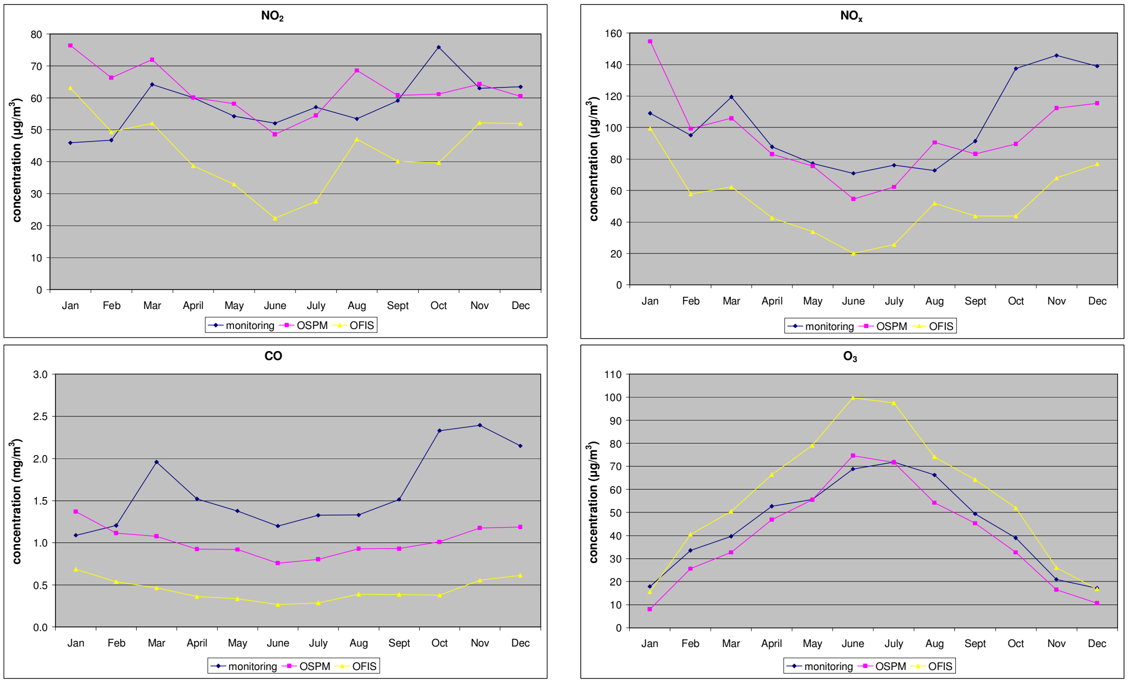

Figure 6.3: Results of OSPM for the monthly variation of NO_2, NO_x CO and O_3 concentrations at street level in Ermou in 2001 compared with observations

Overall, the OSPM results provide a good impression of the observations. The results for CO are less satisfactory and generally underestimated. The evening peak observed in the diurnal variation of the CO monitoring data may perhaps be due to erroneous measurements and is under investigation. For NO_2 the results are very close to the observations. For O_3 the modelled results are very close to the monitoring data which can be explained by the fact that O_3 titration caused by NO emissions from cars reduces the background concentrations at street level.

6.2.2 Stockholm, Sweden

Street level concentrations of $PM_{2.5}$ and NO_2 in Hornsgatan were calculated for 2000 using the OSPM model. Urban background was assumed to be properly described by the data from the corresponding monitoring station. Emission data were computed using COPERT III and the local traffic data. It should be noted that these emission data account for the $PM_{2.5}$ exhaust emissions of diesel vehicles only.

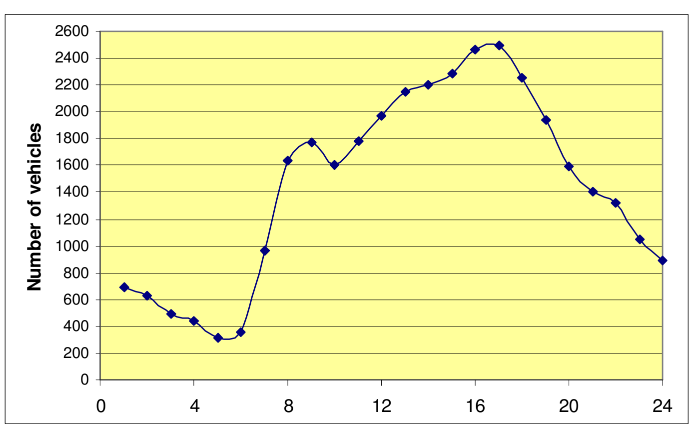

Figure 6.4: Diurnal variation of the traffic data in Hornsgatan

In Figure 6.5, the OSPM results for the mean hourly concentrations in 2000 are compared with corresponding values from the traffic (street level) monitoring station.

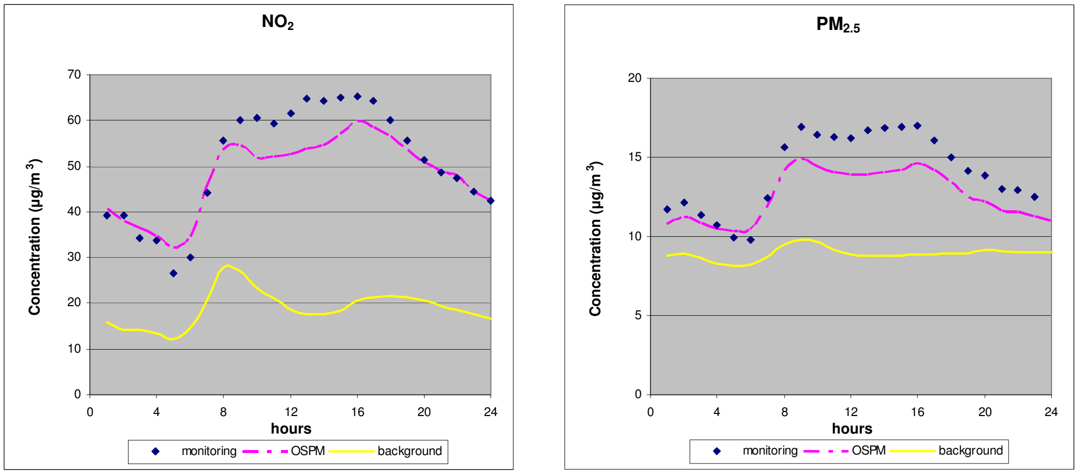

Figure 6.5: Results of OSPM for the mean hourly NO_2 and $PM_{2.5}$ concentrations at street level in Hornsgatan in 2000 compared with observations

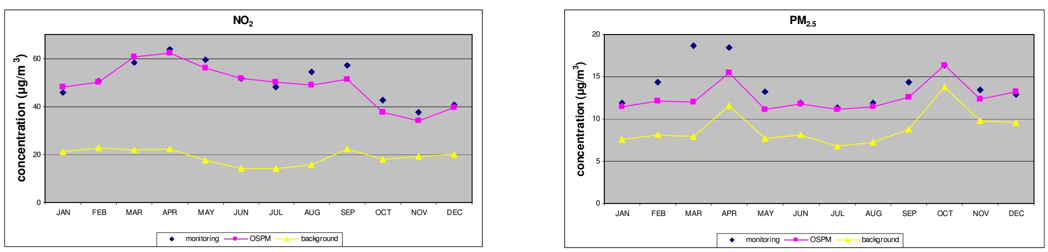

Figure 6.6: Results of OSPM for the monthly variation of NO_2 and $PM_{2.5}$ concentrations at street level in Hornsgatan in 2000 compared with observations

Overall, the OSPM results provide a good impression of the observations. The slight underestimation for $PM_{2.5}$ may indicate that emission sources other than diesel vehicles (e.g. contributions of gasoline vehicles and road dust resuspension) should be taken into account in the calculations. The underestimation of NO_2 concentrations is under investigation.

6.3 The CAR II model application

Calculations with the Dutch street canyon model CAR II have been done only for Stockholom because the model is not applicable to the Thessaloniki site (at a street junction and between traffic lanes) This section gives some information about the CAR II-model, the calculations, the measurements and the comparison between calculations and measurements. The comparison is made for NO_2 and PM_{10}.

6.3.1 CAR II model

The CAR-model is a simple parameterised and an easy to use model for the determination of the air quality in streets. The model calculates the contribution of the road traffic to air pollution based on the emission from the traffic, the street type, the distance to the road

axis and the yearly averaged wind speed and for NO_2 the background concentrations of NO_2 and ozone.. The model is uses average traffic intensities and yearly averaged wind speed. Using simple relations the model also calculates the number of exceedances of the numerical value of the hourly limit value of NO_2 and the daily limit value for PM_{10}.

6.3.2 Measuring locations

The street used for the comparison is the Hornsgatan in Stockholm (Sweden), which is classified for CAR II as a street canyon. The measuring site is around 10 meters north of the street. For the other street location, Agia Sofia in Thessaloniki, no calculations could be done because the measuring point is situated on the pavement in the middle of the street, a situation for which the CAR II model is not suitable; the model is designed to give an estimate of the concentration on the side (pavement) of the street, not at the centre of the road. Furthermore, CAR II it is not applicable to a street junction like the Thessaloniki situation. This is in accordance with the provisions in the European air quality directives, which exclude sites close to major street junctions.

The background concentrations were derived from the data of nearby urban background station. The measured street and background concentrations are given in the table below.

Table 6.1: Annual averaged NO_2, PM_{10}, $PM_{2.5}$ and O_3 street and background concentrations (µg/m^3)

		NO_2	PM_{10}	$PM_{2.5}$	O_3
Stockholm	Background	18.3	-	8.3	45.7
	Street	50.4	-	14.0	-

Traffic emission

In standard applications, the traffic emission of pollutants in the street is calculated from traffic data by the model. For the comparison in this study the emission of the traffic in the street were calculated with the COPERT model, see Chapter 4.

6.3.3 Comparison measurements and calculations

Based on the information provided, the concentrations in the street have been calculated (see Table 6.2).

Table 6.2: Measured and calculated NO_2 and PM concentrations (µg/m^3)

		NO_2	PM_{10}	$PM_{2.5}$
Stockholm	Measured	50.4	-	14.0
	Calculated	42.9	-	14.0

The calculated $PM_{2.5}$ concentration is Stockholm corresponds very well with the measured concentration. The calculated NO_2-concentration in the Stockholm street is lower than the measured concentration. This seems to be caused by the expression used to convert locally generated NO_x to NO_2, because the calculated NO_x concentration is in good agreement with the measured NO_x concentration (not presented here). In the case presented here the model underestimates the annual averaged NO_2 concentration by 15%.

6.4 Conclusions

The first model results for the two case studies show that the concentrations measured at street level can be satisfactorily reproduced by using either background concentrations and a street scale model or a suitable multiscale model cascade. In principle the model cascade EMEP-OFIS-OSPM has been successful. Further data collection and model applications for a number of cases is planned for 2004, using other street scale models such as the EPISODE model suit or the ROADAIR model (URL2). This will enable an inter-comparison of the results and the tools used.

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Concluding remarks

The results from the various tasks of the Street Emission Ceilings exercise summarised in the present report show the feasibility of the approach selected for quantifying the contributions of street scale emissions to the pollutant concentration levels at hotspots. For demonstrating the usefulness of the approach with regard to policy related applications it is necessary to extend it to more urban areas and additional street canyon situations in individual cities. The involvement of further modeling groups in the exercise would also be beneficial for its success. Full account of all these aspects is taken in the work for the Street Emission Ceilings exercise planned within the 2004 subvention of ETC/ACC.

ANNEX A

Index outlining projects and case studies

<u>Air Pollution in Europe report 1990-2000</u>

http://reports.eea.eu.int/topic_report_2003_4/en
<u>*Authors*</u>
S. Larssen (Ed.), M.L. Adams, K.J. Barrett, M.vh. Bolscher, F. de Leeuw and T. Pulles

<u>*Objectives*</u>
The report assesses the air pollution situation in Europe in the year 2000, particularly in the 31 EEA member countries and its evolution since 1990 in relation to developments in the main economic sectors.

<u>*Key Findings*</u>
Among other finding, those of interest to this review are related to air quality in Europe and the relationship between the decreasing pollutant emissions and the observed concentrations. In the year 2000 concentrations in many areas and locations in Europe were higher than the EU Air Quality directives limit and target values, to be met by 2005–2010. An overall decrease in the concentrations of PM_{10} and NO_2 is observed. The result of the analysis of a consistent set of monitoring stations reveals that:

- For PM_{10} the annual average concentration, relevant to the EU limit value, decreased by 16–18 % between 1997 and 1999, but between 1999 and 2001 concentrations stabilised (and even slightly increased); the daily average concentration relevant to the EU limit value decreased between 1997 to 1999 by about 21 %, with little change between 1999 and 2000.
- For NO_2 the annual average and hourly concentration relevant to the EU limit value decreased by about 15 % since 1996, with some interannual variations including a peak in 1997.

The influence of meteorological conditions on the interannual variations has not yet been analysed.

<u>AIRESUND:</u> A Multidisciplinary Research School on Travel Patterns – Traffic – Air Quality – Health Impact in the Öresund Region (2001), Denmark

<u>*Partners*</u>
Centre for Environmental Studies, Lund University; Institute of Geography, University of Copenhagen; Department of Traffic Planning, Lund University; National Environmental Research Institute, Denmark; Institute of Public Health, University of Copenhagen; Traffic Research Centre, DTU; GIS Centre, Lund University; Department of Physics, Lund University

<u>*Objectives*</u>
The general aims of the programme were to: (a) provide an improved understanding of the dynamic links between population distribution, traffic, air quality, health impacts and societal responses related to air pollution; (b) based on this understanding, to provide scenarios for the future sustainable development of the region in order to assist efficient regional air quality management and physical planning; and (c) create a multi-disciplinary research school in the Öresund region, in which the above research will be carried out in order to establish a more creative

research milieu based on multi-disciplinary thinking and bridging gaps between natural and social sciences.
The research linked a number of key research groups in Denmark and Sweden in order to form a unique competitive research environment. The uniqueness stemmed from the fact that the research school has a strong focus (traffic – air pollution – health – responses) and at the same time a broad approach capable of finding comprehensive solutions to complex problems. In this context, some of the subprojects aimed at: (a) investigating (for different parts of the street network) the relationships between (different aspects of) traffic volume on the one hand, and driving patterns on the other, and the effect this relationship has on emission and fuel consumption factors; and (b) to assist in the development of a fully functional bottom-up emissions database. Emission categories included were gases, particles, noise, and congestion. Focus was on particles due to the emerging indications that that play a major role for health impacts from air pollution.

Expected Findings
Modelling tools that will be developed and evaluated within AIRESUND will be able to provide results covering the variety of the relevant parameters, and with an accuracy and spatial/temporal resolution adequate for health effect studies. By linking these results with those from other subprojects in AIRESUND (the regional air quality model and drivers' route choice behavior model), a better understanding of how environmental (airborne) problems caused by traffic in the Öresund region may be reduced through the introduction of different road pricing scheme *(Olsson et al., 2001)*.

AOPI: AUTO-OIL PROGRAMME I (1994 - 1997)

Objectives
The aim of the project was to use oil industry and motor manufacturing expertise to determine the most cost effective way of ensuring that pollution from motor vehicles didn't lead to air quality problems that would damage human health. One of the key goals was to make accurate predictions of traffic emissions for scenarios in the year 2005 and 2010 for a number of European cities (Dublin, London, Utrecht, Cologne, Berlin, Milan, Madrid, Athens, Lyon and Helsinki – "the auto-oil cities") and to collate a vast array of data on the comparative emissions of different formulations of petrol and diesel collected from both light and heavy goods vehicles.

Key findings
The Auto Oil Programme demonstrated that, despite the introduction of catalytic converters, further significant reductions in the emissions of cars, light goods vehicles and heavy duty vehicles are needed if air quality targets are to be achieved. It was concluded that with regard to CO, by 2005 urban background concentrations in all the cities studied will be below the level of the most stringent air quality standards. With regard to benzene the results indicate a marked improvement in urban background concentrations, but emissions reductions are foreseen to be necessary in a number of the most polluted cities. With regard to NO_x, the air quality modelling results clearly demonstrate that if one uses the more stringent air quality standard (93 $\mu g/m^3$ as a 98% percentile of hourly averages) it will be necessary to make reductions in emissions of up to 50% in the year 2010. With respect to PM, reductions in the range of 50-65% are required in order to meet the air quality standard of 50 $\mu g/m^3$ as a daily

mean in most European cities. As regards O_3, it was found that only when an 80% emission reduction (compared to 1990) of precursors from all sources is achieved, then over 90% of the EU land area is predicted to have a maximum ozone concentration below 180 $\mu g/m^3$. As a result, the Programme concluded that NO_2, O_3 and particulates are the pollutants of greatest concern.
The Programme then identified a range of technologically feasible measures that could be adopted to achieve reductions of these pollutants (or, in the case of ozone, its precursors). These included changes to the vehicles (such as more effective and more durable catalysts), changes to the fuels and changes to inspection and maintenance procedures. The key conclusion was twofold: that long term improvements in new vehicles sold as well as fuels could lead to emissions reductions *(Commission of the EC, 1996).*

<u>AOPII:</u> AUTO-OIL PROGRAMME II (Spring 1997 - 2000)
Led by the Joint Research Centre of the EC
http://europa.eu.int/comm/environment/autooil

<u>Objectives</u>
The aims of the European Auto-Oil II Programme (AOPII) were to make an assessment of the future trends in emissions and air quality and establish a consistent framework within which different policy options to reduce emissions can be assessed. The scope of AOPII included all the main "conventional" pollutants for the period 1990 - 2020 but focused on introducing measures in 2005 which might help meet air quality objectives by 2010 for ten "auto-oil" cities and their nine host countries. It used air quality modelling at regional, urban and local scale (including street canyons) and included a detailed assessment of the full range of potential road transport measures. Furthermore, the emission cost-effect model TREMOVE was also developed to investigate scenarios using emission and traffic data provided (reviewed in section D). A key element to AOPII was the agreement on a base case (or business-as-usual case) which covered all the auto oil cities from 1990 to 2020, all emission sources and 6 conventional pollutants plus CO_2. Within the base case a more detailed road transport base case was also developed which included historic and projected data for transport demand, activity levels and transport system costs. Finally, street canyon modelling was performed for two cities Berlin and Milan to assess air quality at the local scale.

<u>Key findings</u>
The AOPII base case predicted significant reductions in emissions of all the conventional pollutants over the period 1990 – 2020, typically between 40% and 50%. The reductions were expected to occur predominantly in the combustion of energy and road transport sectors. In the road transport base case, emissions were predicted to fall by 70% to 80% between 1995 and 2010 and to fall further as new EURO IV technologies continued to enter the marketplace from 2005 onwards. Furthermore, road transport emissions were expected to take a diminishing share of total EU and national emissions. However, CO_2 emissions from road transport were expected to be 10% to 15% higher in 2010 than in 1995.
With regard to air pollution modelling in Berlin and Milan, the modelling of PM_{10} was subject to a number of important uncertainties such as emission inventories, concentration field measurements and the modelling of secondary PM. The results for 2010 suggested that of the targeted pollutants, neither CO_2 nor Benzene would pose

challenges for the auto-oil cities but that exceedences of the PM objective would be more widespread in more than half of the auto-oil cities. Finally, it was revealed that another major obstacle to improving the air quality was the local climatic conditions which could impair the effectiveness of emission reductions for reactive pollutants *(Commission of the EC, 2000).*

APPETISE: Air Pollution Episodes: Modelling Tools for Improved Smog Management (2000 - 2003)
http://www.uea.ac.uk/env/appetise/external/index.html

Partners
Anglia Polytechnic University, Cesky Hydrometeorologicky Ustav, FMI, Academy of Sciences of the Czech Republic, University of Sheffield, UFZ, Universita degli Studi di Catania, University of East Anglia, University of Kourio

Objectives
The over-arching objective of APPETISE is to trial a variety of advanced statistically based data mining and modelling techniques in application to air quality modelling. Data collected from 20 different towns or cities are being used. The idea is to overcome some of the current problems of knowing which modelling approach is best for which type of local conditions/environment. APPETISE will concentrate upon addressing the key pollutants surface ozone, NO_x, SO_2 and PM.

Key findings
The model inter-comparisons, the statistical and deterministic methods together with models that use linear and nonlinear equations, neural networks and cluster analysis, have resulted in the production of weekly, monthly and yearly pollution data for: PM_{10}, SO_2, O_3, NO_2 and weekly, monthly and yearly meteorological data for: sea level, wet and dry temperature, rainfall, wind speed and direction, cloud cover and visibility for the cities of Belfast and Wattisham in the UK and other city databases are to be developed.

ARTEMIS: Assessment and Reliability of Transport Emission Models and Inventory Systems (Winter 2000 – Summer 2003)
http://www.trl.co.uk/artemis/

Objectives
The goal for the road tunnel studies in ARTEMIS is the validation of fleet weighted emission factors which are based on the ARTEMIS database for vehicle category specific emission factors, which are based in turn on chassis dynamometer tests.

Expected findings
Particular attention is given to the NO_x emissions of heavy duty (diesel) vehicles (HDV) since several tunnel studies of the last few years suggested a large under-prediction of the NO_x emissions of HDV by the emission models. The determination of 'real world emissions' in the tunnel study will be based on statistical modelling. Initially the method yields an average emission factor for the whole fleet operating in the tunnel. Subsequently this factor is disaggregated for different classes of vehicle (e.g. passenger cars, HDV etc.) using statistical models.

ATREUS – Advanced Tools for Rational Energy Use towards Sustainability (August 2002 – August 2005)
http://aix.meng.auth.gr/atreus/

Partners
AUT/LHTEE, CNRS/ECN, MIHU, DNMI, UCAM-DENG, EMAC/UA, TNO

Objectives
ATREUS aims to bring together the knowledge that has been developed on the parameters determining the micro-climatic environment around buildings and to further expand on and use this knowledge to optimise the heating and ventilation of buildings as well as to maximise benefits from renewable energy sources and soft technologies such as passive cooling. Current research work utilises specialised computational fluid dynamic codes and numerical weather prediction models, data from field measurements and experiments, data from wind tunnel experiments, and applies numerical simulation models to deduce the energy behaviour of buildings.
The principle objectives include: a study of the urban energy budget taking into account the local and microclimatic conditions, acquiring knowledge on wind flow modifications by urban structures, their geometry and dimensions, the development of city maps to allow the determination of optimum arrangements of groups of buildings to optimise the exchange processes for an area of the city or for the city as a whole, a study of the flow and turbulence characteristics within a street canyon with special emphasis in the boundary layers of building walls and roofs as well as low wind speed conditions around buildings, an evaluation of the wind field around buildings, a determination of the exploitable RES potential on urban areas and a determination of the heating and cooling loads of buildings and their impact on the urban microclimate.

Expected findings
The expected impacts of ATREUS include: the creation of an inventory of the available experimental data, the addition of new field and wind tunnel measurements, the definition and simulations of synoptical scenarios at the mesoscale, an evaluation of the wind-field around buildings, an evaluation of the thermal convection around buildings and the impact on ventilation and heating of the buildings, optimised modelling methods, a comparison of evolved numerical model results and field measurements and a scrutiny of existing and evolved models.

Berlin, Germany: Application of the urban scale photochemistry model MICRO-CALGRID (MCG) (1995 data)
This project contributed to AUTO OIL2

Objectives
The aim of the study was to develop a 3D microscale photochemistry model inclusive of traffic-induced turbulence effects and to compare base runs with meteorological data from a busy street canyon in Berlin in 1995. The model developed aims to incorporate 3D microscale atmospheric flow and turbulence fields from the flow model MISKAM, emission data from the traffic-related emission model MOBILEV and to include the effects of traffic fleet composition variability and to generate data for comparison with the Berlin field measurements.

<u>*Key findings*</u>
The concentration patterns were simulated for a 5-day period winter episode, adjusted for background meteorological conditions. The overall behaviour of all measured pollutants (CO, NO, NO_2, benzene, SO_2 and TSP) were well reproduced by the model. NO_2 performance was excellent using simpler analytic chemistry for NO, NO_2 and O_3. The inclusion of vehicle-induced turbulence was found to generally reproduce concentrations and led to improved model results *(Stern and Yamartino, 2001.)*

<u>Brno, Czech Republic: A modelling study to investigate the influence of traffic and meteorology on pollutant dispersion (March 2001)</u>

<u>*Objectives*</u>
The principal aim of this study was to establish the influence of traffic in specific urban situations like area around road tunnel openings, street canyons and intersections and to predict the influence of different traffic and meteorological conditions on the dispersion of pollutants at the microscale. The model used a Eulerian-Lagrangian method that was developed for road tunnels in 1998 and 1999 *(Jicha et al. 2000)* which has been further extended and modified for pollutant dispersion in street canyons and crossroads. The method is based on CFD (Computational Fluid Dynamics) modelling and accounts for moving vehicles. The model was applied to real situations at city intersections that had a regular geometry of 4 storey buildings and in street canyons having two way traffic in double lanes. The data on the traffic obtained included: the number of cars that stop in one street canyon at a red light and the number of cars passing in the other street canyon, length of car line waiting at a red light, the stopping distance and driving distance of cars to a terminal speed, the traffic light sequence and timing of stop-and-go of traffic lights and the composition of the fleet of vehicles.

<u>*Key findings*</u>
The main conclusions were that traffic dynamics at very low wind velocities significantly influence the flow field and thus results in a very different array of ground concentrations. Comparison with measurements shows that the time average values are in a very good agreement. The measurements show an average value of 70 ppb NO_x and the predicted value is approximately 82 ppb.

<u>Budapest, Hungary: A source-receptor modelling study using ADMS (since 1997)</u>

University of Budapest and NOAA

<u>*Objectives*</u>
The aim of this study was to characterise sources and to use receptor modelling with ADMS applied in connection with field measurements in order to provide quantitative estimates of source contributions to ambient air PM. A further goal was to assess the temporal variation of particle concentrations based on measurements conducted during several years.

Key findings
It was found that regarding the traffic profile, the most important element is still Pb, however its relative contribution has decreased rapidly during the past five years *(Bozó et al. 2001).*

City-Delta Project (2002 - 2004)

http://rea.ei.jrc.it/netshare/thunis/citydelta/

Objectives
The objectives of the project are inter-comparisons to assess the performance of available models and compare them against available observational data, to use data to assist air-quality managers in quantifying the contribution of regional versus local sources and in identifying and assessing the most effective emission controls.

Expected findings
It is expected that emission data, meteorological information and background concentrations will be collected for 4 major European cities: Paris, London, Prague and Berlin. The local scale model intercomparison exercise is expected to yield important results regarding the validation of models against given quality assured datasets.

CLEAR: Cluster of European Air Quality Research (2002 – 2005)

http://dev.allez.no/clear/

Partners
ENEA, DMI, EUROCITIES, NCSRD(Greece), NILU, University of West of England, University of Birmingham, NERI, EC, University of Hertfordshire, TNO, AUT/LHTEE, FMI

Coordinating projects
ATREUS, FUMAPEX, INTEGAIRE, OSCAR, SAPPHIRE, ISHTAR, URBAN AEROSOL, URBAN EXPOSURE

Objectives
The overall aim of CLEAR is to improve the scientific understanding of urban air pollution and to provide next generation tools for end users and stakeholders to manage air quality in cities. The main objectives are to significantly increase the understanding of sources and processes so as to provide end users and other stakeholders with next generation tools and methodologies for assessing the impacts of indoor and outdoor air pollutants in urban areas, to improve the capability of identifying suitable impact reduction options to improve urban air quality in line with major European initiatives such as CAFE and to enhance the interface between air quality science and technology and urban governance, end users and the citizen thereby optimising local decision making.

Copenhagen, Denmark: Source apportionment of fine and ultrafine particles (winter/spring 1999)

Objectives

The aim of the study was to quantify the emissions of ultrafine particles from diesel and petrol vehicles separately with respect to number and size distribution to assist exposure estimate models. Measurements were performed in Jagtvej street canyon in central Copenhagen which is a 10m wide, 2-lane road having a traffic density of 26,000 vehicles per day and a 6-8% heavy vehicle fraction. Measurements were made with a DMA and particles were separated into 29 size fractions from 0.01 to 0.7 µm as well as half-hourly measurements of CO and NO_x.

Key findings

Significant correlation at street level was observed between CO, NO_x and ultrafine particles indicating that traffic is the major source of ultrafine particles in the air. However, differences between CO and NO_x were observed related to differences in the diurnal and weekly traffic patterns of petrol and diesel vehicles and their different fleet compositions. Higher levels of diesel traffic were found to shift the peak of the particle distribution to smaller sizes. The absence of a known value for the CO/NO_x ratio meant that it was not possible to apportion the sources for petrol and diesel traffic separately *(Wahlin et al., 2001a).*

Copenhagen, Denmark: Characterisation of particle emissions from the driving car fleet and the contribution to ambient and indoor particle concentrations (2000-2003)

Partners

National Environmental Research Institute, Roskilde, Denmark; National Institute of Occupational Health, Copenhagen, Denmark; Danish Building and Urban Research, Hørsholm, Denmark; Riso National Laboratory, Roskilde, Denmark; Joint Research Centre, Ispra, Italy; Physics Department, Division of Nuclear Physics, Lund University, Sweden

Objectives

The main goals of the four-year project on particle studies were: (a) to characterise the geographic and temporal variability in particle composition and size distributions in Danish ambient air; (b) to determine particle emission factors for various vehicle categories; (c) to determine indoor - outdoor relationships for buildings in busy streets; and (d) to determine the role of traffic emissions in formation of indoors particulate irritants.

Most of the measurements in these studies were performed in central Copenhagen in a street canyon, Jagtvej, which is a 10 m wide main road and during rush hours in practise a four lane road. Both sides of the roadway are bicycle lanes and pavement. In addition, Jagtvej is lined on both sides by 5 - 6 storey buildings. The traffic density is 26 000 vehicles per 24 h, including 6 – 8 % heavy vehicles, i.e. buses, lorries and larger vans. A fixed monitoring station of the Danish Air Quality Monitoring Programme has been in operation at this location for many years. Data from this station include half-hour measurements of NO_x, CO and other traditional pollutants. In addition, 24 h particle filter samples were collected of TSP (Total Suspended Particulates) and PM_{10}. Average weekly cycles of particles, NO_x and CO street level concentrations for the entire measurement period were used for the analysis.

Key findings

A clear diurnal variation of the three parameters with a sharp rush hour peak in the morning and another rush hour peak especially for CO during the afternoon was observed on workdays, at both street stations. The pattern is different on Saturdays and Sundays. Although the correlation between particles, NO_x and CO is generally good, some deviations were observed. These differences can be related to differences in the traffic patterns of petrol and diesel vehicles (diesel taxies compared with other traffic peak at night, petrol cars during rush hours). Traffic was the dominating source of ultrafine particles in busy streets, but contribution to PM_{10} was also significant. The shapes seemed very similar with a peak of the size distribution at 20 nm. Small differences exist with shifts to larger sizes in the spectra collected at the urban background location, indicating some growth of the particles or large contributions from other sources. The application of averaged PM data, collected continuously, in combination with routine monitoring data and manually counted traffic rates, were found to be a powerful tool to determine contribution and emission factors of particles from diesel and petrol vehicles from the actual car fleet under normal driving conditions in cities *(Palmgren et al., 2003).*

Copenhagen, Denmark: Particle and trace gas emission factors under urban driving conditions based on street and roof-level observations (2001)

Department of Atmospheric Environment, National Environmental Research Institute, Roskilde, Denmark; Physics Department, Division of Nuclear Physics, Lund University, Sweden

Objectives

Simultaneous measurements of particle size distribution (size/range 10–700 nm) inside an urban street canyon and a nearby urban background location in Copenhagen in May-November 2001 were used to separate the traffic source contribution in the street canyon from the background levels. The method of inverse modelling was applied to estimate average fleet emission factors typical of urban conditions in Denmark. The effect of different sources and formation mechanisms on the size distribution was also examined and diurnal and weekly trends of ultrafine particle concentrations and trace gases were demonstrated.

Key findings

The background concentrations are highly variable due to changing contributions from long-range transport and local sources showing a diurnal pattern with a shift to smaller particle sizes during midday hours. The average ratio background/street concentration is 0.26 for NO_x and 0.35, 0.42, 0.60, 0.64, respectively, for CO, total particle number (ToN), surface and volume.

The particle size distribution of the traffic source shows during daytime and evening hours (6–24) a maximum at particle sizes of 20–30 nm, independent of the changing heavy-duty vehicle share during the same time interval. The particle number concentration highly correlated ($R > 0.83$) with NO_x through a wide range of particle sizes. Emission factors per average vehicle were estimated as $(2.8 \pm 0.5) \times 10^{14}$ particles/km, (1.3 ± 0.2) g NO_x/(veh km) and (11 ± 2) g CO/(veh km).

Two types of 'nanoparticle events' were observed (a) in background, probably due to photochemistry and (b) in the night hours when traffic is dominated by diesel taxis. During night hours (0–5), the maximum in the emitted particle size distribution is shifted to smaller sizes of about 15–18 nm. This shift to smaller particle sizes is

related to an increase in the average NO_x and ToN emission per vehicle by a factor of 2–3 and a reduced CO emission also by a factor of 2–3 *(Ketzel et al., 2003).*

Copenhagen, Denmark: Actual car fleet emissions estimated from urban air quality measurements and street pollution models (1997)

National Environmental Research Institute, Roskilde, Denmark; Main Geophysical Observatory, Kurbysheva, St. Petersburg, Russia

Objectives

The main objective was to develop a method to determine emissions from the actual car fleet under realistic driving conditions. The method was based on air quality measurements, traffic counts and inverse application of street air quality models. Determination of the emissions of NO_x, benzene and CO in a street in Copenhagen has been used to demonstrate the method. Especially for benzene, as there is an increasing concern about the role of VOCs in air pollution and their adverse health effects.

Key findings

Significant correlation was observed between VOCs and CO concentrations, indicating that the petrol engine vehicles are the major sources of VOC air pollution in central Copenhagen. Hourly mean concentrations of benzene were observed to reach values of up to 20 ppb, what is critically high according to the WHOs recommendations.

The inter-annual trends of the contributions from different vehicle categories to the total emissions of NO_x, CO and benzene show that the relative contribution from heavy traffic trucks and buses to NO_x emissions increases with increasing percentage of passenger cars equipped with catalytic converters. The contribution of the diesel traffic to CO and benzene emissions is, on the other hand, small.

Comparison of the estimated emission factors with literature data shows good agreement for NO_x. However, CO and especially benzene emission factors are larger than given in the literature. Concerning CO emission factors, the higher value could be due to different driving conditions, which are known to strongly influence the CO emissions. The much higher emission factor of benzene is mainly due to the higher content of benzene in the Danish petrol and partly to the driving conditions *(Palmgren et al., 1999).*

Elimäki, Finland: A local scale field campaign (1995)

Graz University of Technology, Austria, and FMI

Objectives

This local scale field campaign in a roadside environment in Elimäki in Southern Finland aimed to develop a dispersion dataset suitable for the evaluation of a street scale Gaussian finite line source dispersion model (CAR-FMI) and a Lagrangian dispersion model (GRAL). The dispersion of NO, NO_2 and O_3 was investigated on both sides of a road at 3 locations and 3 vertical elevations and found to be dependent upon traffic densities and relevant meteorological parameters.

Key Findings

At wind speeds lower than approximately 2 m/s, there are excessively high predicted concentrations compared with the measured data. Model performance deteriorates for

situations with the lowest wind speeds possibly due to plume meandering. Both models were found to underestimate concentrations in the and non-parallel wind directions *(Kukkonen et al. 2001b, Ottl et al. 2001).*

ENV-e-CITY: ENvironmentally Viable electronic CITY (2002 - 2003)
http://www.env-e-city.org/

Partners
AUT/LHTEE, FMI, Environmental Software and Services, NIAR, IES, ERPI, Forschungsinstitut fur Anwendungsorientierte Wissensverarbeitung (Germany), NORGIT Senteret AS (Norway), German Institute of Energy Economics and the Rational Use of Energy, Ingenieurburo, Belgian National Institute of Public Health and the Environment

Objectives
ENV-e-CITY's objective is to develop an internet-based application for environment information related services. The e-content domain extends over four environmental application areas: air emission, air quality, topography and meteorology. Once ENV-e-CITY is in place, it will serve as a shell for hosting and
organising all available environmental information in a multi-layer way where a number of raw data, meta-
data, and basic services will be combined and structured under a modular framework. Among others, ENV-
e-CITY will provide user friendly interfaces for air quality (AQ) models, air emissions calculations, city
AQ data ranking and benchmarking, cost calculation tools and on-line shopping tools.

Expected findings
The overall system is expected to facilitate access to data and provide tools related to air emissions, air quality, topography and meteorology, needed for environmental impact assessments.

A European aerosol phenomenology
A study conducted by the Joint Research Centre of the EC

Objectives
The study aimed to synthesize data from 34 sites in Europe on PM physical and chemical characteristics at free troposphere, natural, rural, near-city, urban and street sites during the past decade including PM_{10} and $PM_{2.5}$ mass concentrations, chemical compositions and particle size distributions from monitoring networks such as EMEP and EUROAIRNET. Furthermore, it had as a goal a study of the sources of aerosols, their effect of human health and their role in the radiation balance of the atmosphere and an investigation into how they could be used to validate atmospheric models.

Key findings
Background annual PM_{10} and $PM_{2.5}$ mass concentrations for Europe are 7.0 ± 4.1 and 4.8 ± 2.4 μg/m^3 from natural and long range transport of anthropogenic particles. The EU 2005 annual average PM_{10} standard of 40 μg/m^3 is exceeded at a few sites and the EU 2010 annual average PM_{10} standard of 20 μg/m^3 and the $PM_{2.5}$ standard of 15

μg/m^3 is exceeded at ALL near-city, urban and street sites monitored. It was found that there is neither universal ratio between PM_{10} and $PM_{2.5}$ mass sizes nor any correlation between PM values and total particle values or chemical composition. Traffic is responsible for the high concentrations of PM_{10} and $PM_{2.5}$ concentrations in urban areas either from resuspended coarse fraction dust at street level or by contributing VOCs and nitrates in the fine and coarse fractions of the aerosol in the urban background. These levels are even higher in winter due to reduced mixed boundary layer height and greater condensation in the particle phase. Sulfates and organic matter are the two main contributors to PM while black carbon contributes only 5-10% to $PM_{2.5}$ and 15-20% to PM_{10} *(Putaud et al. 2003).*

FUMAPEX: Integrated systems for forecasting urban meteorology, air pollution and population exposure (2002-2004)
http://fumapex.dmi.dk/

Partners
DMI, German Weather Service*,* Hamburg University*,* Centro De Estudios Ambientales Del Mediterrano*, ECN, FMI, ARIANET Consulting, EPA Emilia, NMI, NIAR,* University of Hertfordshire*, INSA, EPA Peidmont, JRC,* Swiss Federal Institute of Technology

Objectives
The main aims of FUMAPEX are to: map emissions, quantify the urban air pollution and air pollution models so as to improve meteorological forecasts in urban areas.

Expected findings
A deliverable of FUMAPEX is the forecast and prevention of the worst air pollution episodes in large cities according to air quality directives *(Baklanov et al. 2002).*

Helsinki, Finland: Source apportionment of urban ambient $PM_{2.5}$ in two successive measurement campaigns (1996-7 and 1998-9)
Unit of Environmental Epidemiology, National Public Health Institute, Kuopio; Laboratory of Air Hygiene, National Public Health Institute, Kuopio; Department of Environmental Sciences, University of Kuopio

Objectives
The main goal of the study was to carry out source apportionment of urban fine particle mass ($PM_{2.5}$) in Helsinki, Finland. For this purpose, $PM_{2.5}$ and several other air pollutants were measured during two 6-month periods in 1996–97 and 1998–99 at the same location. Sources were identified and their contribution to daily $PM_{2.5}$ concentration estimated by performing principal component analysis and multivariate linear regression. In addition to $PM_{2.5}$ elemental composition data, 24-h average concentrations of ultrafine particles (diameter <0.1 μm) and accumulation mode particles (diameter 0.1–1.0 μm), as well as absorption coefficients of $PM_{2.5}$ filters and concentrations of NO_x and SO_2 were used as input data to $PM_{2.5}$ source modelling.

Key findings
Five similar source categories of $PM_{2.5}$ were identified separately for both measurement periods: local traffic source characterised by NO_x, absorption coefficient and ultrafine particle counts; long-range transboundary air pollution characterised by

S, K, Zn, Pb and accumulation mode particle counts; crustal source characterised by Si, Al, Ca, Fe and K; oil combustion characterised by V, Ni and SO_2; and salt source characterised by Na and Cl.

Long-range transboundary air pollution was the major contributor to $PM_{2.5}$ during both 1996–97 and 1998–99 accounting for 51 % and 50 %, respectively, of the average $PM_{2.5}$. Local traffic accounted for 30 % and 23 %, oil combustion for 3 % and 13 %, crustal source for 12 % and 5 %, and salt for 2 % and 7 % of the average $PM_{2.5}$ during 1996–97 and 1998–99, respectively. Despite differences in atmospheric concentrations and availability of several elements for statistical analyses in 1996–97 and 1998–99, the estimates of $PM_{2.5}$ source contributions were both qualitatively and quantitatively comparable for the two measurement periods. Using non-elemental markers proved very useful for both source identification and estimation of source contributions at this measurement site *(Vallius et al., 2003)*.

Helsinki, Finland: Evaluation of the OSPM model combined with an urban background model against the data measured in Runeberg Street (1997)

Finnish Meteorological Institute; Helsinki Metropolitan Area Council, Finland; National Environmental Research Institute, Roskilde, Denmark

Objectives

The objective of the study was to evaluate the Operational Street Pollution Model (OSPM) street canyon dispersion model against measured data. Therefore, a measuring campaign was conducted in a street canyon (Runeberg Street) in Helsinki. Hourly street level measurements and on-site electronic traffic counts were conducted throughout the whole of 1997; roof level measurements were conducted for approximately two months during the so-called intensive measuring campaign. Hourly mean concentrations of NO_x, NO_2, O_3 and CO were measured at street and roof levels; the relevant hourly meteorological parameters were measured at roof level. As the roof level concentrations and meteorological measurements were not available for the whole year, computed or meteorologically pre-processed values were utilised. The study therefore aims to gain insight into how accurately street canyon dispersion models could be applied without using actual roof level concentration and meteorological measurements at each specific street.

Key findings

The measured and predicted urban background concentration values at roof level during the intensive measuring campaign showed a fairly good agreement for all pollutants considered (NO_x, NO_2, O_3 and CO). The use of modelled urban background concentrations and meteorological values (instead of on-site roof level measurements) did not lessen the agreement between modelled and measured average concentration values at street level. The agreement between the temporal variations of predictions and measured data was also fairly good; for instance, the corresponding index of agreement values for NO_x, NO_2 and CO were 0.89, 0.81 and 0.87, respectively. However, as expected, the agreement in the temporal variations was somewhat better using actual measured on-site data during the intensive measuring campaign, than when using modelled urban background concentrations and meteorological values. This study demonstrates that it is possible to utilise the street canyon dispersion model OSPM with reasonable accuracy using modelled urban background and pre-processed meteorological values as model input *(Kukkonen et al., 2003, Kukkonen et al. 2000, 2001a, Granberg et al. 2000)*.

Helsinki, Finland: Street level versus rooftop concentrations of submicron aerosol particles and gaseous pollutants in an urban street canyon

Department of Physics, University of Helsinki; Technical University of Helsinki; Department of Environmental Sciences, University of Kuopio; Environmental Protection Centre, City of Lahti

Objectives

Gaseous air pollutants and aerosol particle concentrations were monitored in an urban street canyon for two weeks. The measurements were performed simultaneously at two different heights: at street level (gases 3 m, aerosol particles 1.5 m) and at a rooftop (25 m above the ground). The main objective of the study was to investigate the vertical changes in concentrations of pollutants and the factors leading to the formation of the differences. The physical parameters controlling the concentration gradients (e.g. the flow and micrometeorology) were not directly measured and the conclusions of the study relied mostly on the high time resolution concentration measurements.

Key findings

The concentrations of gaseous impurities as well as submicron aerosol particles had clear diurnal patterns that can be related to emissions from traffic. However, the concentration levels and their diurnal behavior were strongly affected also by different weather conditions.

The main results of the field study were the vertical differences of gas and particle concentrations between the street and rooftop levels. The dilution factor was observed to be on average 5 between street and rooftop levels. However, the formation of secondary pollutants significantly changed the gradient of NO, NO_2 and O_3 from that due to dilution only.

The possibility of new particle formation was investigated with an aerosol model that connects the observed gas concentrations and meteorological parameters with aerosol properties. In the street canyon at street level the number of pre-existing particles was so high, that precursor gases probably condensed on them. On the other hand only 22 m higher the nucleation probability was significantly increased, and some nucleation events could have taken place. This implies that secondary aerosol formation might occur also within urban areas during favourable weather conditions (*Väkevä et al., 1999*).

Hong Kong: Suspended Particle Study (November 1998 – January 1999)

Hong Kong Polytechnic University Environmental Engineering Unit

Objectives

The aim of this study was to measure the vertical distribution of TSP, PM_{10} and $PM_{2.5}$ during the months when the highest suspended concentrations exist, and in an urban area of Hong Kong at 4 buildings residing in different street configurations and aspect ratios to investigate airflow dispersion effects on re-suspension of PM.

Key findings

The particulate matter dispersion in street canyons is affected by the prevailing wind direction and the aspect ratio. In open streets the vertical concentration of PM depends instead on vertical mixing, local dilution and local influential factors (sea breeze, nearby trunk roads). Fine particles were found to contribute a major part of PM in

Hong Kong and can have an impact even as high as 10 floors from the ground. The $PM_{2.5}$ level is very high with 80% of cases recorder being in exceedence of the EPA NAAQS standards *(Chan and Kwok 2000).*

ISHTAR: Integrated Software for Health, Transport Efficiency and Artistic Heritage Recovery

Institute for Internal Combustion Engines and Thermodynamics, Graz University of

Technology, ENEA, NERI

http://dev.allez.no/clear/proj7.htm

Objectives

The aim of the ISHTAR Project is to build advanced software to model transport, vehicles emissions pollutant dispersion and building-related atmospheric emissions. The microscale dispersion model GRAMM and the Lagrangian particle model GRAL are being developed and applied with dispersion models in a model chain from transport, emissions to dispersion and impact. Furthermore, GRAMM is being applied to the tracer gas dispersion experiments near a highway tunnel portal and the influence of the traffic induced wind speed, the buoyancy and the traffic induced turbulence on the pollution dispersion is being studied.

Key findings

Key findings are that there is a difficulty to simulate dispersion from major road emissions, when there are low ambient wind velocities prevailing and the wind direction is parallel to the line source. Other applications of the dispersion model GRAL in complex terrain show difficulties with flow field realizations which fulfill the continuity equation and are fast enough to result in reasonable calculation times *(Öttl et al. 2001).*

Leipzig, Germany: Particle number size distributions in a street canyon and their transformation into the urban-air background: measurements and a simple model study

Institute for Tropospheric Research, Leipzig

Objectives

Measurements of particle number size distributions and trace gas concentrations in a street canyon in a German urban area were performed. The objective was the characterization of these emissions as the aerosol in a street canyon can be considered to be dominated by car-traffic emissions.

Key findings

Maximum number concentrations occurred during morning hours from Monday to Friday when the traffic density is highest. The maximum of the number size distribution measured during rush hour near a busy city street was at a particle diameter of 15 nm. This differs significantly from size distributions directly measured in vehicle exhaust (vehicles placed on chassis dynamometers used for vehicle emissions certification), which typically show a peak at about 50 nm.

The size distributions measured in the urban area depended on the distance to the nearest road. With increasing distance, the maximum of the size distribution increased, and the total number concentration decreased. This seems to be a result of particle growth due to processes such as coagulation and condensation, and dilution with the surrounding air. To clarify the transformation of the particle number size distributions measured in a street canyon into the urban air background, a sectional aerosol model was used to calculate the evolution of the number size distribution, and included the effect of condensation, coagulation, dilution, and continuous entrainment of freshly emitted particles yielding good agreement with measurements (*Wehner et al., 2002).*

London, UK: Source Apportionment of fine $PM_{2.5}$ (Summer 1999, Winter 2000)

Partners
The project was funded by the UK Engineering & Physical Science Research Council, under their Inland Surface Transport programme, with additional support from Go-Ahead Group plc and other transport operators, and collaboration with CERC Ltd.

Objectives
The local scale London campaign investigated the variability of road-users (cyclists, bus and cars users) exposure to fine particulate matter ($PM_{2.5}$) for different routes. Road user exposure to $PM_{2.5}$ fine particulate air pollution was measured using high-volume personal sampling equipment along 3 fixed routes within Central London during a 3-week summer 1999 and 3-week winter 2000 campaign, for the three modes of transport bicycle, bus and car. Each sample was analysed in the laboratory for total mass of PM collected (including correction for humidity and pressure effects) and for blackness as a calibrated measure of the contribution of carbon principally from diesel exhaust.

Key Findings
Time-series of modelled or measured roadside or urban background air quality correlate well with road-user exposure. The road-user exposure, however, is more variable than roadside concentration and twofold the urban background concentration. Most of the exposure variability at individual level and between routes is attributable to the black carbon fraction of the $PM_{2.5}$, while the non-carbon fraction was found to be more important in the day-to-day variability. For the black carbon part of $PM_{2.5}$, it was also possible to detect almost a factor of two differences between modes of transport, with car drivers having greater exposure than cyclists. Regression modelling showed that the main determinants of exposure are wind speed and route provided that data for secondary transboundary $PM_{2.5}$ is available for inclusion in the model input. The average measured exposure is similar to the modelled concentration at the most polluted part of the route, not the average along the route assuming steady movement at constant speed. A large difference was found between the most polluted 10% of a route and the less polluted 90%. The source apportionment of $PM_{2.5}$ at the exposure hotspots is also quite different to that along the rest of the route. At the hotspot, emissions from the nearest road dominates. Along the rest of the route, the contribution of imported secondary transboundary particulate matter is the same order of magnitude as that of the local emissions. (*Adams et al. 2001a, 2001b, 2001c, 2002*)

London, UK: Source apportionment of $PM_{2.5}$ (2002 – 2006)

Objectives

Dispersion modelling using an operational street canyon plume model in ADMS-Urban was used to investigate likely causes and implications of the observed variability in road-user exposure to $PM_{2.5}$.

Key findings

The modelled exposure was found to be dominated by very high concentrations of $PM_{2.5}$ at the most congested, poorly ventilated canyons along the route, with differences as large as a factor of ten being found between some pairs of road links. This is capable of explaining, in part, the individual level variability in exposure, as small differences in cyclist behaviour including speed lead to differences in the amount of time spent at the most polluted locations. It is also consistent with the observation that the individual level exposure is found in the carbonaceous fraction of the PM. Furthermore, the modelling shows how the source apportionment of the $PM_{2.5}$ is very different at the most polluted locations to other parts of the route (*Adams et al. 2001b, 2002*).

London, UK: Tracer – model validation study (1998 - 2000)

Objectives

The airflow and pollution dispersion in an intersection was to be investigated using flow and wind speed measurements in a model scale wind tunnel, the use of tracer balloons in a central London street and the use of the general purpose CFD code StarCD.

Key findings

The model succeeded in reproducing well the flow direction and speed observed in the wind tunnel, and modelled tracer concentrations in the same street as the source were within tens of per cent of the wind tunnel measurement. Good predictions of tracer concentration in the side streets were also made, although errors of a factor of two in the decay rate away from the intersection are sufficient to give concentrations further into the side streets that are wrong by an order of magnitude *(Scaperdas et al. 1999, 2000).*

London, UK: M25 Motorway study

The University of Herfortshire

Objectives

The study aimed to apply the CALINE4 and ADMS roadside dispersion models that incorporate the effects of thermal and mechanical turbulence to a high traffic volume motorway section in London and to compare with field measurements to assess PM_{10} emissions. In addition to air quality monitoring, the site also included traffic counts and meteorological measurements.

Key findings

With regard to PM_{10}, CALINE4 and ADMS predictions show good agreement with measured data. In this case the measurements along with the model predictions

indicate that the 24 hour running mean standard of 50 µg/m^3 will be exceeded. However, this needs further investigation, as there can be considerable contribution from urban background in terms of mass of particles *(Benson 1984, Sokhi et al. 1998).*

Lyon, France: A traffic emission model application using the model TREMOVE (since 1996)
http://www.tremove.org/currentmodel/description/description.htm

Partners
KU Leuven, Transport & Mobility Leuven, DG ENV, WSP, TRL, TRT, INFRAS, GAMS, COWI, adpC

Objectives
The TREMOVE model has been developed to support the European policy making process concerning emission standards for vehicles and fuel specifications. TREMOVE is calibrated for nine European countries and calculates for each year from 1996 to 2020 the difference in costs for all transport modes between alternative transport scenarios. The model computes the size and composition of the vehicle stock, the vehicle usage, the emissions and the average speeds in cities, on motorways and on other rural roads. TREMOVE covers 9 European countries. For each country analysed, a distinction is made between three regions or domains, i.e. a sample city, the other urban areas (considered as a whole) and the non-urban areas. TREMOVE is a partial equilibrium model for the transport market. The volume of passenger and freight traffic for each transport mode (small car, big car, carpooling/taxi, motorcycle, train, bus, metro, vans, trucks, waterways) is modelled. TREMOVE models also the vehicle stocks for the road transport modes (cars, motorcycles, buses, vans and trucks). The vehicle stock for trucks, for instance, is detailed with respect to load capacity, fuel (leaded gasoline, unleaded gasoline, diesel), technology (conventional, EURO I, II, III, IV) and vintage. In addition, the influence of speed, load, ambient temperature (cold start and evaporative emissions) and wear and tear on the emissions, are accounted for in the model. The following pollutants are considered: CO, CO_2, NO_x and N_2O, VOCs (split in methane and non-methane VOCs), benzene, SO_2 and PM_{10}. On top of that the model computes the size and composition of the vehicle stock, the vehicle usage, the emissions and the average speeds in cities, on motorways and on other rural roads.
TREMOVE uses input data from ARTEMIS to calculate emission factors, TRENDS to calculate vehicle fleet composition and from SCENES which provides transport base scenarios.

Key findings
It is expected that TREMOVE will provide a baseline scenario to PRIMES and CAFE and will provide indicators to TERM.

Nantes campaign, France (June – July 1999)
ECN/CNRS, CSTB, CERMA Lab, Air Pays de la Loire, UMIST and DERA. Funded by the French Ministry of the Environment. A contribution to project SATURN

Objectives
The aim was to investigate the mechanisms of air pollution dispersion in a typical street canyon, specifically the level of turbulence generated by the traffic motion in a

street. The experiment provided a unique detailed database for street scale modellers for assessing their models. The project had four main objectives, namely the study of the wind field in the street, the determination of the production of turbulent kinetic energy induced by the motion of vehicles, the quantification of the influence of the distribution of street surface temperatures on the structure of the flow and consequently on the pollutant dispersion within the street, and the validation of several models developed by the teams participating in the campaign. The "rue de Strasbourg" is a high traffic, one-way, 3 lane street canyon with approximately North-South orientation (332° from North) and a great homogeneity in buildings construction (the width of the street is 15 m and the mean height of the buildings is 22 m with aspect ration H/W = 1.4). The wind field and the vehicle induced turbulence, air temperature and the temperature of the walls, CO were measured at three levels on each side of the street. Radiation budget components (global, diffuse, and Infra-Red) were continuously measured over the roof. They were also measured at pedestrian level during one day, at several locations (on the sunny side, in the shadow). Traffic was measured by vehicle counters at eight different places within the street and within the lateral streets: traffic flux per lane, mean vehicle velocities, heavy to light vehicle ratios. CO, NO_x, SO_2, dust and O_3 at 3.5 m from the ground, temperature and relative humidity at 5 m, and wind speed and direction at 10 m were also measured with 15 minute resolution. An ACCESS database was constructed and a 1:20 scale wind tunnel scale at Karlsruhe version was used for comparison.

Key Findings

Surface temperature time evolution was found to be correctly modelled in conditions of radiation trapping, while it is being underestimated sunshine periods due to a high sensitivity of the model to the surface albedo and to the convective heat transfer coefficient. Regarding the flow within the street in the presence of an important differential wall heating, it appeared that the thermal turbulent boundary layer at the wall is much thinner than expected, leading to an overestimation of the heat transfer at the wall by the numerical model. On the other hand, the investigation of the generation of turbulence by the traffic motion showed its influence on the pollutant dispersion and demonstrated its importance during low wind conditions. Finally, it could be quantified to what extent thermal conditions and traffic induced turbulence affect the distribution of pollutant concentrations within the street as a function of time and meteorology while it was demonstrated that it is important to properly position sensors for monitoring hotspot pollutant concentrations *(Vachon 2001, Vachon et al. 2000a, 2000b, 2002; Berkowicz et al. 2002, Louka et al. 2002).*

OSCAR: Optimised Expert System for Conducting Environmental Assessment of Urban Road Traffic (2002-2004)

http://www.eu-oscar.org/

Partners

ASRG, University of Hertfordshire, Westminster City Council, Transport Research Laboratory, Finnish MeteoroloFMI), Helsinki Metropolitan Area Council (YTV), Norwegian Institute for Air Research (NILU), Oslo Department of Public Health (ODPH), National Center for Scientific Research " Demokritos" (NCSRD), Technical University of Madrid (UPM), Sociedad Ibérica de Construcciones Eléctricas, S.A. (SICE), Netherlands Organisation for Applied Scientific Research (TNO), Municipality of Utrecht (Utrecht), Netherlands

Objectives

The *over*all aim of OSCAR will be to assess the environmental impact of road traffic in terms of traffic flows, emissions and air pollution, integrated with the capability of identifying suitable impact reduction options for the end user. Work packages focus on the comparison and analysis of current urban datasets, an assessment of traffic parameters and emission factors relevant to congested flows, the measurement of NO_x, PM_{10}, $PM_{2.5}$ and meteorological parameters and the improvement and evaluation of predictive air pollution models for urban streets.

PARTICULATES: Characterisation of Exhaust Particulate Emissions from Road Vehicles

http://vergina.eng.auth.gr/mech/lat/particulates/

Objectives

The goal is to improve the understanding and measurement of automotive particulates and emission models. To assess the impacts of different emissions abatement measures, accurate air quality models based on proper understanding of the relative contributions from the various emissions sources are required, together with knowledge on the health effects of those emissions.

Expected findings

The PARTICULATES project aims at collecting and analysing particles emitted from motor vehicles in a scientifically and technically sound manner. It contains the following basic work tasks: (a) Definition of the exhaust aerosol properties for both accumulation and nucleation mode particles and evaluation of the available measurement instruments and techniques. (b) Development of a harmonised protocol for the measurement of exhaust aerosol. (c) Examination of the particulate emissions of current light duty vehicles and heavy duty engines in order to identify the current vehicle emission performance. (d) Investigation of the influence of engine technology, fuel quality and after-treatment on particulate emissions. The effect of measures taken so far to reduce PM emissions in mass terms are examined in the light of the particulate properties under investigation. The tests investigate the effect of engine and combustion system characteristics, fuels and currently available after-treatment devices (particulate trap, oxidation catalyst, etc.).

SAPPHIRE: Source Apportionment of Urban Airborne Particles and Polycyclic Aromatic Hydrocarbons in Europe (October 2002-September 2005)

http://www.ges.bham.ac.uk/sapphire/

Partners

Birmingham City Council, Direccao Regional do Ambiente e Ordenamento do Territorio. Oporto, Athens City Authority, EPA Copenhagen, Helsinki Metropolitan Area Council, University of Birmingham, University of Hertfordshire, Universidade de Aveiro, Demokritos University of Thrace, NERI, FMI

Objectives

SAPPHIRE aims to develop and validate a readily transferable common pan-European methodological approach to source apportionment of atmospheric PM and PAH that will be utilised by city authorities. It also aims to improve air quality by identifying (or apportioning) the principal sources of pollutants PM and PAH for city authorities to effectively target source control strategies. To do so, a series of campaigns monitoring air pollution at 2 locations in each of the following partner cities: Athens, Birmingham, Copenhagen, Helsinki, and Oporto will be made. Data from these campaigns will be used to develop and validate the source apportionment methodology. A further aim is to produce a user friendly customised software package to assist in the data analysis required for source apportionment.

SAPPHIRE involves the collection of a broad range of air quality monitoring data (e.g. airborne PM concentrations, selected organic, anionic, and elemental species concentrations, and ultra-fine particle size distributions) in a series of intensive ambient monitoring campaigns, 2 each (one summer, one winter, both of 28 days' duration) at each of 5 monitoring locations, namely Athens, Birmingham, Copenhagen, Helsinki, and Oporto.

Complementary to the ambient air quality monitoring, samples of pollutant emissions from various sources will be collected. These will include diesel and gasoline-fuelled vehicles and provide a database of pollution source profiles.

Expected Findings

These ambient and source profile data, along with local traffic count and meteorological data for each of the monitoring locations, will be used to apportion sources of PM_{10}, $PM_{2.5}$, and PAH. The source apportionment techniques used will include receptor modelling (primarily principal component analysis/multiple linear regression analysis but also cluster analysis, target transformation factor analysis, multiple marker species linear regression and chemical mass balance), local traffic count-based inverse modelling, and deterministic (emission inventory/dispersion) modelling.

Ultimately, the findings of various components of the SAPPHIRE project will be combined to develop a comprehensive and co-ordinated approach to atmospheric pollution source apportionment, covering sampling, chemical analysis, and statistical interpretation of data, and applicable for use throughout Europe by scientists, policy-makers, and enforcement agencies alike. The ultimate outputs of SAPPHIRE will be a user-friendly technical report designed to facilitate the widest possible use of SAPPHIRE methodologies and an accompanying customised software package to assist in the data analysis required for source apportionment. To ensure widespread uptake of the technical report and software, both will be critically appraised and reviewed by the affiliated city authorities and other typical end-users at various stages during development *(Harrad et al. 2003)*.

SATURN: Studying Atmospheric Pollution in Urban Areas (1997 – 2002)

http://aix.meng.auth.gr/saturn/

http://www.springer.de/cgi/svcat/search_book.pl?isbn=3-540-00842-X

Partners

AUT/LHTEE, TNO, NERI, MIHU, Universitat Politecnica de Catalunya, University of Aveiro, Hungarian Meteorological Service, University of Cambridge, University di

Brescia, JRC, FMI, Norwegian Institute for Air Research, Technical University Graz. A contributing sub-project to EUREKA.

Objectives
The main scientific objective of this project umbrella was to substantially improve our ability of establishing source-receptor relationships at the urban scale. The goal of SATURN in line with EUROTRAC-2, is lead to a better understanding of urban air pollution as a prerequisite for finding effective solutions to air quality problems and for a sustainable development in the urban environment.

Key findings
The advances in the science of urban air pollution achieved within SATURN may be summarised as follows *(Moussiopoulos 2003)*:

- Contributions of field studies to a better insight into the characteristics of polluted urban air
- Significant refinement of urban scale models and methods used therein; valuable new knowledge regarding quality assurance of these models resulting from inter-comparison activities and sensitivity studies
- Substantial progress in the development and application of local scale models and establishment of a methodology for their validation
- Development of versatile Urban Air Quality Management Systems and their installation for use by city authorities; successful integration of urban air pollution research into the areas of information and communication technology.

Second Position Paper on Particulate Matter (draft of August 2003)
CAFE Working Group on Particulate Matter

Objectives
This position paper was prepared by the EU Working Group on Particulate Matter in response to a request by the European Commission. It updates the 1997 Position Paper on Particulate Matter that helped the European Commission prepare the First Daughter Directive on ambient air quality (1999/30/EC). Since 1997 there is considerably more information available on current and future ambient levels of PM in Europe and on their health impacts. The paper assesses current and future ambient levels of PM in the context of the targets set in the First Daughter Directive. It assesses the attainability of current targets and also discusses the possible need and consequences of revising these targets for PM. This review is part of the policy development work within the Clean Air For Europe (CAFE) programme of the European Commission. It also supports the review of the First Daughter Directive under the Air Quality Framework Directive 96/62/EC. The Working Group on Particulate Matter comprised experts from EU Member States, Switzerland, Industry, NGOs, the World Health Organization (WHO) and the European Environment Agency.

Key findings
The key findings of this report with relevance to the current review are linked to source apportionment and resuspension of PM. The results from the many studies and models on resuspension of PM from roads show a large spread in the results in terms of emission factors for various PM fractions, as well as in terms of calculated total national emissions. The uncertainty is very large. Estimates of the ratio of

resuspension to tail pipe PM_{10} emissions differ largely from a factor of 0.5 to 10. This ratio is considerably lower for $PM_{2.5}$, since all tail pipe emissions are in this size fraction, while the main part of resuspension falls under the coarse mode.

The main conclusions as regards source apportionment can be summarised as follows:

- Natural PM

As a mean, the natural input to PM_{10} in Europe varied from 3 to 8 µg/m^3 in most EU regions, with the highest values recorded in Southern EU. In $PM_{2.5}$ the marine and mineral regional contributions were significantly lower compared with PM_{10}, but it is still present in a concentration range from 1-2 µg/m^3 in Central EU to 3-4 µg/m^3 in Southern and Northern EU.

- Anthropogenic mineral dust

At road side sites, road dust accounted for an additional fraction of 3 to 6 µg/m^3 in PM_{10} and from <0.5 to 2 µg/m^3 of $PM_{2.5}$ in most regions of EU. The highest mean annual mineral dust contributions were reported for Southern EU. These differences in levels of crustal components may be attributed largely to the higher soil-resuspension effect during dry conditions in the Southern EU, while higher rainfall in Northern EU may lower the frequency of dry surfaces. In Nordic countries, road wear and sanding of roads substantially contributed to PM_{10} and $PM_{2.5}$ annual mean values.

- Carbonaceous PM

Carbonaceous PM (both organic matter and elemental carbon), in urban areas mainly emitted by traffic, usually ranged from 7 to 13 µg/m^3, both in PM_{10} and in $PM_{2.5}$. At roadside sites, an additional 6 to 9 µg/m^3 input was usually observed both in PM_{10} and $PM_{2.5}$.

- Secondary inorganic aerosol

The contribution of secondary inorganic phases (arising from traffic, industrial emissions including power generation and agriculture) reached levels from 4 to 9 µg/m^3 and 4 to 8 µg/m^3 at most regional sites for PM_{10} and $PM_{2.5}$ respectively. In areas with high industrial influence there was often an input from 2 to 5.5 µg/m^3 and 1 to 5 µg/m^3 of secondary inorganic aerosols, on top of the above contributions for PM_{10} and $PM_{2.5}$.

- Long range transport

The importance of long range transport of anthropogenic pollutants is manifested in concentrations found in the Swedish regional background stations, ranging from 8 to 16 µg/m^3 PM_{10} and 7 to 13 µg/m^3 $PM_{2.5}$ (annual averages). The higher values were for the southern parts and the lower for the northern parts of Sweden. This implies a significant fraction of long range transported PM also for other European sites.

- Traffic hot spots

At roadside stations in most examples, local traffic accounted for the major contribution (including exhaust and abrasion products), with 40 to 55% of the annual PM_{10} levels and 45-60% of $PM_{2.5}$.

Singapore: CO modelling from transportation sources using street canyon and Gaussian line source modules

Department of Chemical and Environmental Engineering, National University of Singapore

Objectives

Street canyon module and Gaussian line source module of a regional-scale dispersion model were used to simulate ambient CO concentrations due to traffic flow at two roadside monitoring locations in Singapore. The fleet average emission factors for

each vehicle category were estimated from US EPA MOBILE 5 A guidelines as a function of speed, vehicle deterioration rates and model years. 1-h CO concentrations and worst-case 8-h levels have been simulated and compared with measurements. Model-simulated rooftop concentration levels from non-localised sources were used as background levels at the two sites.

Key findings
The predicted CO concentrations were comparable to the measured levels at the two sites with a significantly different street geometry.
The analysis of the two detailed scenarios showed that (a) an increase in average speed beyond 85-88 km/h on the expressway with the current volume of traffic could result in ambient 8-h CO levels closer to applicable standards; (b) an increase in the traffic volume with associated reduction in the average speed on the expressway would result in higher ambient air quality than the current levels; (c) an increase in the traffic volume up to 30 % does not affect the current average speed levels significantly on the main road, however, it would impact ambient air quality CO level to the same proportion at which the traffic volume increases (*Mukherjee and Viswanathan, 2001)*.

Stockholm PM and Health Study, Sweden: (1998 - 2000)
University of Stockholm and the EPA Stockholm

Objectives
The goal of this study was to obtain data in order to evaluate source-receptor relationships of both gaseous and particulate air pollution in the urban area of Stockholm with a special emphasis on particle resuspension. The project includes both emission and air quality measurement campaigns, and modelling using dispersion models and source receptor models. Detailed emission databases have been created and include NO_x, CO, PM, benzene and polycyclic aromatic hydrocarbons. The aerosol and gas measurements that were performed were: aerosol size distributions, PM mass, coarse and fine fraction elemental composition, organic and elemental carbon (ACPM), CO, NO, NO, and VOCs. These measurements were carried out with a time resolution of between 15 minutes and 1 hour. Furthermore, categorised traffic flows and speeds were recorded as well as the wind velocity, temperature and relative humidity in a street canyon with around 40 000 vehicles per day, a residential area just outside the centre and a rooftop site in central Stockholm.

Key findings
Most of the particles are in the size range from 10 to 60 nm diameter. Total numbers of particles in the size range from 3 to 7 nm tend to decrease significantly during morning rush hours, due to coagulation and deposition. The results suggest that local traffic is the main source of ultra-fine particles and most of the particles close to traffic are in the range from 3 to 30 nm. The size distribution changes markedly as a function of distance from the traffic. At the rooftop location, the size distribution shifts towards larger sizes, compared with the corresponding results at the street level location. Local vehicle exhaust particles have a dominant contribution to the number concentration of particles less than 200 nm, whereas long-range transport dominates the sizes between 200 and 600 nm. For the large particles (> 600 nm), local vehicles are again the main source, but these particles are mainly originated from the wear of roads, tyres, brakes etc. Principal component analysis was performed to aerosol and

gas phase data from measurements. NO_x, CO, CO_2, VOC's and copper were mainly associated with gasoline exhaust, whereas particulate organic carbon and NO_2 shows high loadings on both the gasoline and diesel factor. Particle number concentration is dominated by particles with a diameter around 20 nm and associated with diesel exhaust. The road dust factor has high loadings of PM and a number of elements (Si, Fe, Mn). Furthermore, it was also concluded that the modelling of the resuspension of particles in street canyon models was unsatisfactory *(Johansson 1999a, Kristensson et al. 2000, Gridhagen et al. 2002).*

SUTRA: Sustainable Urban Transportation (1999 - 2003)
http://www.ess.co.at/SUTRA/

Partners

Environmental Software & Services GmbH, PTV Planung Transport Verkehr AG, Fondazione Eni Enrico Mattei, Environment, Transport & Planning, Agenzia Regionale per la Protezione dell'Ambiente Ligure, Ministry of the Environment in Israel, AUT/LHTEE, Universidade de Aveiro, University of Geneva, Technical University of Gdaρsk, Fundacion Universidad de Belgrano, Comune di Genova, Direzione Mobilita, Trasporti e Parcheggi.

Objectives
With reference to air quality modelling, SUTRA aims to use traffic equilibrium modelling to evaluate alternative transportation policies and air quality modelling to translate transportation scenarios and their resultant emissions into ambient air quality estimates and population exposure.

Thessaloniki, Greece: Source apportionment of fine and coarse air particles (1994-1995)

Objectives
The aims of the chemical characterisation campaign were to investigate the distribution of particle mass and particle components in the fine and coarse size range in an urban location and to apply a suite of aerosol data to identify the sources and apportion them. Sampling was done on 45 working days throughout the year of the study and each sampling had a 24 hour duration. Factor analysis was performed with the statistical package SPSS to identify the main sources.

Key findings
It was found that 76±6% of the total ambient aerosol mass was distributed in the fine size fraction. The fine sized PAH fractions were between 95% and 99% for all species. The size distribution of aerosol mass and PAH had significant seasonal dependence with a shift to larger fine fractions in winter. The compositional structure of paved-road dust was found to be strongly correlated to coarse particles suggesting a significant contribution of resuspended road dust to this fraction. Traffic was found to be the largest contributor (38%) to fine-sized aerosol followed by road dust (28%) which dominated the coarse fraction (57%) *(Manoli et al., 2002).*

<u>TRAKER system study</u>: Testing Re-entrained Aerosol Kinetic Emissions from Roads (1998 - 1999)
Las Vegas Desert Research Institute.
http://www.dustmonitor.com/Articles/TRAKER.htm

<u>Objectives</u>
The aim of this study was to develop a new system to measure the concentration of dust suspended off a road while a vehicle is in motion. The TRAKER system uses real-time aerosol sensors mounted on a vehicle to measure. The project involved coupling the TRAKER system with a Global Positioning System instrument to efficiently survey the changes in suspendable particles due to varying road conditions over a large spatial domain (300 miles of paved roads). The TRAKER system was also compared with collocated silt loading measurements.

<u>Key findings</u>
Results of this study indicate that road dust emissions are exponentially related to vehicle speed. This is a significant finding because current road dust emission estimation methods do not include vehicle speed as a factor in the emissions calculations. The experiment also demonstrated that the distribution of suspendable material on roadways is highly variable and that a large number of samples are needed to represent road dust emissions potential on an urban scale for a variety of road and activity conditions. A slight increase in the mass median diameter was observed with increasing speed. This is consistent with Nicholson et al. (1989) who show particle size and emissions rate increasing with vehicle speed due to higher energy transfer through surface contact and turbulent wakes *(Kuhns et al. 2000, Mollinger et al. 1993).*

<u>UK: Studies of the coarse particle (2.5-10 μm) component in urban atmospheres</u>
Institute of Public & Environmental Health, University of Birmingham; AEA Technology, National Environmental Technology Centre; Environmental Protection Unit, Birmingham; Stanger Science and Environment

<u>Objectives</u>
An analysis is presented of continuous simultaneous measurement data for PM_{10} and $PM_{2.5}$ using TEOM instruments from five sites in the United Kingdom. The results were analysed specifically in relation to the sources and processes influencing the coarse particle fraction (2.5-10 μm).

<u>Key findings</u>
The data generally show a strong correlation between fine and coarse particle concentrations at all sites, with a generally higher proportion of coarse particles in the dryer months of the year. The one rural site shows a notably lower proportion of coarse particles than the urban and suburban sites. Whilst it is possible to disaggregate the coarse particle concentrations into a component, which is diluted by increasing wind speed, and a component, which increases with wind speed and is hence possibly attributable to wind-induced resuspension processes, the latter is only a minor proportion of the total coarse particle concentration. There are appreciable weekday-to-weekend and day-to-night differences between coarse particle concentrations which are most marked at the urban sites indicative of anthropogenic activities being a source of coarse particles. The clearest indication of the likely predominant source of

coarse particles arises from an analysis of a data set derived from an urban street canyon site after subtraction of measurements from a nearby urban background location. The data indicate strong relationships of both fine and coarse incremental particle concentrations in the street canyon with incremental NO_x. If incremental fine particles and coarse particles are attributed to exhaust emissions and vehicle-induced resuspension, respectively, then it may be concluded that vehicle-induced resuspension provides source strength approximately equal to that of exhaust emissions. An analysis of the coarse particle concentration data suggest that episodes of elevated coarse particle concentrations alone very rarely lead to exceedence of the UK air quality standard for PM_{10} of 50 $\mu g/m^3$ measured as a 24-h running mean *(Harrison et al., 2001).*

URBAN AEROSOL: Characterisation of Urban Air Quality Indoor/Outdoor Particulate Matter Chemical Characteristics and Source-to-Inhaled Dose Relationships (2001 - 2003)
http://www.nilu.no/projects/urban-aerosol/

Partners
NILU, Technical University of Crete, JRC, NCSR, Demokritos, University of Athens, ASCR, Charles University Faculty of Science Prague, FIT

Objectives
The main objectives are: to characterise chemically the PM associated with actual human exposure in selected residential European urban areas, to provide an integrated European exposure assessment database for urban PM characterization through indoor/outdoor monitoring and modelling, to study and evaluate the mechanisms controlling the outdoor/indoor relationships of PM by taking into account infiltration, meteorological conditions, indoor sources of PM, physical and chemical processes indoors, and the composition/size distribution of indoor generated PM, by using mechanistically based models and to link human exposure to PM indoor with physiologically based mechanistic dosimetry models. An integrated microenvironmental model is to be applied and will include gaseous and aerosol dynamics, new particle formation, condensation, chemical reactions, resuspension and deposition. It will then be compared with observations with regard to the following issues: dynamics of photochemical pollutants and fine particles at the indoor environment and identification of the contribution of outdoor sources.

Key findings
Measurements have been made of fine particle and photochemical gases' physico-chemical characteristics at indoor/outdoor locations in 6 urban areas (Athens, Oslo, Milano, London, Hanover, Prague) and 22 residential places (in summer and in winter) and a detailed chemical analysis and bioaerosol contribution study has been made and the factors affecting the indoor/outdoor PM characteristics (mass/number/chemical composition/size distribution) have been characterised *(Rezacova et al. 2002, Domasova et al. 2002, Brozova and Blazek 2002).*

<u>VALIUM</u>: Development and Validation of Tools for the Implementation of European Air Quality Policy in Germany (2000 - 2002): A field campaign in Hanover, Germany

http://project.ifu.fhg.de/valium/

http://www.mi.uni-hamburg.de/technische_meteorologie/valium/

Partners

IER, NLO, IMK/IFU, Lower Saxony State Agency, MIUH

Objectives

The aim of the project was to take field measurements inside a street canyon and in the surrounding area of 1 km x 1 km (Göttinger Str. and Podbielski Str. in Hanover) to produce a validation data set for the meso/micro-scale model system M-SYS with the interpretation of measurements being combined with wind tunnel measurements. Air pollutants (NO, NO_2, SO_2, O_3, CO, HC, benzene, toluene, p-xylene, dust, PM_{10}, $PM_{2.5}$, soot) and meteorological parameters (wind speed, wind direction, temperature, global radiation, humidity, pressure, turbulence parameters) were measured continuously by in situ stations at four sites inside the street canyon since beginning of 2001 at ground and roof level. Path-integrated concentrations of CO, CH_4, N_2O, CO_2 and of the tracer SF_6 were measured.

A further goal established by measurements in Podbielski Str. was to show the possible spread of the resulting concentrations predicted by different organisations/persons and/or different procedures if all users had the same input parameters at their disposal. In addition, the 24 modellers from 21 institutions used their normal operational models to make these predictions. The aim of the exercise was to obtain an indication of the magnitude of the variation in the procedures used and results obtained, and to aim to reduce them. The meteorological parameters recorded were the wind direction and speed at 42 m above ground, 10 m over roof level. Measurements of pollutant concentrations at the station provided background concentrations of benzene, soot, NO_2, NO and CO as well as the 98-percentiles for NO_2, NO and CO). Traffic data were available (number of vehicles) between 06.30 and 18.30, providing mean traffic time series over the day, on weekdays, on Saturdays and on Sundays. For benzene, a mean value was taken for ten months of 5 $\mu g/m^3$. Furthermore, tracer experiments were conducted in August 2001 and August 2002 in Gottinger Str. with SF_6 at 12 positions along the street and at roof level with a 30 minute sampling rate.

Key findings

In Gottinger Str., the measured mean annual soot concentration in was 3.1 $\mu g/m^3$. The measured annual mean for NO_2 was 50 $\mu g/m^3$ and for NO_x 95 $\mu g/m^3$. The 98-percentiles amounted to 88 $\mu g/m^3$ for NO_2 and 247 $\mu g/m^3$ for NO_x.

In Podbielski Str., the results showed a plausible distribution of the concentration fields and flow in the street area such as the typical windward-leeward-effect for street canyons. The influence of traffic induced turbulence and advection of the concentration field along the street by the traffic was shown to be significant because the concentration field is shifted according to the direction of the motion of the traffic. Furthermore, it was found that: no standard procedure for street level pollution

modelling exists, the use of different tools yielded different results, individual modellers obtained different results even with the same model, emission modelling results differed by a factor of 4 between participants, maximum concentrations were largely within 50% of the average prediction and the quality of the calculated concentrations was seems to depend on the quality of the input data significantly *(Lohmeyer et al. 2002, Kuhlwein and Friedrich, 2001).*

YOGAM: Year of Gas phase and Aerosol Measurements (February 2001 – May 2002), Switzerland

Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, Switzerland

Objectives

The major objective was the measurement of on-road ambient concentrations of a large set of trace gases and aerosol parameters with high time resolution (<15 s for most instruments), along with geographical and meteorological information. The approach followed (mobile laboratory) allows for pollutant level measurements both near traffic (in urban areas or on freeways/main roads) and at rural locations far away from traffic, within short periods of time and at different times of day and year, without the need of a dense network of stationary measuring sites. The mobile laboratory followed a selected route in the Zurich (Switzerland) area on a regular base to monitor the seasonal and spatial variation of relevant ambient aerosol parameters and trace gases. Among others, the main parameters measured are ozone, CO, CO_2, NO_x, peroxide, formaldehyde, aerosol number, aerosol number size distribution, aerosol mass. The route included downtown Zurich, suburban areas (small towns, airport and industry) and rural regions. In addition to seasonal variations, short-time variations between daytime and night time or between weekday and Sunday were investigated. Within short-time intervals, ambient air under heavy traffic conditions could be compared to ambient air far away from traffic. Main goals and innovations of YOGAM were the spatially and temporally resolved mapping of aerosol parameters for the selected area in detail, and the investigation of the indicators for NO_x or VOC sensitivity of the ground-near ozone formation in the same area.

Key findings

The study confirms that there is a large diurnal and regional variation of ultra nanoparticles for both urban and rural areas, showing the different origins and the dynamic nature of the formation and transformation of these particles. Diurnal variations showed that neither the ultra nanoparticle fraction nor the total particle number concentration is an exclusive indicator of primary traffic emissions. Since nanoparticles are subject to investigation in current medical research with respect to possible adverse health effects, detailed knowledge on their origin, dynamics and composition is important for highly populated regions *(Bukowiecki et al., 2002).*

ANNEX B

B. Hornsgatan, Stockholm

B.1 Street canyon and monitoring station data

Figures B.1, B.2 and B.3 show that this is a "pure" street canyon located in downtown Stockholm in an area with a regular street and building pattern and topography, and buildings of approximately the same height throughout the street. There are traffic lights at both ends of the canyon section.

The street station is located close to the middle of the canyon section (N in Figure B2). The background station is located at roof-top on a nearby building (R in Figure B2). Measurements have also been carried out on the opposite side of the street (S).

Table B.1: Street canyon data, Hornsgatan, Stockholm

Length	Width	Height	Gradient
160 m	24 m	20 m	3%, upwards past the N station

Figure B.1: Hornsgatan street canyon, and location of street station, Stockholm

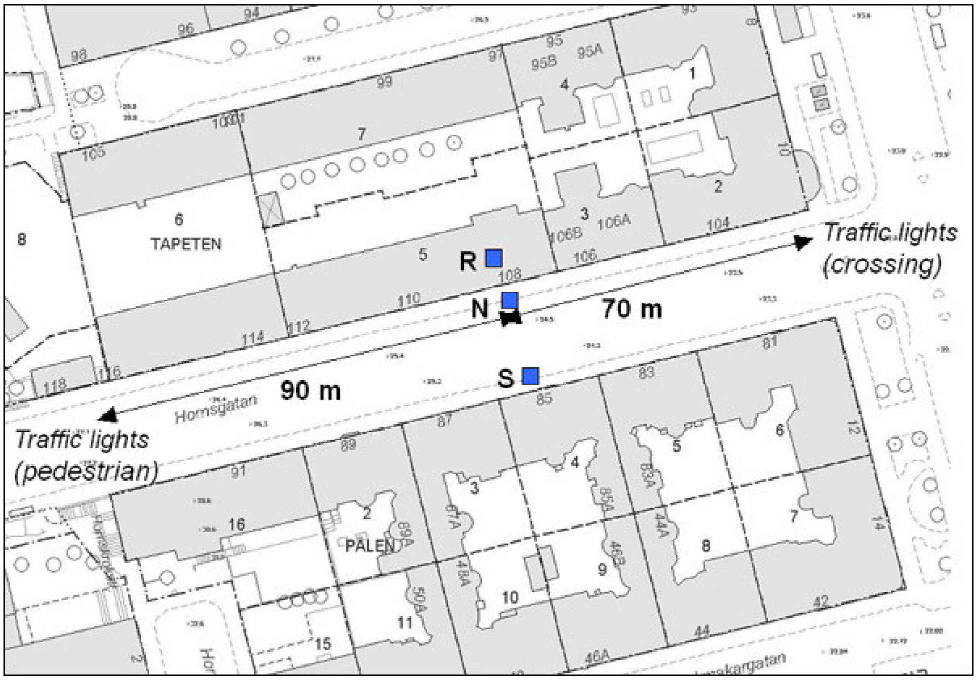


Figure B.2: Street station in Hornsgatan, Stockholm

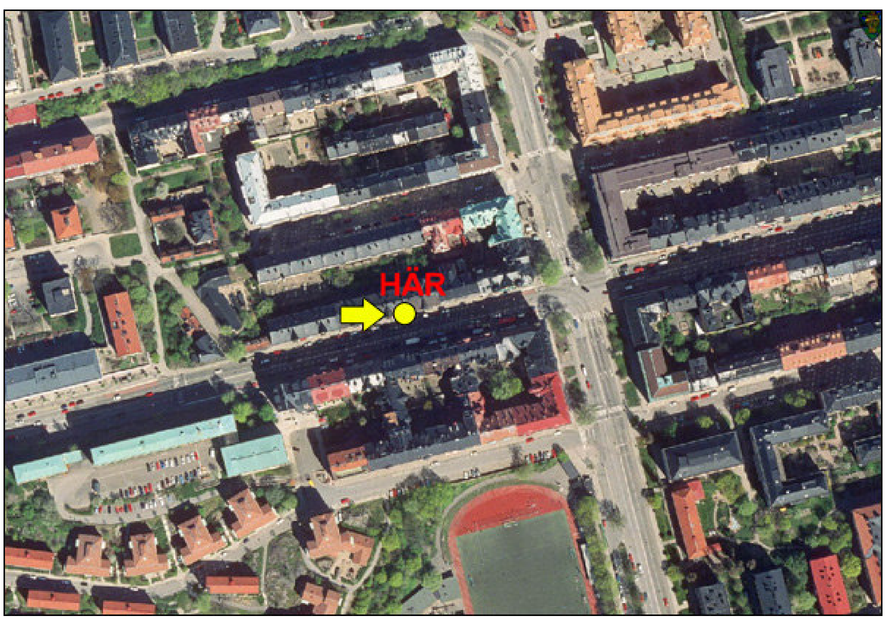


Figure B.3: Overview of Hornsgatan and street station.

B.2 Traffic data

Table B2: Annual average traffic parameters

AADT (cars)	Heavy duty (%)[1]	Speed (km/h)
N side, both lanes:34 820 S side, both lanes: approx as N side	10.0	47

Figure B.4 shows the traffic variation over the year (2000). Variations are limited, but the summer and mid-winter traffic is a bit lower than the rest of the year, with the heavy duty fraction a bit higher in July-August.

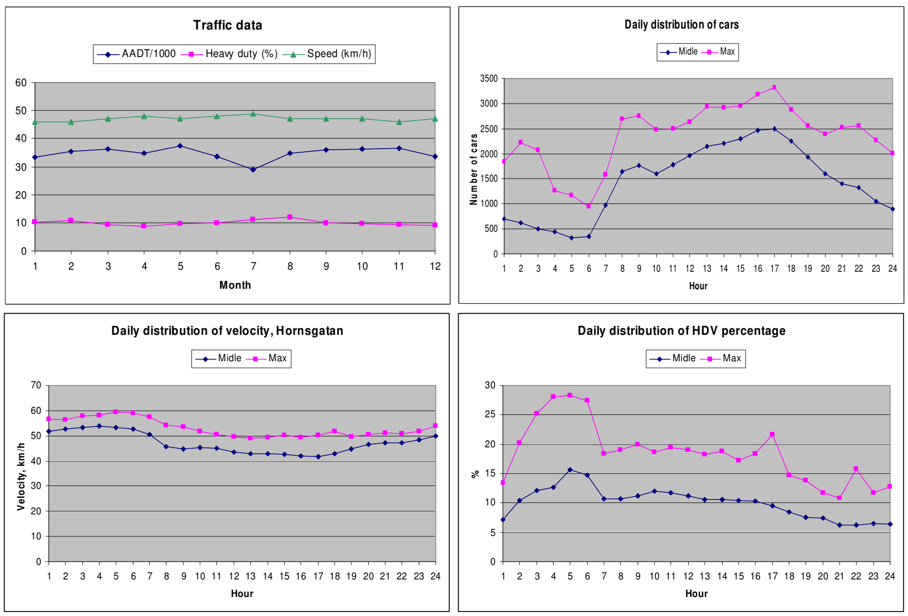
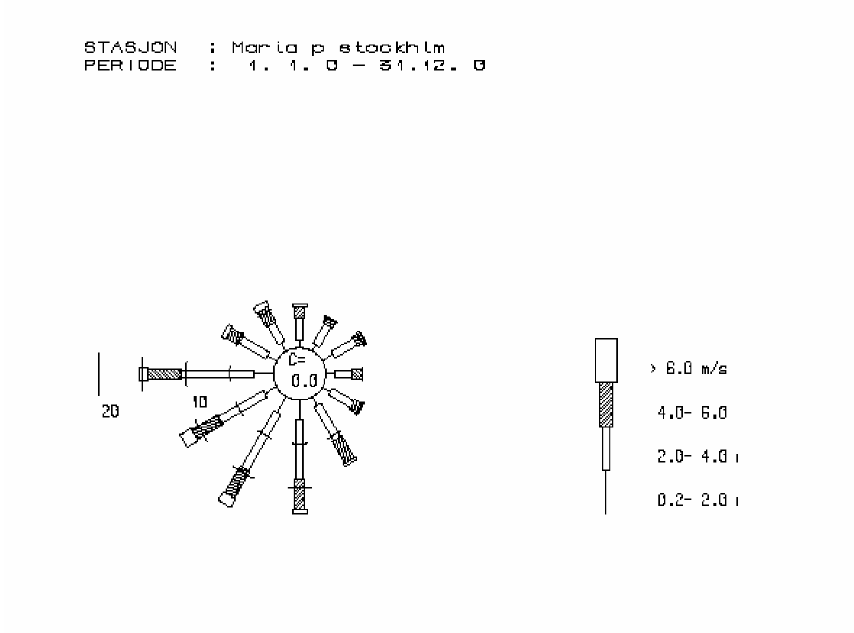


Figure B.4: Monthly traffic data for Hornsgatan.

[1]Vehicles longer than 5 meters

B.2 Meteorological data



(Monthly average wind speed and hour-of-day dependence to be added)

B.3 Pollution data

B.3.1 Annual and monthly data

Table B.3: Annual average concentrations, 2000.

	NO_x µg/m³	PM_{10} µg/m³	$PM_{2.5}$ µg/m³	NO_2 µg/m³	PM_{10}/NO_x	$PM_{2.5}/NO_x$	NO_2/NO_x
Street	188.0	38.8	14.0	50.8			
Urban Backgr.	32.7	14.3	8.9	21.0			
Delta[1]	155.3	24.5	5.2	29.8	0.158	0.033	0.192

Figure B.5 shows the variation over the year in monthly averages of NO_x, PM_{10} and $PM_{2.5}$ at street and urban background, as well as the Deltas and Delta-ratios.

The variation in NO_x is limited, and is guided mostly by the parallel variations in meteorological conditions (and to a lesser extent by the traffic variations over the year, which are small (see Fig. B.4).

$PM_{2.5}$ varies more, as a result of re-suspension of road dust during the winter months, particularly in March-April. The effect of this is as expected much more pronounced for PM_{10}, which is up to 4 times higher in winter (monthly average) as in summer.

[1]Street concentration minus background concentration

NO_2 is higher in summer than in winter, as can be expected. This is even true for the NO_2-Delta and also NO_2-Delta-ratio relative to NO_x, indicating the effect of the higher summer O_3 concentrations to result in a higher NO_2 produced within the street canyon from the NO-O_3 reaction.

From the Delta-ratios, emission factors for PM can be estimated relative to NO_x, on an annual basis. For NO_2, it is necessary to take the NO_2 production within the street canyon into account. Thus, the NO_2 delta-ratio cannot be used directly to calculate NO_2 emission factors.

In Figure B.6, daily averages of PM_{10} are shown for a 3-year period for Hornsgatan, the urban background station and for a rural background station in Southern Sweden (Aspvreten). Here it is clear that on a daily basis, the resuspension can cause PM_{10} concentrations that are 10 times higher than the contribution from the vehicle exhaust separately.

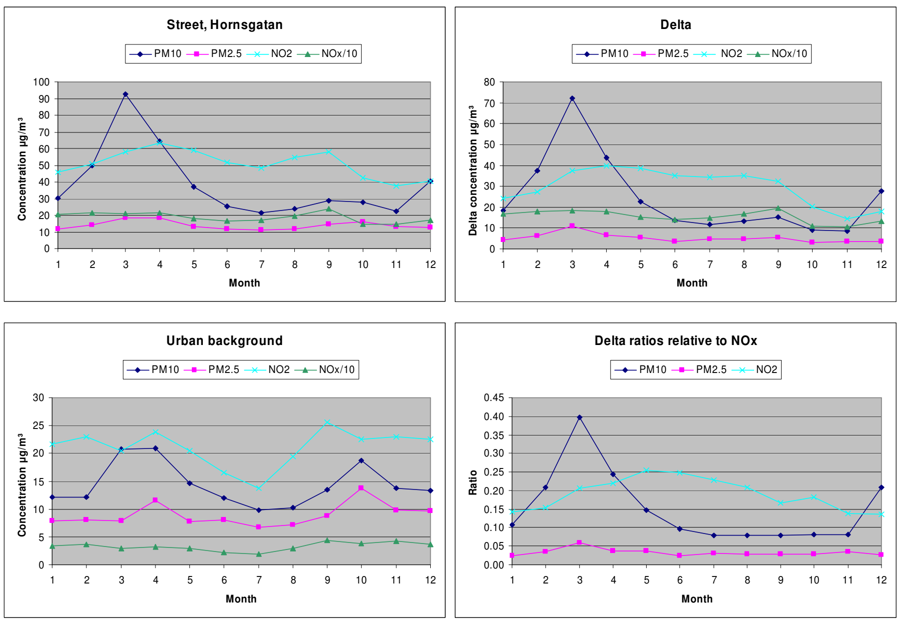


Figure B.5: Monthly average concentration of PM_{10}, $PM_{2.5}$, NO_2 and NO_x at Hornsgatan station pair.
Delta: Diff. Street – urban background
Ratios: Deltas relative to Delta-NO_x

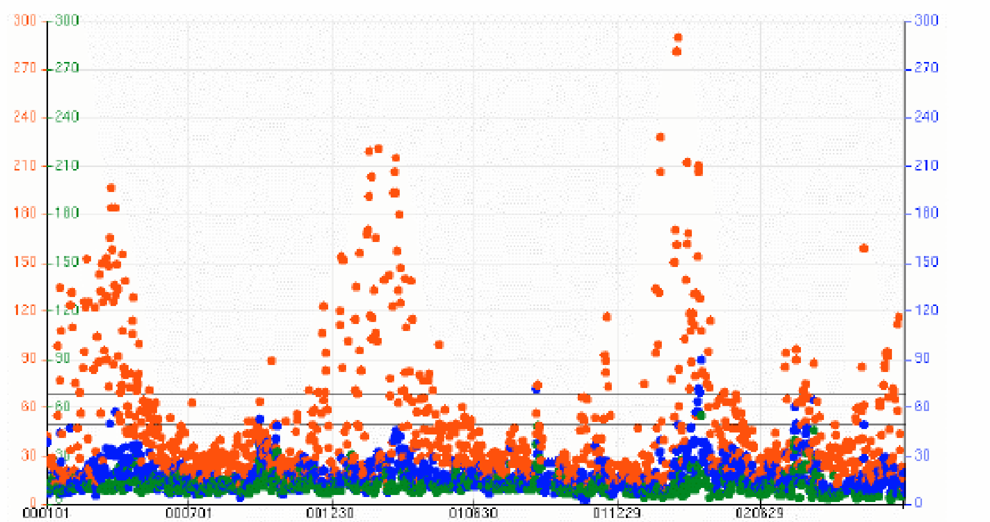


Figure B.6: Annual variation three last years at different exposed locations (daily averages). Red bullets: PM_{10} ($\mu g/m^3$) Hornsgatan, street canyon. Blue bullets PM_{10} ($\mu g/m^3$) Rosenlundsgatan, upon roof, urban background. Green bullets: PM_{10} ($\mu g/m^3$) Aspvreten, rural station.

B.3.2 Hourly data

The figures below show the average (or maximum) concentrations of NO_x, $PM_{2.5}$ and PM_{10} (NO_2 to be added) per hour of the day. Each set of 4 subfigures show this for the street station, the urban background station, the Delta and the Delta-ratio, for the following situations:

- Annual time series, average concentrations per hour of day;
- Annual time series, maximum concentration per hour of the day;
- Winter workdays, average per hour;
- Winter, weekends, average per hour;
- Summer workdays, average per hour;
- Summer weekends, average per hour.

Data extracted from these figures are suitable for providing emission factor ratios relative to NO_x. When looking separately at winter/summer/workdays/weekends, it is possible to study the re-suspension source compared to the vehicle exhaust (for PM), and also to study emission factors from light and heavy duty vehicles separately, as the heavy duty fraction is considerable less during the weekends.

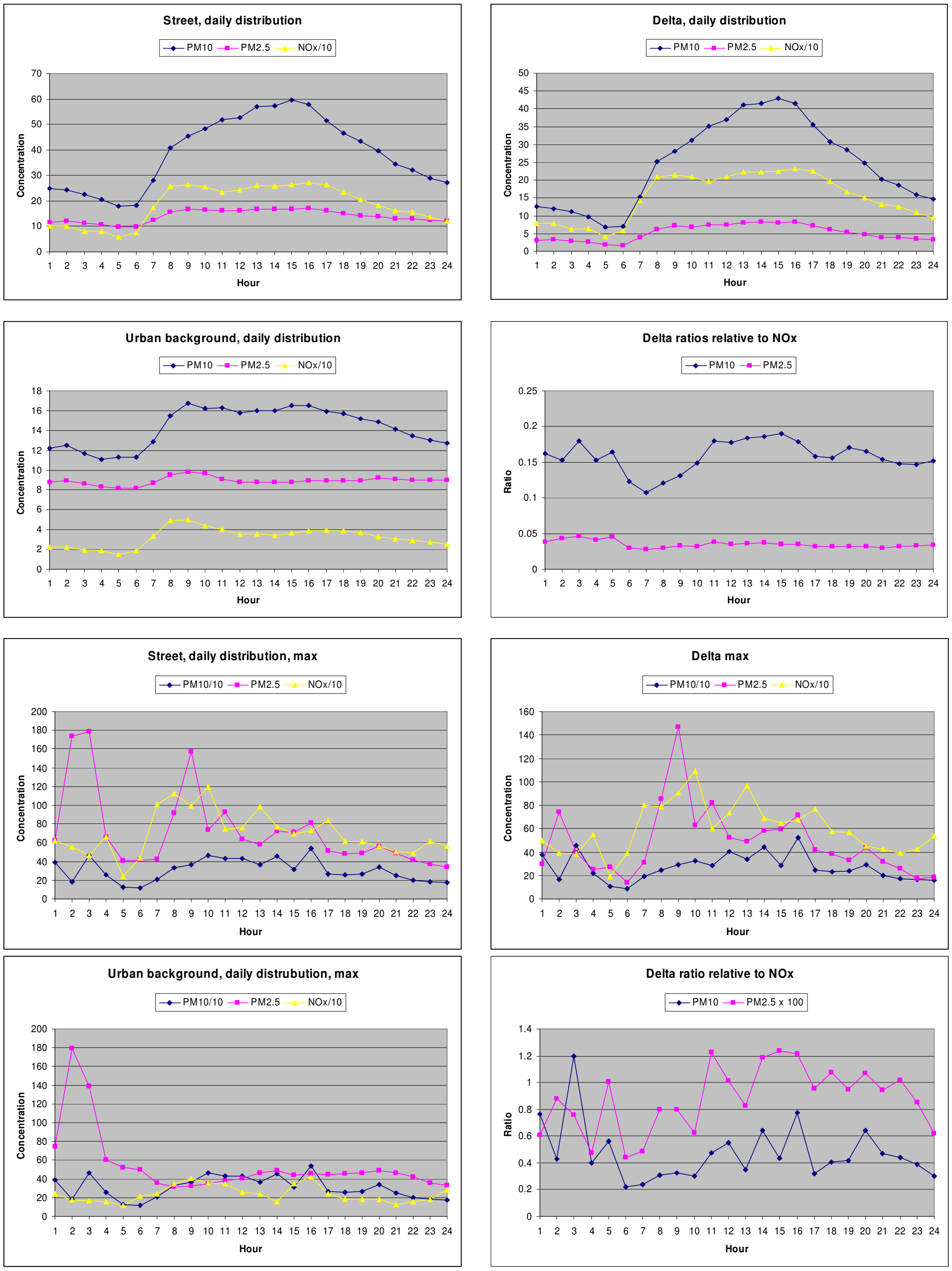


Figure B7: Daily distribution of working day vs weekend and winter vs summer

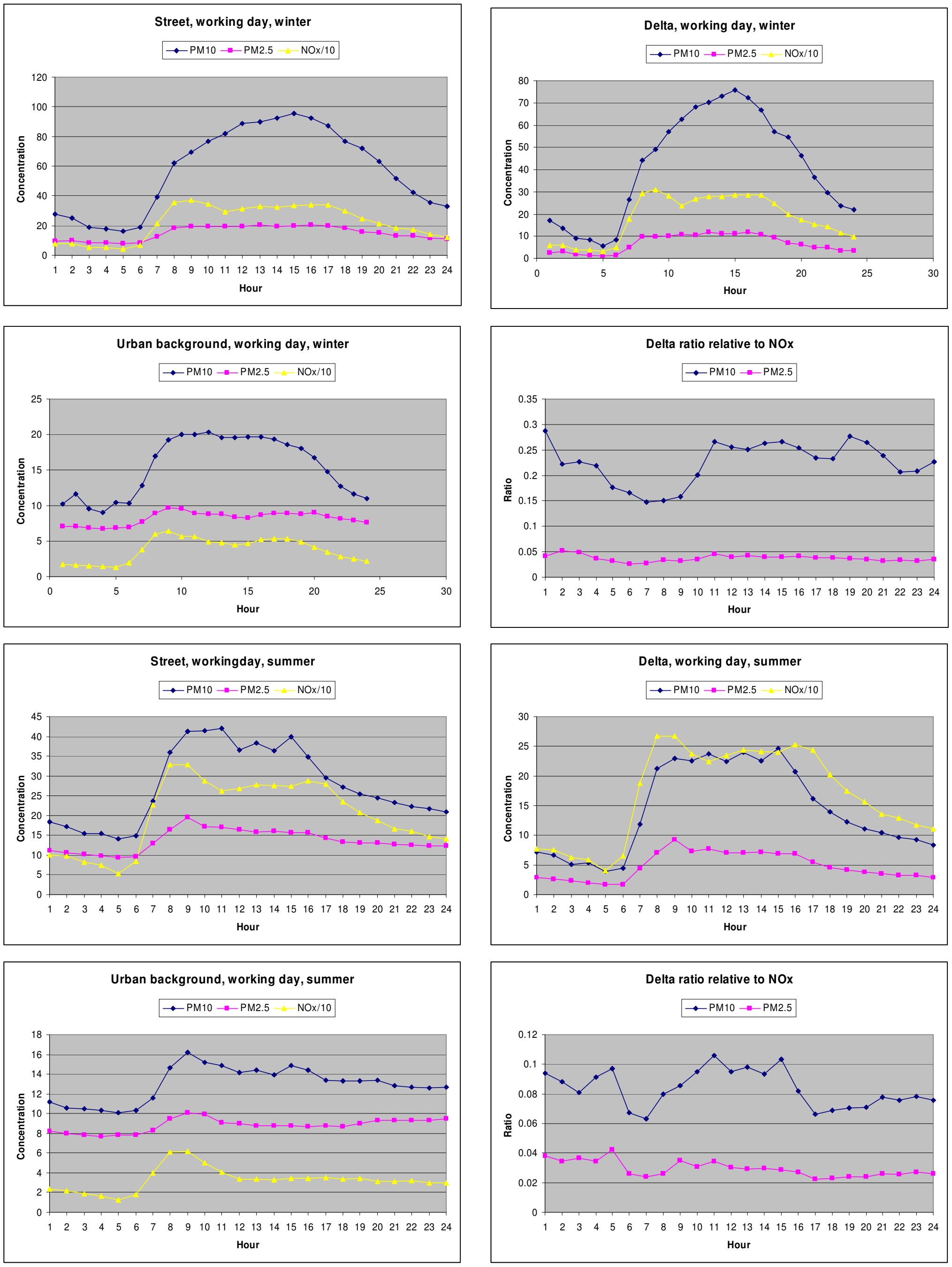


Figure B7: (continued): Daily distribution of working day vs weekend and winter vs summer

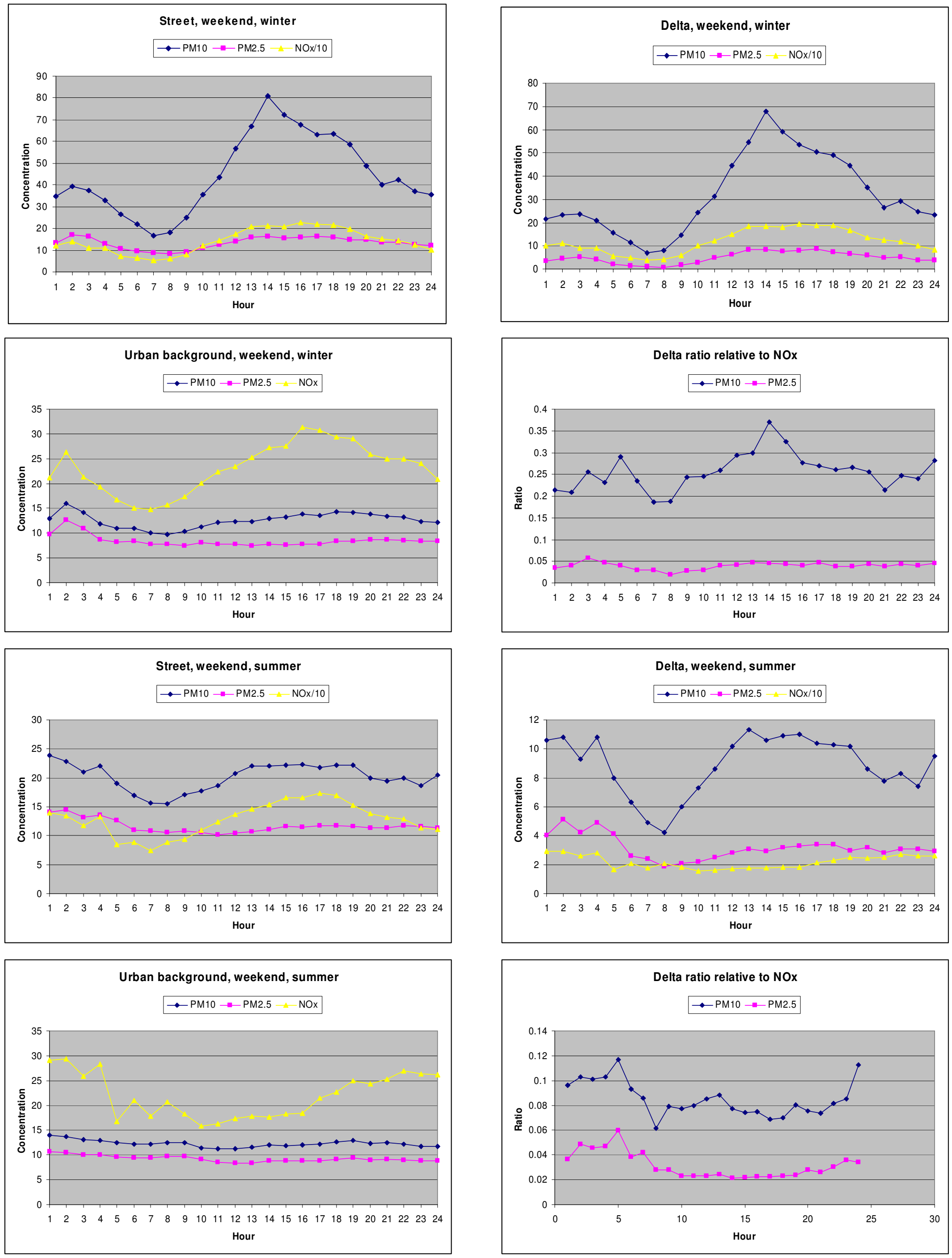


Figure B7: (continued): Daily distribution of working days vs weekend days and winter vs summer

ANNEX C

Table C.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	805	752	871	784	905	784	665	826	847	834	842	796
		ECE 15/03	24346	22741	26353	23720	27367	23712	20104	24990	25609	25218	25463	24065
		ECE 15/04	80918	75583	87589	78837	90960	78811	66819	83057	85116	83816	84630	79984
		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	93753	87572	101482	91343	105388	91313	77418	96232	98618	97111	98054	92671
		Euro II - 94/12/EC	109408	102195	118427	106595	122985	106560	90345	112300	115085	113326	114427	108145
		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	1088	1016	1178	1060	1223	1060	898	1117	1144	1127	1138	1075
		ECE 15/03	32896	30728	35608	32051	36979	32040	27165	33766	34603	34074	34406	32517
		ECE 15/04	109337	102128	118351	106525	122905	106491	90286	112228	115010	113252	114353	108075
		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	126680	118328	137123	123423	142401	123382	104608	130029	133253	131216	132491	125218
		Euro II - 94/12/EC	147832	138086	160020	144031	166178	143984	122075	151741	155503	153126	154614	146126
		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	265	248	287	259	298	259	219	273	279	275	278	262
		ECE 15/03	8028	7499	8690	7822	9025	7819	6629	8241	8445	8316	8397	7936
		ECE 15/04	26683	24924	28883	25997	29995	25989	22034	27389	28068	27639	27908	26375
		Euro I - 91/441/EEC	30916	28878	33465	30121	34753	30111	25529	31733	32520	32023	32334	30559
		Euro II - 94/12/EC	36078	33700	39052	35150	40555	35139	29792	37032	37950	37370	37733	35662
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <2,0 l	Conventional	8531	7969	9235	8312	9590	8309	7045	8757	8974	8837	8923	8433
		Euro I - 91/441/EEC	4735	4422	5125	4613	5322	4611	3910	4860	4980	4904	4952	4680
		Euro II - 94/12/EC	9472	8847	10253	9228	10647	9225	7822	9722	9963	9811	9906	9363
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel >2,0 l	Conventional	5687	5313	6156	5541	6393	5539	4697	5838	5983	5891	5948	5622
		Euro I - 91/441/EEC	3156	2948	3417	3075	3548	3074	2606	3240	3320	3269	3301	3120
		Euro II - 94/12/EC	6315	5898	6835	6152	7098	6150	5214	6482	6642	6541	6604	6242
		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	33563	31350	36330	32700	37728	32689	27715	34450	35304	34765	35102	33175
		Euro I - 93/59/EEC	2509	2344	2716	2445	2820	2444	2072	2575	2639	2599	2624	2480
		Euro II - 96/69/EC	88	82	95	86	99	86	73	90	93	91	92	87
		Euro III - 98/69/EC Stage2000	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel <3,5 t	Conventional	5787	5406	6264	5638	6505	5637	4779	5940	6087	5994	6053	5720
		Euro I - 93/59/EEC	4302	4018	4656	4191	4836	4190	3552	4416	4525	4456	4499	4252
		Euro II - 96/69/EC	13659	12759	14785	13308	15354	13304	11279	14020	14368	14148	14286	13502
		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	24812	24782	24263	21183	27226	24690	23238	30867	25813	24249	24163	22305
		Euro I - 91/542/EEC Stage I	5764	5757	5637	4921	6325	5736	5398	7171	5997	5633	5613	5182
		Euro II - 91/542/EEC Stage II	8251	8241	8069	7045	9054	8211	7728	10265	8584	8064	8036	7418
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Diesel 7,5 - 16 t	Conventional	27260	27227	26657	23273	29912	27126	25531	33913	28360	26642	26548	24506
		Euro I - 91/542/EEC Stage I	6333	6325	6193	5407	6949	6302	5931	7878	6588	6189	6167	5693
		Euro II - 91/542/EEC Stage II	9066	9055	8865	7740	9948	9021	8491	11278	9431	8860	8829	8150
		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	12922	12907	12636	11032	14179	12859	12103	16076	13443	12629	12584	11617
		Euro I - 91/542/EEC Stage I	1261	1259	1233	1076	1384	1255	1181	1569	1312	1232	1228	1134
		Euro II - 91/542/EEC Stage II	1638	1636	1602	1398	1797	1630	1534	2038	1704	1601	1595	1472
		Euro III - 2000 Standards	0	0	0	0	0	0	0	0	0	0	0	0
	Coaches	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

Table C.2: Hourly vehicle distribution in Hornsgatan, Stockholm, 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	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	0,6	0,5	0,4	0,3	0,2	0,3	0,8	1,3	1,4	1,2	1,4	1,5
		ECE 15/03	16,9	14,7	11,5	10,2	6,9	7,9	22,7	38,5	41,2	37,1	41,3	45,9
		ECE 15/04	56,3	48,9	38,2	33,8	23,0	26,4	75,4	127,8	137,1	123,3	137,3	152,7
		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	65,2	56,6	44,3	39,2	26,7	30,5	87,3	148,1	158,8	142,9	159,1	176,9
		Euro II - 94/12/EC	76,1	66,1	51,7	45,7	31,2	35,6	101,9	172,8	185,3	166,7	185,6	206,4
		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 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	0,8	0,7	0,5	0,5	0,3	0,4	1,0	1,7	1,8	1,7	1,8	2,1
		ECE 15/03	22,9	19,9	15,5	13,7	9,4	10,7	30,6	52,0	55,7	50,1	55,8	62,1
		ECE 15/04	76,1	66,0	51,6	45,7	31,1	35,6	101,9	172,7	185,2	166,6	185,5	206,3
		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	88,2	76,5	59,8	52,9	36,1	41,3	118,0	200,1	214,6	193,0	214,9	239,0
		Euro II - 94/12/EC	102,9	89,3	69,8	61,8	42,1	48,2	137,7	233,5	250,4	225,3	250,8	278,9
		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
	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	5,6	4,8	3,8	3,4	2,3	2,6	7,5	12,7	13,6	12,2	13,6	15,1
		ECE 15/04	18,6	16,1	12,6	11,1	7,6	8,7	24,9	42,2	45,2	40,7	45,3	50,3
		Euro I - 91/441/EEC	21,5	18,7	14,6	12,9	8,8	10,1	28,8	48,8	52,4	47,1	52,5	58,3
		Euro II - 94/12/EC	25,1	21,8	17,0	15,1	10,3	11,8	33,6	57,0	61,1	55,0	61,2	68,1
		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 <2,0 l	Conventional	5,9	5,2	4,0	3,6	2,4	2,8	7,9	13,5	14,5	13,0	14,5	16,1
		Euro I - 91/441/EEC	3,3	2,9	2,2	2,0	1,3	1,5	4,4	7,5	8,0	7,2	8,0	8,9
		Euro II - 94/12/EC	6,6	5,7	4,5	4,0	2,7	3,1	8,8	15,0	16,0	14,4	16,1	17,9
		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	4,0	3,4	2,7	2,4	1,6	1,9	5,3	9,0	9,6	8,7	9,7	10,7
		Euro I - 91/441/EEC	2,2	1,9	1,5	1,3	0,9	1,0	2,9	5,0	5,3	4,8	5,4	6,0
		Euro II - 94/12/EC	4,4	3,8	3,0	2,6	1,8	2,1	5,9	10,0	10,7	9,6	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	23,4	20,3	15,8	14,0	9,6	10,9	31,3	53,0	56,9	51,1	56,9	63,3
		Euro I - 93/59/EEC	1,7	1,5	1,2	1,0	0,7	0,8	2,3	4,0	4,3	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	4,0	3,5	2,7	2,4	1,6	1,9	5,4	9,1	9,8	8,8	9,8	10,9
		Euro I - 93/59/EEC	3,0	2,6	2,0	1,8	1,2	1,4	4,0	6,8	7,3	6,6	7,3	8,1
		Euro II - 96/69/EC	9,5	8,2	6,4	5,7	3,9	4,5	12,7	21,6	23,1	20,8	23,2	25,8
		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
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	12,3	16,1	14,8	13,7	12,0	12,8	25,4	43,0	48,5	47,2	51,1	54,0
		Euro I - 91/542/EEC Stage I	2,8	3,7	3,4	3,2	2,8	3,0	5,9	10,0	11,3	11,0	11,9	12,6
		Euro II - 91/542/EEC Stage II	4,1	5,4	4,9	4,5	4,0	4,2	8,4	14,3	16,1	15,7	17,0	18,0
		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	13,5	17,7	16,2	15,0	13,1	14,0	27,9	47,2	53,3	51,8	56,1	59,4
		Euro I - 91/542/EEC Stage I	3,1	4,1	3,8	3,5	3,1	3,3	6,5	11,0	12,4	12,0	13,0	13,8
		Euro II - 91/542/EEC Stage II	4,5	5,9	5,4	5,0	4,4	4,7	9,3	15,7	17,7	17,2	18,7	19,7
		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	6,4	8,4	7,7	7,1	6,2	6,6	13,2	22,4	25,3	24,6	26,6	28,1
		Euro I - 91/542/EEC Stage I	0,6	0,8	0,8	0,7	0,6	0,6	1,3	2,2	2,5	2,4	2,6	2,7
		Euro II - 91/542/EEC Stage II	0,8	1,1	1,0	0,9	0,8	0,8	1,7	2,8	3,2	3,1	3,4	3,6
		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
	Coaches	Conventional	1,6	2,1	1,9	1,8	1,6	1,7	3,3	5,6	6,3	6,1	6,6	7,0
		Euro I - 91/542/EEC Stage I	0,2	0,2	0,2	0,2	0,2	0,2	0,3	0,5	0,6	0,6	0,6	0,7
		Euro II - 91/542/EEC Stage II	0,2	0,3	0,2	0,2	0,2	0,2	0,4	0,7	0,8	0,8	0,8	0,9
		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

Table C.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	0:00
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	2,0	1,8	1,6	1,3	1,1	1,1	0,9	0,7
		ECE 15/03	50,5	51,7	53,9	58,1	59,4	54,2	47,1	38,8	34,6	32,5	25,8	21,9
		ECE 15/04	167,9	171,9	179,2	193,2	197,5	180,2	156,5	129,0	114,9	107,9	85,7	72,8
		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	194,5	199,1	207,6	223,8	228,8	208,7	181,3	149,5	133,1	125,0	99,3	84,3
		Euro II - 94/12/EC	227,0	232,4	242,2	261,2	267,0	243,6	211,5	174,4	155,3	145,9	115,8	98,4
		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 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	2,3	2,3	2,4	2,6	2,7	2,4	2,1	1,7	1,5	1,5	1,2	1,0
		ECE 15/03	68,2	69,9	72,8	78,5	80,3	73,2	63,6	52,5	46,7	43,9	34,8	29,6
		ECE 15/04	226,8	232,2	242,1	261,0	266,8	243,4	211,4	174,3	155,2	145,8	115,7	98,4
		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	262,8	269,0	280,5	302,4	309,1	282,1	244,9	202,0	179,8	168,9	134,1	114,0
		Euro II - 94/12/EC	306,7	314,0	327,3	352,9	360,8	329,2	285,8	235,7	209,8	197,1	156,5	133,0
		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
	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	0,6	0,6	0,6	0,6	0,6	0,6	0,5	0,4	0,4	0,4	0,3	0,2
		ECE 15/03	16,7	17,1	17,8	19,2	19,6	17,9	15,5	12,8	11,4	10,7	8,5	7,2
		ECE 15/04	55,4	56,7	59,1	63,7	65,1	59,4	51,6	42,5	37,9	35,6	28,2	24,0
		Euro I - 91/441/EEC	64,1	65,7	68,5	73,8	75,4	68,8	59,8	49,3	43,9	41,2	32,7	27,8
		Euro II - 94/12/EC	74,8	76,6	79,9	86,1	88,0	80,3	69,8	57,5	51,2	48,1	38,2	32,5
		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	17,7	18,1	18,9	20,4	20,8	19,0	16,5	13,6	12,1	11,4	9,0	7,7
		Euro I - 91/441/EEC	9,8	10,1	10,5	11,3	11,6	10,5	9,2	7,5	6,7	6,3	5,0	4,3
		Euro II - 94/12/EC	19,7	20,1	21,0	22,6	23,1	21,1	18,3	15,1	13,4	12,6	10,0	8,5
		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	11,8	12,1	12,6	13,6	13,9	12,7	11,0	9,1	8,1	7,6	6,0	5,1
		Euro I - 91/441/EEC	6,5	6,7	7,0	7,5	7,7	7,0	6,1	5,0	4,5	4,2	3,3	2,8
		Euro II - 94/12/EC	13,1	13,4	14,0	15,1	15,4	14,1	12,2	10,1	9,0	8,4	6,7	5,7
		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
	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	69,6	71,3	74,3	80,1	81,9	74,7	64,9	53,5	47,6	44,7	35,5	30,2
		Euro I - 93/59/EEC	5,2	5,3	5,6	6,0	6,1	5,6	4,9	4,0	3,6	3,3	2,7	2,3
		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	12,0	12,3	12,8	13,8	14,1	12,9	11,2	9,2	8,2	7,7	6,1	5,2
		Euro I - 93/59/EEC	8,9	9,1	9,5	10,3	10,5	9,6	8,3	6,9	6,1	5,7	4,6	3,9
		Euro II - 96/69/EC	28,3	29,0	30,2	32,6	33,3	30,4	26,4	21,8	19,4	18,2	14,5	12,3
		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
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	55,9	57,2	58,4	62,2	58,2	47,0	36,1	29,4	21,7	20,4	16,7	14,0
		Euro I - 91/542/EEC Stage I	13,0	13,3	13,6	14,5	13,5	10,9	8,4	6,8	5,0	4,7	3,9	3,2
		Euro II - 91/542/EEC Stage II	18,6	19,0	19,4	20,7	19,3	15,6	12,0	9,8	7,2	6,8	5,6	4,6
		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	61,4	62,8	64,1	68,4	63,9	51,6	39,7	32,3	23,8	22,4	18,4	15,3
		Euro I - 91/542/EEC Stage I	14,3	14,6	14,9	15,9	14,8	12,0	9,2	7,5	5,5	5,2	4,3	3,6
		Euro II - 91/542/EEC Stage II	20,4	20,9	21,3	22,7	21,3	17,2	13,2	10,7	7,9	7,4	6,1	5,1
		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	29,1	29,8	30,4	32,4	30,3	24,5	18,8	15,3	11,3	10,6	8,7	7,3
		Euro I - 91/542/EEC Stage I	2,8	2,9	3,0	3,2	3,0	2,4	1,8	1,5	1,1	1,0	0,8	0,7
		Euro II - 91/542/EEC Stage II	3,7	3,8	3,9	4,1	3,8	3,1	2,4	1,9	1,4	1,3	1,1	0,9
		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
	Coaches	Conventional	7,3	7,4	7,6	8,1	7,6	6,1	4,7	3,8	2,8	2,7	2,2	1,8
		Euro I - 91/542/EEC Stage I	0,7	0,7	0,7	0,8	0,7	0,6	0,5	0,4	0,3	0,3	0,2	0,2
		Euro II - 91/542/EEC Stage II	0,9	0,9	1,0	1,0	1,0	0,8	0,6	0,5	0,4	0,3	0,3	0,2
		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

Table C.4: Monthly vehicle distribution in Skårersletta, Oslo

Type	Class	Legislation	Jan	Feb	Mar	Apr
Passenger Cars	Gasoline <1,4 l	PRE ECE	0	0	0	0
		ECE 15/00-01	0	0	0	0
		ECE 15/02	9	8	8	9
		ECE 15/03	7201	6546	6746	7446
		ECE 15/04	68934	62664	64571	71271
		Improved Conventional	0	0	0	0
		Open Loop	0	0	0	0
		Euro I - 91/441/EEC	96739	87940	90617	100019
		Euro II - 94/12/EC	114060	103686	106842	117928
		Euro III - 98/69/EC Stage2000	42004	38184	39346	43428
	Gasoline 1,4 - 2,0 l	PRE ECE	0	0	0	0
		ECE 15/00-01	0	0	0	0
		ECE 15/02	12	11	11	12
		ECE 15/03	9731	8846	9115	10061
		ECE 15/04	93144	84672	87249	96302
		Improved Conventional	0	0	0	0
		Open Loop	0	0	0	0
		Euro I - 91/441/EEC	130714	118826	122442	135147
		Euro II - 94/12/EC	154119	140101	144365	159344
		Euro III - 98/69/EC Stage2000	56756	51594	53164	58680
	Gasoline >2,0 l	PRE ECE	0	0	0	0
		ECE 15/00-01	0	0	0	0
		ECE 15/02	3	3	3	3
		ECE 15/03	2375	2159	2224	2455
		ECE 15/04	22732	20664	21293	23502
		Euro I - 91/441/EEC	31901	28999	29882	32982
		Euro II - 94/12/EC	37612	34191	35232	38888
		Euro III - 98/69/EC Stage2000	13851	12591	12975	14321
	Diesel <2,0 l	Conventional	7381	6710	6914	7631
		Euro I - 91/441/EEC	4913	4466	4602	5080
		Euro II - 94/12/EC	9875	8977	9250	10210
		Euro III - 98/69/EC Stage2000	4624	4203	4331	4781
	Diesel >2,0 l	Conventional	4921	4473	4609	5088
		Euro I - 91/441/EEC	3275	2977	3068	3386
		Euro II - 94/12/EC	6583	5985	6167	6807
		Euro III - 98/69/EC Stage2000	3083	2802	2887	3187
	LPG	Conventional	0	0	0	0
		Euro I - 91/441/EEC	0	0	0	0
		Euro II - 94/12/EC	0	0	0	0
		Euro III - 98/69/EC Stage2000	0	0	0	0
	2-Stroke	Conventional	0	0	0	0
Light Duty Vehicles	Gasoline <3,5t	Conventional	25761	23418	24131	26634
		Euro I - 93/59/EEC	681	619	638	704
		Euro II - 96/69/EC	1923	1748	1801	1988
		Euro III - 98/69/EC Stage2000	0	0	0	0
	Diesel <3,5 t	Conventional	4334	3940	4060	4481
		Euro I - 93/59/EEC	3397	3088	3182	3512
		Euro II - 96/69/EC	17120	15563	16037	17701
		Euro III - 98/69/EC Stage2000	0	0	0	0
Heavy Duty Vehicles	Gasoline >3,5 t	Conventional	0	0	0	0
	Diesel 3,5 - 7,5 t	Conventional	9570	8919	8533	10559
		Euro I - 91/542/EEC Stage I	4574	4264	4079	5047
		Euro II - 91/542/EEC Stage II	4076	3799	3634	4497
		Euro III - 2000 Standards	926	863	825	1021
	Diesel 7,5 - 16 t	Conventional	10586	9629	9537	12295
		Euro I - 91/542/EEC Stage I	5060	4603	4559	5877
		Euro II - 91/542/EEC Stage II	4508	4101	4062	5236
		Euro III - 2000 Standards	1024	931	922	1189
	Diesel 16 - 32 t	Conventional	2448	2072	2045	2590
		Euro I - 91/542/EEC Stage I	1170	991	977	1238
		Euro II - 91/542/EEC Stage II	1043	883	871	1103
		Euro III - 2000 Standards	237	200	198	250
	Diesel >32t	Conventional	4335	3868	3719	5178
		Euro I - 91/542/EEC Stage I	2072	1849	1778	2475
		Euro II - 91/542/EEC Stage II	1846	1647	1584	2205
		Euro III - 2000 Standards	419	374	360	501
Buses - Coaches	Urban Buses	Conventional	7038	6480	6308	7970
		Euro I - 91/542/EEC Stage I	757	697	679	858
		Euro II - 91/542/EEC Stage II	1343	1237	1204	1521
		Euro III - 2000 Standards	409	376	366	463
	Coaches	Conventional	1759	1620	1577	1993
		Euro I - 91/542/EEC Stage I	189	174	170	214
		Euro II - 91/542/EEC Stage II	336	309	301	380
		Euro III - 2000 Standards	102	94	92	116
Mopeds	<50 cm³	Conventional	22070	20063	20673	22818
		97/24/EC Stage I	4030	3664	3775	4167
		97/24/EC Stage II	8355	7595	7826	8638
Motorcycles	2-stroke >50 cm³	Conventional	0	0	0	0
		97/24/EC	0	0	0	0
	4-stroke <250 cm³	Conventional	6092	5538	5707	6299
		97/24/EC	3419	3108	3203	3535
	4-stroke 250 - 750 cm³	Conventional	6092	5538	5707	6299
		97/24/EC	3419	3108	3203	3535
	4-stroke >750 cm³	Conventional	6092	5538	5707	6299
		97/24/EC	3419	3108	3203	3535

Table C.5: Hourly vehicle distribution in Skårersletta, Oslo, 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	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	0,3	0,2	0,1	0,1	0,1	0,3	1,6	2,7	2,1	1,4	1,4	1,6
		ECE 15/03	221,0	141,4	105,5	91,3	95,5	260,3	1370,3	2248,5	1715,1	1166,4	1133,9	1300,1
		ECE 15/04	2115,8	1353,7	1010,2	874,0	913,9	2491,9	13116,9	21522,9	16417,6	11165,1	10854,0	12445,1
		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	2969,3	1899,7	1417,7	1226,5	1282,6	3497,1	18407,7	30204,3	23039,9	15668,7	15232,0	17465,0
		Euro II - 94/12/EC	3500,9	2239,8	1671,5	1446,2	1512,2	4123,2	21703,6	35612,3	27165,1	18474,2	17959,3	20592,0
		Euro III - 98/69/EC Stage2000	1289,3	824,8	615,5	532,6	556,9	1518,4	7992,6	13114,6	10003,9	6803,3	6613,7	7583,2
	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	0,4	0,2	0,2	0,1	0,2	0,4	2,2	3,6	2,8	1,9	1,8	2,1
		ECE 15/03	298,7	191,1	142,6	123,4	129,0	351,8	1851,6	3038,1	2317,5	1576,1	1532,1	1756,7
		ECE 15/04	2858,9	1829,1	1365,0	1181,0	1234,9	3367,1	17723,6	29081,8	22183,6	15086,4	14666,0	16815,9
		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	4012,1	2566,9	1915,5	1657,3	1733,0	4725,2	24872,7	40812,3	31131,6	21171,7	20581,6	23598,8
		Euro II - 94/12/EC	4730,5	3026,5	2258,5	1954,1	2043,3	5571,3	29326,0	48119,6	36705,6	24962,4	24266,7	27824,1
		Euro III - 98/69/EC Stage2000	1742,0	1114,5	831,7	719,6	752,5	2051,7	10799,6	17720,6	13517,3	9192,7	8936,5	10246,5
	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	0,1	0,1	0,0	0,0	0,0	0,1	0,5	0,9	0,7	0,5	0,4	0,5
		ECE 15/03	72,9	46,6	34,8	30,1	31,5	85,8	451,9	741,4	565,6	384,6	373,9	428,7
		ECE 15/04	697,7	446,4	333,1	288,2	301,4	821,7	4325,4	7097,4	5413,9	3681,8	3579,2	4103,9
		Euro I - 91/441/EEC	979,1	626,4	467,5	404,5	422,9	1153,2	6070,1	9960,1	7597,6	5166,9	5022,9	5759,2
		Euro II - 94/12/EC	1154,5	738,6	551,2	476,9	498,7	1359,7	7156,9	11743,5	8957,9	6092,0	5922,2	6790,4
		Euro III - 98/69/EC Stage2000	425,1	272,0	203,0	175,6	183,6	500,7	2635,6	4324,7	3298,9	2243,5	2180,9	2500,6
	Diesel <2,0 l	Conventional	226,6	144,9	108,2	93,6	97,9	266,8	1404,5	2304,6	1757,9	1195,5	1162,2	1332,6
		Euro I - 91/441/EEC	150,8	96,5	72,0	62,3	65,1	177,6	934,9	1534,0	1170,1	795,8	773,6	887,0
		Euro II - 94/12/EC	303,1	193,9	144,7	125,2	130,9	357,0	1879,0	3083,2	2351,9	1599,4	1554,9	1782,8
		Euro III - 98/69/EC Stage2000	141,9	90,8	67,8	58,6	61,3	167,1	879,8	1443,7	1101,2	748,9	728,0	834,8
	Diesel >2,0 l	Conventional	151,0	96,6	72,1	62,4	65,2	177,9	936,3	1536,4	1172,0	797,0	774,8	888,4
		Euro I - 91/441/EEC	100,5	64,3	48,0	41,5	43,4	118,4	623,2	1022,7	780,1	530,5	515,7	591,3
		Euro II - 94/12/EC	202,1	129,3	96,5	83,5	87,3	238,0	1252,7	2055,5	1567,9	1066,3	1036,6	1188,5
		Euro III - 98/69/EC Stage2000	94,6	60,5	45,2	39,1	40,9	111,4	586,5	962,4	734,1	499,3	485,4	556,5
	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	790,7	505,9	377,5	326,6	341,5	931,2	4901,8	8043,2	6135,4	4172,5	4056,2	4650,8
		Euro I - 93/59/EEC	20,9	13,4	10,0	8,6	9,0	24,6	129,5	212,5	162,1	110,2	107,2	122,9
		Euro II - 96/69/EC	59,0	37,8	28,2	24,4	25,5	69,5	365,9	600,4	458,0	311,5	302,8	347,2
		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	133,0	85,1	63,5	55,0	57,5	156,7	824,7	1353,2	1032,2	702,0	682,4	782,5
		Euro I - 93/59/EEC	104,3	66,7	49,8	43,1	45,0	122,8	646,4	1060,7	809,1	550,2	534,9	613,3
		Euro II - 96/69/EC	525,5	336,2	250,9	217,1	227,0	618,9	3257,7	5345,4	4077,4	2772,9	2695,7	3090,8
		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
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	188,0	143,8	130,8	116,3	230,0	787,2	2007,2	2170,1	2351,3	2844,4	2931,0	2864,6
		Euro I - 91/542/EEC Stage I	89,9	68,7	62,5	55,6	109,9	376,3	959,5	1037,3	1123,9	1359,6	1401,0	1369,3
		Euro II - 91/542/EEC Stage II	80,1	61,2	55,7	49,5	97,9	335,3	854,9	924,2	1001,4	1211,4	1248,3	1220,0
		Euro III - 2000 Standards	18,2	13,9	12,7	11,3	22,2	76,1	194,1	209,9	227,4	275,1	283,5	277,1
	Diesel 7,5 - 16 t	Conventional	118,9	79,1	91,2	212,4	302,0	764,9	2392,3	3154,1	3266,3	3381,7	3370,4	3194,2
		Euro I - 91/542/EEC Stage I	56,8	37,8	43,6	101,5	144,4	365,6	1143,5	1507,6	1561,3	1616,4	1611,0	1526,8
		Euro II - 91/542/EEC Stage II	50,6	33,7	38,8	90,5	128,6	325,8	1018,9	1343,3	1391,1	1440,2	1435,4	1360,4
		Euro III - 2000 Standards	11,5	7,7	8,8	20,5	29,2	74,0	231,4	305,1	315,9	327,1	326,0	309,0
	Diesel 16 - 32 t	Conventional	47,0	51,0	24,0	39,5	48,5	209,4	450,9	902,7	843,2	690,3	629,8	618,8
		Euro I - 91/542/EEC Stage I	22,5	24,4	11,5	18,9	23,2	100,1	215,5	431,5	403,1	330,0	301,0	295,8
		Euro II - 91/542/EEC Stage II	20,0	21,7	10,2	16,8	20,6	89,2	192,0	384,5	359,1	294,0	268,2	263,5
		Euro III - 2000 Standards	4,5	4,9	2,3	3,8	4,7	20,3	43,6	87,3	81,6	66,8	60,9	59,9
	Diesel >32t	Conventional	104,5	53,5	47,5	64,5	101,0	248,9	877,7	938,7	1166,1	1403,1	1532,0	1555,0
		Euro I - 91/542/EEC Stage I	49,9	25,6	22,7	30,8	48,3	119,0	419,6	448,7	557,4	670,7	732,3	743,3
		Euro II - 91/542/EEC Stage II	44,5	22,8	20,2	27,5	43,0	106,0	373,8	399,8	496,7	597,6	652,5	662,3
		Euro III - 2000 Standards	10,1	5,2	4,6	6,2	9,8	24,1	84,9	90,8	112,8	135,7	148,2	150,4
Buses - Coaches	Urban Buses	Conventional	108,5	79,1	78,4	113,5	185,0	543,6	1533,5	1847,2	1951,0	2170,2	2198,2	2115,1
		Euro I - 91/542/EEC Stage I	11,7	8,5	8,4	12,2	19,9	58,5	165,0	198,8	210,0	233,6	236,6	227,6
		Euro II - 91/542/EEC Stage II	20,7	15,1	15,0	21,7	35,3	103,8	292,7	352,6	372,4	414,2	419,6	403,7
		Euro III - 2000 Standards	6,3	4,6	4,5	6,6	10,7	31,6	89,0	107,3	113,3	126,0	127,6	122,8
	Coaches	Conventional	27,1	19,8	19,6	28,4	46,3	135,9	383,4	461,8	487,8	542,6	549,5	528,8
		Euro I - 91/542/EEC Stage I	2,9	2,1	2,1	3,1	5,0	14,6	41,3	49,7	52,5	58,4	59,1	56,9
		Euro II - 91/542/EEC Stage II	5,2	3,8	3,7	5,4	8,8	25,9	73,2	88,1	93,1	103,6	104,9	100,9
		Euro III - 2000 Standards	1,6	1,1	1,1	1,6	2,7	7,9	22,3	26,8	28,3	31,5	31,9	30,7
Mopeds	<50 cm³	Conventional	677,4	433,4	323,4	279,8	292,6	797,8	4199,5	6890,8	5256,3	3574,6	3475,0	3984,4
		97/24/EC Stage I	123,7	79,1	59,1	51,1	53,4	145,7	766,9	1258,4	959,9	652,8	634,6	727,6
		97/24/EC Stage II	256,5	164,1	122,4	105,9	110,8	302,0	1589,8	2608,7	1989,9	1353,3	1315,6	1508,4
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	187,0	119,6	89,3	77,2	80,8	220,2	1159,3	1902,2	1451,0	986,8	959,3	1099,9
		97/24/EC	104,9	67,1	50,1	43,3	45,3	123,6	650,6	1067,5	814,3	553,8	538,3	617,3
	4-stroke 250 - 750 cm³	Conventional	187,0	119,6	89,3	77,2	80,8	220,2	1159,3	1902,2	1451,0	986,8	959,3	1099,9
		97/24/EC	104,9	67,1	50,1	43,3	45,3	123,6	650,6	1067,5	814,3	553,8	538,3	617,3
	4-stroke >750 cm³	Conventional	187,0	119,6	89,3	77,2	80,8	220,2	1159,3	1902,2	1451,0	986,8	959,3	1099,9
		97/24/EC	104,943	67,141	50,1041	43,3497	45,3301	123,596	650,583	1067,51	814,296	553,778	538,345	617,263

Table C.6: Hourly vehicle distribution in Skårersletta, Oslo, 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	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	1,9	2,2	3,1	3,2	2,4	1,9	1,6	1,3	1,0	0,8	0,5
		ECE 15/03	1442,9	1622,2	1873,4	2566,8	2634,0	1983,3	1622,0	1312,1	1070,1	862,0	663,2	437,8
		ECE 15/04	13812,2	15528,6	17932,7	24570,1	25213,3	18984,5	15525,9	12559,5	10242,9	8250,9	6348,0	4191,1
		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	19383,5	21792,2	25166,0	34480,7	35383,3	26642,0	21788,5	17625,5	14374,5	11579,0	8908,5	5881,6
		Euro II - 94/12/EC	22854,1	25694,0	29671,9	40654,3	41718,6	31412,2	25689,6	20781,3	16948,2	13652,2	10503,5	6934,7
		Euro III - 98/69/EC Stage2000	8416,3	9462,1	10927,0	14971,4	15363,4	11567,9	9460,5	7652,9	6241,3	5027,6	3868,0	2553,8
	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	2,3	2,6	3,0	4,2	4,3	3,2	2,6	2,1	1,7	1,4	1,1	0,7
		ECE 15/03	1949,7	2192,0	2531,3	3468,3	3559,1	2679,8	2191,6	1772,9	1445,9	1164,7	896,1	591,6
		ECE 15/04	18663,2	20982,3	24230,8	33199,2	34068,4	25651,9	20978,7	16970,5	13840,2	11148,7	8577,4	5663,0
		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	26191,1	29445,7	34004,5	46590,5	47810,2	35998,9	29440,7	23815,7	19422,9	15645,7	12037,2	7947,2
		Euro II - 94/12/EC	30880,6	34717,9	40092,9	54932,4	56370,5	42444,4	34712,0	28079,8	22900,5	18447,0	14192,4	9370,2
		Euro III - 98/69/EC Stage2000	11372,1	12785,3	14764,7	20229,5	20759,1	15630,6	12783,1	10340,7	8433,4	6793,3	5226,5	3450,7
	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	0,6	0,6	0,7	1,0	1,0	0,8	0,6	0,5	0,4	0,3	0,3	0,2
		ECE 15/03	475,8	534,9	617,8	846,4	868,6	654,0	534,9	432,7	352,9	284,2	218,7	144,4
		ECE 15/04	4554,7	5120,7	5913,5	8102,2	8314,3	6260,3	5119,8	4141,6	3377,7	2720,8	2093,3	1382,0
		Euro I - 91/441/EEC	6391,9	7186,2	8298,7	11370,3	11668,0	8785,4	7184,9	5812,2	4740,1	3818,3	2937,6	1939,5
		Euro II - 94/12/EC	7536,3	8472,8	9784,6	13406,1	13757,1	10358,5	8471,4	6852,8	5588,8	4501,9	3463,6	2286,8
		Euro III - 98/69/EC Stage2000	2775,3	3120,2	3603,3	4937,0	5066,2	3814,6	3119,7	2523,6	2058,1	1657,9	1275,5	842,1
	Diesel <2,0 l	Conventional	1479,0	1662,7	1920,2	2630,9	2699,7	2032,8	1662,4	1344,8	1096,8	883,5	679,7	448,8
		Euro I - 91/441/EEC	984,4	1106,8	1278,1	1751,2	1797,0	1353,1	1106,6	895,1	730,0	588,1	452,4	298,7
		Euro II - 94/12/EC	1978,6	2224,5	2568,9	3519,7	3611,9	2719,6	2224,1	1799,2	1467,3	1182,0	909,4	600,4
		Euro III - 98/69/EC Stage2000	926,5	1041,6	1202,8	1648,0	1691,2	1273,4	1041,4	842,4	687,0	553,4	425,8	281,1
	Diesel >2,0 l	Conventional	986,0	1108,5	1280,1	1753,9	1799,8	1355,2	1108,3	896,5	731,2	589,0	453,1	299,2
		Euro I - 91/441/EEC	656,3	737,8	852,1	1167,4	1198,0	902,0	737,7	596,8	486,7	392,0	301,6	199,1
		Euro II - 94/12/EC	1319,1	1483,0	1712,6	2346,5	2407,9	1813,1	1482,8	1199,5	978,2	788,0	606,2	400,3
		Euro III - 98/69/EC Stage2000	617,6	694,4	801,9	1098,7	1127,5	848,9	694,3	561,6	458,0	369,0	283,9	187,4
	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	5161,7	5803,1	6701,5	9182,0	9422,3	7094,6	5802,1	4693,5	3827,8	3083,4	2372,3	1566,2
		Euro I - 93/59/EEC	136,4	153,3	177,1	242,6	248,9	187,4	153,3	124,0	101,1	81,5	62,7	41,4
		Euro II - 96/69/EC	385,3	433,2	500,3	685,5	703,4	529,6	433,1	350,4	285,8	230,2	177,1	116,9
		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 <3,5 t	Conventional	868,4	976,3	1127,5	1544,8	1585,2	1193,6	976,2	789,6	644,0	518,8	399,1	263,5
		Euro I - 93/59/EEC	680,7	765,3	883,8	1210,9	1242,6	935,6	765,1	619,0	504,8	406,6	312,8	206,5
		Euro II - 96/69/EC	3430,4	3856,6	4453,7	6102,2	6261,9	4714,9	3856,0	3119,2	2543,9	2049,2	1576,6	1040,9
		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	3209,0	3255,1	3177,7	3001,5	2210,1	1670,9	1289,9	1021,7	733,8	600,3	405,0	242,2
		Euro I - 91/542/EEC Stage I	1533,9	1556,0	1518,9	1434,7	1056,4	798,7	616,5	488,4	350,7	286,9	193,6	115,8
		Euro II - 91/542/EEC Stage II	1366,7	1386,4	1353,4	1278,3	941,3	711,6	549,3	435,2	312,5	255,7	172,5	103,1
		Euro III - 2000 Standards	310,4	314,9	307,4	290,3	213,8	161,6	124,8	98,8	71,0	58,1	39,2	23,4
	Diesel 7,5 - 16 t	Conventional	3462,3	3421,0	3418,7	3104,6	2447,2	1865,8	1336,6	974,6	677,7	513,2	302,8	194,8
		Euro I - 91/542/EEC Stage I	1655,0	1635,2	1634,1	1484,0	1169,8	891,8	638,9	465,9	323,9	245,3	144,7	93,1
		Euro II - 91/542/EEC Stage II	1474,6	1457,0	1456,0	1322,2	1042,3	794,6	569,3	415,1	288,6	218,6	129,0	83,0
		Euro III - 2000 Standards	334,9	330,9	330,7	300,3	236,7	180,5	129,3	94,3	65,5	49,6	29,3	18,8
	Diesel 16 - 32 t	Conventional	634,8	650,8	633,8	657,8	598,8	432,9	296,4	225,4	170,9	131,5	104,0	63,0
		Euro I - 91/542/EEC Stage I	303,4	311,1	303,0	314,4	286,2	206,9	141,7	107,8	81,7	62,8	49,7	30,1
		Euro II - 91/542/EEC Stage II	270,4	277,2	269,9	280,2	255,0	184,4	126,2	96,0	72,8	56,0	44,3	26,8
		Euro III - 2000 Standards	61,4	62,9	61,3	63,6	57,9	41,9	28,7	21,8	16,5	12,7	10,1	6,1
	Diesel >32t	Conventional	1541,0	1480,0	1351,1	1182,1	1015,7	711,8	438,9	371,4	311,4	251,9	199,4	153,5
		Euro I - 91/542/EEC Stage I	736,6	707,5	645,8	565,1	485,5	340,2	209,8	177,5	148,9	120,4	95,3	73,4
		Euro II - 91/542/EEC Stage II	656,3	630,3	575,4	503,5	432,6	303,1	186,9	158,2	132,6	107,3	84,9	65,4
		Euro III - 2000 Standards	149,1	143,2	130,7	114,3	98,2	68,8	42,4	35,9	30,1	24,4	19,3	14,8
Buses - Coaches	Urban Buses	Conventional	2330,7	2333,9	2304,7	2135,4	1626,1	1234,6	918,5	699,5	494,9	391,2	249,4	153,7
		Euro I - 91/542/EEC Stage I	250,8	251,2	248,0	229,8	175,0	132,9	98,9	75,3	53,3	42,1	26,8	16,5
		Euro II - 91/542/EEC Stage II	444,9	445,5	439,9	407,6	310,4	235,7	175,3	133,5	94,5	74,7	47,6	29,3
		Euro III - 2000 Standards	135,3	135,5	133,8	124,0	94,4	71,7	53,3	40,6	28,7	22,7	14,5	8,9
	Coaches	Conventional	582,7	583,5	576,2	533,8	406,5	308,6	229,6	174,9	123,7	97,8	62,4	38,4
		Euro I - 91/542/EEC Stage I	62,7	62,8	62,0	57,5	43,8	33,2	24,7	18,8	13,3	10,5	6,7	4,1
		Euro II - 91/542/EEC Stage II	111,2	111,4	110,0	101,9	77,6	58,9	43,8	33,4	23,6	18,7	11,9	7,3
		Euro III - 2000 Standards	33,8	33,9	33,5	31,0	23,6	17,9	13,3	10,2	7,2	5,7	3,6	2,2
Mopeds	<50 cm³	Conventional	4422,1	4971,6	5741,4	7866,4	8072,3	6078,1	4970,8	4021,1	3279,4	2641,6	2032,4	1341,8
		97/24/EC Stage I	807,6	907,9	1048,5	1436,5	1474,1	1110,0	907,8	734,3	598,9	482,4	371,1	245,0
		97/24/EC Stage II	1674,1	1882,2	2173,5	2978,0	3056,0	2301,0	1881,8	1522,3	1241,5	1000,1	769,4	508,0
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	1220,7	1372,4	1584,9	2171,5	2228,4	1677,9	1372,2	1110,0	905,3	729,2	561,0	370,4
		97/24/EC	685,1	770,2	889,4	1218,6	1250,6	941,6	770,1	622,9	508,0	409,2	314,9	207,9
	4-stroke 250 - 750 cm³	Conventional	1220,7	1372,4	1584,9	2171,5	2228,4	1677,9	1372,2	1110,0	905,3	729,2	561,0	370,4
		97/24/EC	685,1	770,2	889,4	1218,6	1250,6	941,6	770,1	622,9	508,0	409,2	314,9	207,9
	4-stroke >750 cm³	Conventional	1220,7	1372,4	1584,9	2171,5	2228,4	1677,9	1372,2	1110,0	905,3	729,2	561,0	370,4
		97/24/EC	685,07	770,199	889,441	1218,65	1250,55	941,607	770,068	622,936	508,035	409,237	314,852	207,873

Table C.7: Hourly vehicle distribution in Ermou St., Thessaloniki, 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	2,7	1,8	1,2	1,2	3,4	13,7	31,7	26,2	14,0	12,0	10,7	17,4
		ECE 15/00-01	14,9	9,9	6,8	6,8	18,6	75,8	175,2	144,9	77,5	78,7	58,8	95,8
		ECE 15/02	12,4	8,2	5,7	5,7	15,5	63,0	145,6	120,4	64,4	65,4	48,9	79,6
		ECE 15/03	20,5	13,6	9,4	9,4	25,6	104,4	241,2	199,4	106,7	108,4	81,0	131,9
		ECE 15/04	33,7	22,4	15,5	15,5	42,1	171,6	396,6	328,0	175,4	178,2	133,2	216,9
		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	0,8	0,5	0,4	0,4	1,0	4,0	9,3	7,7	4,1	4,2	3,1	5,1
		Euro I - 91/441/EEC	50,8	33,7	23,3	23,3	63,5	258,4	597,2	493,8	264,1	268,4	200,6	326,7
		Euro II - 94/12/EC	38,6	25,6	17,7	17,7	48,2	196,3	453,7	375,1	200,6	203,9	152,4	248,2
		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 1,4 - 2,0 l	PRE ECE	0,4	0,3	0,2	0,2	0,5	2,0	4,6	3,8	2,0	2,1	1,5	2,5
		ECE 15/00-01	2,1	1,4	1,0	1,0	2,7	10,9	25,2	20,8	11,1	11,3	8,5	13,8
		ECE 15/02	1,8	1,2	0,8	0,8	2,2	9,1	20,9	17,3	9,3	9,4	7,0	11,5
		ECE 15/03	3,0	2,0	1,4	1,4	3,7	15,0	34,7	28,7	15,3	15,6	11,7	19,0
		ECE 15/04	4,9	3,2	2,2	2,2	6,1	24,7	57,1	47,2	25,2	25,6	19,2	31,2
		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	0,1	0,1	0,1	0,1	0,1	0,6	1,3	1,1	0,6	0,6	0,4	0,7
		Euro I - 91/441/EEC	7,3	4,8	3,4	3,4	9,1	37,2	85,9	71,0	38,0	38,6	28,9	47,0
		Euro II - 94/12/EC	5,6	3,7	2,5	2,5	6,9	28,2	65,3	54,0	28,9	29,3	21,9	35,7
		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 >2,0 l	PRE ECE	0,1	0,0	0,0	0,0	0,1	0,4	0,8	0,7	0,4	0,4	0,3	0,4
		ECE 15/00-01	0,4	0,3	0,2	0,2	0,5	2,0	4,5	3,7	2,0	2,0	1,5	2,5
		ECE 15/02	0,3	0,2	0,1	0,1	0,4	1,6	3,7	3,1	1,7	1,7	1,3	2,0
		ECE 15/03	0,5	0,4	0,2	0,2	0,7	2,7	6,2	5,1	2,7	2,8	2,1	3,4
		ECE 15/04	0,6	0,4	0,3	0,3	0,8	3,3	7,5	6,2	3,3	3,4	2,5	4,1
		Euro I - 91/441/EEC	1,6	1,0	0,7	0,7	1,9	7,9	18,3	15,1	8,1	8,2	6,1	10,0
		Euro II - 94/12/EC	1,0	0,7	0,5	0,5	1,2	5,1	11,7	9,7	5,2	5,2	3,9	6,4
		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
	Diesel <2,0 l	Conventional	20,1	13,3	9,2	9,2	25,1	102,3	236,4	322,6	154,6	194,8	150,6	129,3
		Euro I - 91/441/EEC	3,4	2,3	1,6	1,6	4,3	17,5	40,5	55,2	26,5	33,4	25,8	22,1
		Euro II - 94/12/EC	0,4	0,3	0,2	0,2	0,6	2,3	5,2	7,1	3,4	4,3	3,3	2,8
		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	13,4	8,9	6,1	6,1	16,7	68,2	157,6	215,1	103,1	129,9	100,4	86,2
		Euro I - 91/441/EEC	2,3	1,5	1,1	1,1	2,9	11,7	27,0	36,8	17,7	22,2	17,2	14,8
		Euro II - 94/12/EC	0,3	0,2	0,1	0,1	0,4	1,5	3,5	4,7	2,3	2,9	2,2	1,9
		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	0,3	0,2	0,1	0,1	0,4	1,5	3,5	2,9	1,5	1,6	1,2	1,9
		Euro I - 91/441/EEC	0,1	0,1	0,0	0,0	0,1	0,4	0,9	0,7	0,4	0,4	0,3	0,5
		Euro II - 94/12/EC	0,1	0,1	0,0	0,0	0,1	0,5	1,2	1,0	0,5	0,5	0,4	0,7
		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
	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	14,8	9,8	6,8	6,8	18,5	75,4	174,2	452,0	241,8	245,7	183,6	95,3
		Euro I - 93/59/EEC	1,2	0,8	0,6	0,6	1,5	6,1	14,2	36,8	19,7	20,0	14,9	7,7
		Euro II - 96/69/EC	1,8	1,2	0,8	0,8	2,3	9,3	21,5	55,9	29,9	30,4	22,7	11,8
		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 <3,5 t	Conventional	0,0	0,0	0,0	0,0	0,0	0,1	0,3	0,7	0,4	0,4	0,3	0,1
		Euro I - 93/59/EEC	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	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	0,0	0,1	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
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	2,7	1,8	1,2	1,2	3,4	13,7	31,6	54,1	17,9	27,5	21,4	17,3
		Euro I - 91/542/EEC Stage I	0,4	0,2	0,2	0,2	0,4	1,8	4,2	7,1	2,4	3,6	2,8	2,3
		Euro II - 91/542/EEC Stage II	0,3	0,2	0,2	0,2	0,4	1,8	4,1	7,0	2,3	3,6	2,8	2,2
		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	5,6	3,7	2,5	2,5	6,9	28,2	65,3	111,7	37,0	56,9	44,1	35,7
		Euro I - 91/542/EEC Stage I	0,7	0,5	0,3	0,3	0,9	3,7	8,6	14,7	4,9	7,5	5,8	4,7
		Euro II - 91/542/EEC Stage II	0,7	0,5	0,3	0,3	0,9	3,7	8,4	14,4	4,8	7,4	5,7	4,6
		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	1,0	0,7	0,5	0,5	1,3	5,2	11,9	45,2	22,6	12,3	8,8	6,5
		Euro I - 91/542/EEC Stage I	0,2	0,2	0,1	0,1	0,3	1,2	2,8	10,4	5,2	2,8	2,0	1,5
		Euro II - 91/542/EEC Stage II	0,2	0,1	0,1	0,1	0,3	1,1	2,6	9,7	4,9	2,6	1,9	1,4
		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	1,0	0,7	0,5	0,5	1,3	5,2	11,9	62,2	15,8	5,5	4,7	6,5
		Euro I - 91/542/EEC Stage I	0,2	0,2	0,1	0,1	0,3	1,2	2,8	14,3	3,6	1,3	1,1	1,5
		Euro II - 91/542/EEC Stage II	0,2	0,1	0,1	0,1	0,3	1,1	2,6	13,4	3,4	1,2	1,0	1,4
		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 cm³	Conventional	22,3	14,8	10,2	10,2	27,9	113,5	262,2	202,9	171,8	266,3	217,7	143,4
		97/24/EC Stage I	3,3	2,2	1,5	1,5	4,2	17,0	39,2	30,3	25,7	39,8	32,5	21,4
		97/24/EC Stage II	1,7	1,1	0,8	0,8	2,1	8,6	19,8	15,3	13,0	20,1	16,4	10,8
Motorcycles	2-stroke >50 cm³	Conventional	3,6	2,4	1,7	1,7	4,5	18,5	42,7	33,0	28,0	43,3	35,4	23,3
		97/24/EC	0,8	0,5	0,4	0,4	1,0	4,2	9,6	7,4	6,3	9,7	8,0	5,3
	4-stroke <250 cm³	Conventional	4,8	3,2	2,2	2,2	6,0	24,4	56,4	43,7	37,0	57,3	46,8	30,9
		97/24/EC	1,1	0,7	0,5	0,5	1,3	5,5	12,7	9,8	8,3	12,9	10,5	6,9
	4-stroke 250 - 750 cm³	Conventional	4,8	3,2	2,2	2,2	6,0	24,4	56,4	43,7	37,0	57,3	46,8	30,9
		97/24/EC	1,1	0,7	0,5	0,5	1,3	5,5	12,7	9,8	8,3	12,9	10,5	6,9
	4-stroke >750 cm³	Conventional	4,8	3,2	2,2	2,2	6,0	24,4	56,4	43,7	37,0	57,3	46,8	30,9
		97/24/EC	1,1	0,7	0,5	0,5	1,3	5,5	12,7	9,8	8,3	12,9	10,5	6,9

Table C.8: Hourly vehicle distribution in Ermou St., Thessaloniki, 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	27,2	33,3	24,1	16,5	16,2	12,2	12,2	17,6	11,4	9,0	6,4	3,5
		ECE 15/00-01	150,0	183,8	133,2	91,3	89,5	67,2	67,4	97,3	63,1	49,9	35,5	19,3
		ECE 15/02	124,6	152,7	110,7	75,9	74,4	55,8	56,0	80,8	52,4	41,5	29,5	16,0
		ECE 15/03	206,5	253,0	183,4	125,7	123,2	92,5	92,7	133,9	86,8	68,7	48,9	26,5
		ECE 15/04	339,5	416,0	301,6	206,8	202,7	152,0	152,5	220,2	142,8	113,0	80,4	43,6
		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	8,0	9,7	7,1	4,8	4,7	3,6	3,6	5,2	3,3	2,6	1,9	1,0
		Euro I - 91/441/EEC	511,2	626,4	454,1	311,3	305,2	228,9	229,6	331,5	214,9	170,2	121,0	65,7
		Euro II - 94/12/EC	388,4	475,9	345,0	236,5	231,8	173,9	174,4	251,9	163,3	129,3	91,9	49,9
		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
	Gasoline 1,4 - 2,0 l	PRE ECE	3,9	4,8	3,5	2,4	2,3	1,7	1,8	2,5	1,6	1,3	0,9	0,5
		ECE 15/00-01	21,6	26,4	19,2	13,1	12,9	9,7	9,7	14,0	9,1	7,2	5,1	2,8
		ECE 15/02	17,9	22,0	15,9	10,9	10,7	8,0	8,1	11,6	7,5	6,0	4,2	2,3
		ECE 15/03	29,7	36,4	26,4	18,1	17,7	13,3	13,3	19,3	12,5	9,9	7,0	3,8
		ECE 15/04	48,8	59,8	43,4	29,7	29,2	21,9	21,9	31,7	20,5	16,3	11,6	6,3
		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	1,1	1,4	1,0	0,7	0,7	0,5	0,5	0,7	0,5	0,4	0,3	0,1
		Euro I - 91/441/EEC	73,5	90,1	65,3	44,8	43,9	32,9	33,0	47,7	30,9	24,5	17,4	9,5
		Euro II - 94/12/EC	55,9	68,5	49,6	34,0	33,4	25,0	25,1	36,2	23,5	18,6	13,2	7,2
		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	0,7	0,9	0,6	0,4	0,4	0,3	0,3	0,5	0,3	0,2	0,2	0,1
		ECE 15/00-01	3,9	4,7	3,4	2,4	2,3	1,7	1,7	2,5	1,6	1,3	0,9	0,5
		ECE 15/02	3,2	3,9	2,8	2,0	1,9	1,4	1,4	2,1	1,3	1,1	0,8	0,4
		ECE 15/03	5,3	6,5	4,7	3,2	3,2	2,4	2,4	3,4	2,2	1,8	1,3	0,7
		ECE 15/04	6,5	7,9	5,7	3,9	3,9	2,9	2,9	4,2	2,7	2,1	1,5	0,8
		Euro I - 91/441/EEC	15,6	19,2	13,9	9,5	9,3	7,0	7,0	10,1	6,6	5,2	3,7	2,0
		Euro II - 94/12/EC	10,0	12,2	8,9	6,1	6,0	4,5	4,5	6,5	4,2	3,3	2,4	1,3
		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	202,3	247,9	179,7	138,9	168,0	168,1	133,6	131,2	85,1	67,4	47,9	26,0
		Euro I - 91/441/EEC	34,6	42,5	30,8	23,8	28,8	28,8	22,9	22,5	14,6	11,5	8,2	4,5
		Euro II - 94/12/EC	4,5	5,5	4,0	3,1	3,7	3,7	2,9	2,9	1,9	1,5	1,1	0,6
		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
	Diesel >2,0 l	Conventional	134,9	165,3	119,8	92,6	112,0	112,1	89,1	87,5	56,7	44,9	31,9	17,3
		Euro I - 91/441/EEC	23,1	28,3	20,5	15,9	19,2	19,2	15,3	15,0	9,7	7,7	5,5	3,0
		Euro II - 94/12/EC	3,0	3,6	2,6	2,0	2,5	2,5	2,0	1,9	1,2	1,0	0,7	0,4
		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
	LPG	Conventional	3,0	3,6	2,6	1,8	1,8	1,3	1,3	1,9	1,3	1,0	0,7	0,4
		Euro I - 91/441/EEC	0,8	0,9	0,7	0,5	0,5	0,3	0,3	0,5	0,3	0,3	0,2	0,1
		Euro II - 94/12/EC	1,0	1,3	0,9	0,6	0,6	0,5	0,5	0,7	0,4	0,3	0,2	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
	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	149,1	182,7	132,4	285,0	279,3	209,6	210,2	96,7	62,7	49,6	35,3	19,2
		Euro I - 93/59/EEC	12,1	14,9	10,8	23,2	22,7	17,0	17,1	7,9	5,1	4,0	2,9	1,6
		Euro II - 96/69/EC	18,4	22,6	16,4	35,2	34,5	25,9	26,0	12,0	7,7	6,1	4,4	2,4
		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
	Diesel <3,5 t	Conventional	0,2	0,3	0,2	0,4	0,4	0,3	0,3	0,1	0,1	0,1	0,1	0,0
		Euro I - 93/59/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 - 96/69/EC	0,0	0,0	0,0	0,1	0,1	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
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	27,1	33,2	24,0	19,3	12,0	8,6	8,5	17,5	11,4	9,0	6,4	3,5
		Euro I - 91/542/EEC Stage I	3,6	4,4	3,2	2,5	1,6	1,1	1,1	2,3	1,5	1,2	0,8	0,5
		Euro II - 91/542/EEC Stage II	3,5	4,3	3,1	2,5	1,5	1,1	1,1	2,3	1,5	1,2	0,8	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
	Diesel 7,5 - 16 t	Conventional	55,9	68,5	49,6	39,9	24,7	17,7	17,5	36,2	23,5	18,6	13,2	7,2
		Euro I - 91/542/EEC Stage I	7,3	9,0	6,5	5,2	3,3	2,3	2,3	4,8	3,1	2,4	1,7	0,9
		Euro II - 91/542/EEC Stage II	7,2	8,9	6,4	5,2	3,2	2,3	2,3	4,7	3,0	2,4	1,7	0,9
		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	10,2	12,5	9,1	15,3	20,1	12,4	10,6	6,6	4,3	3,4	2,4	1,3
		Euro I - 91/542/EEC Stage I	2,4	2,9	2,1	3,5	4,6	2,9	2,4	1,5	1,0	0,8	0,6	0,3
		Euro II - 91/542/EEC Stage II	2,2	2,7	2,0	3,3	4,3	2,7	2,3	1,4	0,9	0,7	0,5	0,3
		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	10,2	12,5	9,1	13,3	6,1	2,4	1,2	6,6	4,3	3,4	2,4	1,3
		Euro I - 91/542/EEC Stage I	2,4	2,9	2,1	3,1	1,4	0,6	0,3	1,5	1,0	0,8	0,6	0,3
		Euro II - 91/542/EEC Stage II	2,2	2,7	2,0	2,9	1,3	0,5	0,3	1,4	0,9	0,7	0,5	0,3
		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	224,5	275,1	199,4	208,7	199,5	164,1	143,3	145,6	94,4	74,7	53,1	28,9
		97/24/EC Stage I	33,6	41,1	29,8	31,2	29,8	24,5	21,4	21,8	14,1	11,2	7,9	4,3
		97/24/EC Stage II	16,9	20,7	15,0	15,7	15,0	12,4	10,8	11,0	7,1	5,6	4,0	2,2
Motorcycles	2-stroke >50 cm³	Conventional	36,5	44,8	32,5	34,0	32,5	26,7	23,3	23,7	15,4	12,2	8,6	4,7
		97/24/EC	8,2	10,1	7,3	7,6	7,3	6,0	5,2	5,3	3,5	2,7	1,9	1,1
	4-stroke <250 cm³	Conventional	48,3	59,2	42,9	44,9	42,9	35,3	30,8	31,3	20,3	16,1	11,4	6,2
		97/24/EC	10,9	13,3	9,7	10,1	9,7	7,9	6,9	7,0	4,6	3,6	2,6	1,4
	4-stroke 250 - 750 cm³	Conventional	48,3	59,2	42,9	44,9	42,9	35,3	30,8	31,3	20,3	16,1	11,4	6,2
		97/24/EC	10,9	13,3	9,7	10,1	9,7	7,9	6,9	7,0	4,6	3,6	2,6	1,4
	4-stroke >750 cm³	Conventional	48,3	59,2	42,9	44,9	42,9	35,3	30,8	31,3	20,3	16,1	11,4	6,2
		97/24/EC	10,9	13,3	9,7	10,1	9,7	7,9	6,9	7,0	4,6	3,6	2,6	1,4