Preparation of national emission reduction and ambient air quality assessment programmes

EuropeAid/114743/D/SV/LT

Pilot air quality modelling study for Panevėžys

Pilot study report

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Vilnius

Contents

1. Introduction

As part of the project “Preparation of national emission reduction and ambient air quality assessment programmes” an air quality modelling case study has been carried out for the city of Panevežys. Local and national data have been used to compile an emissions inventory for the city which has then been used to carry out air quality modelling using the ADMS-Urban model. The following sections describe the input data, model set-up and modelling results.

This report describes the data used and assumptions made in the modelling and the model output. Section 2 gives details of the model set-up and Section 3 describes the emissions data used for the city. Sections 4 and 5 describe the meteorological and background data respectively. The monitoring data available is described in Section 6 and the comparison of measured and modelled concentrations is given in Section 7. Section 8 presents the concentration map generated for the city and Section 9 gives a discussion of the results and ideas for further work to improve the study.

2. Model Set-up

The modelling was carried out using ADMS-Urban, version 2.2.0.0. Various parameters are used to describe the characteristics of the surrounding area and their effect on the dispersion of pollutants. Table 2.1 gives a summary of the parameters used in this study.

A length scale parameter called the surface roughness length is used to characterise the study area in terms of the effects it will have on wind speed and turbulence, which are key factors in the modelling.

In urban areas, the significant amount of heat emitted by buildings and traffic warms the air within and above a city or large town. This is known as the urban heat island and its effect is to prevent the atmosphere from becoming very stable. In general, the larger the area the more heat is generated and the stronger the effect becomes. In the ADMS-Urban model, the stability of the atmosphere is represented by the Monin-Obukhov parameter, which has the dimension of length. The effect of the urban heat island is that, in stable conditions the Monin-Obukhov length will never fall below some minimum value; the larger the city, the larger the minimum value.

Grid source emissions are distributed evenly throughout each 1km square and vertically up to a given height. The grid source height is set to represent the vertical spread of the emissions.

Table 2.1 Model set-up parameters

Surface roughness	1m
Surface roughness at met site	0.5m
Minimum Monin-Obhukov length	30m
Grid source height	10m

3. Emissions data

3.1. Road sources

3.1.1. Traffic flow data

Daily traffic flows were available for the major roads in the city, broken down into separate counts for cars, light goods vehicles (LGV), buses and rigid and articulated heavy goods vehicles (HGV). The road links were digitised using ArcGIS and combined with the traffic flow data. The roads for which data were available are shown in Figure 3.1.

3.1.2. Fleet composition data

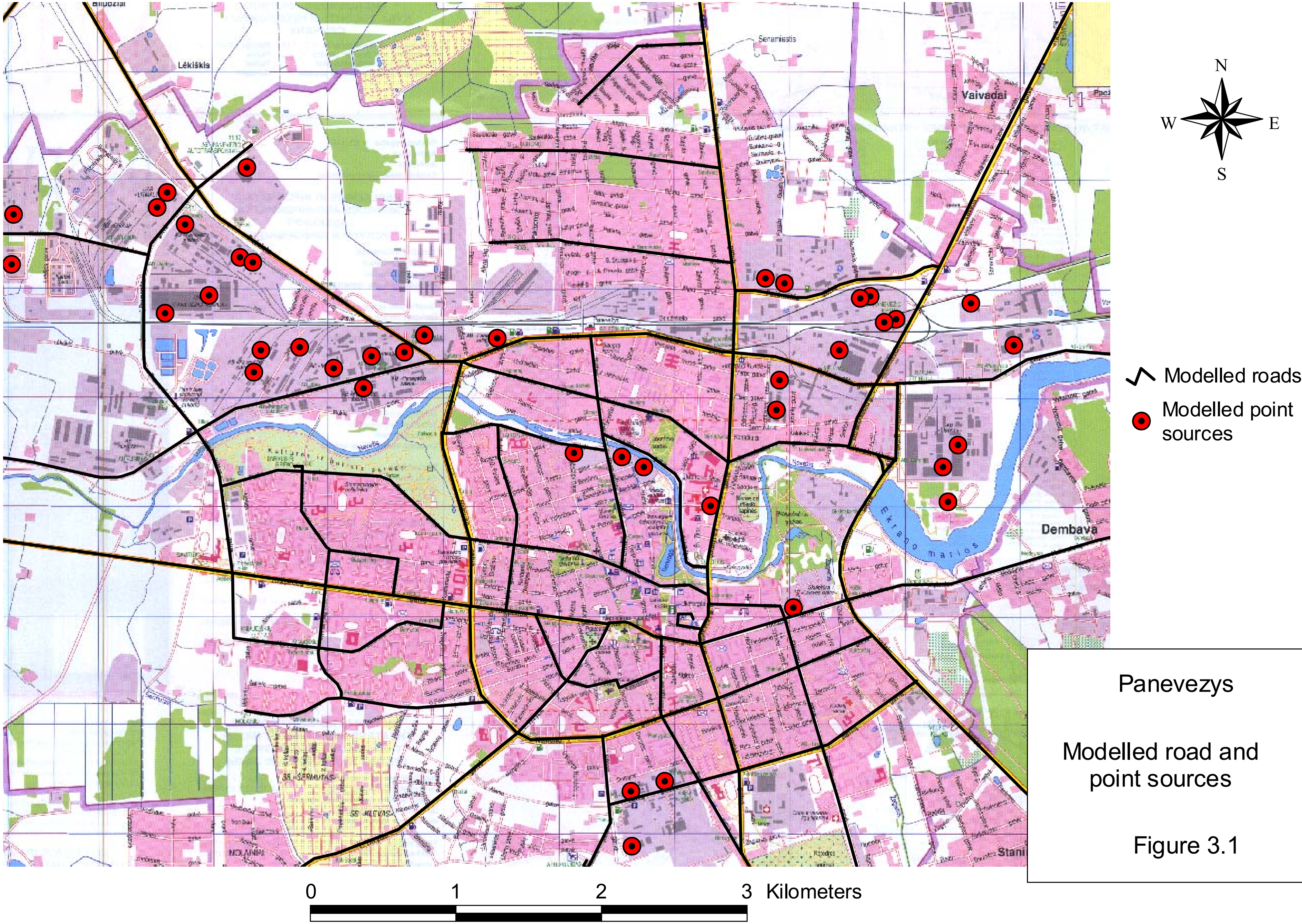
Emission rates for each road were calculated using the traffic flow and speed and the UK NAEI emission factors. The emission factors are defined for combinations of engine types (EURO categories) and engine size ranges and so a breakdown of each vehicle type into these categories is required. Vehicle registration data for Lithuania were provided giving detailed vehicle age and engine size data. The ages of the vehicles have been used together with the dates of introduction of the EURO standards to apportion the vehicles to the appropriate EURO categories, and the engine sizes grouped appropriately. A profile has therefore been derived giving the breakdown of each vehicle type into the appropriate EURO categories and engine sizes so that emission rates for each road can be calculated. Table 3.1 shows the percentage of cars using petrol and diesel and Table 3.2 shows the distribution of car engine sizes. Tables 3.3a to c show the vehicle ages for cars, LGVs and buses, respectively. Note that the vehicle breakdown will change year-by-year and the one calculated for Lithuania is appropriate only for 2005.

Table 3.1 M1 Personal Car, input data by fuel

	Petrol cars	**Diesel cars**	**Total**
Number of cars	613,719	198,217	811,936
Percentage of cars	**75.6**	**24.4**	**100**

Table 3.2 M1 Personal Car, input data by engine size

	Petrol cars by engine size (litres)			**Diesel cars by engine size (litres)**	
	<1.41	1.4 - 2.01	>2.01	<2.01	>2.01
Number of cars	84,830	413,137	115,752	137,486	60,731
Percentage of cars	**13.8**	**67.3**	**18.9**	**69.4**	**30.6**



Panevezys

Modelled road and point sources

Figure 3.1

Table 3.3a Vehicle ages - cars

	Date in service (UK)	Corresponding period in Lithuania	Number	Percentage
M1 Personal cars (Petrol)				
Pre ECE - 15.00		<1971	1,590	0.3
ECE - 15.00	01/01/1971	1971 - 1975	2,161	0.4
ECE - 15.01	01/07/1975	1976	560	0.1
ECE - 15.02	01/07/1976	1977 - 1979	2,033	0.4
ECE - 15.03	01/07/1979	1980 - 1983	17,890	3.1
ECE - 15.04	01/07/1983	1984 - 1992	355,371	60.8
Euro 1	01/07/1992	1993 - 1995	109,398	18.7
Euro 2	01/01/1996	1996 - 1999	51,569	8.8
Euro 3	01/01/2000	2000 - 2004	36,174	6.2
Euro 4	01/10/2005	2005 - 2006	7,698	1.3
Sub total			**584,444**	**100**
M1 Personal Cars (Diesel)				
Pre-EC stage I		<1993	110,398	59.2
EC stage I, Euro 1	01/01/1993	1993 - 1995	34,285	18.4
Euro 2, IDI	01/01/1996	1996	5,939	3.2
Euro 2, DI	1996.01a	1997 - 1999	13,825	7.4
Euro 3	01/01/2000	2000 - 2004	18,461	9.9
Euro4	01/10/2005	2005 - 2006	3,491	1.9
Sub total			**186,399**	**100**

Table 3.3b Vehicle ages – LGVs

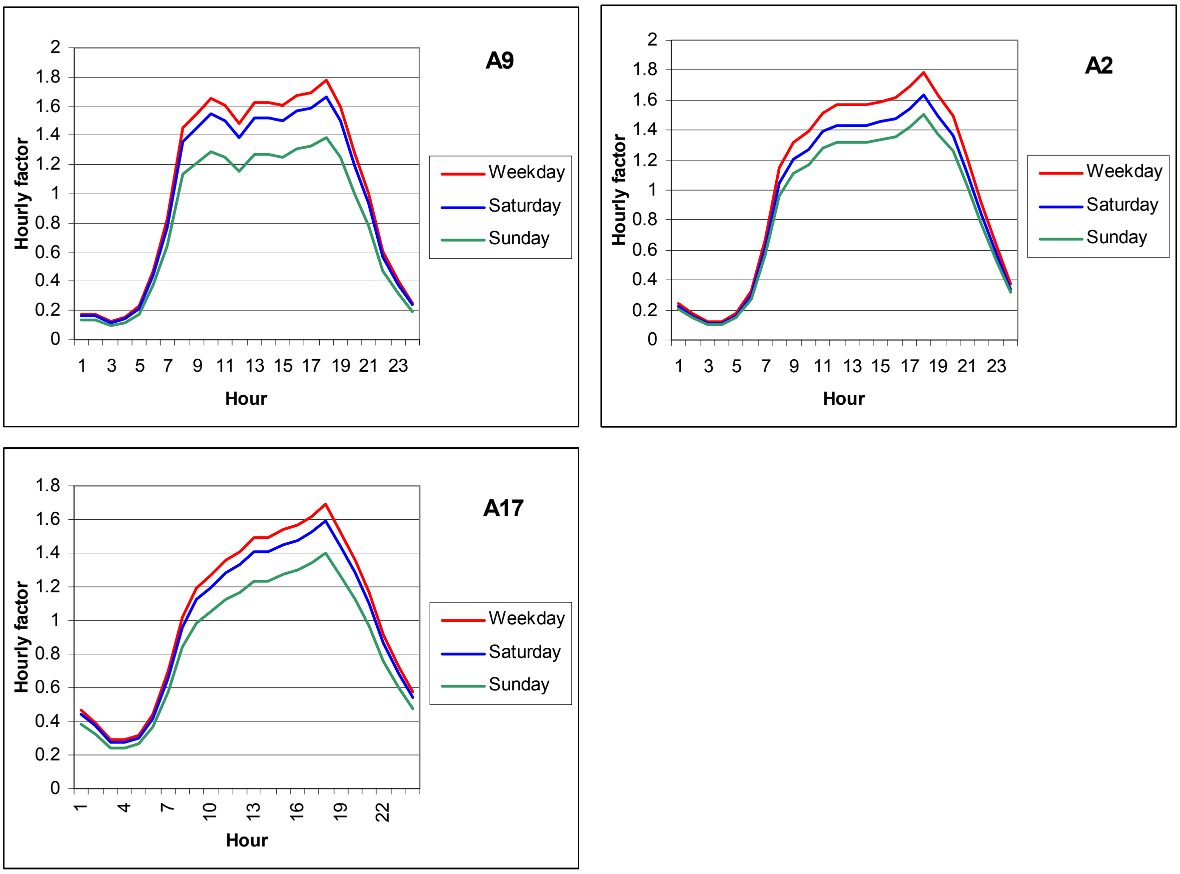
	Date in service (UK)	Corresponding period in Lithuania	Number	Percentage
N1 LGV (Petrol)				
Pre-EC Stage I		<1994 and 1994	4,064	63.0
Euro 1	01/10/1994	1995-1997	525	8.1
Euro 2	01/01/1998	1998-1999	416	6.5
Euro 3	01/01/2000	2000-2004	883	13.7
Euro 4	01/01/2005	2005-2006	565	8.8
Sub total			**6,453**	**100**
N1 LGV (Diesel)				
Pre-EC Stage I		<1994 and 1994	15,860	51.1
Euro 1	01/10/1994	1995-1997	3,711	12.0
Euro 2 IDI	01/01/1998	1998-1999	2,604	8.4
Euro 2, DI	1998,01a	2000	870	2.8
Euro 3	01/01/2001	2001-2005	7,863	25.3
Euro 4	01/01/2006	2006	135	0.4
Sub total			**31,043**	**100**

Table 3.3c Vehicle ages – buses

	Date in service (UK)	Corresponding period in Lithuania	Number	Percentage
M2 + M3 Buses (Diesel)				
Old		<1988 and 1988	2,316	31.9
Pre-EC stage I	01/10/1988	1989 - 1993	2,106	29.0
EC stage I	01/10/1993	1994 - 1996	376	5.2
EC stage II	01/10/1996	1997 and >1997	2,469	34.0
Sub total			**7,267**	**100**

3.1.3. Daily profile data

Traffic flows in the city vary during the day, and data representing this variation were input to the model. Automatic traffic counts at a number of sites around the city provided information regarding the daily variation of traffic flows. All roads used the profile from the A9 site, apart from Basanaviciaus and Smelynes which used data from the A2 site, and the A17 which used its own data. Figures 3.2a to c show the profiles used.



Figures 3.2a to c. Diurnal profiles for the A9, A2 and A17, respectively.

3.2. Industrial sources

Emissions data for 79 significant industrial sources were included in the modelling. The locations of these sources are shown in Figure 3.1. Emission rates for all sources were assumed to be constant throughout the year.

3.3. Domestic Heating

A significant source of emissions in Panevezys is domestic heating. Additional information was available regarding the number of properties connected to district heating systems in certain areas, but information on the use of other fuels was not available so this information was not used in the modelling; all domestic heating emissions being included in the national emissions sources (see Section 3.5).

3.4. Petrol Stations

Locations of petrol stations in the city were provided but throughput of fuel was not available for each station. Therefore, the petrol station emissions contained in the national emissions estimates have been used (see Section 3.5).

3.5. National emissions

National emissions estimates were provided by Ecolas[1] (as part of Activity C) on a 1km square resolution grid. A grid of 50 by 50 of these emissions have been included in the modelling for Panevezys, centred on the city. The national emissions include emissions from major roads outside the city boundaries, and emissions from all other sources across the whole region. Table 3.3 shows the total emissions of NO_x, VOC and PM_{10} used in the modelling, taken from the national emissions estimates. Note that the national emissions totals include emissions from roads outside the city boundary. Figure 3.3 shows the gridded emissions of NO_x for the Panevezys area.

Table 3.4 Total emissions for Panevezys area (t/yr)

	NO_x	**VOC**	**PM_{10}**
Major Roads	417	207	14.9
Industrial	676	147	99.4
National	1111	1853	1.5
Total	**2205**	**2207**	**115.9**

[1] Draft report on Activities C2, C4, C5 and C6, Central Project Management Agency Lithuania, April 12th, 2006

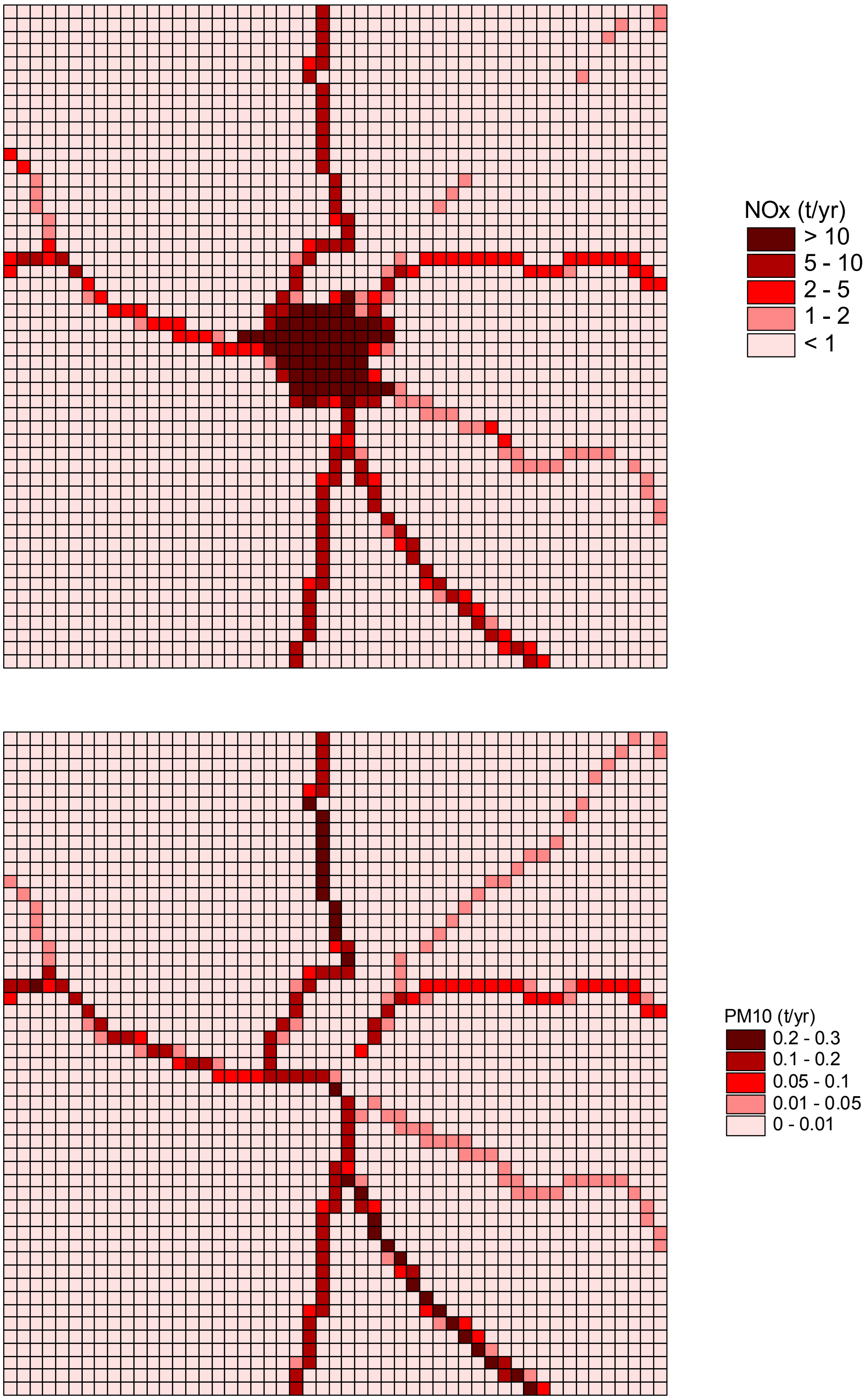


Figure 3.3. National emissions of NO_x and PM_{10}

4. Meteorological data

Modelling was carried out using hourly sequential meteorological data obtained from Panevezys for the year 2005. The data were provided as three-hourly values and have been interpolated to give an hourly sequential dataset. A summary of the data provided is given below in Table 4.1.

Table 4.1 Summary of meteorological data

	Panevezys		
Data capture	99.5%		
Height	10m		
Roughness length	0.5m		
Statistics	Mean	Minimum	Maximum
Temperature (°C)	7.0	-25.0	30.1
Wind speed (m/s)	2.8	0.0	15.0
Cloud cover (oktas)	5.3	0.0	8.0

The ADMS meteorological pre-processor, written by the UK Met Office, uses these data to calculate the parameters required by the program. Figure 4.1 shows the wind rose for the station giving the frequency of occurrence of wind from different directions for a number of wind speed ranges, for the year 2005.

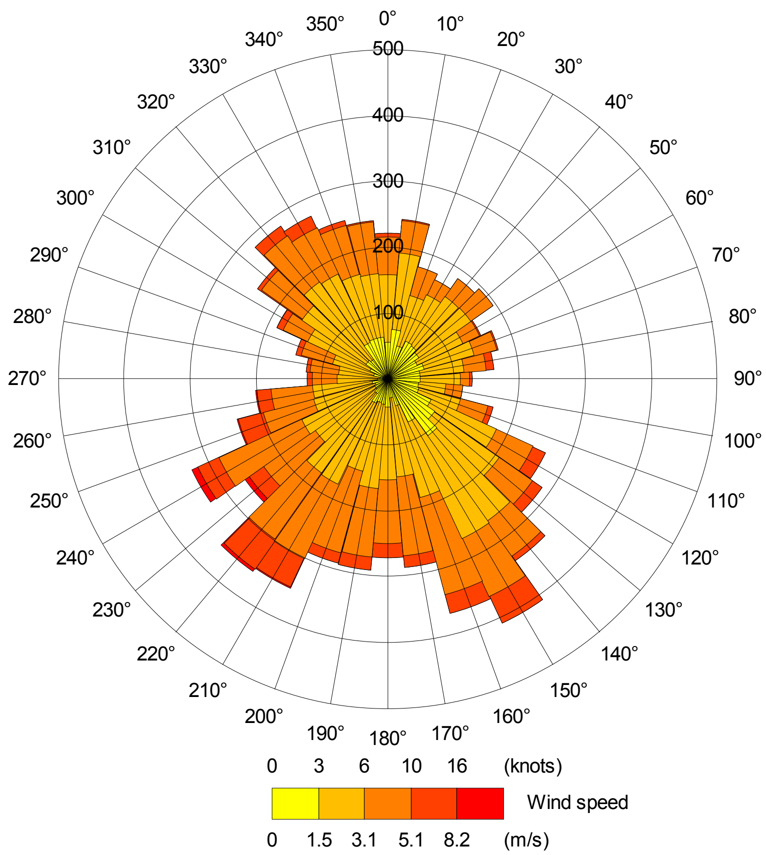


Figure 4.1 Wind rose for Panevezys 2005

5. Background concentrations

Background concentrations are input to the model to represent the concentration of pollutants in the air entering the modelled area. For this study, background concentrations of NO_2 and SO_2 were taken from the Preila rural monitoring site. A NO_x concentration was estimated. An average concentration of O_3 was estimated from monitoring data recorded at the Preila, Aukstatija and Zemaitija national parks.

Annual average concentrations have been used in the modelling, as given in Table 5.1, however, for more accurate results and for calculating short-term concentrations, a file of hourly average data should be used.

For PM_{10}, an annual average background concentration has been estimated by interpolating sulphate and nitrate concentrations between four rural monitoring sites in and around Lithuania. Ammonium sulphate and ammonium nitrate concentrations have been calculated and added together to give a total background PM_{10} concentration using the following expression:

$$PM_{10} = Sulphate \times (126/32) + Nitrate \times (79/14)$$

Table 5.1 Annual average background concentrations

	Concentration
NO_x (ppb)	3
NO_2 (ppb)	2
O_3 (ppb)	30
SO_2 (ppb)	1
PM_{10} (µg/m^3)	5

6. Monitoring data

Concentrations of NO_2 in Panevezys in 2005 were measured using three diffusion tubes at different locations, and a continuous monitor which moved location in the summer. The diffusion tube monitoring was carried out over three short periods during the year.

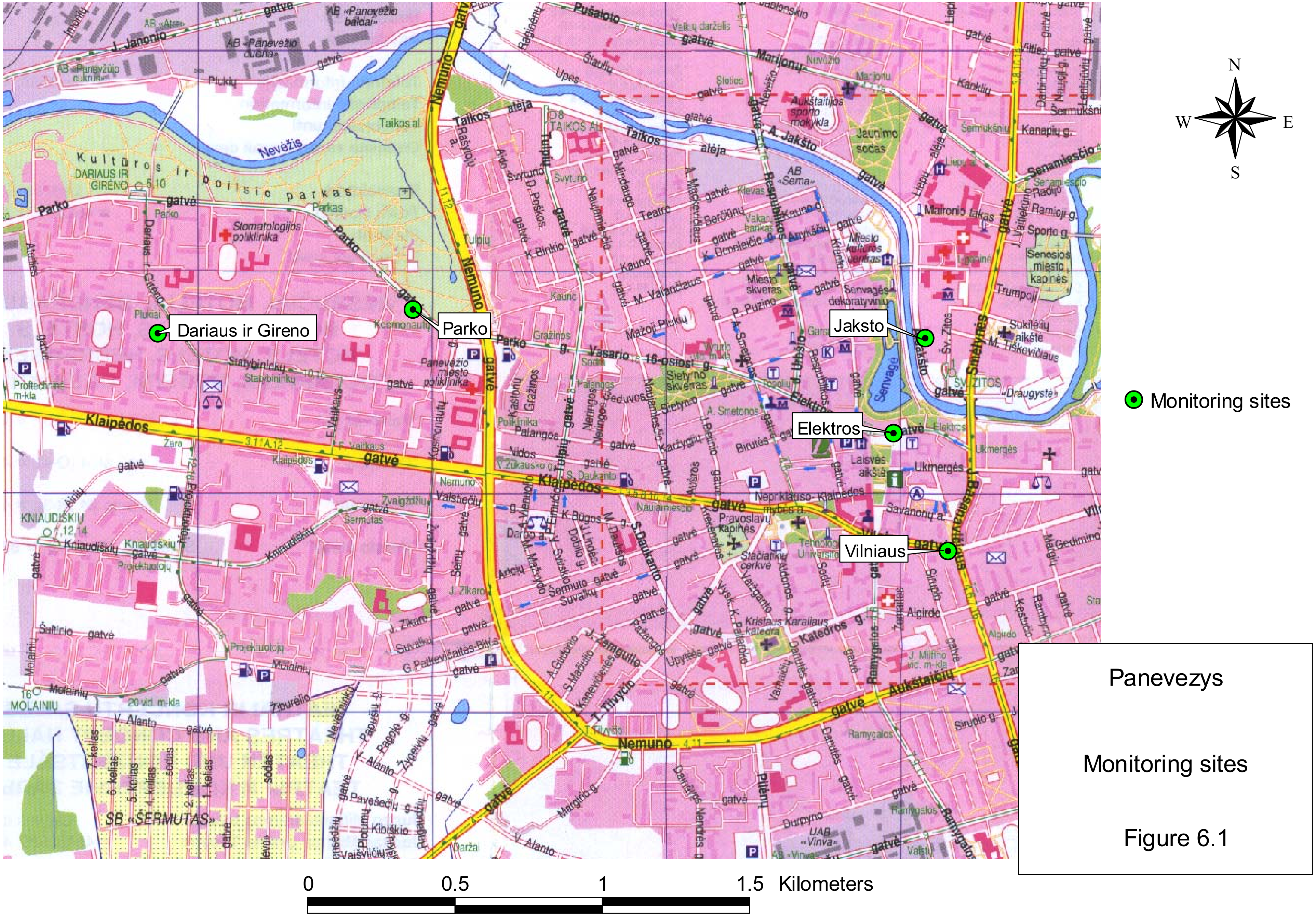
Tables 6.1 and 6.2 show details of the periods during which monitoring was carried out. Figure 6.1 shows the locations of the monitoring sites.

Table 6.1 Diffusion tube monitoring periods

	Winter		Summer	
	Start	End	Start	End
Vilniaus	04-02-2005	04-03-2005	03-06-2005	30-06-2005
Dariaus ir Girėno	04-02-2005	04-03-2005	03-06-2005	30-06-2005
Elektros	04-02-2005	04-03-2005	03-06-2005	30-06-2005

Table 6.2 Continuous monitoring periods

	Start	End
Jaksto	01-01-2005	25-07-2005
Parko	25-07-2005	31-12-2005



Panevezys

Monitoring sites

Figure 6.1

7. Model Verification

Hourly average concentrations of NO_x and NO_2 were calculated at the locations of the monitoring sites, and the measured and modelled concentrations were compared for the appropriate monitoring periods. Table 7.1 and Figure 7.1 show the measured and modelled long-term averages for each site, ie monthly or half-year averages for diffusion tubes and continuous monitors respectively.

Table 7.1 Measured and modelled NO_2 concentrations

Site	Monitoring period	Measured NO_2	Modelled NO_2
Jaksto	Jan - Jul	22.0	22.4
Parko	July - Dec	24.8	35.4
Vilniaus	Winter	41.9	38.8
	Summer	37.4	31.4
Dariaus ir Girėno	Winter	16.7	28.3
	Summer	9.4	18
Elektros	Winter	30.1	32.5
	Summer	18.6	25.7

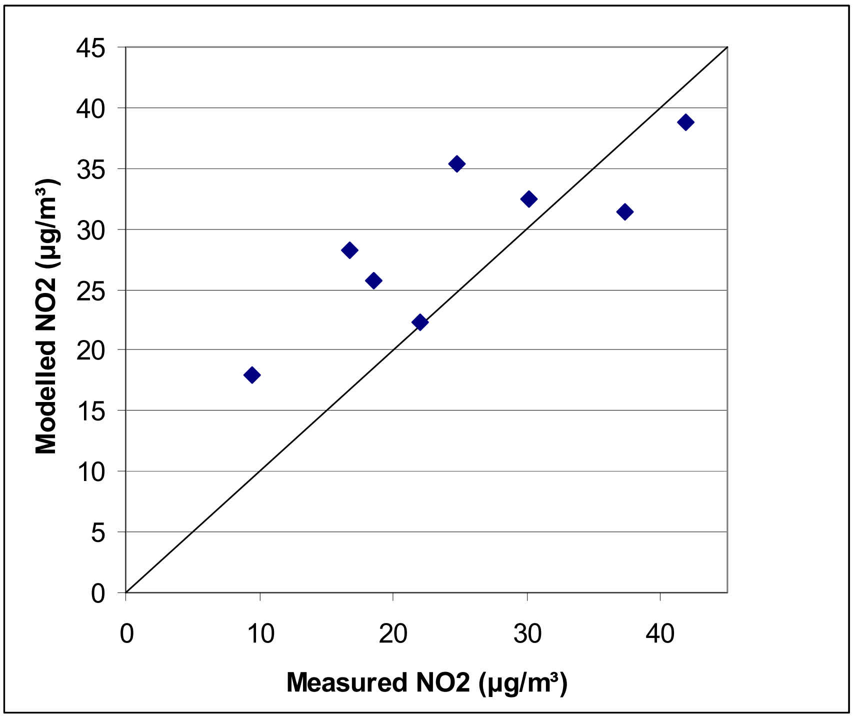


Figure 7.1 Measured and modelled NO_2 concentrations

The modelled concentrations generally show good agreement with the measured concentrations. The most significant difference is at Dariaus ir Girėno, at which the modelled concentrations are significantly higher than the measured values. This could be due to the estimation of domestic emissions in this area. The site lies in an area in which the majority of houses are connected to the district heating system and will therefore have small emissions, but the national emissions estimates have assumed an average emission per population, without taking into account any local information on fuel use.

Table 7.2 shows the measured and modelled annual average PM_{10} concentrations at the monitoring sites in Panevezys. Note that the concentrations presented include a contribution of 10µg/m³ which represents additional sources of PM_{10} such as resuspended material, salt and wind-blown dust.

Table 7.2 Measured and modelled PM_{10} concentrations

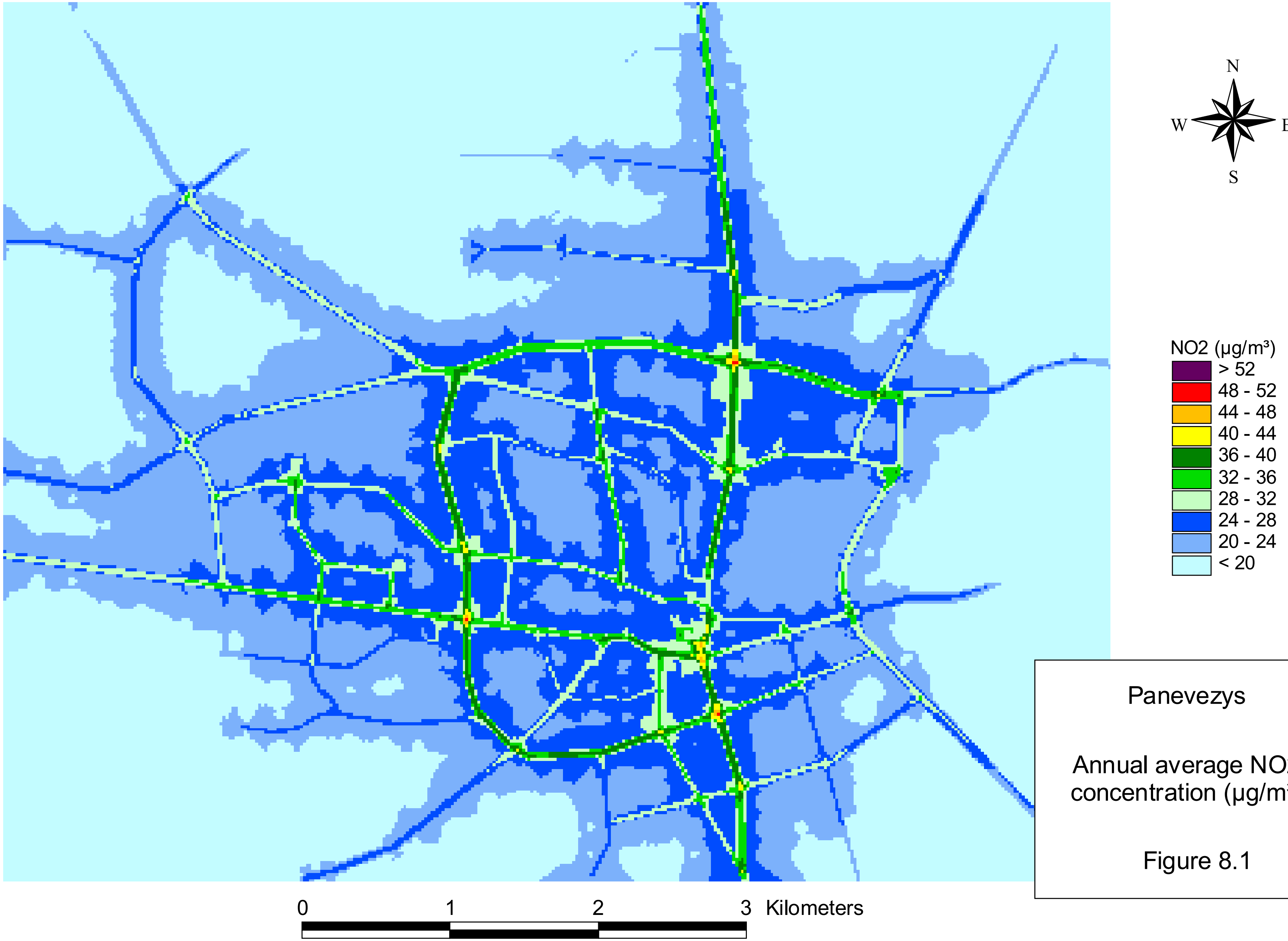
Site	Monitoring period	Measured PM_{10}	Modelled PM_{10}
Jaksto	Jan - Jul	33.3	18.6
Parko	July - Dec	25.6	25.4

Using the background and additional component described, the modelled concentration at the Parko monitoring site agrees well with the measured concentration, but this is not the case at the Jaksto site. It should be noted that for NO_x, both the measured and modelled concentrations were higher at Parko than at Jaksto, and this is also the case for the modelled PM_{10} concentration. However, the measured PM_{10} concentration at Jaksto is substantially higher than at Parko. This indicates that either there is a significant source of PM_{10} in the vicinity of the Jaksto site which has not been included in the modelling, or that there are uncertainties in the monitoring data. Further investigation has also revealed that the national emissions estimates have emissions data for both PM_{10} and TSP (total suspended particulates). However, some grid squares within the city have significant TSP emissions but zero PM_{10} emissions. The national emissions estimates should therefore be investigated to determine a realistic breakdown of TSP and PM_{10} for each source type.

8. Concentration maps

The comparison of measured and modelled NO_2 concentrations has shown reasonable agreement, indicating that the input data and model setup are appropriate for the city. This lends confidence to the calculation of concentrations in other parts of the city. Concentrations have been calculated throughout the city, calculated on a regular grid of points with additional points close to the roads where the concentration gradients are steepest. Figure 8.1 shows the annual average NO_2 concentration, with areas shaded yellow to red exceeding the EU limit value of 40µg/m³.

City-wide concentrations of PM_{10} have not been calculated, due to poor agreement between measured and modelled concentrations which have highlighted uncertainties in the emissions data or monitoring data.



Panevezys

Annual average NO2 concentration (µg/m³)

Figure 8.1

9. Conclusions and Future Work

Local traffic and industrial source data have been used together with national emissions estimates for other sources to generate an emissions inventory for Panevezys for 2005. Modelling of concentrations of NO_2 and PM_{10} at the monitoring sites has shown good agreement between measured and modelled NO_2 concentrations but has shown some uncertainty in the PM_{10} monitoring or emissions data. Further investigation into the PM_{10} data should be carried out before progressing with generating maps of PM_{10} concentrations.

Concentrations of NO_2 have been calculated over the whole city to generate a map of annual average NO_2 concentrations. This has shown that the annual average is predicted to exceed 40µg/m^3 at several of the busiest junctions in the city. The next stage of the modelling would be to calculated future concentrations based on projected changes to traffic flows, fleet compositions, other emissions data and background concentrations.

There are various ways in which aspects of the study and input data could be improved, for example:

- Use hourly background data rather than an annual average;
- Break-down of national emissions into source groups and improving data where possible, for example domestic heating and petrol stations;
- Investigation into PM_{10} and TSP data in national emissions estimates;
- Input of street canyon data, if appropriate;
- Use time varying industrial emission rates.