Generation of input parameters for OSPM calculations

Sensitivity analysis of a method based on a questionnaire

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Data sheet

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Abstract:	A method for generation of input parameters for OSPM calcualtions has been developed. This method is described and a sensitivity analysis is performed
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1 Introduction

An American study has indicated that children living close to busy streets have an increased risk for developing cancer (Savitz and Feingold, 1989). This work has generated an interest for investigating similar relationships between development of cancer among Danish children and air pollution from traffic.

Epidemiological study on 7500 Danish children

The hypothesis of such a relationship is investigated in a large epidemiological study including 2000 Danish children who in the period 1968 to 1991 were diagnosed to have developed cancer, and 5500 control children randomly chosen from the entire Danish population. A questionnaire is used to collect information about traffic, street configuration etc. at all the addresses of the 7500 children. These addresses cover the period from the conception (starting nine month before birth) to the time of diagnosis of the children.

Input for OSPM generated from a questionnaire

The information from the questionnaires are used for generating the needed input data for calculations with the Operational Street Pollution Model (OSPM) developed at the National Environmental Research Institute (NERI). The data from the questionnaires are supplied with information concerning historical evolution in emission factors for traffic and some statistical data derived from the available air pollution measurements in the Danish air quality monitoring programmes. OSPM calculates the outdoor air pollution levels at the addresses. These results will form the basis for estimating the long term exposure of the children.

Present work

This report describes the procedure used to interpret the information contained in the questionnaires and creation of the necessary input data for the air pollution model OSPM. Furthermore, some tests are performed on available measurements from the Danish monitoring programmes in order to elucidate the sensitivity of the model results to different parameters gained from the questionnaires.

Pilot study

An ongoing study "Danish children exposure to traffic exhaust fumes" includes among other things long-term measurements of NO_2 carried out at 200 addresses. These results will facilitate further testing of the model tool (Raaschou-Nielsen et al., 1994, 1995).

Framework

All the aforementioned activities are carried out under the framework of the Danish Environmental Research Programme as multi disciplinary co-operation between the Danish Cancer Society (coordinating the activities), National Environmental Research Institute, The Danish National Institute of Occupational Health and the University of Odense.

Exposure related to levels outside the home

It is a basic assumption in the childhood cancer study that the exposure of children to cancer causing airborne chemical compounds and subsequent dosage can be related to the pollution levels outside their home. This part is investigated through a monitoring study concerning the 200 children. Considering that this basic assumption is valid, the next step is to establish a method for computation of the pollution levels outside the homes of the children. This method is based on the air pollution model OSPM.

The questionnaire

In order to establish the needed input data for OSPM, a questionnaire was developed at the Danish Cancer Society based on input from NERI and the Danish Road Directorate. The local municipalities were requested to fill out the questionnaires for all the addresses of the children both in the pilot study concerning the 200 children and the epidemiological study of the 7,500 children. Additionally questionnaires were requested to be filled out for locations covering street pollution monitoring stations. These data are used in the test of the computational method.

Objectives

Comparison of model results with the data from the monitoring stations provides an excellent opportunity to evaluate the accuracy and sensitivity of the method especially in view of the uncertainties in the generated input data.

2 The Operational Street Pollution Model

Since the calculation method is based on OSPM, a short description of the model is given in this section. Emphasis is put on the different input parameters, the model variables, and their physical meaning.

2.1 Short description of the OSPM

The OSPM was developed with the aim to provide an efficient tool for calculation of traffic pollution dispersion in urban street canyons (Hertel and Berkowicz, 1989a; Hertel et al., 1990).

Test of the street pollution model

The model calculates hour by hour concentrations of car exhaust gases in the street. A number of tests have shown that the model is able to reproduce very well the observed behaviour of pollution concentrations in the street and especially the dependency of pollution levels on the meteorological conditions and street configuration.

Wind flow in a street canyon

The main properties of the wind flow in a street canyon are illustrated in (Fig. 2.1). When the wind direction is perpendicular to the street axis a vortex is generated such that the wind flow at street level is opposite to the flow above roof level. Formation of this vortex is gradually attenuated for wind speeds below 2 m/s.

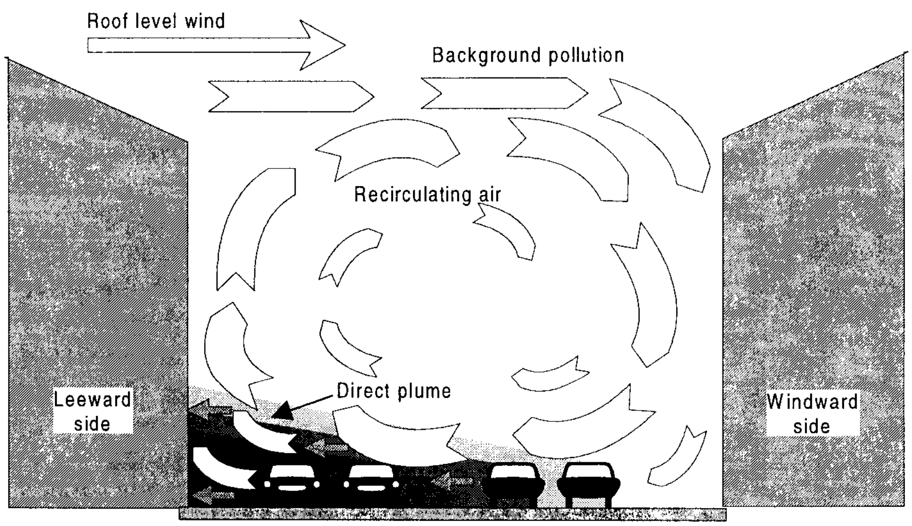


Figure 2.1 Wind circulation in a street canyon

Three contributions to levels in the street

Considering a chemically passive compound, concentrations in the street are calculated in the model as a sum of three contributions: the direct contribution from the traffic to the receptor point at the pavement on one side of the street, the contribution from recirculation inside the street and finally the contribution from sources outside the street - the city background (Berkowicz et al., 1996; Berkowicz et al., 1997a).

The direct contribution

The direct contribution is calculated by applying a plume dispersion formula, which gives the concentration variation depending on the *emissions* in the street (per length and time units), the *width* of the street, the average *vehicle speed*, the *number of vehicles* per time unit, and the wind speed at street level. It is assumed that the dispersion of the plume is solely governed by the mechanical turbulence, which is generated by two mechanisms: by the wind and by the traffic in the street. The average driving speed and the number of vehicles are used for the estimate of the mechanical turbulence generated by the traffic (Hertel and Berkowicz, 1989c), while the wind speed at street level is calculated using the *wind speed* at roof level and the depth of the street, given by the *height of the buildings* along the street.

Contribution from recirculation

The recirculation inside the street due to the vortex is simulated by a "recirculation zone", whose extension is calculated based on the length of the street vortex. It is assumed that the recirculation zone has the shape of a trapeze, with the upper edge being the half of the vortex length which is estimated by the height of the upwind buildings and the wind speed.

For a receptor on the leeward side the direct contribution is calculated taking into account the emissions from traffic in the recirculation zone only. For a receptor on the windward side only contributions from the emissions outside the recirculation zone are taken into account. If the recirculation zone extends through the whole canyon, no direct contribution is given for the receptor on the windward side.

The concentrations in the recirculation zone are calculated assuming that the inflow rate of pollutants into the recirculation zone is equal to the outflow rate and that the pollutants are well mixed inside the zone. The recirculation contribution depends on *emissions* in the street (per length and time unit), the *width* of the street, the *wind speed* and the dimensions of the recirculation zone inside the street (given by *wind speed, height of upwind and downwind buildings*).

Dependence of pollution levels on wind direction

The wind circulation conditions result in a characteristic dependence of pollution in the street on *wind direction* relative to the street axis. Concentrations on the windward side are much lower than on the leeward side. If the street is open on one side or there are openings between the buildings this dependence is much less pronounced (Berkowicz et al., 1997b; Hertel et al., 1995). This is illustrated in Fig. 2.2 where model results are presented for two East West oriented streets; one with buildings on both side and one with buildings on one side only.

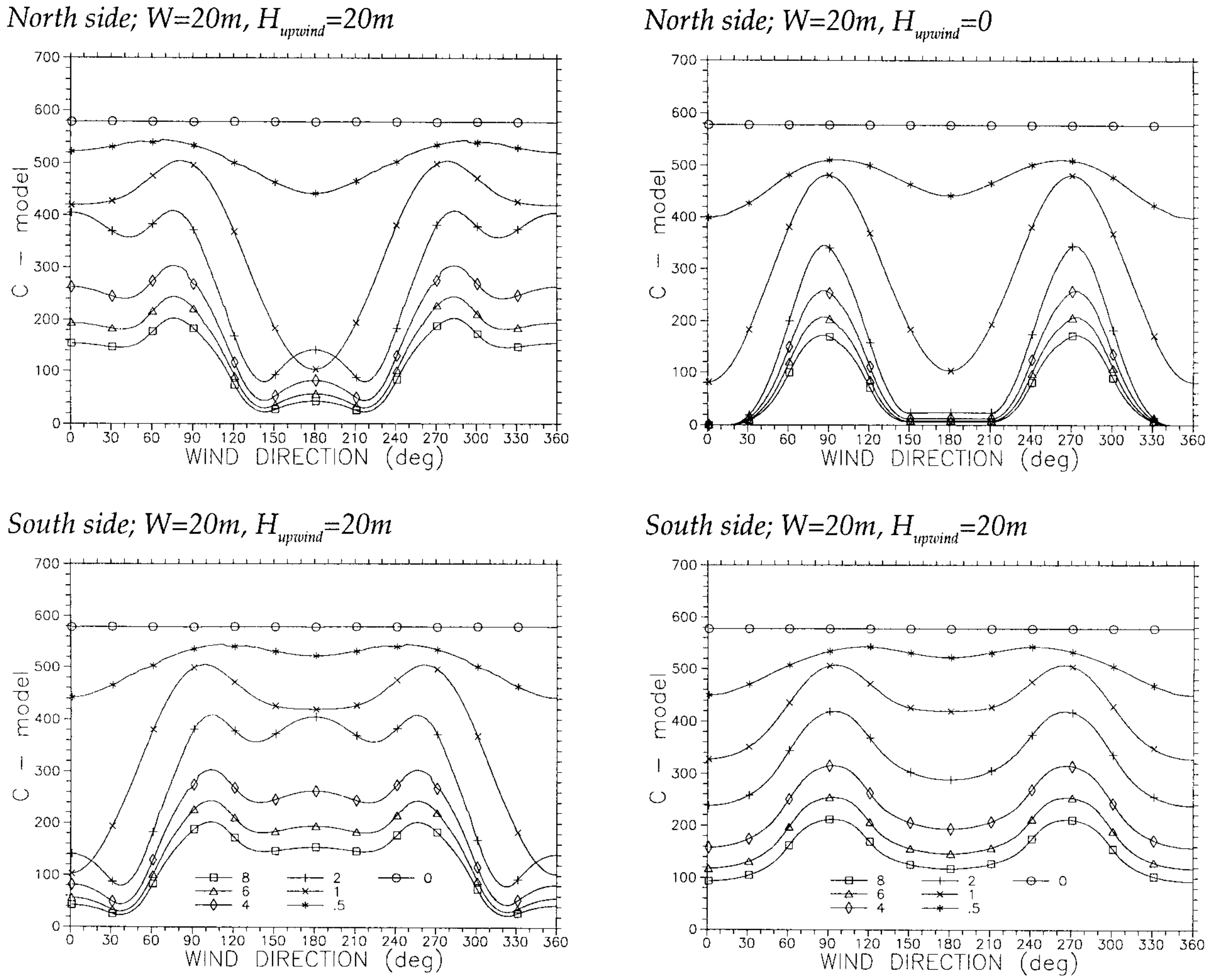


Figure 2.2 Modelled concentrations as function of wind direction and wind speed for a 20m wide East-West oriented street canyon with 20m high buildings on both sides (on left) and 20m high buildings on the south side only (on right) (from Berkowicz et al. 1997b).

Submodel for NO_2 calculation

OSPM contains a simple chemical submodel which is used for calculation of NO_2 concentrations (Hertel and Berkowicz, 1989b, Hertel and Berkowicz, 1990a). Only about 5% of NO_x emissions from gasoline driven cars are emitted as NO_2 and the rest as harmless NO. The main part of the NO_2 in the street is chemically formed. Due to the short residence time in the street only the reaction between NO and ozone and photo dissociation of NO_2 to NO and O radical (quickly reacting with O_2 to reform ozone), given by

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$NO_2 + h\nu \rightarrow NO + O$$

are of importance in the Danish urban streets. The reaction rate of the first reaction is *temperature* dependent, while *solar radiation* determines the transformation rate of NO_2 back to NO. The ozone concentrations have been shown in most cases to be the limiting factor for the NO_2 levels in the Danish urban streets (Palmgren et al., 1996).

The city background is the contribution from long range transport and from other sources in the urban area i.e. traffic in other streets. Therefore background concentrations of NO_2, NO_x, CO, and O_3 are input parameters for the model.

NO_2 fraction of NO_x ($NO+NO_2$)

The street canyon NO_2/NO_x relationship computed according to the method implemented in OSPM is shown in Fig. 2.3. Here calculations are made for three values of background ozone concentrations: $[O_3]_b$=5, 40 and 80 ppb. For simplicity, the background concentrations of NO_x are assumed to be zero. The meteorological conditions for this example correspond to a summer day with a wind speed of 5 m/s. The direct emission of NO_2 is set to 5% of NO_x. For comparison, predictions from two other simple models are also shown in the figure.

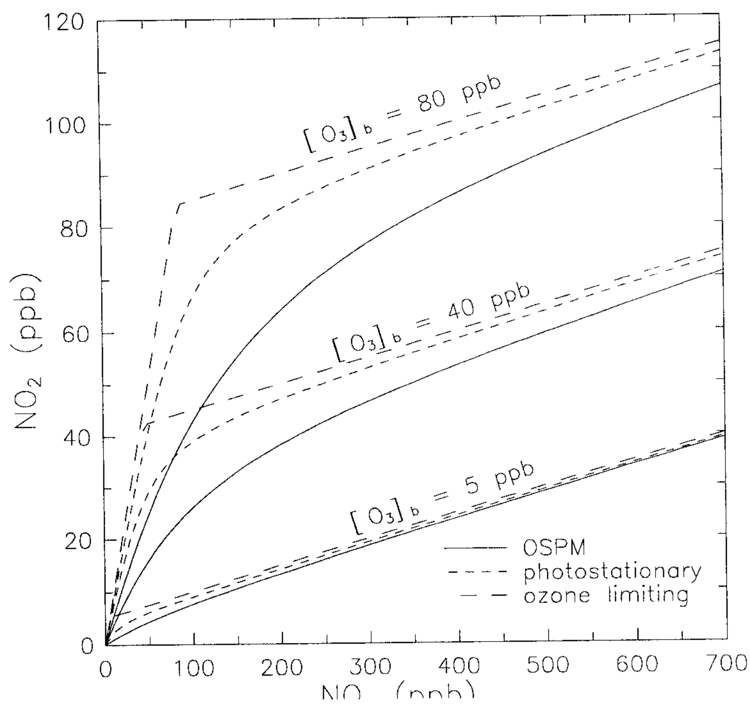


Figure 2.3 Relationship between NO_2 and NO_x for three values of background ozone as computed by OSPM and two other simple models (from Berkowicz et al. 1997b).

Compounds included in OSPM

The present version of the model is prepared for calculations of NO_x, NO_2, NO, CO, and benzene. Benzene background concentrations are estimated from corresponding concentrations of CO.

Dispersion from street edge in case of distant buildings

Some few additional features were elaborated into the model in order to make it suitable for the present application. If the address (receptor point) is not at the street edge, the contribution at the receptor is calculated assuming a linear dilution with distance from the street edge. In the case where a busy street crosses in the vicinity of the address site, emissions from the crossing street are accounted for in the calculations of the pollution levels at the address. The crossing street is considered as a line source and concentrations are calculated assuming a linear dilution with the distance and an initial dispersion which is equal to the height of the surrounding buildings.

2.2 Input parameters to the OSPM calculations

Model structure

The general structure of the input for the OSPM is shown in Fig. 2.4.

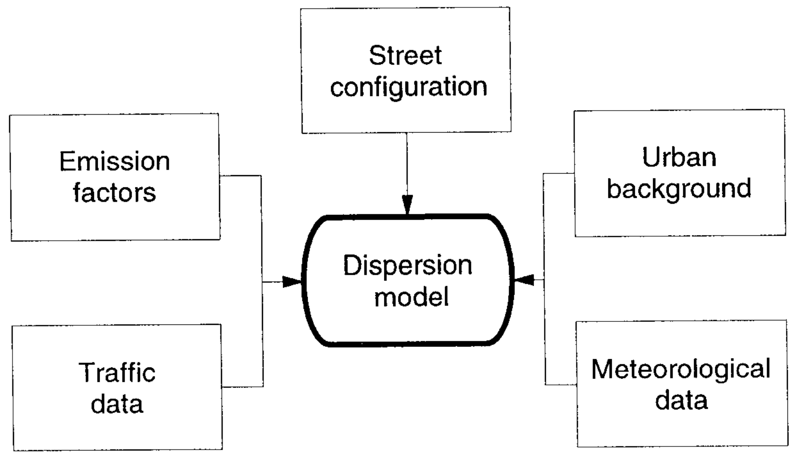


Figure 2.4 The general structure of the input for the OSPM.

Street configuration

The street configuration data include:

- orientation of the street,
- street width,
- average height of the buildings,
- location of the receptor point,
- length of the street seen from the receptor point in the two directions,
- sectors without buildings or with buildings of different heights.

Traffic data

Traffic data are given as average diurnal profiles for the traffic density over the day, distinguishing between working days, Saturdays and Sundays. Furthermore, separate diurnal profiles are specified for the Danish summer holiday period in July. The diurnal profiles include specification of numbers of:

- passenger cars,
- vans,
- heavy vehicles (lorries and buses),
- their mean driving speed,
- percentage of cold starts.

Emission factors

Emission factors are specified for NO_x, CO and benzene together with NO_2 fraction of NO_x for each vehicle category. The emission factors are given as function of the mean driving speed and the year for which the calculations are performed.

Needed hourly input data

The OSPM calculates street pollution concentrations hour by hour, and therefore hour by hour input data are needed for:

- wind speed (roof level),
- wind direction (roof level),
- global radiation,
- temperature and
- urban background concentrations.

In the present project the required input data are generated from the information contained in the questionnaires supplied by different statistical and climatological data. The detailed procedure is described in the following chapters.

3 The questionnaire

The questionnaire was formulated to provide information about the address and surrounding area for the actual time period. The amount and degree of detail of the acquired information were limited to data which could easily be collected by the local municipalities. An English translation of the questionnaire is given in Appendix A.

Structure of information

The structure of the information gathered from the questionnaires can be divided into three groups:

1) information concerning the street at the address point

2) information about the traffic in the street

3) information about the surrounding area

Information about the street

The street data (1) cover:

- location of the street identified by the municipality number and the postal code
- administrative street category (municipal, county or state)
- street type with respect to configuration of buildings.

The street type and the interpretation in terms of input data for OSPM is discussed in details in Chapter 6.

Information about the traffic

The traffic data (2) cover:

- traffic amount (Average Daily Traffic, ADT)
- fraction of heavy traffic
- average driving speed

Information for estimation of urban background

The last part of the questionnaire concerns information needed mainly for estimation of the urban background pollution levels (3). This information concerns:

- number of inhabitants in the city
- the distance from the address point to the centre of the city
- qualitative characterisation of the traffic in the quarter around the address
- general characterisation of the type and density of buildings of the area

Finally the questionnaire contains some space left for additional information, if relevant.

Information stored on digital media

All the data from the collected questionnaires have been converted into digital media and have then been used to generate input files for the OSPM model. The procedure is described in the following chapters.

4 Structure of the computational system

Calculation procedure

The system used for calculation of pollution concentrations at the address points is illustrated by the flow chart in Fig. 4.1.

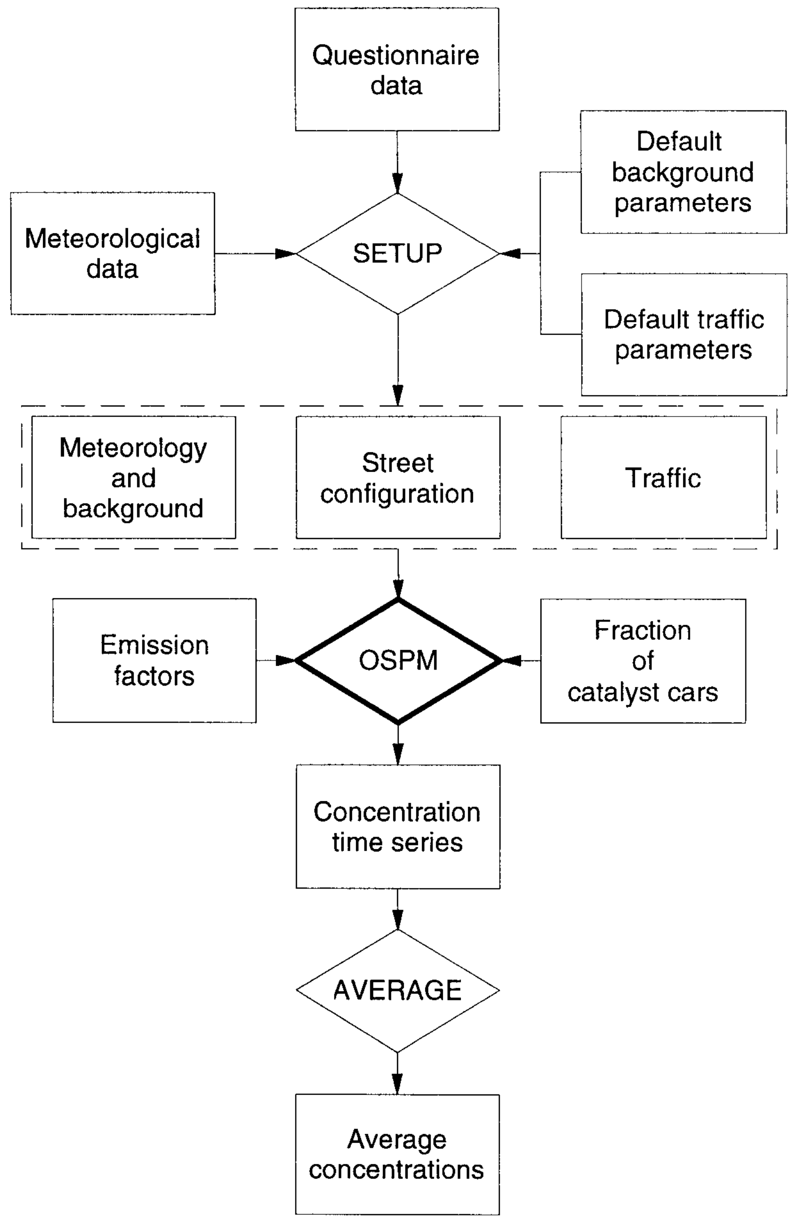


Figure 4.1 Diagram of the computational system. Programs are shown as diamonds. Input and output files are shown by rectangles.

Meteorological data for the different studies

In the pilot study for the 200 children actual meteorological data from Kastrup Airport for the years 1994 and 1995 are used. For the epidemiological study data from 1995 will be used as a standard input.

The program, SETUP, reads the digital data from the questionnaires and generates a number of input files for OSPM. Beside the information from the questionnaire meteorological data, as well as default background and traffic parameters, are used as input to the SETUP program.

Generated input files for OSPM

For each address the following files are generated:

1. file with meteorological and background data for the selected period

2. file with street configuration data

3. file with the average diurnal traffic data

These three files together with the files containing emission factors and year by year changes of the percentage of catalyst cars are used as input for OSPM calculations.

Averaging calculated pollution levels

The generated time series of hourly concentrations of NO_x, NO_2, CO and benzene are processed by the program AVERAGE which generates averages over the specified period.

5 Generation of input parameters for OSPM

In this section the generation of input files for OSPM performed by the SETUP program and based on the information from the questionnaire is described. Depending on the street type different information is available and various assumptions have been necessary to invoke concerning the street geometry. For each street type the chosen assumptions are given in the following.

5.1 Traffic and emission data

Default traffic profiles

The questionnaire data contain only information on the average daily traffic, so diurnal profiles of traffic have been generated based on traffic statistics from the Danish Road Directorate. Those profiles are specified for municipality and county/state streets, respectively (Jensen, 1997a). Furthermore separate profiles are generated for July. For all street types the fraction of vans is assumed to be 12%.

A prescribed diurnal variation of fraction of cold starts is used depending on the administrative street type (Jensen, 1997a).

Emission factors and their variation

Emission factors for each vehicle category, their dependence on vehicles speed and the variation through the years are predefined and listed in Appendix B, C and D for NO_x, CO and benzene, respectively. The evolution in emission factors during the years from 1960 to 1990 have been estimated by S. Sorensen and J. Schramm, Danish Technical University (DTU) (personal communication).

Fraction of gasoline vehicles with catalysator is predefined as well, and the variation through the years is given in Table 5.1. These data are based on the car sale statistics.

Table 5.1 Percentage of cars with catalysts in Denmark during the period 1960-95

Year	1960-1989	1990	1991	1992	1993	1994	1995
%	0.0	0.02	0.07	0.12	0.17	0.25	0.30

5.2 Street configuration

Default parameters

The data required by OSPM regarding street configuration (Chapter 2) are not included in the questionnaire explicitly, but had to be derived from the information supplied by the local municipalities. However, for some of the parameters default values had to be defined, since no information was available. This regards the geographical orientation of the street and the location of the address point in the street. For all the streets it is therefore arbitrarily assumed that:

- the street is oriented North-South,
- the address point is on the West side of the street, and
- the length of the street seen from the receptor point is predetermined to 100 m in both directions.

Estimation of street width

As a rule, the street width parameter is not explicitly defined in the questionnaire. Therefore, a method based on an empirical relationship between the traffic density and the road dimension is applied (Jensen, 1997a).

The width of the carriageway is given for municipality and county/state streets respectively, as a function of the average daily traffic (ADT), Table 5.2. The two pavements are assumed to have a width of 2m each.

Table 5.2 The empirical relationship applied for estimating the street width as function of traffic density. Two meter wide pavements are assumed for both sides of the street.

	ADT	width (m)
County and state roads	< 7000	10
	7000 ≤ and < 11000	12
	11000 ≤ and < 18000	15
	≥ 18000	22
Municipality roads[1]		$4.5 + 4.85 \cdot 10^{-4} \cdot ADT + 4$

[1]The parametres in this formula has been slightly modified in the final procedure to read: $6.5 + 3 \cdot 10^{-4} \cdot ADT + 4$

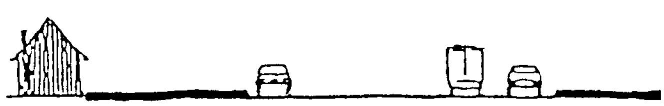
Street profiles

The main part of the information concerning street configuration is included in a specification of a street profile. The street profile categories in the questionnaire are based on the categorisation used in the Dutch street pollution model CAR (Eerens et al., 1993). For a detailed description of the street categories see the questionnaire in Appendix A. The treatment of the different street categories in the SETUP program is described in the following.

General assumptions

- In the case in which a cross with a more trafficked street is within 50 m, the length is reduced to 50 m in both directions.
- The width of the house is assumed to be 14 m.
- A 6 m height of the house is assumed, when the questionnaire does not contain this information.

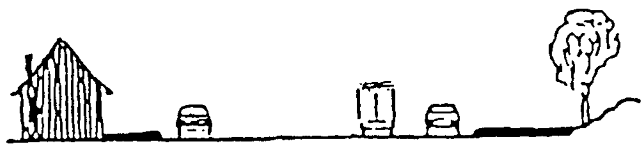
Street category A



This category covers streets with only few houses. In most cases this will be a single family house in a generally open area. It is therefore assumed that the height of the house at the address point is 6 m, while the average height of the buildings around the street is set to 2.5 m, which corresponds to a practically open street. Therefore, the wind sector covered by the building at the address point is treated as an exception and the width of this sector is derived assuming the width of the building to be 14 m. The angle is calculated from the centre line of the street.

The distance between the address point and the furthest road edge is given in the questionnaire. If this distance is smaller than the street width given in Table 5.2, the width of the street is assumed to be equal to this specified distance. On the contrary, the house is assumed to be located at a certain distance from the street, while the width of the street is as given in Table 5.2.

Street category B



This category covers three different street sub-types:

1. A street with a row of low houses on one side and practically no houses on the other.In this case, the average height of the houses along the street is set to the specified height at the address point. The wind sector covering the opposite street side is treated as an exception with no buildings.

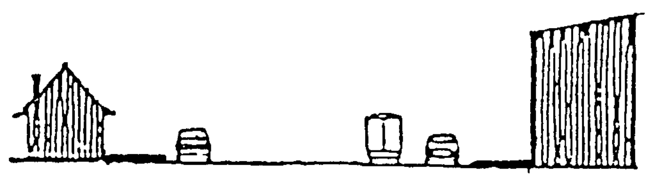
2. A street with villas on both sides with space between the houses. The average height of the houses along the street is set to the specified height at the address point. It is assumed that there are only few houses along the street. Particularly, it is anticipated that a single house is located opposite to the address house. Three wind sectors are treated here as exceptions. The one covering a sector with the house on the opposite side of the street and two covering the remaining sectors in between the two houses.

3. A uniform build up area with open areas in between .
   The street is considered to be open on the opposite side of the address. The address house is assumed to be on the side with an unbroken building raw.

The height of houses on both sides of the street is given in the questionnaire.

The street width parameter is calculated in the same way as for the category A.

Street category C

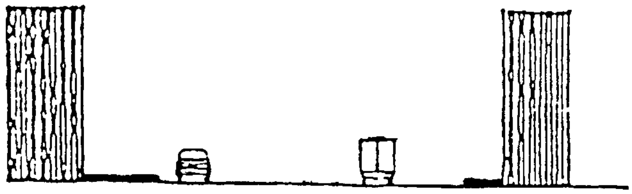


Street category C is a street canyon with low houses on one side of the street and high houses on the other side. Height of the houses and the distance between building facades are given explicitly in the questionnaire.

The building height on the address side is defined as the average building height in the street. The opposite side of the street is handled as a sector with a different building height.

The street width parameter is set to the specified distance between the building facades.

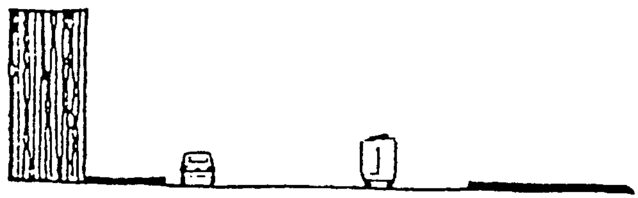
Street category D



Street category D is a street canyon with high houses on both sides of the street. Height of the houses and the distance between building facades is given explicitly in the questionnaire.

The procedure for estimation of the street configuration parameters is as for the street category C.

Street category E



This category covers streets with high buildings on one side of the street and practically no houses on the other. The address can be either at the side with the high buildings or on the open side. The questionnaire gives only information about the height of the buildings on the address side of the street. In the case where the address is on the side with the high buildings, it is assumed that there are no buildings on the other side. In the case where the address is on the open side of the street, it is assumed that the height of the high buildings on the other side is 20 m. The average building height is set to the height of the high buildings.

In the case where the address point is on the side with high buildings, the wind sector covering the other side of the street is treated as a sector with no buildings. In the opposite case, an additional sector is specified covering the house at the address point. The procedure for estimation of the width of the sectors with exceptions is as described for the street category A.

The street width parameter is calculated in the same way as for the categories A and B.

5.3 Generation of urban background data

In the frames of this project a procedure was developed for estimation of the necessary background concentrations and a short description of this method based on measurements is presented here. More detailed description is given by Jensen (1997b).

Outline of the method

The urban background model, used in this investigation, is mainly based on empirical data from locations in Copenhagen and rural background stations Lille Valby and Frederiksborg (The Danish National Urban Air Quality Monitoring Programme LMP III, The Danish National Environmental Research Programme SMP, and the Rural Background Monitoring programmes).

Input parameters

The model is used for generation of hourly values of the urban background concentrations of NO_x, NO_2, O_3, CO and Benzene. The prime input parameters for the model are:

- yearly average of the urban background NO_x concentration ($[NOX]_{au}$)
- yearly average of the rural background NO_2 concentration ($[NO2]_{ar}$)
- yearly average of the rural background O_3 concentration ($[O3]_{ar}$)

Beside these parameters, the actual meteorological data (wind speed, global radiation and temperature) are required. Note that $[NOX]_{au}$ represents here the city contribution only. The total background concentrations are calculated as a sum of city contribution and rural background (regional contribution).

Pollution data used in the procedure

$[NOX]_{au}$ is obtained from measurements performed in 1994 at the roof site of the Copenhagen University Building (HCØ Institute). $[NO2]_{ar}$ and $[O3]_{ar}$ are calculated from the measurements at the rural LMP-site at Lille Valby, also for the year 1994 or the rural background station Frederiksborg. For the last location the NO_2 data are from the year 1993, while O_3 is from 1994. The site Lille Valby is located about 30 km west of Copenhagen, while Frederiksborg is situated about 40 km north-west of Copenhagen.

For each of the mentioned parameters a seasonal (month to month) and diurnal (hourly for each month) profile is calculated from the measurements. Using the yearly averages and the seasonal and diurnal profile factors, the hourly values are consequently calculated, according to the formula:

$$[NOX]_{hr} = [NOX]_{au} \cdot f_m \cdot f_{mh}$$

where f_m and f_{mh} are the monthly and hourly profile factors, respectively.

A similar procedure is used for $[NO2]_{hr}$ and $[O3]_{hr}$ using corresponding profile factors calculated from the measurements at the rural site Lille Valby.

Assumed chemical equilibrium for NO_x background

Using an assumption of a photochemical equilibrium condition for NO, NO_2 and O_3 (more detailed description and verification is given in Jensen, 1997b), the hourly values of the rural background concentrations, $[NOX]_{hr}$, are calculated. Finally, the hourly values of urban background concentrations of NO_2 and O_3 are calculated using a method described in Hertel and Berkowicz (1990b). This method is similar to the one used for calculation of NO_2 concentrations in street canyons in OSPM, but with the exchange time of gases in the street replaced by the transport time over the city.

CO and benzene background derived from NO_x

In order to calculate corresponding values for CO and Benzene, empirical relationships were established between concentrations of these species and NO_x concentrations, using available measurements from Copenhagen.

Other locations than Copenhagen

The procedure described here is also used for other urban locations than Copenhagen, but with the yearly average concentrations corrected according to the size of the actual, urban location, assuming proportionality between emissions of NO_x and the size of the city (Jensen, 1997b). What is given in the questionnaire is the city size in terms of magintude of populations, and the geographic extension of the city is estimated from these figures. For this purpose, results from the traffic emission inventory performed in the frames of the SMP-project on Air Pollution from Traffic, were utilised (Vejdirektoratet, 1996). It was furthermore assumed that the seasonal and diurnal factors are the same as established for the Copenhagen and the respective rural site.

The choice of the rural data depends on the location of the address. For the Greater Copenhagen area the rural data from the Lille Valby site are used. Otherwise, rural data from Frederiksborg are applied.

Trends in background levels

In order to provide an estimate of the background concentrations for the years prior to 1994, empirical correction factors were established based mainly on available information on historical development of NO_x and CO emissions and literature data on trends in rural ozone concentrations (Jensen, 1997b). Due to very few data on this matter, a significant uncertainty in estimation of the historical background concentrations must be expected.

6 Comparison with measurements

In the following a number of different tests of the calculation procedure are performed. The purpose of these tests is to evaluate the limitations of the method and to provide some qualitative estimation of the sensitivity of the method regarding the generated input parameters.

Street pollution data used for the tests

Tests are performed using measurements from routine monitoring stations operated in the frames of the LMP (Danish National Urban Air Quality Programme) and HLU (The Greater Copenhagen Air Quality Monitoring Programme) programmes (Kemp et al., 1996; Miljøkontrollen, 1996). The selected locations are the streets Jagtvej and H.C. Andersens Boulevard in Copenhagen and Vesterbro in Aalborg.

Actual meteorological and pollution background data in the tests

The main emphasis in the presented tests is on evaluation of the procedure for generation of street configuration and traffic data. Therefore the actual meteorological and pollution background data are applied in the presented comparisons. For the streets in Copenhagen the meteorological and background pollution data originate from the measuring station on the roof of the Copenhagen University building, H.C. Ørsted Institute. For the site in Aalborg the corresponding data are from a roof station located on the roof of the Municipality building in the same street as the monitoring station. Evaluation of the procedure for generation of the background data is presented in Chapter 7.

The data from the mentioned locations were previously used for development and improvement of the OSPM. In connection with this procedure, the optimal street configuration parameters for these locations were determined (Berkowicz et al., 1997a, Hertel et al., 1995) and are here used as a reference.

Four types of basic scenarios

In the tests four different model calculations are performed using the following input data:

1. Optimal street configuration and measured traffic data
2. Generated street configuration and measured traffic data
3. Optimal street configuration and generated traffic data
4. Generated street configuration and traffic data

The optimal street configuration does not necessarily reflect the actual parametres, but the choice of parameters giving the best agreement with observations.

Tests are performed for hourly, monthly and yearly mean concentrations of NO_x and NO_2.

It should be remembered that the final model tool is supposed to give long term average values for the street concentrations. As it will appear from the tests, the uncertainties are considerably smaller for the long term mean values than for the short term values.

6.1 Test on data from Jagtvej

Jagtvej is a street canyon with 4-5 storey buildings on both sides and is thus classified as a street type D.

Optimal and generated street configuration

The optimal street configuration is shown in Table 6.1. The street configuration generated from the questionnaire is given in Table 6.2. As mentioned in Chapter 5, the default street orientation is set to 0 degree and the street lengths in both directions are set to 100 m. The monitoring station is located on the East side of the street but according to the procedure for generation of street configuration data the default location will always be the West side.

Table 6.1 Optimal street configuration for Jagtvej

Average building height (m)	Street width (m)	Street length_1 (m)	Street length_2 (m)	Street orientation (deg)
18	25	70	50	30
	sector 1	**sector2**	**sector3**	
Wind sectors with exceptions (deg)	45 - 55	15 - 230	325 - 330	
Building height in this sector (m)	0	25	0	

Table 6.2 Generated street configuration for Jagtvej

Average building height (m)	Street width (m)	Street length_1 (m)	Street length_2 (m)	Street orientation (deg)
18	25	100	100	0
Wind sectors with exceptions (deg)	none			

Hourly mean values

In Figure 6.1 the results from test runs are presented for hourly values of NO_x with data from the year 1994. The runs are performed using different combinations of generated and optimal street configuration data as well as measured and generated traffic data. However, the location of the receptor point is here chosen to correspond to the real situation, even in the case when generated street configuration data are used.

Figure 6.1a shows the modelled versus measured NO_x concentrations in the optimal case. The OSPM is seen to reproduce the observed concentrations very well, the $R^2 = 0.88$.

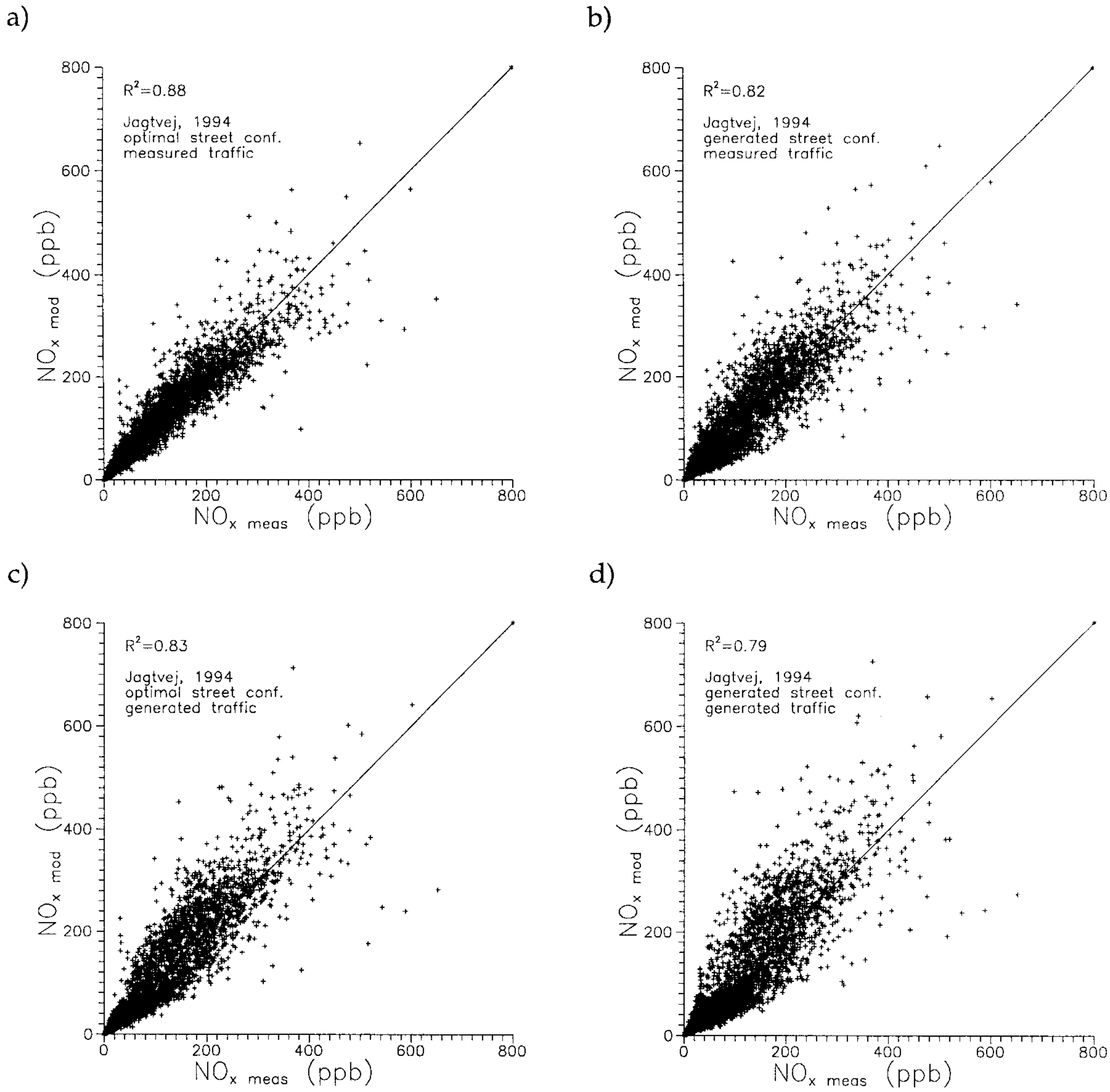


Figure 6.1 Modelled versus measured hourly NO_x concentrations for Jagtvej, Copenhagen 1994. Calculations using: a) optimal street configuration and measured traffic, b) generated street configuration and measured traffic, c) optimal street configuration and generated traffic, d) generated street configuration and traffic. The location of the receptor point is here on the East side even in the case of generated street configuration.

Results shown in Figure 6.1b correspond to the case when the optimal street configuration is replaced with the generated parameters. The comparison shows that the model results are still in good accordance with the observations, and the R^2 is only slightly lower (0.82) than in the optimal case.

The effect of replacement of the measured traffic data with the generated data is presented in Figure 6.1c. The results are seen to give more or less the same agreement with observations as the previous run (R^2 is 0.83). Closer analyses (not presented here) shows that there is a slight tendency for overestimation by the model during the daytime and an underestimation during night-time hours, indicating some systematic deviations between the generated and measured traffic profiles. Detailed evaluation of the performance of the procedure for generation of traffic data is given in Jensen (1997a).

The last result (Figure 6.1d) corresponds to a model run where both street configuration and traffic data are generated. Also in this case the model reproduces the observed concentrations well, although the correlation is somewhat lower than in the previous runs ($R^2 = 0.79$).

A special model run is performed in order to evaluate the effect of placement. In this case the calculations are performed with optimal street configuration and traffic data but for a receptor point located on the opposite side of the street than the monitoring station. This can be a frequent situation, since the questionnaire does not contain information about the street orientation and therefore also which side of the street the address point is placed. The results of these calculations are shown in Figure 6.2. It is seen that the correlation is now very poor ($R^2 = 0.26$) what means that the correct placement of the receptor point is very important for the short term average values.

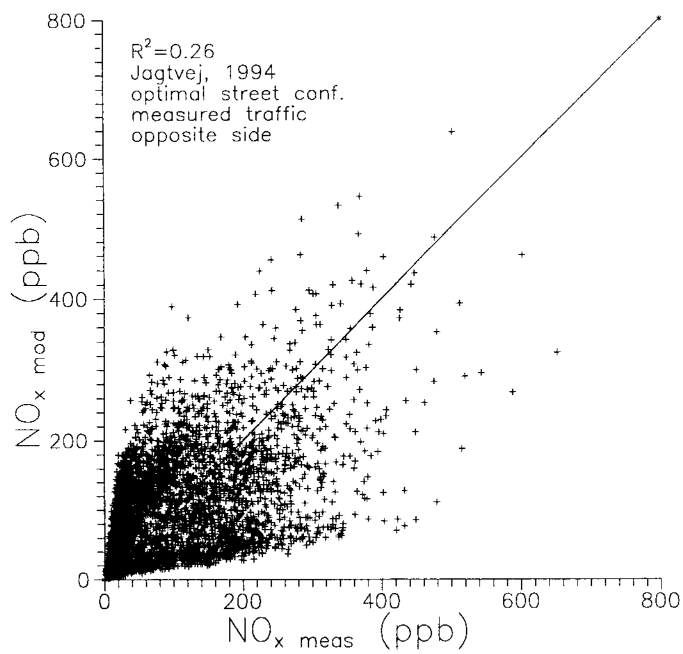


Figure 6.2 Test results for conditions as in Figure 6.1a but with the receptor point placed on the opposite side of the street than the monitoring station.

Monthly mean values

Figure 6.3 shows calculated and measured monthly mean NO_x values for Jagtvej for the same 5 previously discussed scenarios. The comparison shows that also for the monthly values the placement of the receptor point can be crucial. For all the scenarios with the receptor point on the monitoring side of the street the differences between observed and calculated concentrations are very small (less than 10%).

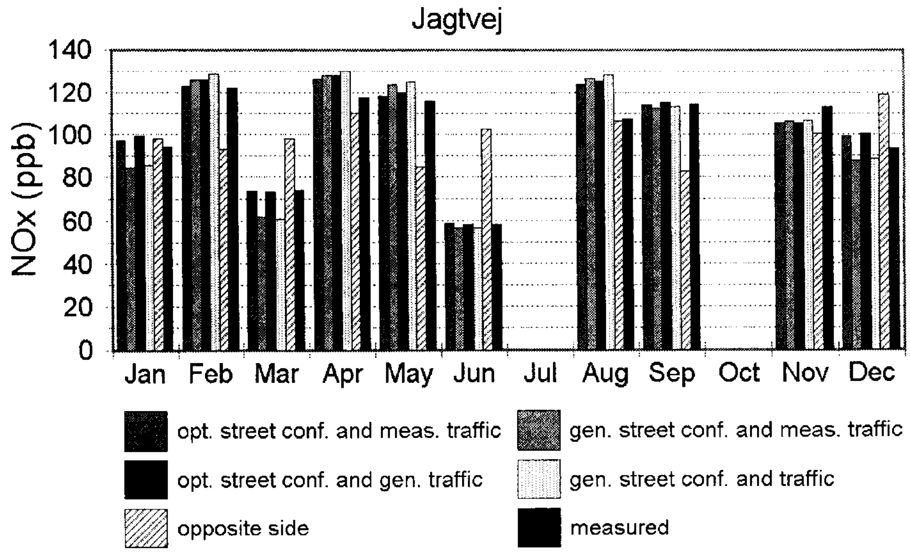


Figure 6.3 Monthly mean values for NO_x in Jagtvej: comparison between different cases of input files and measurements.

In figure 6.4 the same comparison is shown for NO_2. The performance is similar to the one for NO_x.

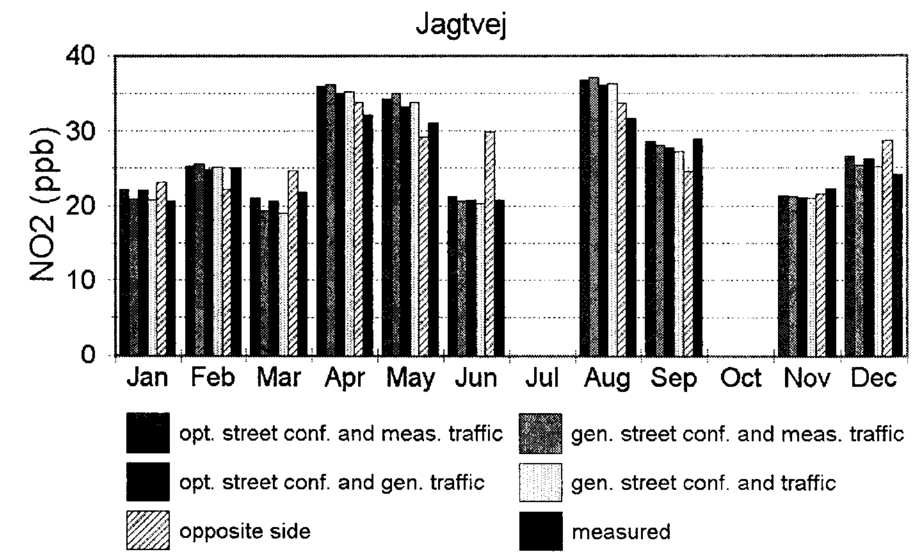


Figure 6.4 Monthly mean values for NO_2 in Jagtvej: comparison between different cases of input files and measurements.

Yearly mean values

All the available data for 1994 are taken into account for the calculation of the yearly mean concentrations. Table 6.3 shows the comparison between the same scenarios as for the hourly and monthly mean values, but in this case for yearly mean values. The large difference for the case where the receptor point is placed on the opposite side of the street is seen to vanish for longer average times and it keeps within 10 %. Good agreement with the measurements is reached in all cases, also with the generated input files.

Table 6.3 Yearly average concentrations computed for different scenarios for Jagtvej, 1994.

scenario		NO_x (ppb)	NO_2 (ppb)
street config.	traffic		
optimal	measured	103.20	27.55
generated	measured	100.26	27.13
optimal	generated	104.40	26.98
generated	generated	101.21	26.58
optimal *	measured	107.97	27.55
measured		99.65	25.89

*receptor point placed on the opposite side of the street.

6.2 Test on H.C. Andersens Boulevard data

H.C. Andersens Boulevard is a very broad street, with buildings only on one side and the amusement park, Tivoli, on the opposite side of the street. The street belongs to street type E. The monitoring station is on the build up side of the street (north-east side).

Table 6.4 Optimal street configuration for H.C. Andersens Boulevard

Average building height (m)	Street width (m)	Street length_1 (m)	Street length_2 (m)	Street orientation (deg)
20	60	50	50	130

	sector 1	**sector2**	**sector3**	**sector4**	**sector5**
Wind sectors with exceptions (deg)	75 - 130	150 - 160	160 -210	210 - 240	250 - 300
Building height in this sector (m)	0	0	35	0	35

Table 6.5 Generated street configuration for H.C. Andersens Boulevard

Average building height (m)	Street width (m)	Street length_1 (m)	Street length_2 (m)	Street orientation (deg)
20	37	100	100	0

	sector1
Wind sectors with exceptions (deg)	0 - 180
Building height in this sector (m)	0

Optimal and generated street configuration

In Tables 6.4 and 6.5 the optimal and generated street configuration parameters are reported. The optimal street configuration parameters for the H.C. Andersens Boulevard were derived after detailed examination of model results and measurements. The street width parameter is somewhat larger than the actual geometrical dimensions of the street. In the case of the generated configuration data the street width parameter is estimated from the traffic amount using the method given in Table 6.2. This results in a much smaller value than the optimal one.

Hourly mean values

In Figure 6.5 the results from test runs for hourly values of NO_x with data from the year 1993 are presented. Here we use the same combinations of generated and optimal street configuration data as well as measured and generated traffic data as for the Jagtvej case.

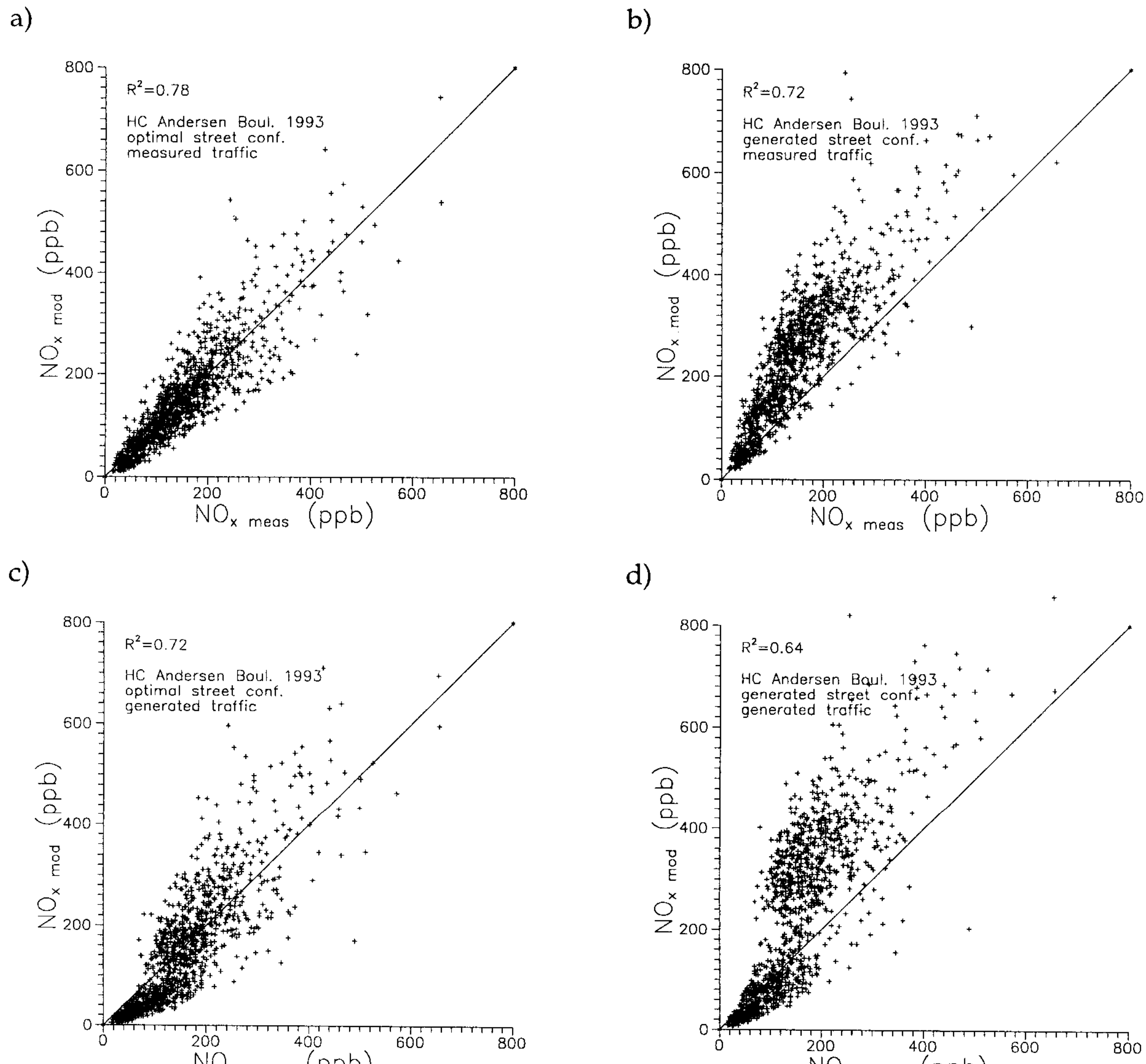


Figure 6.5 Modelled versus measured hourly NO_x concentrations for H.C. Andersens Boulevard, Copenhagen 1993. Calculations using: a) optimal street configuration and measured traffic, b) generated street configuration and measured traffic, c) optimal street configuration and generated traffic, d) generated street configuration and traffic.

For the optimal case (Figure 6.5a) a quite good agreement between the modelled and measured concentrations is observed ($R^2 = 0.78$).

The case with generated street configuration but measured traffic profiles is shown in Figure 6.5b. Although, the correlation is still reasonable ($R^2 = 0.72$) a systematic overestimation is observed here. The main reason for this overestimation is the value of the street width parameter, which is significantly smaller than the value resulting in the optimal performance of OSPM. The difference between the actual street orientation (130 degree) and the default value used for the generated configuration (0 degree) is less important in this case. This counts generally for this type of streets which have buildings on one side only and for which the dependence of concentrations on wind direction is considerably weaker than for street canyons (see Figure 2.2).

The effect on model performance of replacing the measured traffic data with generated profiles is shown in Figure 6.5c. The behaviour observed in this figure can be explained by systematic deviations between the diurnal variation of traffic in H.C. Andersens Boulevard and the default variation used in the generation procedure (Jensen 1997a). Night time traffic in this street is significantly higher than one would expect from the typical diurnal variation for this type of street. This results in underestimation of the NO_x concentrations for night time hours (the lower left corner of the figure) when the generated traffic data are used.

In Figure 6.5d results are shown for the case when both street configuration and traffic are replaced by the generated data. The R^2 is in this case 0.64.

Monthly mean values

Monthly mean values for NO_x and NO_2 are shown in Figures 6.6 and 6.7. Because of missing measurements (background and meteorology) the results are shown here for April, May, June and November months only. Both diagrams show that the cases with generated street configuration result in higher monthly mean values compared to measurements. The uncertainties in the generated traffic profiles generally do not influence the monthly averages much. The differences between the calculations using different input configurations are much smaller for NO_2 than for NO_x.

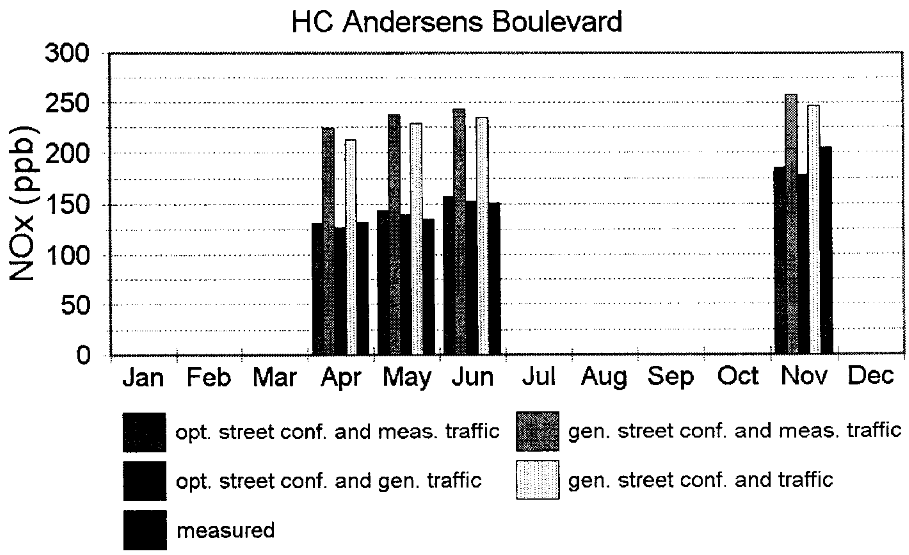


Figure 6.5 Monthly mean values for NO_x in H.C. Andersens Boulevard: comparison between different cases of input files and measurements.

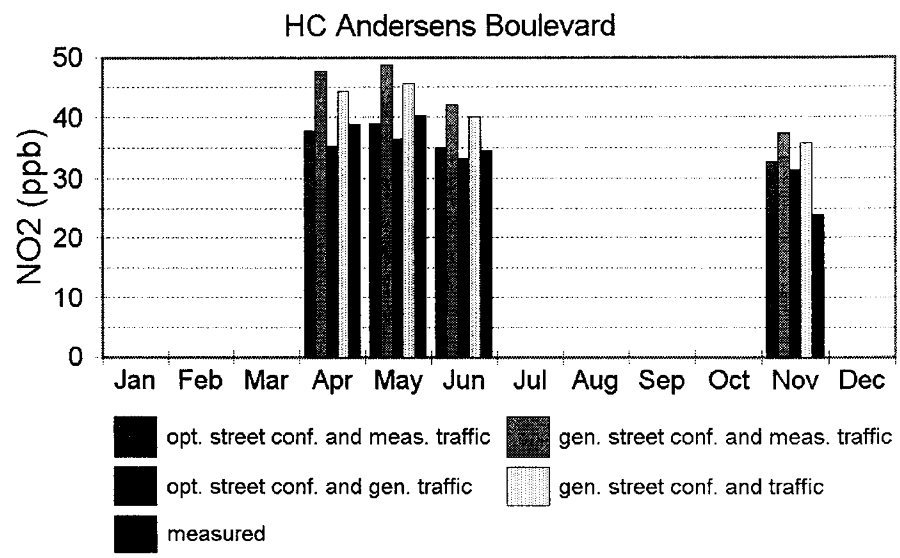


Figure 6.6 Monthly mean values for NO_2 in H.C. Andersens Boulevard: comparison between different cases of input files and measurements.

Yearly mean values

The comparison between the measured and modelled yearly mean values (all the available data are used) of NO_x and NO_2 is shown in Table 6.6. In the cases in which the optimal street configuration is used the agreement is very good, but significant overestimation is observed when the optimal configuration data are substituted with the generated ones. The overestimation is in this case more than 50 % for NO_x and 25 % for NO_2.

Table 6.6 Yearly average concentrations computed for different scenarios for H.C. Andersens Boulevard, 1993.

Scenario		NO_x (ppb)	NO_2 (ppb)
street config.	traffic		
optimal	measured	151.61	36.02
generated	measured	239.72	44.11
optimal	generated	146.83	34.04
generated	generated	229.59	41.53
measured		151.77	34.86

6.3 Test on data from Vesterbro in Aalborg

Vesterbro is a street with a complex geometry. The monitoring station is situated close to the Limfjord Bridge between Aalborg and Nørresundby. The street is oriented close to North-South with the monitoring station placed on the East side. At the station the street width is about 42m. On the East side of the street the building height is about 11m and on the West side the building height is about 14m. In the sectors 180-260 degrees and 270-320 degrees, two buildings of 19m and 38m are placed, respectively.

The street is a category E street. In the questionnaire the location of the receptor point was defined as being on the side with the high buildings, while in reality the monitoring station is place on the opposite side.

Optional and generated street configuration

The optimal and generated street configuration data are shown in Tables 6.7 and 6.8, respectively.

Table 6.7 Optimal street configuration for Vesterbro in Aalborg.

Average building height (m)	Street width (m)	Street length_1 (m)	Street length_2 (m)	Street orientation (deg)
11	42	100	50	20

	sector 1	**sector2**	**sector3**	**sector4**	**sector5**
Wind sectors with exceptions (deg)	180 - 260	260 - 270	270 - 320	320 - 360	0 - 50
Building height in this sector (m)	19	0	38	0	0

Table 6.8 Generated street configuration for Vesterbro in Aalborg.

Average building height (m)	Street width (m)	Street length_1 (m)	Street length_2 (m)	Street orientation (deg)
20	19	100	100	0

	sector1
Wind sectors with exceptions (deg)	0 - 180
Building height in this sector (m)	0

Hourly mean values

In Figure 6.8 the results from test runs for hourly values of NO_x with data from the year 1994 are presented. Here we use the same combinations of generated and optimal street configuration data as well as measured and generated traffic data as for the Jagtvej and H.C. Andersens Boulevard cases.

For the runs with both the optimal and the generated street configuration data the calculations are performed for a receptor point corresponding to the real location of the monitoring station, i.e the East side of the street.

Figure 6.8a shows the modelled hourly mean NO_x concentrations versus measurements for optimal street configuration and measured traffic profiles. The R^2 is 0.75 reflecting the difficulty for the OSPM to reproduce the concentrations at this complex site, compared to a simpler configuration as Jagtvej. However the correlation between measurements and calculated values is reasonably good.

In Figure 6.8b the results are shown for the case where the generated street configuration and measured traffic data are used. Here the agreement between observations and calculated data is very poor, mainly due to the assumption that there are no buildings on the side of the street where the receptor point is located. As shown in Figure 2.2, this leads to very low concentrations except in the case of winds parallel with the street.

Replacing measured traffic data with the generated profiles (Figure 7.8c) results in slightly worse agreement with measurements (R^2=0.63) than in the optimal case (Figure 7.8a).

In the case when both street configuration and traffic profiles are generated (Figure 6.8d), practically identical results as for the case in Figure 6.8b are obtained.

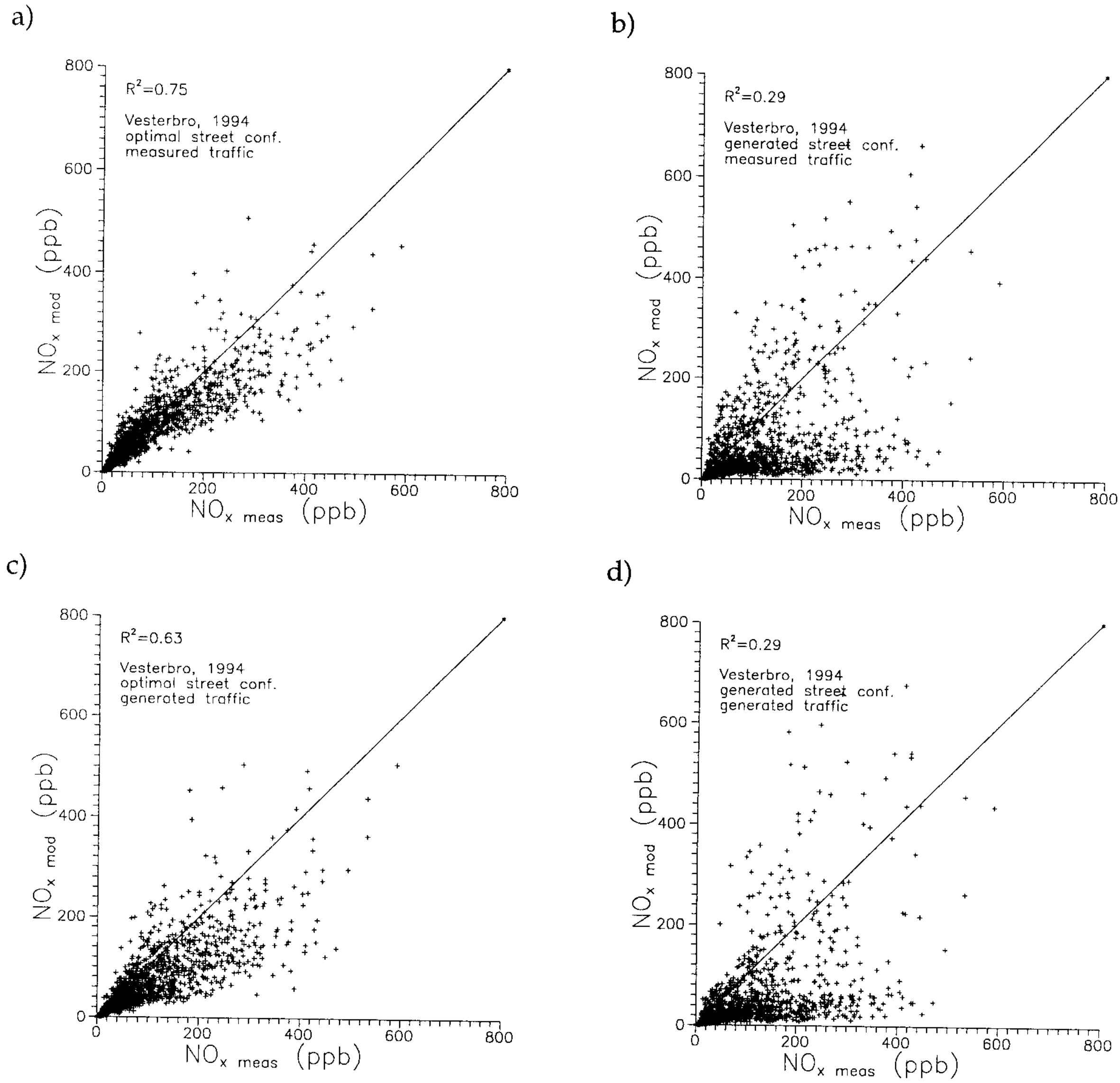


Figure 6.8 Modelled versus measured hourly NO_x concentrations for Vesterbro in Aalborg, 1994. Calculations using: a) optimal street configuration and measured traffic, b) generated street configuration and measured traffic, c) optimal street configuration and generated traffic, d) generated street configuration and traffic. The location of the receptor point is here on the East side even in the case of generated street configuration.

In order to elucidate the influence of the placement of the receptor point, a special test run was performed with the optimal street configuration but for a receptor point on the opposite side of the street than the monitoring station. In fact, this corresponds to the information given in the questionnaire, where the address point was specified to be on the side with high buildings. The results are shown in Figure 6.9. In this case the correlation (R^2=0.51) is considerably decreased compared to the results shown in Figure 6.8a. However, the placement is seen to be less crucial than for the street canyon case of Jagtvej.

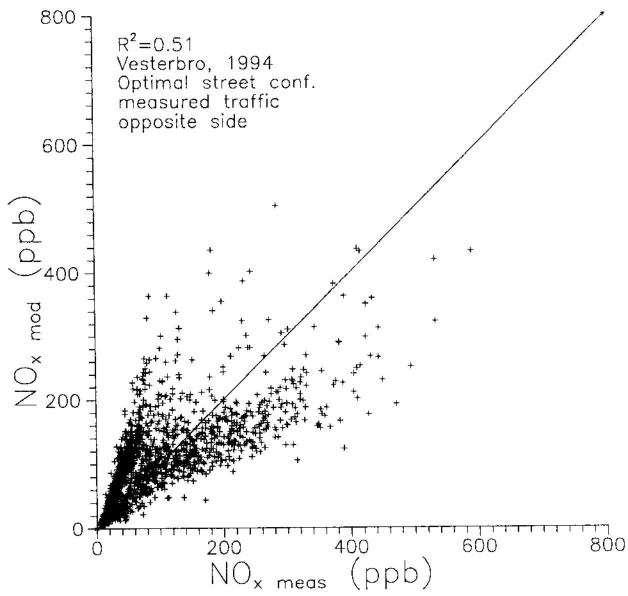


Figure 6.9 Comparison for the case as in figure 6.8a but here calculations are performed with the receptor point placed on the opposite side of the street.

Monthly mean values

Monthly mean values are shown in Figures 6.10 and 6.11 for the same scenarios as used in Figure 6.8 and 6.9. The results cover only few months in which the necessary background data were available. Even for the optimal configuration the differences between calculated and measured concentrations can be large, as is the case for May. The largest deviations are however attributed to the cases with the generated street configuration which is explained by the wrong placement of the calculation point. The differences are generally smaller for NO_2 than for NO_x.

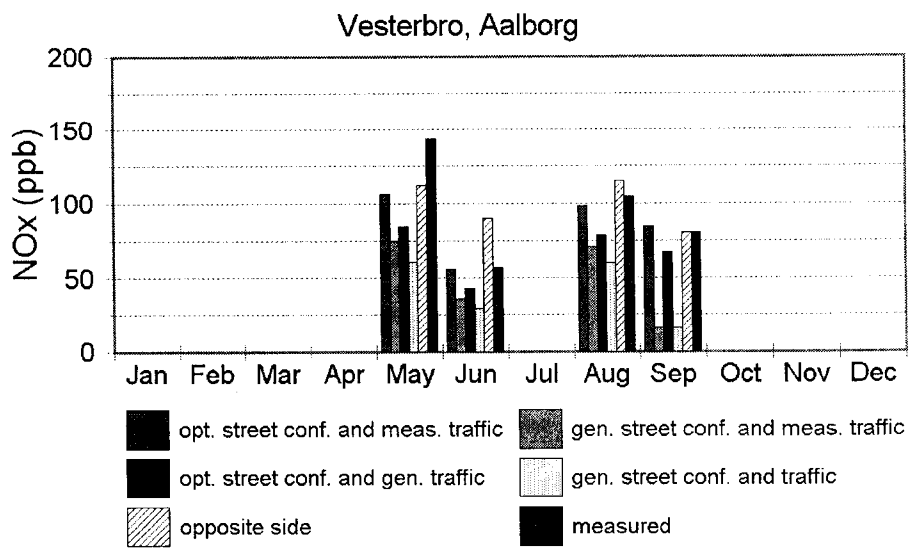


Figure 6.10 Monthly mean values for NO_x in Vesterbro, Aalborg 1994. Comparison between different cases of input files and measurements.

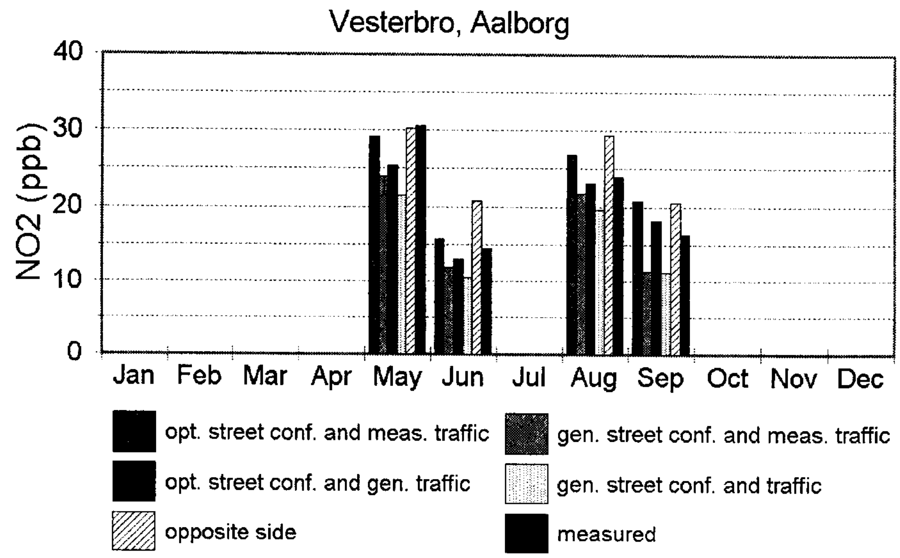


Figure 6.11 Monthly mean values for NO_2 in Vesterbro, Aalborg 1994. Comparison between different cases of input files and measurements.

Yearly mean values

Yearly mean values of NO_x and NO_2 are shown in Table 6.9. The general tendency is that the calculations with the generated configuration data lead to significant underestimation of NO_x concentrations. The underestimation is somewhat smaller for NO_2. When the measured traffic is replaced with the generated data this also leads to underestimation of the NO_x concentrations. Calculations for the opposite side of the street reveal concentrations that are not significantly different from the side of the monitoring station.

Table 6.9 Yearly average concentrations computed for different scenarios for Vesterbro, Aalborg 1994.

Scenario		NO_x (ppb)	NO_2 (ppb)
street config.	traffic		
optimal	measured	86.02	23.58
generated	measured	58.63	18.74
optimal	generated	67.93	20.24
generated	generated	48.56	16.82
optimal *	measured	104.93	26.53
measured		98.74	22.39

*receptor point placed on the opposite side of the street.

7 Test of the urban background model

The test results, presented until now, were all performed with measured values of the urban background data. Using measured background concentrations is, however, only possible for the few locations where such data are available (Copenhagen, Odense, Aalborg). In general, the background concentrations must be estimated using the best available information about the actual locations.

Meteorological and pollution data

For the present test of the background model, air pollution and meteorological measurements from the roof site on the University Building in Copenhagen are used. In order to provide an independent test, data for the year 1995 are used, reminding that the year 1994 was used for model development. Another test of the background model will be performed using measurements collected in connection with the pilot project on Danish Children Exposure to Traffic Exhaust Fumes and will be reported elsewhere.

Test on monthly data

The average modelled and measured monthly values of urban background concentrations of NO_x, NO_2, O_3 and CO are shown in Figure 7.1, while in Figure 7.2 are shown corresponding results for the average hourly values. For comparison, the respective values of the rural concentrations are also shown in the figures. Those values are used as input to the model.

The results presented here show in general a good agreement between the modelled and the measured average concentrations, although somewhat larger deviations are evident for e.g. winter months in the case of NO_x whereas O_3 concentrations are slightly underestimated by the model. The average diurnal profile of NO_x is slightly underestimated, but the agreement for NO_2 is very good. Average hourly concentrations of ozone are in general underestimated by the model, but by no more than about 15%.

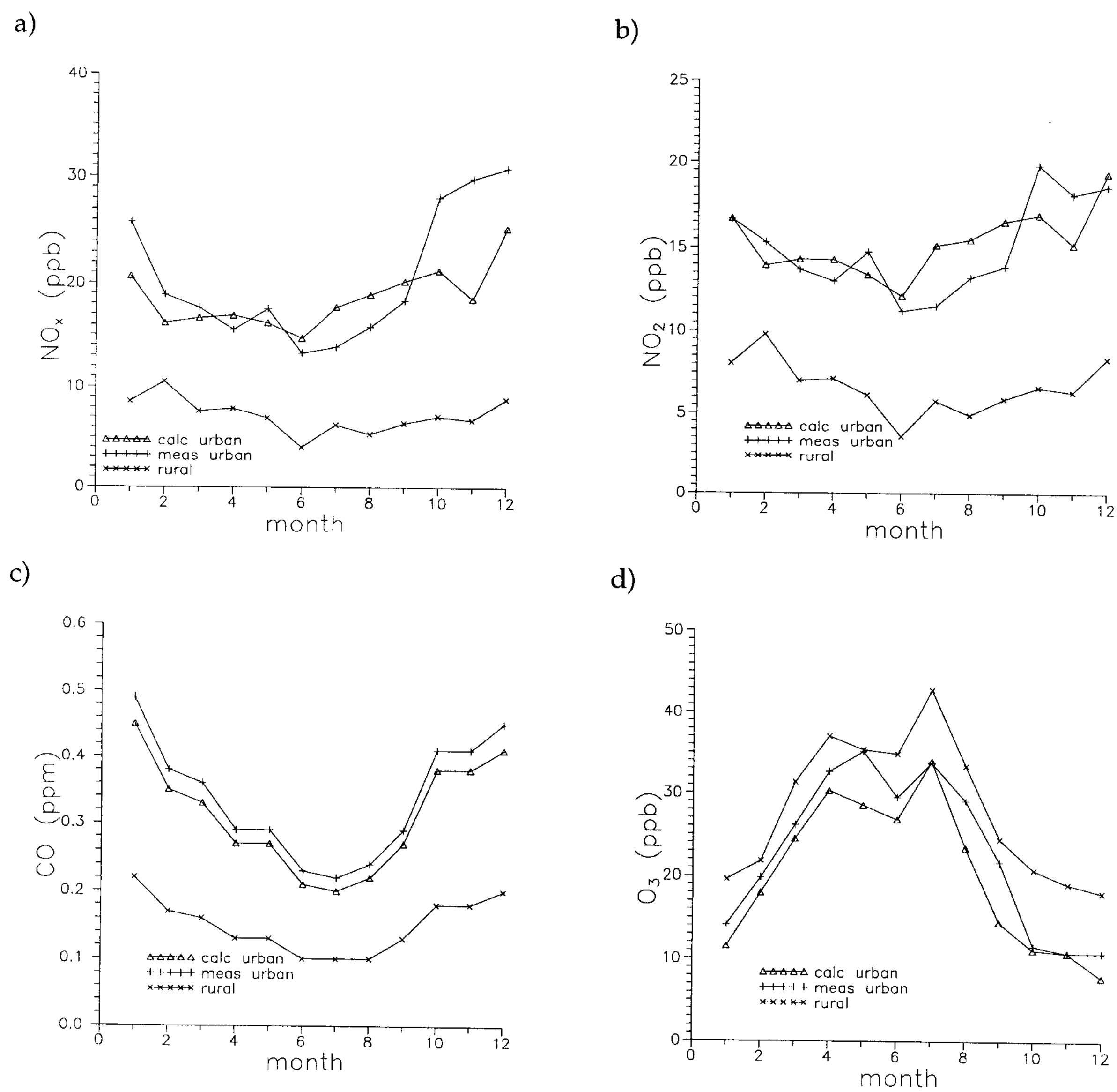


Figure 7.1 Comparison between modelled and measured average monthly mean values of urban background concentrations of a) NO_x, b) NO_2, c) CO, d) O_3 Measurements are from the roof site at the University Building in Copenhagen for the year 1995. For comparison, the corresponding rural concentrations are also shown.

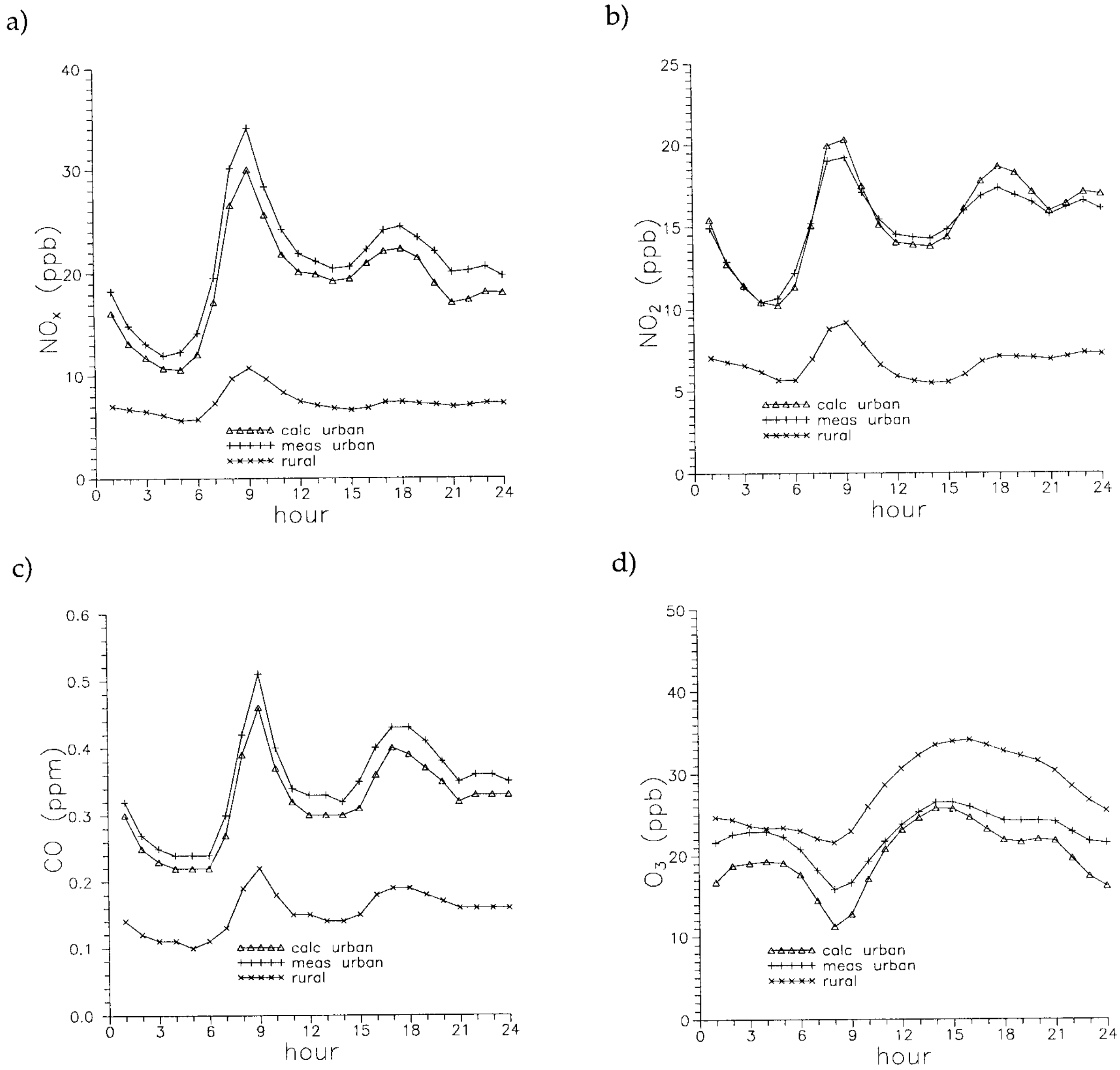


Figure7.2 Comparison between modelled and measured average hourly mean values for urban background concentrations of a) NO_x, b) NO_2, c) CO, d) O_3 Measurements are from the roof site at the University Building in Copenhagen for the year 1995. For comparison, the corresponding rural concentrations are also shown

7.1 Comparison with measurements at Jagtvej

Results of the test of the modelling system on data from the monitoring station at Jagtvej are presented here, but now with background concentrations generated by the background model.

Hourly mean

Comparison between modelled and measured NO_x concentrations in the case of optimal street configuration and measured traffic data is shown in Figure 7.3a. The scatter is larger than in the case of measured background concentrations (Figure 7.1a), but the correlation is still good (R^2=0.84). The most remarkable feature is the underestimation by the model of the highest concentrations. The reason for this is that the used background concentrations account for climatological average values only and the extreme situations are hardly covered.

In Figure 7.3b the test results are shown with all the input data generated by the modelling system. The scatter is here significantly larger than in the case of only generated background data. The correlation between modelled and measured values is, however still fair (R^2= 0.72).

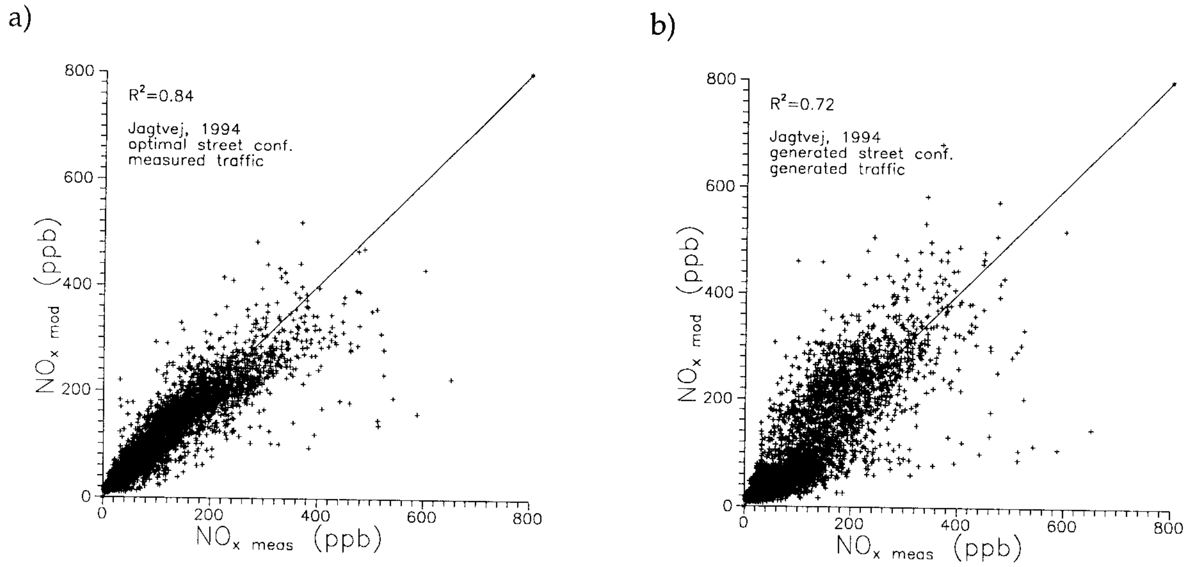


Figure 7.3 Comparison between modelled and measured hourly mean values of NO_x in Jagtvej. a) optimal street configuration and measured traffic but generated urban background, b) all input parameters are generated. Measurements are for the year 1994.

Monthly mean

Measured and calculated monthly mean NO_x concentrations for the two scenarios are shown in Figure 7.4. The agreement with measured concentrations is good in all cases, showing that using average values for the background concentrations is reasonable for calculation of long term averages.

The agreement is even better in the case of NO_2 (Figure 7.5), proving again the usefulness of the presented method, at least for a location like Jagtvej.

Yearly mean

The results for yearly averages are shown in Table 7.1, and as expected, the agreement with measurements is very good, even in the case when both the background concentrations as well as street configuration and traffic data are generated by the modelling system.

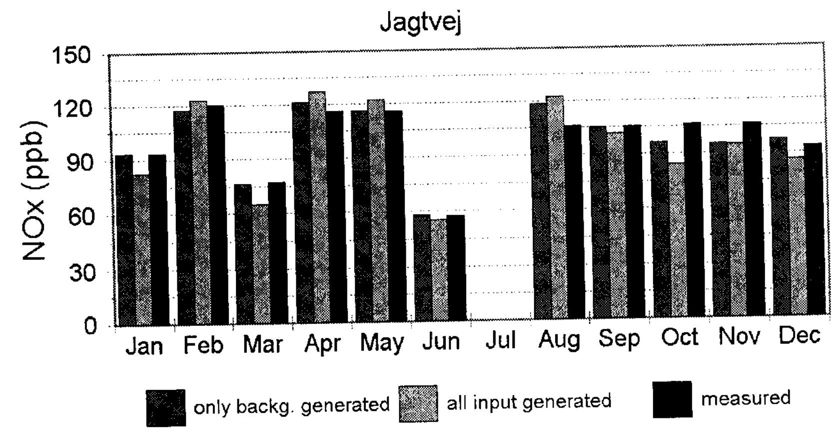


Figure 7.4 Monthly mean values for NO_x in Jagtvej: comparison between different cases of input files and measurements. Also urban background concentration data are generated.

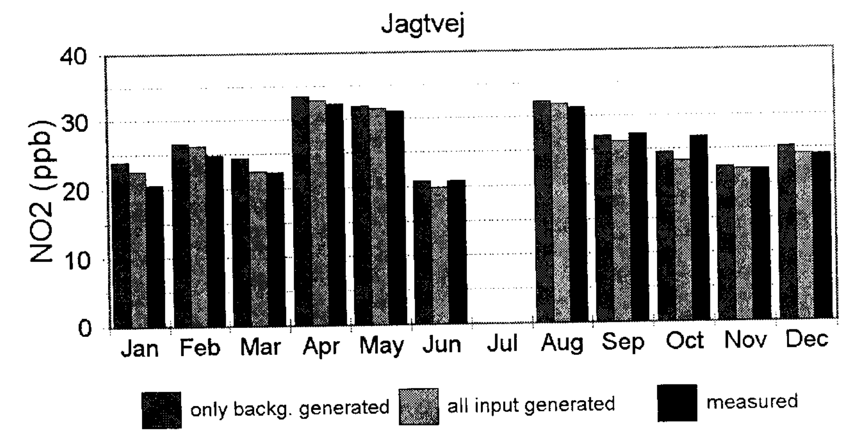


Figure 7.5 Monthly mean values for NO_2 in Jagtvej: comparison between different cases of input files and measurements. Also urban background concentration data are generated.

Table 7.1 Yearly average concentrations computed for different scenarios for Jagtvej, 1994. Also urban background concentration data are generated.

scenario			NO_x (ppb)	NO_2 (ppb)
background	street config.	traffic		
generated	optimal	measured	99.14	26.68
generated	generated	generated	96.14	25.78
measured			98.85	25.81

Conclusions

The method for generation of the input data for the calculations with OSPM is presented in this report. The described method which is based on information provided from a questionnaire, will be used for model calculations of long term exposure for a large number of children in connection with an epidemiological study.

Tests on three locations

A test of the calculation method has been performed on a few locations in which detailed measurements of air pollution, meteorological data and traffic were available. These locations, which belong to the urban monitoring networks (LMP and HLU), were on the streets Jagtvej and H.C. Andersens Boulevard in Copenhagen and Vesterbro in Aalborg. The limited number of locations makes the tests only indicative and a more detailed test will be performed at a later stage on data from the pilot study (described in the introduction).

Comparisons between measured and calculated concentrations were made for hourly, monthly and yearly values. Beside the measured concentrations, the test results were compared to results obtained with the optimal street configuration data and measured traffic.

Main conclusions

The main conclusions drawn from this investigation are:

- The calculation method works satisfactory well for long term averages, whereas the uncertainties are high when short term averages are considered.
- The street width is one of the most crucial input parameters for the calculation of street pollution levels for both short and long term averages. Using H.C. Andersens Boulevard as an example, it was shown that estimation of street width based on traffic amount can lead to large overestimation of the concentration levels (in this case 50 % for NO_x and 30 % for NO_2).
- The street orientation and geometry is important for prediction of short term concentrations but this importance diminishes for longer term averages. The comparison for Jagtvej data showed that yearly mean values for the opposite side of the street differed by no more than 10%.
- The uncertainties in diurnal traffic profiles can influence the accuracy of short term averages, but are less important for long term averages.

Vesterbro, a complex site

The complexity of the Vesterbro site makes the model performance less good than in the previous two cases, even for optimal input parameters.

Test of total system

The comparison with the NO_x values measured in Jagtvej shows that the correlation is still good between modelled and measured concentrations when the actual background concentrations are replaced with the generated values. Even though extreme situations are difficult to reproduce with this method, the comparison between the yearly averaged modelled and measured concentrations is very good.

Acknowledgements

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APPENDIX A: The Questionnaire

The address ______________________________

The time period ___________________________

(This part is filled out by the Danish Cancer Society)

The questions below refer to the middle of the time period considered.

If there have been major traffic changes during the period, please indicate this in question No. 10.

For all questions you are requested to make the best judgement, when precise information is not available.

1. Was the type of road mentioned on the front page , a

1) ___ municipality street or private street

2) ___ county road, give county number ___, administrative road number ___, and kilometric position at address

3) ___ state road, give administrative number ___ and kilometric position at address ___.

Note. If it is a county or state road and the municipality does not have traffic figures, go to question No. 4. If the municipality has traffic data, or these can be estimated, you are requested to answer question No. 2 and No. 3 for county and state roads.

2. How much traffic was there on the street at the address?

___ vehicles/day (Average Daily Traffic)

The Average Daily Traffic is the annual average for all 365 days for traffic in both directions. Please indicate if the figure is given in other terms than the Average Daily Traffic.

3. How much heavy traffic (busses and vans over 3500 kg) did the street carry?

The exact fraction of heavy traffic was ___ %

If the exact fraction is not known, you are requested to use your best judgement to choose on of the below options

1) ___ Almost no heavy traffic (less than 1% of traffic)

2) ___ Small fraction (1-4% of traffic)

3) ___ Moderate fraction (5-8% of traffic)

4) ___ Large fraction (9% of traffic or more)

4. What was the actual mean speed at the address?

If the actual speed cannot be estimated, use the speed limit as a basis for an estimate. Unsteady driving patterns due to e.g. traffic lights lowers the mean driving speed.

1) ___ *00-35 km/h*
2) ___ *35-45 km/h*
3) ___ *45-55 km/h*
___ *above 65 km/h*

5. Which of the below road surroundings suits best the address: (A-E) ___.

A A house in an open street. The house can be situated close to or far from the street. There may be other houses nearby.

What was the distance from the facade of the address house to the furthest road edge on the furthest driving lane?

About ___ *m*

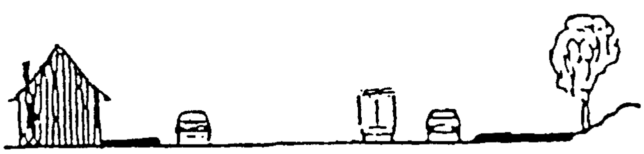
B Low scattered houses. Choose the one which fits best.

1) ___ *A row of low houses on one side of the street. Almost no houses on the other side.*
2) ___ *Villas on both sides with space (gardens) in between.*
3) ___ *Low houses with open front areas (parking lots, gardens etc.)*

What was the distance from the facade of the address house to the furthest road edge on the furthest driving lane?
Approximate distance ___ *m*

How high are the houses at the address side of the street?
___ *storeys*

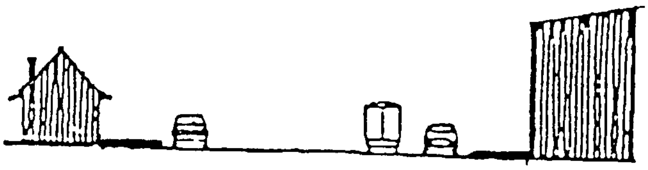
How high are the houses on the other side of the street (if no houses write 0)?
___ *storeys*



C Low houses on one side of the street and high houses on the other side of the street.

What was the distance between the house facades?
Approximately ___ *m*

How high are the houses on the other side of the street?
___ *storeys*

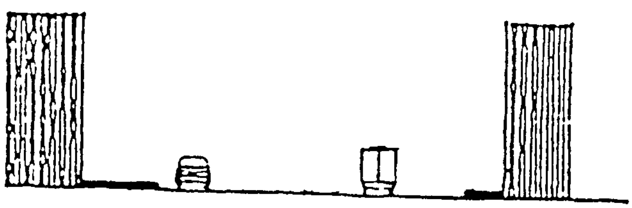


D High houses on both sides of the street

What was the distance between the house facades?
Approximately ___ *m*

How high are the houses on the address side of the street?
___ *storeys*

How high are the houses on the other side of the street?
___ *storeys*

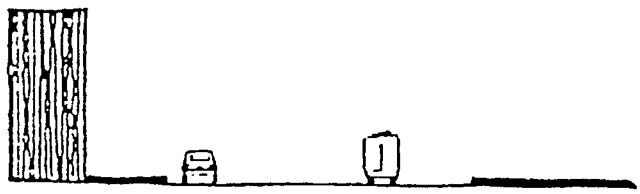


E High houses on one side of the street. Almost no houses on the other side.

What was the distance from the address house facade to the furthest road edge on the furthest driving lane?
Approximately ___ m

How high is the address house?
___ storeys

Was the address side
1) ___ *On the side of the street with high houses*
2) ___ *A single house on the other side*



6. Was there within 50 m from the address a cross road, which had more traffic than the street at which the address is located?
1) ___ *Yes*
2) ___ *No*

If yes, how many vehicles were on this street? (If there were several cross roads, answer for the most trafficked)
1) ___ *0-2,000 vehicles/day*
2) ___ *2,000-5,000 vehicles/day*
3) ___ *5,000-10,000 vehicles/day*
4) ___ *10,000-15,000 vehicles/day*
5) ___ *more than 15,000 vehicles/day*

7. How was the traffic in the quarter around the address? (Within 300 m around the address)
1) ___ *Rural area or other, where almost no other streets than the one with the address*
2) ___ *Urban areas with residential of low speed streets or other streets with low traffic intensity (only local traffic)*
3) ___ *Urban traffic, however without heavily trafficked streets (below 10,000 vehicles/day)*
4) ___ *Heavy urban traffic, where one or more of the streets were heavily trafficked (above 10,000 vehicles/day)*
5) ___ *Other*

8. How was the main part of the houses in the quarter around the address? (Within 300 m around the address)
1) ___ *No or almost no houses*
2) ___ *Low density built-up areas (e.g. villages, small towns and residential neighbourhoods)*
3) ___ *Semi-dense built-up areas (e.g. 2-3 storeyed buildings in central areas in middle-sized cities)*
4) ___ *Scattered multi-storey buildings (e.g. Gellerup-Parken in Aarhus)*
5) ___ *Dense built-up areas (e.g. 4-6 storeyed buildings with street in between, e.g. "Bro-kvartererne" in Copenhagen)*

9. How many inhabitants had the city in which the address was situated? (A city is a coherent built-up area. If almost all of the municipality is urban area, the municipality is regarded as one city. Copenhagen and Frederiksberg Municipalities are regarded as one city),
1) ___ *The address was located within a urban area (go to question No. 10)*
2) ___ *Less than 2,000 inhabitants (go to question No. 10)*
3) ___ *2,000-20,000 inhabitants (go to question 10)*
4) ___ *20,000-40,000 inhabitants*
5) ___ *40,000-80,000 inhabitants*
6) ___ *80,000-150,000 inhabitants*
7) ___ *More than 150,000 inhabitants*

If the city had more than 20,000 inhabitants:

What was the distance (direct line) from the address to the centre of the city? *Approximately* ___ *km.*

What was the distance (direct line) from the address to a larger area without built-up area, e.g. forest, field or water? *Approximately* ___ *km.*

A larger area has to be at least 1 x 1 km^2 e.g. Horsens Fjord, Jægersborg Dyrehave, Hareskov at Værløse, Vest-amager and Utterslev Mose at Copenhagen. The following are **not** large enough: Sports stadia, parks and smaller lakes (e.g. Damhussøen at Rødovre).

10. Are there special conditions, which you think should be mentioned?
If there have been major traffic changes during the period given on the front page, please indicate what has happened and when it happened ______________________________
____
____

Thank you for your help.

11. This questionnaire has been filled out

by ______________________________ / Institution ______________________________

APPENDIX B: NO_x emission factors

This appendix contains the defined values for NO_x emissions used in the OSPM. The three categories "pas", "van" and "hea" are respectively personal cars (account for both diesel and gasoline vehicles), small vens and heavy duty vehicles (accounts for both buses and heavy trucks). In order to account for the emissions dependence on driving speed, for each 10 km/h in the interval 10-100 km/h a factor has been defined.

Pas Van Hea
2.32.3 19.5 Basic emission factors NO_x (g/km) without catalyst 1993
0.2 Basic emission factors NO_x (g/km) with catalyst 1993

=============== Emission factors ===================

Speed	F_NO_x_Pas	F_NO_x_Cat	F_NO_x_Van	F_NO_x_Hea
10	1.60	1.60	1.60	1.50
20	1.36	1.36	1.36	1.39
30	1.15	1.15	1.15	1.28
40	1.04	1.04	1.04	1.17
50	1.00	1.00	1.00	1.00
60	1.00	1.00	1.00	1.02
70	1.02	1.02	1.02	1.04
80	1.08	1.08	1.08	1.06
90	1.19	1.19	1.19	1.08
100	1.31	1.31	1.31	1.10

=========== Yearly emission factors ==================

Year	Y_NO_x_Pas	Y_NO_x_Hea	Year	Y_NO_x_Pas	Y_NO_x_Hea
1960	0.70	0.41	1987	1.00	0.88
1961	0.70	0.43	1988	1.00	0.90
1962	0.70	0.45	1989	1.00	0.91
1963	0.70	0.47	1990	1.00	0.93
1964	0.70	0.50	1991	1.00	0.95
1965	0.70	0.51	1992	1.00	0.98
1966	0.75	0.53	1993	1.00	1.00
1967	0.75	0.54	1994	1.00	1.00
1968	0.75	0.56	1995	1.00	1.00
1969	0.75	0.58			
1970	0.75	0.59			
1971	0.75	0.60			
1972	0.75	0.62			
1973	0.75	0.64			
1974	0.75	0.65			
1975	0.80	0.66			
1976	0.85	0.68			
1977	0.90	0.69			
1978	0.90	0.71			
1979	0.95	0.73			
1980	1.00	0.75			
1981	1.00	0.77			
1982	1.00	0.79			
1983	1.00	0.80			
1984	1.00	0.83			
1985	1.00	0.84			
1986	1.00	0.86			

APPENDIX C: CO emission factors

This Appendix contains the same factors as in Appendix B, but for CO

Pas	Van	Hea	
33.3	18.5	3.2	Basic emission factors CO (g/km) without catalyst 1993
3.3			Basic emission factors CO (g/km) with catalyst 1993

=============== Emission factors ================

Speed	F_CO_Pas	F_CO_Cat	F_CO_Van	F_CO_Hea
10	3.57	3.57	3.57	3.57
20	2.07	2.07	2.07	2.07
30	1.31	1.31	1.31	1.31
40	1.21	1.21	1.21	1.21
50	1.00	1.00	1.00	1.00
60	0.75	0.75	0.75	0.75
70	0.69	0.69	0.69	0.69
80	0.66	0.66	0.66	0.66
90	0.66	0.66	0.66	0.66
100	0.69	0.69	0.69	0.69

=========== Yearly emission factors ===============

Year	Y_CO_Pas	Y_CO_Hea
1960	3.68	4.00
1961	3.59	3.87
1962	3.51	3.70
1963	3.43	3.57
1964	3.35	3.43
1965	3.27	3.30
1966	3.19	3.17
1967	3.11	3.03
1968	3.02	2.87
1969	2.95	2.73
1970	2.86	2.57
1971	2.78	2.43
1972	2.70	2.30
1973	2.62	2.13
1974	2.54	2.00
1975	2.46	1.83
1976	2.38	1.70
1977	2.29	1.53
1978	2.22	1.40
1979	2.14	1.30
1980	2.05	1.23
1981	1.97	1.17
1982	1.89	1.10
1983	1.81	1.07
1984	1.73	1.07
1985	1.65	1.07
1986	1.56	1.07
1987	1.48	1.07
1988	1.41	1.03
1989	1.32	1.03
1990	1.24	1.03

Year	Y_CO_Pas	Y_CO_Hea
1991	1.16	1.03
1992	1.08	1.00
1993	1.00	1.00
1994	1.00	1.00
1995	1.00	1.00

APPENDIX D: Benzene emission factors

This Appendix contains the same factors as in Appendix C, but for benzene.

Pas	Van	Hea	
0.410	0.410	0.01	Basic emission factors BENZENE (g/km) without catalyst 1993
0.040			Basic emission factors BENZENE (g/km) with catalyst 1993

=============== Emission factors ==================

Speed	F_BNZ_Pas	F_BNZ_Cat	F_BNZ_Van	F_BNZ_Hea
10	3.57	3.57	3.57	3.57
20	2.07	2.07	2.07	2.07
30	1.20	1.20	1.20	1.20
40	1.10	1.10	1.10	1.10
50	1.00	1.00	1.00	1.00
60	0.75	0.75	0.75	0.75
70	0.69	0.69	0.69	0.69
80	0.66	0.66	0.66	0.66
90	0.66	0.66	0.66	0.66
100	0.69	0.69	0.69	0.69

=========== Yearly emission factors =================

Year	Y_BNZ_Pas	Y_BNZ_Hea	Year	Y_BNZ_Pas	Y_BNZ_Hea
1960	0.70	0.41	1991	1.00	0.95
1961	0.70	0.43	1992	1.00	0.98
1962	0.70	0.45	1993	1.00	1.00
1963	0.70	0.47	1994	1.00	1.00
1964	0.70	0.50	1995	1.00	1.00
1965	0.70	0.51			
1966	0.75	0.53			
1967	0.75	0.54			
1968	0.75	0.56			
1969	0.75	0.58			
1970	0.75	0.59			
1971	0.75	0.60			
1972	0.75	0.62			
1973	0.75	0.64			
1974	0.75	0.65			
1975	0.80	0.66			
1976	0.85	0.68			
1977	0.90	0.69			
1978	0.90	0.71			
1979	0.95	0.73			
1980	1.00	0.75			
1981	1.00	0.77			
1982	1.00	0.79			
1983	1.00	0.80			
1984	1.00	0.83			
1985	1.00	0.84			
1986	1.00	0.86			
1987	1.00	0.88			
1988	1.00	0.90			
1989	1.00	0.91			
1990	1.00	0.93			

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