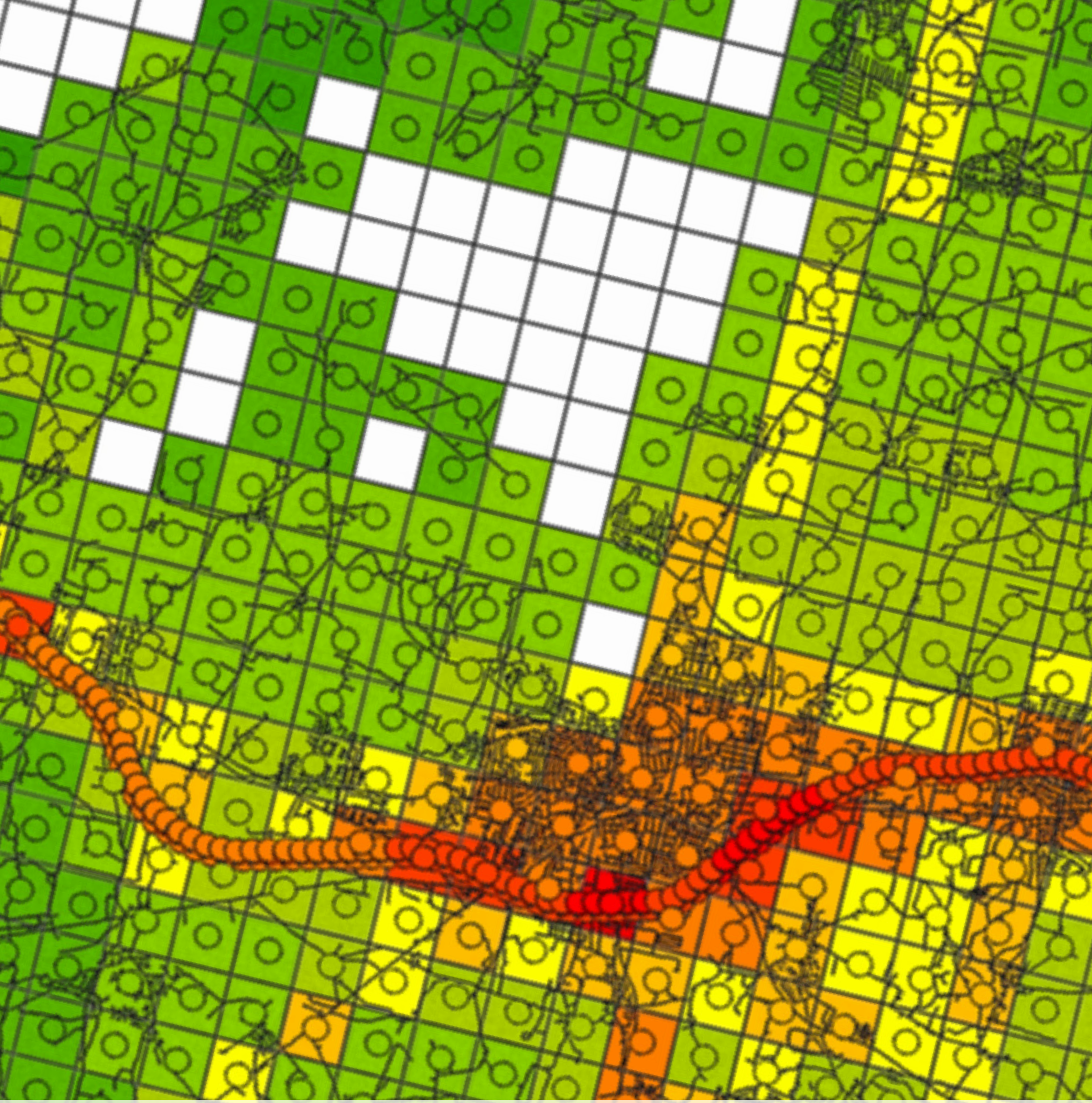

OML-HIGHWAY WITHIN THE FRAMEWORK OF SELMA[GIS]

FINAL REPORT

Faglig rapport fra DMU nr. 771
2010

DANMARKS MILJØUNDERSØGELSER
AARHUS UNIVERSITET

[Tom side]

OML-HIGHWAY WITHIN THE FRAMEWORK OF SELMA^{GIS}

FINAL REPORT

Faglig rapport fra DMU nr. 771 2010

Steen Solvang Jensen
Thomas Becker
Matthias Ketzel
Per Løfstrøm
Helge Rørdam Olesen
Helmut Lorentz

DANMARKS MILJØUNDERSØGELSER
AARHUS UNIVERSITET

Data sheet

Series title and no.:	NERI Technical Report No. 771
Title:	OML-Highway within the framework of $SELMA^{GIS}$
Subtitle:	Final Report
Authors:	Steen Solvang Jensen[1], Thomas Becker[1], Matthias Ketzel[1], Per Løfstrøm[1], Helge Rørdam Olesen[1] & Helmut Lorentz[2]
Department:	[1]Department of Atmospheric Environment, National Environmental Research Institute, Aarhus University & [2] Ingenieurbüro Lohmeyer, Germany
Publisher:	National Environmental Research Institute © Aarhus University - Denmark
URL:	http://www.neri.dk
Year of publication:	June 2010
Editing completed:	May 2010
Referee:	Matthias Ketzel.
Financial support:	Danish Road Directorate.
Please cite as:	Jensen, S.S., Becker, T., Ketzel, M., Løfstrøm, P., Olesen, H.R., Lorentz, H. (2010): OML-Highway within the framework of $SELMA^{GIS}$. Final Report. National Environmental Research Institute, Aarhus University, Denmark, 26 p, NERI Technical Report No. 771. http://www.dmu.dk/Pub/FR771.pdf.
	Reproduction permitted provided the source is explicitly acknowledged
Abstract:	This report describes the OML-Highway model and its integration into $SELMA^{GIS}$. The National Environmental Research Institute (NERI) has developed the OML-Highway model and Ingenieurbüro Lohmeyer from Germany has developed $SELMA^{GIS}$. The OML-Highway model is able to calculate air pollution concentration levels at receptor points along a highway road network, while $SELMA^{GIS}$ is a framework for calculating and representing air pollutant emissions and concentrations in a geographical information system (GIS).
Keywords:	Highway, traffic, air quality, model, GIS, OML, $SELMA^{GIS}$.
Layout:	Majbritt Pedersen-Ulrich
Front page photo:	ATMI
ISBN:	978-87-7073-160-7
ISSN (electronic):	1600-0048
Number of pages:	26
Internet version:	The report is available in electronic format (pdf) at NERI's website http://www.dmu.dk/Pub/FR771.pdf

Contents

1 Introduction

This report describes the OML-Highway model and its integration into SELMA^{GIS}. The National Environmental Research Institute (NERI) at Aarhus University has developed the OML-Highway model and Ingenieurbüro Lohmeyer, Germany has developed SELMA^{GIS}. The OML-Highway model is able to calculate air pollution concentration levels at receptor points along a highway road network, while SELMA^{GIS} is a framework for calculating and representing air pollutant emissions and concentrations in a geographical information system (GIS).

NERI has carried out the OML-Highway project for the Danish Road Directorate. The Danish Road Directorate has funded the OML-project with co-funding by NERI. The OML-Highway project included an air quality measurement campaign at the Holbæk motorway (Holbæk-motorvejen) with focus on measurements of particles reported in a separate report, and the implementation of the OML-Highway into SELMA^{GIS}. A separate user manual for the OML-Highway model has also been produced.

Chapter two and three provide short summaries in English and Danish, respectively.

Chapter four gives an overall description of the OML-Highway model and its integration into the framework of SELMA^{GIS}. The overall data flow, features and graphical user interface are described.

Chapter five describes the potential model applications of the OML-Highway model.

Chapter six gives two examples of applications of the OML-Highway. The first example illustrates the model as a tool for mapping of concentrations along a large part of the motorway network taking the Holbækmotorvejen as an example. The second example is a very detailed and local example where the OML-Highway model is used to model the impact of noise barriers on a small part of the Holbækmotorvejen.

The project was carried out in the period November, 2007 to April, 2010.

A Steering Committee with the following members has guided the project:

Lene Nøhr Michelsen, Danish Road Directorate (Head of Committee)

Jakob Fryd, Danish Road Directorate

Steen Solvang Jensen, National Environmental Research Institute, Aarhus University

Thomas Ellermann, National Environmental Research Institute, Aarhus University

2 Summary in English

In 2007 the first phase of the OML-Highway project was conducted by the National Environmental Research Institute (NERI) at Aarhus University to outline the overall specifications for a new user-friendly Danish highway air pollution model as a tool for environmental impact assessment and mapping of air quality along highways.

Within this report the implementation of OML-Highway into SELMA^{GIS} is described and potential model applications are outlined.

2.1 Background and objectives

Based on the results of Berkowicz et al. (2007), the Danish Road Directorate decided to develop the OML-Highway as a user-friendly Danish highway air pollution model coupled with a geographical information system (GIS). The challenge within the project was the implementation of a complex workflow of inputs to the OML-Highway model into a GIS program.

It was the intention to use the capabilities of GIS to create required inputs for a given road network and to use the possibilities of GIS for visualisation of model results.

With SELMA^{GIS} the German company Ingenieurbüro Lohmeyer is offering a system for air pollution modelling and visualisation. The program has a unique user interface to work with different dispersion models and is based on ArcGIS™, where it is implemented as an extension.

2.2 Model description

In the OML-Highway GIS-extension an emission model and a dispersion model are implemented.

The emission module of the Operational Street Pollution Model (OSPM) is integrated into the OML-Highway. NERI has developed the OSPM model. The emission module is based on the COPERT 4 methodology.

The OML-Highway model is a local Gaussian air pollution model based on boundary layer scaling, which estimates dispersion from point sources and area sources. It has a meteorological pre-processor, which applies Monin-Obukhov similarity theory using synoptic, sonic and radio-sonde data to calculate the required turbulent parameters (Berger et al., 2010). The OML-Highway model may also be used with meteorological input data that alone are based on synoptic data and this feature has been implemented into the OML-Highway in SELMA^{GIS}. The OML-Highway model is used to calculate the air pollution concentration at receptor point level.

2.3 Model applications

The new Danish Highway Air Pollution Model has a number of potential application areas.

Environmental Impact Assessment – to improve information about air pollution as part of legal requirements to assess environmental impacts for new major highway constructions or alteration of existing highways.

EU Ambient Air Quality Limit Values – to be able to assess current or future air quality levels along highways in relation to European Union air quality limit values that have been implemented in Danish legislation.

Systematic Mapping of Air Quality and Human Exposure – to provide overview of the current and future state of air quality and human exposure along a large road network to identify hot spots and areas that merit further analysis and assessment of mitigating measures.

"What-If" Scenario Analysis – to predict future air quality levels under different scenario assumptions e.g. construction of noise barriers, changed traffic volumes and emission factors.

Ranking of Road Investments based on Cost-benefit Analysis – a potential spin-off in a long-term perspective is to provide inputs to cost-benefit analysis of road investments although it is not within the scope of the proposed new highway model at present. The OML-Highway model could be extended to include external costs of air pollution.

3 Resume på dansk

I 2007 udarbejdede Danmark Miljøundersøgelser (DMU) under Aarhus Universitet overordnede specifikationer for en kommende brugervenlig luftkvalitetsmodel for motorveje og hovedlandeveje, som skulle bruges som et værktøj til vurdering og kortlægning af luftkvalitet langs med disse veje. Med udgangspunkt heri besluttede Vejdirektoratet at iværksætte et projekt udført af DMU, som dels gennemførte en målekampagne af luftkvaliteten på en udvalgt motorvejsstrækning, og som skulle udvikle en brugervenlig motorvejsmodel for luftkvalitet.

Denne rapport beskriver, hvordan OML-Highway modellen er blevet integreret i SELMA^{GIS}, som er et GIS-baseret system til luftkvalitets-modellering og visualisering. Endvidere beskrives potentielle anvendelsesmuligheder af OML-Highway, og der gives to konkrete eksempler på anvendelser. Dels et eksempel, hvor der gennemføres en kortlægning af luftkvaliteten langs en længere motorvejsstrækning (Holbækmotorvejen), og dels et meget lokalt eksempel, som belyser effekten af støjskærme på luftkvaliteten på et konkret sted på en motorvejsstrækning.

3.1 Baggrund og formål

De overordnede specifikationer for udvikling af en brugervenlig motorvejsmodel for luftkvalitet er beskrevet i Berkowicz et al. (2007). Udfordringen var at koble den eksisterende OML-Highway model udviklet af DMU med et GIS program for at få en brugervenlig brugerflade til OML-Highway modellen.

Valget faldt på GIS programmet SELMA^{GIS} som er udviklet af det tyske firma Ingenieurbüro Lohmeyer. Programmet indeholder flere tyske luftkvalitetsmodeller og er udviklet som en extension til ArcGIS™. ArcGIS™ er et standard GIS produkt fra ESRI.

3.2 Modelbeskrivelse

Emissionsmodellen i Operational Street Pollution Model (OSPM) er implementeret i OML-Highway. OSPM modellen er udviklet af DMU, og selve emissionsmodulet er baseret på den europæiske emissionsmodel COPERT 4. OSPM modellen er en bygademodel for luftkvalitet.

OML-Highway er en gaussisk lokalskala model specielt udviklet til at beskrive spredning af luftforurening langs med veje i det åbne terræn (Jensen et al. 2004; Berger et al., 2010). OML-Highway er baseret på OML modellen, som benyttes til vurdering af luftkvalitet fra punkt- og fladekilder (Olesen et al. 2007).

3.3 Potentielle anvendelsesmuligheder

OML-Highway modellen implementeret i SELMA^{GIS} har en række anvendelsesmuligheder.

VVM-vurdering - OML-Highway modellen kan forbedre informationsgrundlaget om emission og luftkvalitet i forbindelse med VVM-vurderinger (vurdering af virkningen på miljøet), som skal udføres ved nye større vejanlæg eller væsentlige ændringer af eksisterende større veje. Dette kan bidrage til at forbedre informationsgrundlaget overfor berørte borgere og offentligheden i al almindelighed.

Grænseværdier for luftkvalitet - OML-Highway modellen kan bruges til at vurdere nuværende og fremtidige luftkvalitetsniveauer langs med motorveje og hovedlandeveje i forhold til grænseværdier for luftkvalitet, hvor særligt NO_2 og PM_{10} har relevans.

Systematisk kortlægning af luftkvalitet og befolkningseksponering - OML-Highway modellen kan bruges til systematisk at kortlægge nuværende og fremtidige luftkvalitetsniveauer langs med motorveje og hovedlandeveje og den tilhørende befolkningseksponering for at kunne identificere kritiske strækninger, som kræver yderligere detailstudier og mulige tiltag for at nedbringe luftforureningen. Beregning af befolkningseksponering kræver at beregnet luftkvalitet knyttes til data om befolkning fx CPR oplysninger (Det Centrale Personregister) med antal mennesker og køn knyttet til geografiske adressekoordinator.

Hvad-nu-hvis scenarier - OML-Highway modellen kan beregne den fremtidig luftkvalitet under forskellige forudsætninger fx alternative linieføringer, etablering af støjskærme, ændringer i trafikniveau, ændringer i trafiksammensætning, ændrede emissionsforhold mv.

Prioritering af vejinvesteringer baseret på cost-benefit analyse - OML-Highway modellen kunne på længere sigt bidrage til at videreudvikle de metoder og datagrundlag, som indgår i de cost-benefit analyser, som ligger til grund for prioritering af vejinvesteringer. Her kunne luftkvalitet og befolkningseksponering inddrages som basis for beregning af eksternalitetsomkostninger af luftforurening.

4 Model Description

4.1 Overall description of methodology

The ArcGIS™ extension 'OML-Highway' combines the OML-Highway model and the emission module of the OSPM model.

The OML-Highway model is a local Gaussian air pollution model based on boundary layer scaling, which estimates dispersion from point sources and area sources. It has a meteorological pre-processor, which applies Monin-Obukhov similarity theory using synoptic, sonic and radio-sonde data to calculate the required turbulent parameters. The OML-Highway model may also be used with meteorological input data that alone are based on synoptic data and this feature has been implemented into the OML-Highway in $SELMA^{GIS}$.

Detailed description of the OML-Highway model and evaluation of model performance in comparison with measurements along a Danish motorway (Køge Bugt Motorvejen), and mapping of concentration levels along a large motorway network in the former County of Roskilde is given in Jensen et al. (2004; 2006). An evaluation of the OML-Highway model based on Danish (Køge Bugt Motorvejen) and Norwegian measurements and a comparison with other highway models applied in the Nordic countries is given in Berger et al. (2010). An evaluation of emission factors for PM_{10} and $PM_{2.5}$ at highway conditions were carried out based on a measurement campaign along a Danish motorway (Holbækmotorvejen) (Ellermann et al. 2009). Another study compares measurements of traffic-generated gas and particle pollution at two sites, one near a major highway (Holbækmotorvejen) and one near a busy urban street in Copenhagen, Denmark (Wang et al. 2010). Detailed information about the OML model can be found in Olesen et al. (2007).

The emission module of the Operational Street Pollution Model (OSPM) is integrated into the OML-Highway. NERI has also developed the OSPM model. The emission module is based on the COPERT 4 methodology (EEA 2007).

The first step in the development of the methodology to implement the OML-Highway model into $SELMA^{GIS}$ was to develop a data flow model using the supportive software VisioPro. In a second step, the interface of the model system was developed describing all dialogue boxes as a base for programming of the ArcGIS™ extension.

To support the development of the OML-Highway into $SELMA^{GIS}$ a working report (unpublished) has been prepared with detailed specifications for the OML-Highway Model.

The user interface of the OML-Highway in the ArcGIS™ extension is described in a separate OML-Highway User Manual (Becker et al. 2010).

4.2 Data flow model

A data flow model was developed using the Microsoft VisioPro 2003 supportive software. The data model provides an overview of input and output as well as linkages between data and processes for each element of inputs and outputs. It also specifies the content of all input and output files.

The data flow model is based on the so-called Gane-Sarson data flow model diagrams that consists of Interfaces, Processes, and Data Stores that are connected using Data Flow Connectors.

The top-level data flow model for the OML Highway model is described in Figure 4.1.

For each element in the data flow model a very detailed diagram further describes the inputs, outputs, and processes.

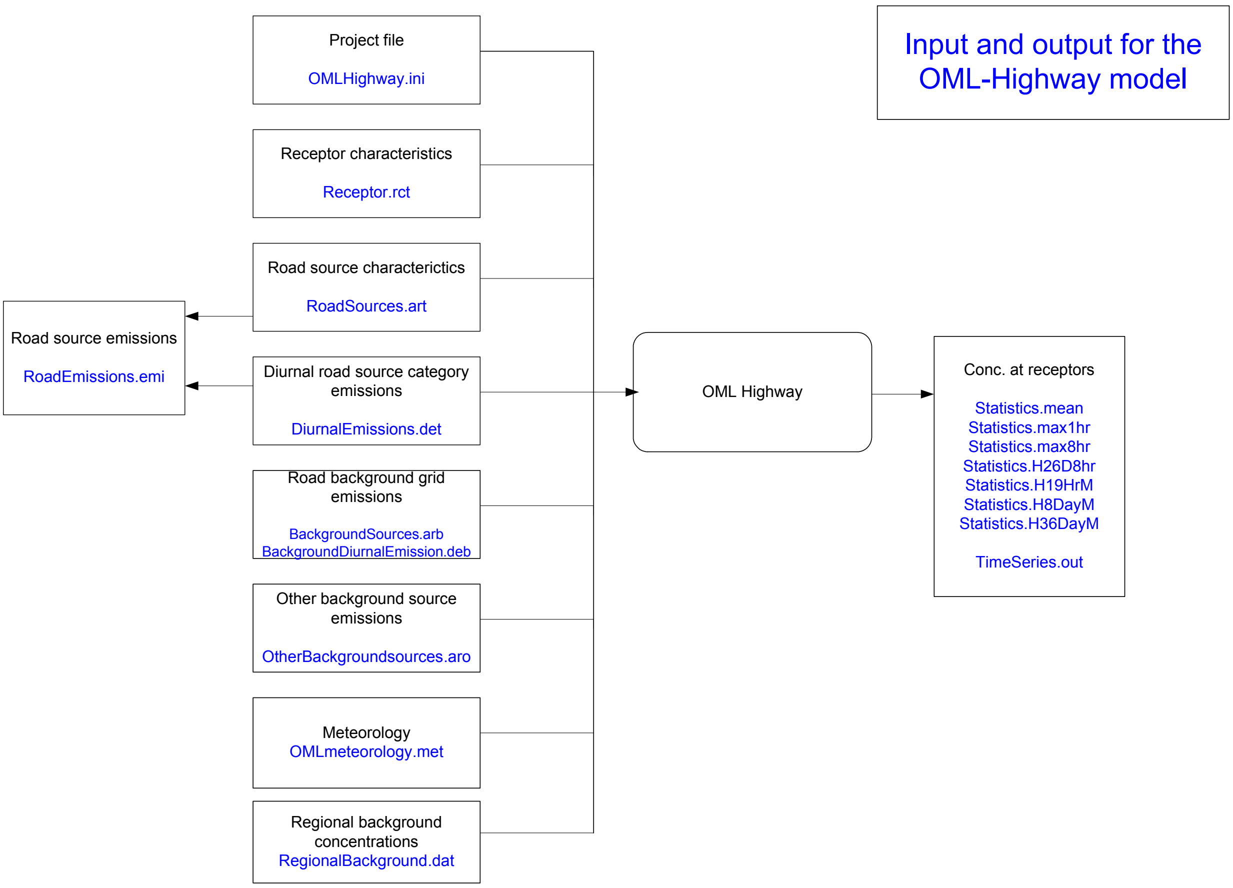

Figure 4.1. Top-level data flow model for the OML-Highway model

4.3 Overall flow diagram

Figure 4.2 illustrates the linkages between key files in the model system.

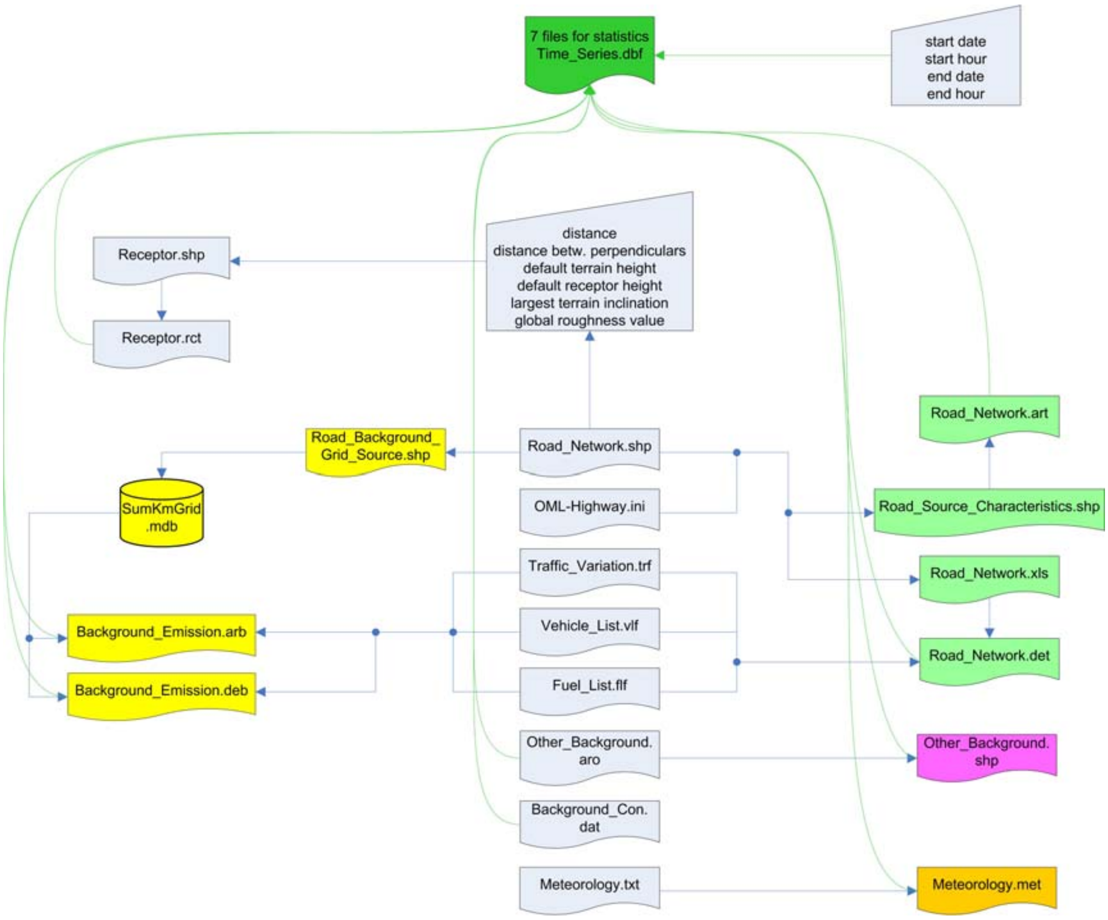

Figure 4.2. Overall data work flow and files in OML-Highway, colours are explained in the text.

Figure 4.2 shows the road network file in the centre of the flowchart. Almost all files required during the calculation process in OML-Highway can be generated from the road network file. All other files listed beneath the road network file in figure 5.1 have to be provided by the user, except the OML-Highway.ini file which is produced automatically when running OML-Highway.

Different colours in the flowchart refer to the single steps within the OML-Highway navigator. The OML-Highway navigator leads the user through the dialogue boxes of the graphical user interface.

Step 1 (Creation of Road Sources) is marked in light green, step 2 (Creation of the Background Road Sources) in yellow, while the output of step 3 (Receptor points) is coloured the same way as all the other input files provided by the user. In step 4 and 5 (Other Background Sources and Meteorology) solely files are generated in every step which are coloured magenta and golden. All input files required to run OML-Highway in step 6 lead to the seven statistical files and the DBase file of the time series, shown at the top of the flowchart.

4.4 Graphical User Interface

A graphical user interface (GUI) has been developed for the OML-Highway as an extension for ArcGIS within the framework of SELMA^{GIS}.

The GUI includes a number of dialogue boxes that guides the user in defining and creating input and output data. An example of a dialogue box from the OML-Highway navigator is shown in **Figure 4.3**. In the left part of the dialogue box a list of the required steps that the user has to go through is shown. The GUI is described in details in the OML-High User Manual (Becker et al. 2010).

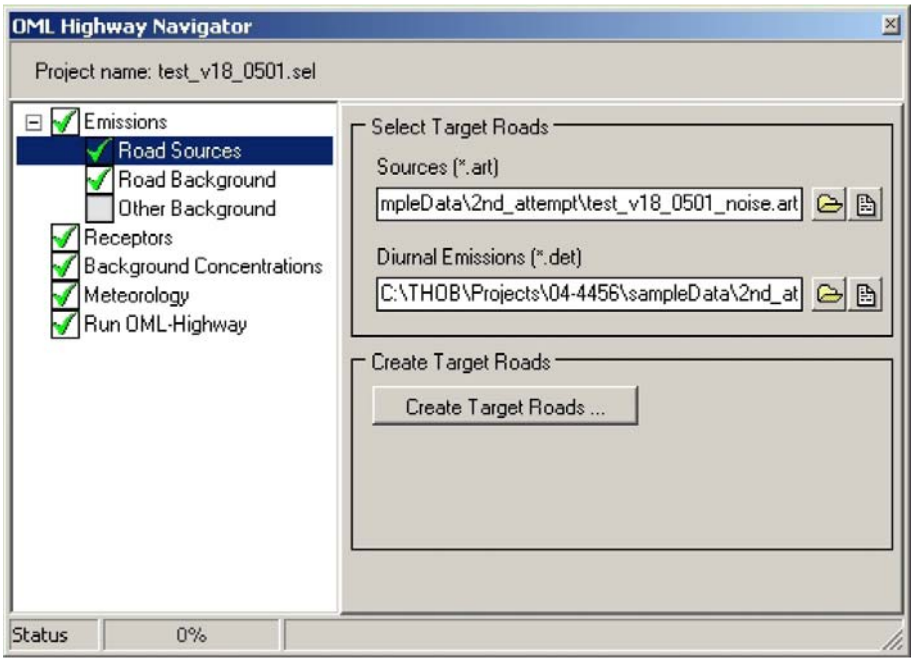

Figure 4.3. Example of a dialogue box in the graphical user interface for the OML-Highway

4.5 Description of features

The OML-Highway represents a model developed by NERI to calculate air pollution concentrations along highways. For the first time at NERI we employ an easy-to- use graphical user interface (GUI) within a GIS. It is built in a way that the user only needs to provide the base data to run a complex model system successfully. The interface takes care of many intermediate calculation and reformatting steps in transforming the base data into suitable input data for the dispersion runs with OML-Highway.

The coupling of OML-Highway with the GIS is a powerful combination to select roads depending on several factors (distance to area of interest, population density, traffic density etc.) using the advanced possibilities of the GIS. Due to the GIS it is also easy to create receptor points along roads with a user specified distance between the receptor points and user specified distances of the receptor points from the roads.

Within the road network the user can choose single road segments and define them as either target or background roads. Target roads are roads for which emissions are created for individual road links and receptor points may be generated along these roads. Background roads are roads where emissions are represented on a grid e.g. of a resolution of 1 km x 1 km. Emissions from target and background roads are taking into account in calculation of concentration levels at a receptor point.

In case of a noise barrier along a specific road segment the user can flag this segment to consider the impact of the noise barrier on concentrations during the calculation.

Furthermore, it is possible to create receptor points on regular grids to calculate the concentrations maps. The extent of the grid can be either user specified via coordinate input or by drawing a rectangle over the area of interest or by using selected features of the road network. However, in any case the user defines the mesh size of the grid.

Since OML-Highway needs meteorological data for the calculation the user has to provide the model with locally adapted information. To convert synoptic data (*.txt) into meteorological files (*.met) with the OML specific format and parameters a convertion routine is implemented.

Finally, the combination of the OML-Highway and GIS offers a very potential opportunity to visualise the input, all data of intermediate steps and the output of the model calculations. Whenever possible the output of OML-Highway can be loaded into the current data frame of the GIS to visualise receptor points, characteristics of roads, emissions of target and background roads, meteorological data, calculated concentrations etc. to create professional maps of the concentration of air pollution.

5 Potential Model Applications

OML-Highway is a powerful tool to assist the Danish Road Directorate in various assessments. In this report five possible applications for OML-Highway are briefly described.

- Environmental Impact Assessment
- EU Ambient Air Quality Limit Values
- Systematic Mapping of Air Quality and Human Exposure
- What if Scenario Analysis
- Ranking of Road Investments based on Cost-benefit Analysis

5.1 Overview of potential applications

Environmental Impact Assessment

The Danish Road Directorate has to carry out environmental impact assessments in case of new major highway constructions or alteration of existing highways. This is due to a European Union (EU) directive on environmental impact assessment implemented into Danish legislation.

The OML-Highway is able to provide information about air concentrations, human exposure and relation to air quality limit values from existing highways as well as new constructions provided that estimated traffic levels are available.

Part of an environmental impact assessment is also to provide information to the public about the potential impacts of proposed new highways and describe possible mitigating measures to reduce impacts. This has to be done for different alternatives of routing.

In addition to the capacity of the Danish Road Directorate to model the impacts of traffic noise, effects of mitigation measures as well as the description of expected traffic noise levels in relation to traffic noise guidelines of the Danish Environmental Protection Agency, the OML-Highway offers similar model capabilities for air pollution. With the OML-Highway, the capacity of the Danish Road Directorate will be broadened to model air quality and human exposure along the highway network and to compare predicted air quality levels with EU limit values.

EU Ambient Air Quality Limit Values

In the context of European environmental regulation the European Union (EU) has established health based air quality limit values or target values for a number of pollutants with the directives on assessment and management of ambient air quality (EU Directive on cleaner air for Europe, 2008/50/EC). According to these EU directives there is a legal obligation for member states to act in response to observed violation of limit values. In Denmark, the Danish Environmental Protection Agency, in cooperation with local authorities and other agencies, has the overall responsibility to ensure compliance with air quality limit values.

In an earlier study, NO_2 concentrations were mapped in 2005 along the Holbækmotorvej in the County of Roskilde in Denmark. This study showed that the motorway complied with the NO_2 limit values plus the margin of tolerance in 2005 (Jensen et al. 2004). This could be considered a worst case scenario as the Holbækmotorvej is one of the busiest motorways in Denmark. The margin of tolerance will gradually decrease until 2010 where the limit value has to be met. The combined effect of expected increase in traffic volumes and decrease in NO_x emissions per vehicle is uncertain and NO_2 emissions might even increase due to higher share of direct NO_2 emission for newer vehicles. There is a risk that at some locations along the road network with high traffic volumes and closely located buildings, the air quality limit values may be exceeded in 2010.

Exposure to particulate matter (PM) especially raises health concerns. There is a PM_{10} limit value (2005) for ambient air and various national exposure reduction targets, exposure concentrations obligations, target and limit values for $PM_{2.5}$ (2010, 2015 and 2020). PM_{10} are particles less than 10 micron and $PM_{2.5}$ are particles less than 2.5 micron in aerodynamic diameter.

The OML-High model in SELMA^{GIS} is a tool that makes it easier and less time consuming to map air pollution concentration levels along the motorway network.

Systematic Mapping of Air Quality and Human Exposure

A model tool as OML-Highway for systematic mapping of air quality and human exposure along the entire state road network can provide an important overview of the current state of air quality and human exposure along the road network. Giving such information hot spots can be identified that merit further analysis and assessment of mitigation measures. Population data (gender, age, number) are available from the Central Person Register (CPR) on address level.

What-if Scenario Analysis

To be able to predict scenarios of future air quality levels for comparison with air quality limit values in the future, an emission module is implemented into OML-Highway based on the OSPM emission module.

The use of the air emission module of the OSPM model in the OML-Highway provides full user control over the vehicle fleet composition and emission factors.

The OML-Highway can answer "what if" questions like what are the impacts on emission and air quality of changes in: road layout, traffic volume, vehicle composition, speed and emissions.

Furthermore, OML-Highway is able to take noise barriers into account and is therefore able to model the impact of such mitigation measures.

Ranking of Road Investments based on Cost-benefit Analysis

The Danish Road Directorate ranks future road construction investments based on cost-benefit principles. Emissions are one of the parameters that are included. A new highway air pollution model that includes air quality and human exposure may further qualify these estimations. However, it is not within the scope of the development of the OML-Highway model to further improve the procedures for ranking of road investments but it might be a potential spin-off in a long-term perspective.

6 Examples of Model Applications

Two examples of model applications have been carried out. The first example illustrates the potential of the OML-Highway model to map concentrations along a large part of the motorway network taking the Holbækmotorvej as an example. The second example is a very detailed and local example where the OML-Highway model is used to model the impact of noise barriers on a short section of the Holbækmotorvej.

6.1 Mapping former County of Roskilde

A section of about 30 km of the Holbækmotorvej around Roskilde was selected as an example to calculate air pollution concentrations along a larger part of the motorway network (Highlighted in Figure 6.1). The Holbækmotorvej is considered the target road and all other streets are considered as background roads. Traffic counts on the road network are from 2005. In Figure 6.1 an extended grid used to aggregate the emissions of the background roads with a mesh size of 1000 meters is also shown.

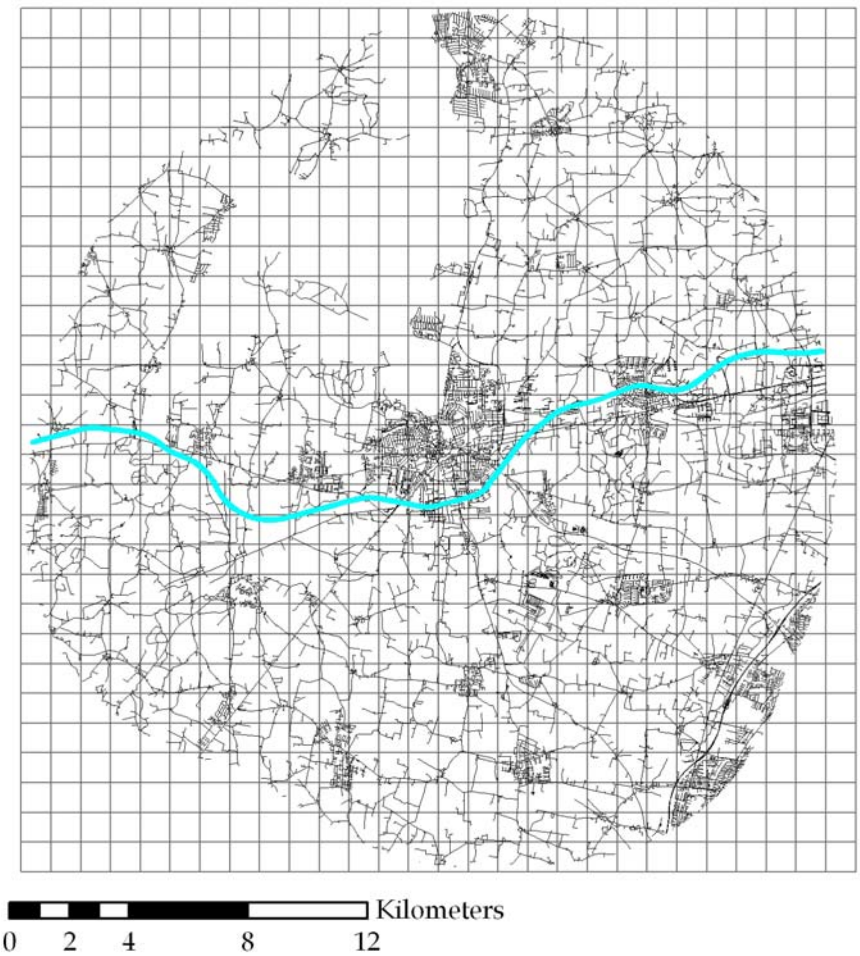

Figure 6.1. The considered road network with Holbækmotorvej as target road (blue) and background roads (black). The shown grid with a mesh size of 1000m is used to aggregate the emissions from the background roads.

Figure 6.2 shows the calculated concentrations of NO_2 in a regular mesh with an overlay of the road network. The receptor point is in the middle of each grid cell and the calculated concentration is represented as the surface of the grid cell. In this figure the contribution of the motorways (Holbækmotorvej in the centre and the Køge Bugt Motorvej at the lower right edge) clearly show higher NO_2 concentrations, however also smaller roads and towns are visible with slightly elevated concentrations. This representation on a regular grid is suitable for more homogeneous distributed emissions e.g. many smaller background roads. For larger single roads e.g. the Bugt Motorway (South East in Figure 6.2) this method is less suitable as the concentration gradient from the motorway is not captured at a 1x1 km² grid resolution as it is more or less random where the receptor point is located in relation to the motorway. However, this presentation may give a first overview of the concentration surface in a larger area.

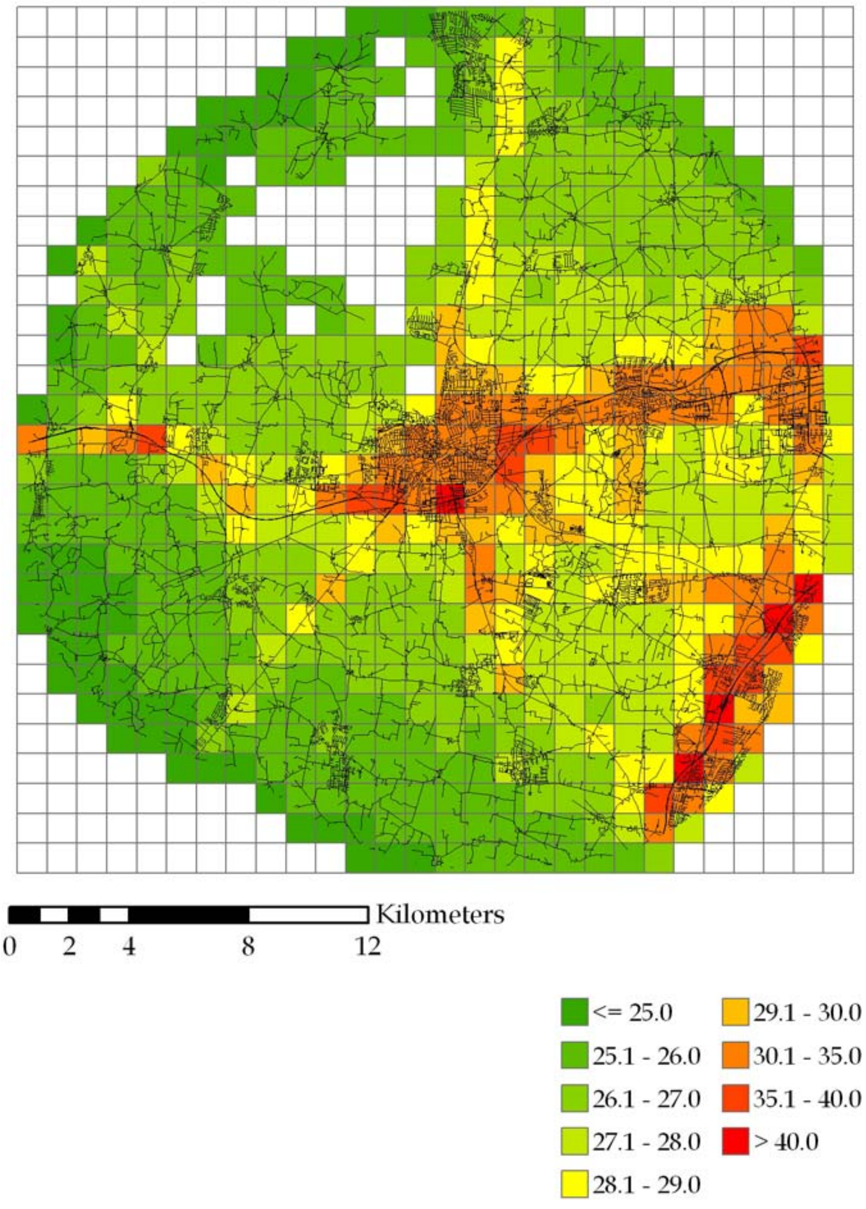

Figure 6.2. Modelled NO_2 ($\mu g/m^3$) concentrations in 2005 on a 1 km x 1km receptor grid displayed as coloured polygons (squares).

Another possibility to visualise model calculations is shown in Figure 6.3. Here only selected defined receptor points along the motorway of Holbækmotorvej are shown. It is seen that concentrations along the motorway are elevated compared to the receptor points in regions with less traffic.

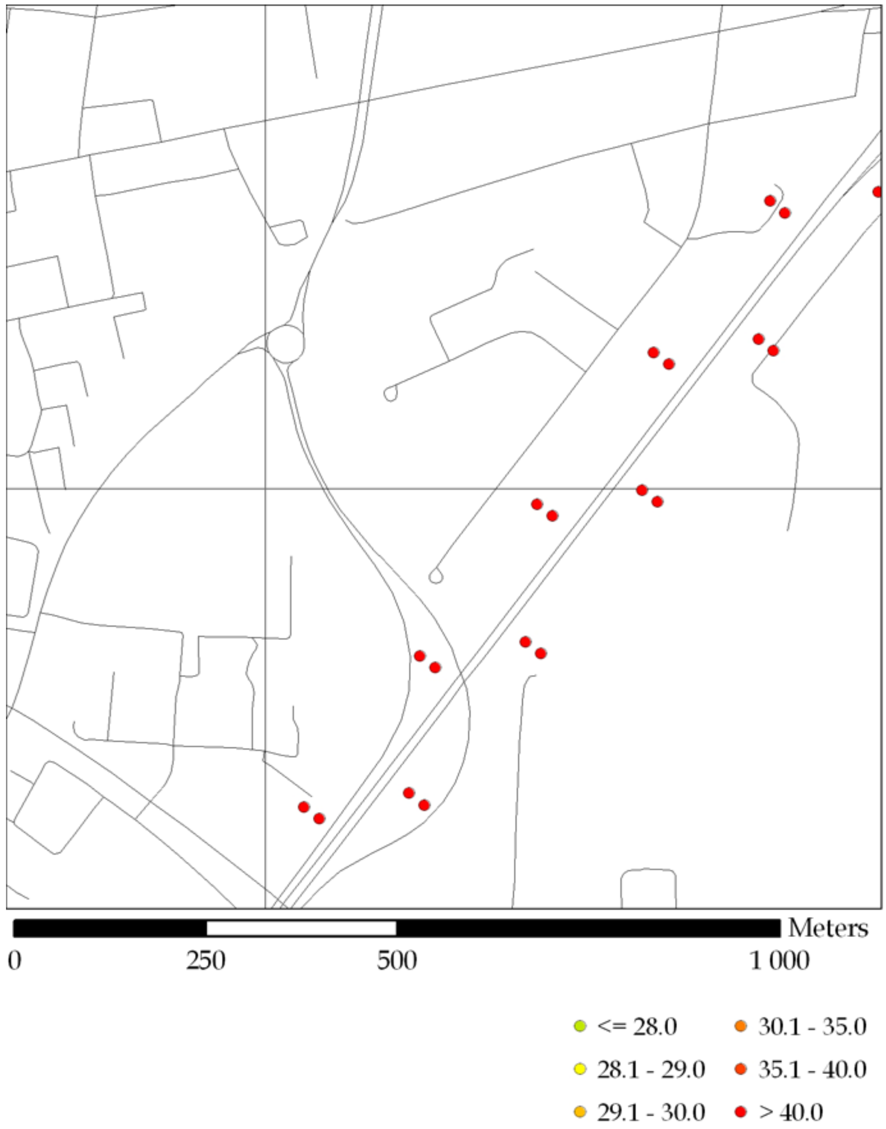

Figure 6.3. NO_2 mean values in µg/m^3 in 2005. Calculated concentrations at receptor points along the target road (Holbækmotorvej). In this example, the receptor points along the road are located at distances of 50 m and 100 m from the road.

In Figure 6.4 a combination of concentrations plotted as receptor points and as polygons is shown, providing a fast overview of the concentration levels and allows the user to quickly identify areas with high concentration levels. In this example, it is clearly seen that the Køge Bugt Motorvej is treated as a background road as it does not have receptor points along the motorway in the same way as the target road of Holbækmotorvej.

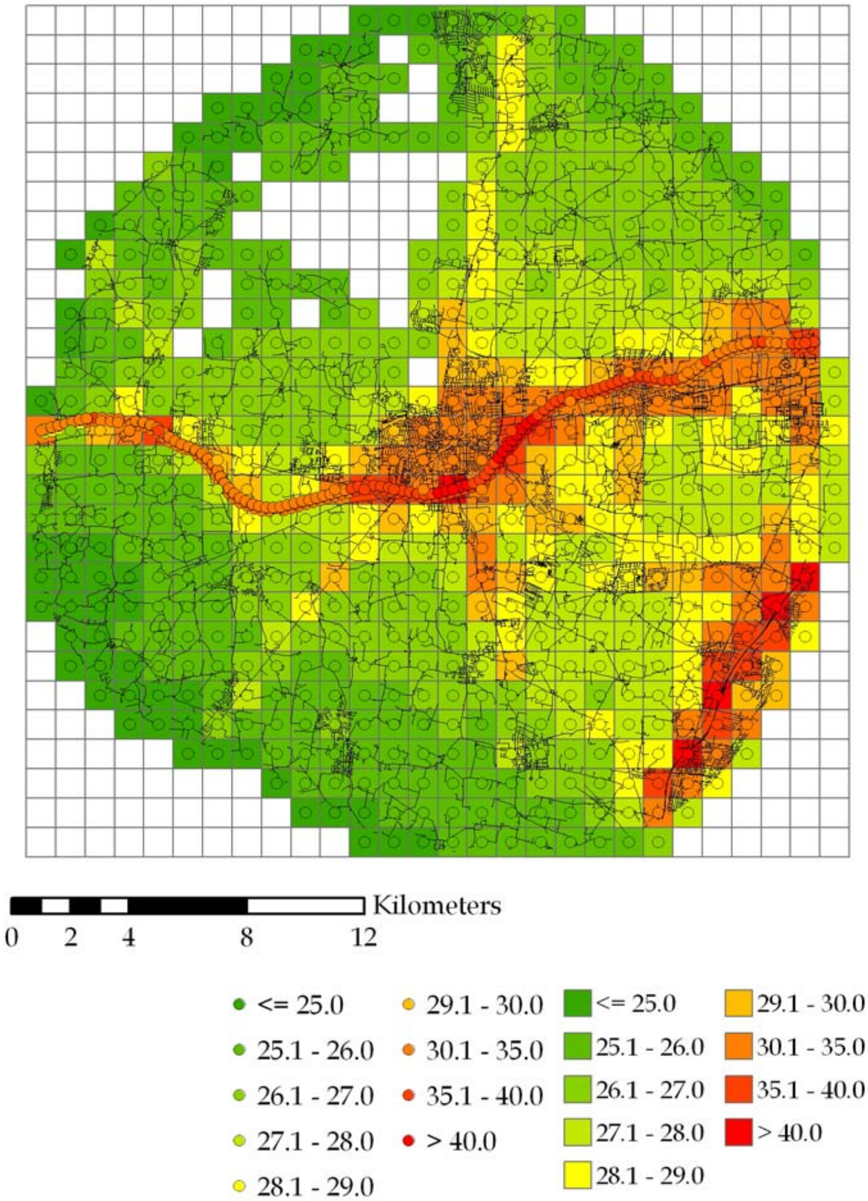

Figure 6.4. Combination of concentrations on a regular receptor grid plotted as polygons and concentrations at receptor points. NO_2 mean values in µg/m^3 in 2005.

6.2 Detailed case with noise barriers for EIA

In the OML-Highway model it is possible to model the influence of noise barriers and embankments in relation to air pollution concentration along roads. A simplified method has been introduced where the additional turbulence created by a noise barrier is taken into account. The simple method is based on an existing German guideline (VDI 1998) that takes the type and the height of the barrier into account, but not the distance of the barrier from the road. This method might be improved in a later update to take the distance into account.

In OML-Highway, four columns are established in the attribute table of the road network GIS file (WallH, EmbankH, NDistance and NSide). While WallH and EmbankH specify the height of either the noise barrier or the embankment the field NDistance quantifies the distance between the road and the noise barrier. The latter parameter is not used in the calculations yet, only for visualisation. The field NSide characterises on which side of the road the noise barrier is located. The orientation of the road is implemented according to the standard in the OSPM model. Here the orientation of the road is defined in relation to north (0 – 180 degree). The value 1 indicates that the barrier is on the more Northern side of the street segment while the value 2 is indicating a barrier on the more Southern side. Side 1 and 2 are defined in the same way as in the OSPM model (Figure 6.5). The length of a barrier is defined by the length of the road segment.

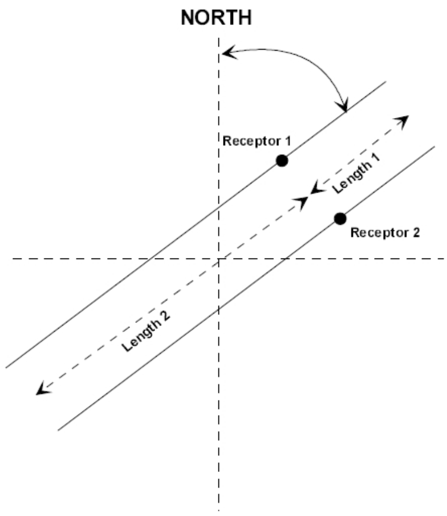

Figure 6.5. The definition of location of noise barriers in relation to a road segment follows the same notation as the location of receptor points in the OSPM model.

To show the influence of a noise barrier along a road segment on the Holbækmotorvej a special case was calculated. The setup for this segment includes a calculation without a barrier, with a barrier of a height of 3 m, and with a noise barrier with a height of 6 m. For this case only the contribution from the target road is considered and no background sources or regional sources are included.

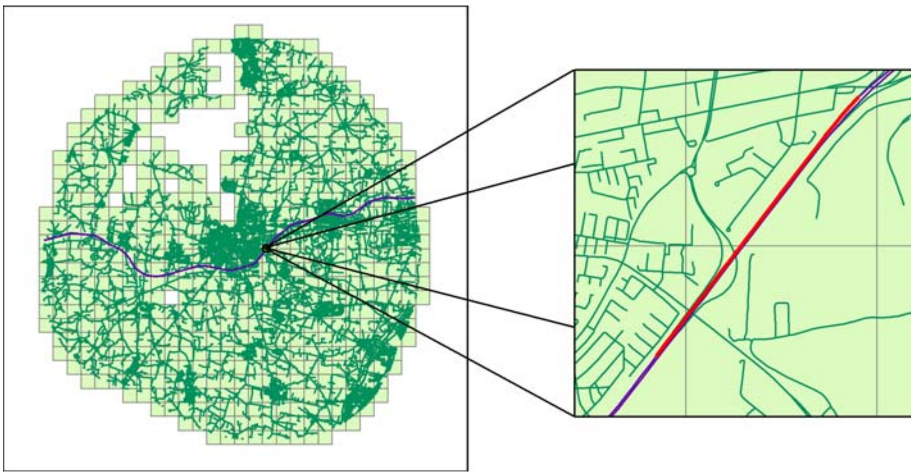

Figure 6.6. Overview of the location of a fictive noise barrier along a road segment of Holbækmotorvej; West of Roskilde on the lane going towards the city of Holbæk (westward direction).

16 receptor points (distances between 4 m and 25 m) were defined along the road segment that has a length of 171 meters. In Figure 6.7 the receptor points are visualised on a map. Table 6.1 shows hourly values of the road contribution of NO_x for all the three model runs described above. The values for the scenarios with noise barriers show the reduction of NO_x in percentage relative to the scenario without noise barrier, where values are given in µg/m³. The influence of the noise barrier was modelled for a single hour on a Monday at 17:00 (meteorological data from 21.04.2003) representing traffic situations under working day conditions during rush hour. The wind direction is perpendicular to the road from South East for maximum effect of the noise barrier.

In Table 6.2 the corresponding hourly values of NO_2 for all the three model runs are shown.

Table 6.1. Modelled hourly values of NO_x for 16 receptor points at Holbækmotorvej in 2005

Distance (m)	**without noise barrier** Rush hour (µg/m³)	**noise barrier (height 3m)** Rush hour (%)	**noise barrier (height 6m)** Rush hour (%)
4	26.8	-10.8%	-29.6%
5	25.0	-10.0%	-28.0%
6	24.6	-9.3%	-26.6%
7	23.9	-8.8%	-25.5%
8	23.0	-8.3%	-24.4%
9	22.4	-8.9%	-24.3%
10	21.6	-7.5%	-22.5%
11	21.0	-7.0%	-21.4%
12	20.3	-6.7%	-20.6%
13	19.8	-6.4%	-19.9%
14	19.4	-6.1%	-19.3%
15	18.9	-5.9%	-18.6%
17	18.1	-5.4%	-17.4%
19	17.4	-5.1%	-16.4%
21	16.6	-4.6%	-15.3%
25	15.5	-4.1%	-13.8%

Table 6.2. Modelled hourly values of NO_2 for 16 receptor points at Holbækmotorvej; in 2005

Distance (m)	**without noise barrier** Rush hour (µg/m³)	**noise barrier (height 3m)** Rush hour (%)	**noise barrier (height 6m)** Rush hour (%)
4	5.1	-10.1%	-27.8%
5	4.8	-9.3%	-26.3%
6	4.8	-8.6%	-24.8%
7	4.7	-8.1%	-23.8%
8	4.5	-7.7%	-22.7%
9	4.5	-8.3%	-22.5%
10	4.3	-6.9%	-21.0%
11	4.2	-6.5%	-19.9%
12	4.1	-6.3%	-19.3%
13	4.0	-5.9%	-18.5%
14	4.0	-5.8%	-18.0%
15	3.9	-5.4%	-17.3%
17	3.8	-5.0%	-16.1%
19	3.7	-4.7%	-15.2%
21	3.6	-4.3%	-14.2%
25	3.5	-3.8%	-12.8%

The highest concentration of NO_x and NO_2 is for the scenario without a noise barrier as seen from Table 6.1 and 6.2. The impact on NO_x and NO_2 concentrations of noise barriers of different heights are shown in column two and three where the concentration close to the road segment is lower compared to the one without noise barrier and the effect diminishes with distance. The lowest concentrations are modelled for the noise barrier with a height of 6 m compared to the one of 3 m. The height of the noise barrier increases the initial dispersion height of the plume. The impact is a little less for NO_2 compared to NO_x due to the chemical formation of NO_2 based on emitted NO from traffic and ambient ozone. This transformation takes a little time.

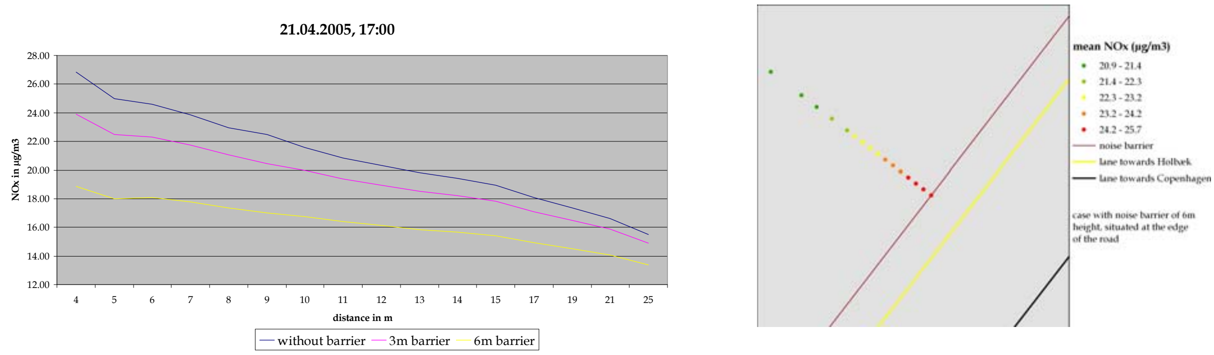

Figure 6.7. Left: Effects of noise barriers of 3 m and 6 m at different distances from the road; right: Visualisation of 16 receptor points at Holbækmotorvej with a noise barrier (height of 6 m).

The dilution of the vehicle emissions from the highway is due to turbulence from the atmospheric boundary layer, the noise barrier and the traffic produced turbulence (TPT). In general, the noise barrier contribute with a fixed amount of turbulence and so does the atmospheric turbulence to a first order estimate, but the effect of TPT depends on the wind speed. Increasing wind speed means shorter transportation time from road to the receptor giving the traffic produced turbulence less time to be active and therefore TPT becomes relative less important. The result is that the effect of noise barriers has a relatively higher influence in higher wind speeds (although the absolute concentration decreases).

This is an estimate of the maximum influence for a single hour without contribution from the background air pollution. On annual average with background contribution the percentage difference will be mush less as the addition of background concentrations will reduce the relative difference and in periods with low emissions from traffic the relative difference will be even lower. Furthermore, about half of the year the wind is from the opposite direction and there is no impact of the noise barrier. Finally, low wind speeds contribute relatively more to the yearly average and as mentioned above in these situations the influence of the noise barrier is relatively low.

7 References

Becker, T., Ketzel, M., Jensen, S.S., Løfstrøm, P., Olesen, H.R. (2010): OML-Highway User Manual. 13 p. Not published as separate report as the manual is part of the graphical user interface of the OML-Highway programme.

Berger J., Walker S-E., Denby B., Berkowicz R., Løfstrøm P., Ketzel M., Härkönen J., Nikmo J. and Karppinen A. 2010. Evaluation and inter-comparison of open road line source models currently in use in the Nordic countries. Boreal Environment Research. Available as preprint at www.borenv.net/BER/pdfs/preprints/Berger.pdf. ISSN 1797-2469 (online), ISSN 1239-6095.

Berkowicz R., Løfstrøm P., Ketzel M., Jensen S.S. and Hvidberg M. 2007.OML Highway – Phase 1: Specifications for a Danish Highway Air Pollution Model. NERI Technical Report no. 633.

Directive 2008/50/EC of The European Parliament and of the Council of 21 May 2008 on Ambient Air Quality and Cleaner Air for Europe.

EEA (2007): EMEP/CORINAIR Atmospheric Emissions Inventory Guidebook 2007. Methodology for the calculation of exhaust emissions. Road Transport. Version 6.0 August 2007. COPERT 4. European Environmental Agency. 105 p.

Ellermann, T., Jensen, S.S., Ketzel , M., Løfstrøm, P., Massling, A. (2009): Measurements of air pollution from a Danish highway. National Environmental Research Institute, Aarhus University. 45 p.- Research Notes from NERI No. 254. http://www2.dmu.dk/Pub/AR254.pdf

Jensen, S.S., Løfstrøm, P., Berkowicz, R., Olesen, H.R., Frydendal,J., Fuglsang, K., Hummelshøj, P. (2004): Air quality along motorways – Measurement campaign and model calculations. National environmental Research Institute, Denmark, 67 p. – NERI report No. 522. http://faglige rapporter.dmu.dk. (In Danish).

Jensen, S.S., Løfstrøm, P., Berkowicz, R., Olesen, H.R., Frydendall, J., Madsen, I-L., Ketzel, M., Fuglsang, K. & Hummelshøj, P. (2006): Mapping of air quality and human exposure along motorways. In: Joumard, R. (ed): Proceedings of the 2nd Conference Environment & Transport including the 15th conference Transport and Air Pollution, Reims, 12-14 June 2006. Institut National de Recherche sur les Transports et leur Sécurité. - Actes 107: 287-294.

Olesen, H.R., Berkowicz, R.B, Løfstrøm, P., 2007: OML: Review of model formulation. National Environmental Research Institute, Denmark. 130pp. -NERI Technical Report No. 609, http://www.dmu.dk/Pub/FR609.

Wang, F., Ketzel, M., Ellermann, T., Wåhlin, P., Jensen, S. S., Fang, D., and Massling, A. (2010): Particle number, particle mass and NO_x emission factors at a highway and an urban street in Copenhagen, Atmos. Chem. Phys., 10, 2745-2764, 2010.

VDI (1998): Draft of guideline VDI 3782, Blatt 8: 1998, Entwurf, Ausbreitungsrechnung fuer Kfz-Emissionen, Beuth Verlag, Berlin).

NERI National Environmental Research Institute
DMU Danmarks Miljøundersøgelser

National Environmental Research Institute, NERI, is a part of Aarhus University.

At NERI's website www.neri.dk you'll find information regarding ongoing research and development projects.

NERI undertakes research, monitoring and consultancy within environment and nature.

Furthermore the website contains a database of publications including scientific articles, reports, conference contributions etc. produced by NERI staff members.

Further information: www.neri.dk

National Environmental Research Institute
Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 4630 1200
Fax: +45 4630 1114

Management
Department of Arctic Environment
Department of Atmospheric Environment
Department of Environmental Chemistry and Microbiology
Department of Marine Ecology
Department of Policy Analysis

National Environmental Research Institute
Vejlsøvej 25
PO Box 314
DK-8600 Silkeborg
Denmark
Tel: +45 8920 1400
Fax: +45 8920 1414

Department of Freshwater Ecology
Department of Terrestrial Ecology

National Environmental Research Institute
Grenåvej 14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 8920 1700
Fax: +45 8920 1514

Department of Wildlife Ecology and Biodiversity

NERI Technical Reports

NERI's website www.neri.dk contains a list of all published technical reports along with other NERI publications. All recent reports can be downloaded in electronic format (pdf) without charge. Some of the Danish reports include an English summary.

Nr./No.	2010
784	Denmark's National Inventory Report 2010. Emission Inventories 1990-2008 – Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. By Nielsen, O.-K., Lyck, E., Mikkelsen, M.H., Hoffmann, L., Gyldenkærne, S., Winther, M., Nielsen, M., Fauser, P., Thomsen, M., Plejdrup, M.S., Albrektsen, R., Hjelgaard, K., Johannsen, V.K., Vesterdal, L., Rasmussen, E., Arfaoui, K. & Baunbæk, L. 1178 pp.
783	Miljøøkonomiske beregningspriser for emissioner. Af Andersen, M.S. 33 s.
782	Screening for kloralkaner i sediment. Relevans for NOVANA. Af Larsen, M.M., Hjorth, M. & Sortkjær, O. 22 s.
781	Emissionskortlægning for decentral kraftvarme 2007 – Energinet.dk miljøprojekt nr. 07/1882. Delrapport 5 Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme, 2006. Af Nielsen, M., Nielsen, O.-K. & Thomsen, M. 105 s.
780	Heavy Metal Emissions for Danish Road Transport. By Winther, M. & Slentø, E. 99 pp.
779	Brændefyrings bidrag til luftforurening. Nogle resultater fra projektet WOODUSE. Af Olesen, H.R., Wåhlin, P. & Illerup, J.B. 71 s.
778	Ynglefugle i Tøndermarsken og Margrethe Kog 1975-2009. En analyse af udviklingen i fuglenes antal og fordeling med anbefalinger til forvaltningstiltag. Af Clausen, P. & Kahlert, J. (red.) 206 s.
777	Air pollution from residential wood combustion in a Danish village. Measuring campaign and analysis of results. By Wåhlin, P., Olesen, H.R., Bossi, R. & Stubkjær, J. 49 pp.
776	Annual Danish Informative Inventory Report to UNECE. Emission inventories from the base year of the protocols to year 2008. By Nielsen, O-K., Winther, M., Mikkelsen, M.H., Hoffmann, L., Nielsen, M., Gyldenkærne, S., Fauser, P., Plejdrup, M.S., Albrektsen, R. & Hjelgaard, K. 565 pp.
775	Environmental monitoring at the former lead-zinc mine in Maarmorilik, Northwest Greenland, in 2009. By Johansen, P., Asmund, G., Rigét, F., Johansen, K. & Schledermann, H. 32 pp.
774	Kvælstofbelastningen ved udvalgte terrestriske habitatområder i Sønderborg kommune. Af Frohn, L. M., Skjøth, C. A., Becker, T., Geels, C. & Hertel, O. 30 s.
773	Geese, seabirds and mammals in North and Northeast Greenland. Aerial surveys in summer 2009. By Boertmann, D. & Nielsen, R.D. 66 pp.
772	Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2009. By Glahder, C.M., Asmund, G. & Riget, F. 32 pp.
769	Biological baseline study in the Ramsar site "Heden" and the entire Jameson Land, East Greenland. By Glahder, C.M., Boertmann, D., Madsen, J., Tamstorf, M., Johansen, K., Hansen, J., Walsh, A., Jaspers, C. & Bjerrum, M. 86 pp.
768	Danish Emission Inventory for Solvent Use in Industries and Households. By Fauser, P. 47 pp.
767	Vandmiljø og Natur 2008. NOVANA. Tilstand og udvikling. Af Nordemann Jensen, P., Boutrup, S., Bijl, L. van der, Svendsen, L.M., Grant, R., Wiberg-Larsen, P., Jørgensen, T.B., Ellermann, T., Hjorth, M., Josefson, A.B., Bruus, M., Søgaard, B., Thorling, L. & Dahlgren. K. 106 s.
766	Arter 2008. NOVANA. Af Søgaard, B., Pihl, S., Wind, P., Laursen, K., Clausen, P., Andersen, P.N., Bregnballe, T., Petersen, I.K. & Teilmann, J. 118 s.
765	Terrestriske Naturtyper 2008. NOVANA. Af Bruus, M., Nielsen, K. E., Damgaard, C., Nygaard, B., Fredshavn, J. R. & Ejrnæs, R. 80 s.
764	Vandløb 2008. NOVANA. Af Wiberg-Larsen, P. (red.) 66 s.
763	Søer 2008. NOVANA. Af Jørgensen, T.B., Bjerring, R., Landkildehus, F., Søndergaard, M., Sortkjær, L. & Clausen, J. 46 s.

[Tom side]

OML-HIGHWAY WITHIN THE FRAMEWORK OF SELMA^{GIS}

Final Report

This report describes the OML-Highway model and its integration into SELMAGIS. The National Environmental Research Institute (NERI) has developed the OML-Highway model and Ingenieurbüro Lohmeyer from Germany has developed SELMAGIS. The OML-Highway model is able to calculate air pollution concentration levels at receptor points along a highway road network, while SELMAGIS is a framework for calculating and representing air pollutant emissions and concentrations in a geographical information system (GIS).

ISBN: 978-87-7073-160-7
ISSN: 1600-0048