6.2 Airviro

6.2.1 The Airviro System Framework

SMHI (Swedish Meteorological and Hydrological Institute) has developed an environmental information system with a graphical user interface called 'Airviro'. Airviro provides dispersion simulation at different scales with options of four models: Street Canyon, Gauss, Grid and Heavy Gas. The dispersion results are overlaid on a map and can be imported/exported to standard GIS software. Airviro has inbuilt wind models, complex terrain handling and direct links to a dynamic emissions database, which can handle unlimited numbers of point, area and line sources.

The Airviro system is made by awk language. Airviro runs on a UNIX platform, which provides a high level of performance. The UNIX server can be accessed by multiple PC users via a standard network.

Airviro consists of the three following parts.

- Emission surveying and modeling with **Emission Database**
- Dispersion modeling with **Dispersion Module**
- Data collection, analysis and presentation with **Indico Package**

6.2.1.1 Emission Database

Emission Data is stored in special databases using a database handler that makes it possible to store emission characteristics of pollution in the atmosphere from large numbers of different source types.

6.2.1.2 Dispersion Module

The dispersion module uses information about weather, emission, physiography and climatology as input data. The module produces air quality calculations in the form of seasonal means or percentiles, time series (grid model only), or calculations for chosen weather and emission scenarios. The four types of dispersion models are shown in Table 6.2.1.1.

Table 6.2.1.1 Airviro Model Type

Name of Model	Type of Model
Gauss	Based on Lagrangean Gaussian formulation and recommended for calculations on smaller scales, for areas in which the topography is reasonably flat.
Grid	Based on Eulerian advection-diffusion and recommended for dispersion calculations for area with complicated topography.
Canyon	For simulating dispersion in roads surrounded by high buildings on both sides.
Heavy Gas	For simulation of tank bursts and pipe leakage of liquids and gases, taking into account molecular characteristics.

6.2.1.3 Indico Package

The Indico package has all the functions necessary for acquiring, storing, presenting, analysis and reporting time series data. The three types of Indico Package are shown in Table 6.2.1.2.

Table 6.2.1.2 Type of Indico Package

Indico Presentation	Data selection can be based on different types of selection criteria Calculation formulae can be applied to data Statistical functions can be used to build models Data can be presented graphically in a number of ways Report styles can be selected and report contents defined
Indico Real Time	Indico Real Time shows a selection of predefined macros in sequence that is updated as new data arrives. Each macro is displayed for fifteen seconds before the next macro is drawn. Indico Real Time can also be run in manual mode where the user can step through the macros by clicking on a button.
Indico Administration	The Indico Administration module has been designed to make it easier to control and monitor data collection activities. The users can easily easy to set up a system to handle automatic data collection from different stations.

6.2.2 Simulation Processes of the Grid Model

The Airviro Grid Model simulates ambient air concentration in the BMR. The simulation proceeding of Grid Model is shown in Figure 6.2.2.1. Simulation processes have main four parts such as Inventory Preprocessor, Grid Model Module, Conversion Formula and Evaluation of Simulation Results.

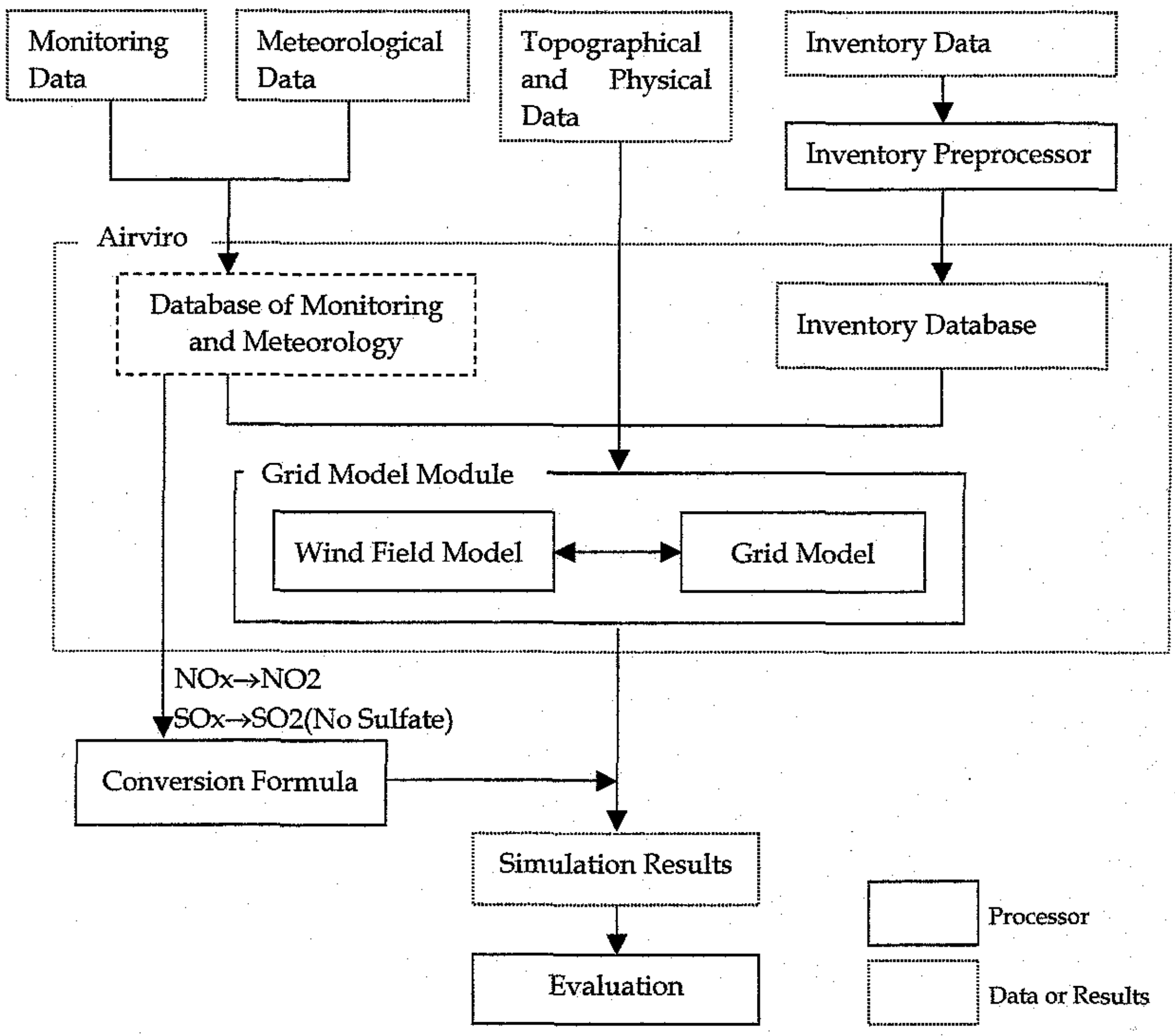


Figure 6.2.2.1 Grid Model Proceeding

6.2.3 Inventory Preprocessing

6.2.3.1 Coordinates and Processing Method

1) Airviro Coordinate

Airviro adopts the UTM (Universal Transverse Mercator's) coordinate grid system. The Inventory data and monitoring station locations are based on the UTM coordinate.

2) Types of Emission Inventory in Airviro

The Airviro emission inventory has the following three types.

- Point sources including emissions from individual plants of manufacturing, airplanes and big ships.
- Area sources including emissions from low intensity sources such as agriculture, residence, coal mining, small ships, minor roads and railways.
- Line sources including main roads.

3) Processing Method

'ArcView 3.2 a' and FORTRAN language was used, and some scripts (programs) were developed for the pollutant emission data processing. FORTRAN was used for the conversion of original inventory text files into Airviro format files.

Stationary and mobile pollutant sources data are compiled in point sources, area sources and line sources.

6.2.3.2 Point Sources and Area Sources of the Year 2000 in the BMR

1) General Information

The emission database for the point sources and area sources have the same structure. General information includes basic information, about the point sources and area sources needed to maintain the database. The following information about each source is required.

- Company name and address
- Address of registered office
- Contact person within the company
- Last updated date
- Registration date

2) Static Information

Static information describes the dimensions of the point of discharge and is vital for dispersion simulations. The figures do not vary over the year and do not affect the emission strength. When each stack of static information has been created, the emission databases are used for their data as first priority. If stack data did not have static information, the stack data would be used default values. The default values are shown in Table 6.2.3.1.

Table 6.2.3.1 Static Information of Point Source and Area Source

Variables	Information
Origin of X Coordinate	Present location of chimney (origin of area source)
Origin of Y Coordinate	Present location of chimney (origin of area source)
End of X Coordinate	Upper right corner of X coordinate (end of area source)
End of Y Coordinate	Upper right corner of Y coordinate (end of area source)
Chimney Height	20m (Min 10m)
Gas Temperature	150°C (Min 100°C)
Exhaust Gas Velocity	10m/s (Min 5m/s)
Chimney Inner Diameter	Chimney inner diameter (Min 30cm) is calculated by formula (chimney diameter[m] = chimney height[m] × 0.0501 + 0.0602) base on data relation chimney height and chimney diameter of major factories.
Chimney Outer Diameter	Same as chimney outer diameter

3) Dynamic Information

Dynamic information is the information that directly controls the emission. Dynamic information is important to create formula that describe the typical variation of emission. The formulae can describe as daily patterns and hourly patterns of working date. Sixty-one working patterns (Supporting Report, Chap5.2.1.1) are used for point sources and area sources in the BMR.

4) Searchkeys

Airviro uses a system of searchkeys, which enable the user to investigate the effects of groups of emissions more readily when carrying out modeling work. Each process, road link and province name is allocated specific searchkeys. There are five groups of searchkeys with different properties. In the first two groups, there are 128 individual searchkeys and the last three have 32 in each group. Searchkeys (Supporting Report, Chap5.2.1.2) in the BMR are shown in Table 6.2.3.2.

Table 6.2.3.2 Searchkeys in the BMR

Name	Contents
Searchkey1	Type of Source
Searchkey2	Amphore(District) Code
Searchkey3	Province Code
Searchkey4	Industrial Estate Code
Searchkey5	Emission Estimation Code (Estimation:1 or Surveying:2)

5) Emission Map for Point Sources and Area Sources

Emission maps for the year 2000 for point sources and area sources in the BMR are shown from Figure 6.2.3.1 to Figure 6.2.3.4. The number of point sources for the year 2000 in the BMR is approximately 7400 factories. The size of area source is 500m × 500m. The number of area sources for the year 2000 in the BMR is approximately 35000 grids. The SOx emission of point sources is 100 times as much as the area sources. The high SOx emission areas of the point sources are located around the Chao Phraya River and central area of Samut Sakhon. Point source emission of Nonthaburi shows a lower value than other areas. SOx area sources in the Bangkok province show relatively higher values. The high NOx emission area of the point sources are located around the South Bangkok Power Plant and the Bangkok province. Also, NOx area sources of railways show relatively high emission. Compared with SOx emission, NOx point sources have a low contribution rate against the total emission. NOx area sources have a high contribution rate against the total emission.

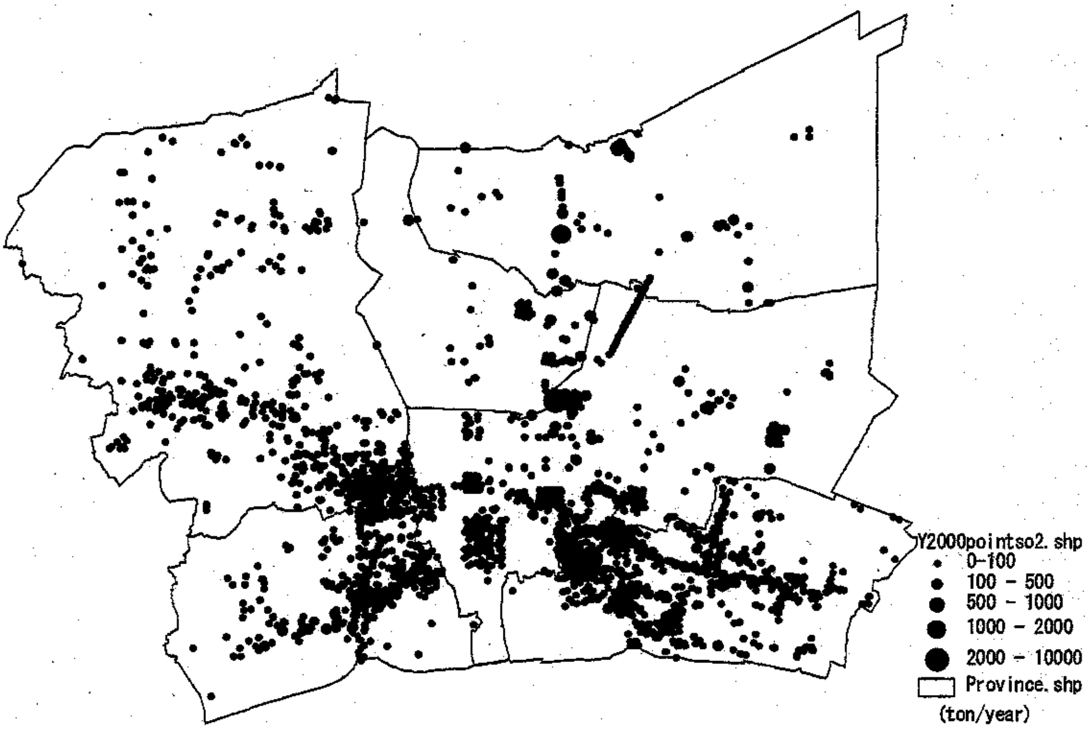


Figure 6.2.3.1 SOx Emission for the Year 2000 in the BMR (Point Source)

Figure 6.2.3.2 SOx Emission for the Year 2000 in the BMR (Area Source)

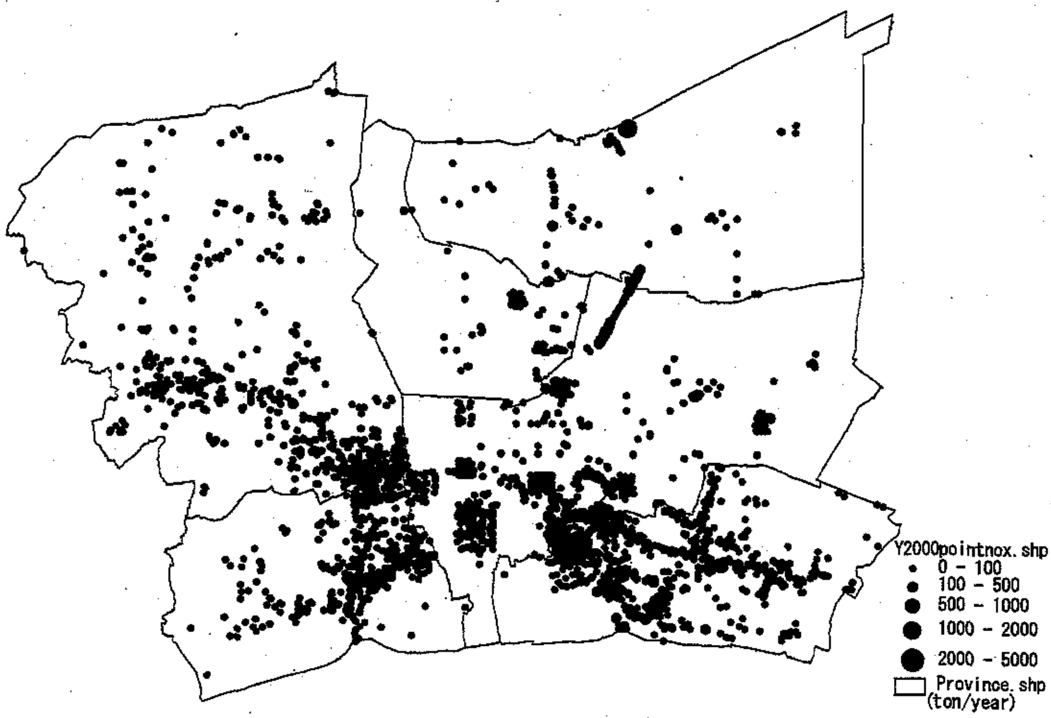


Figure 6.2.3.3 NOx Emission for the Year 2000 in the BMR (Point Source)

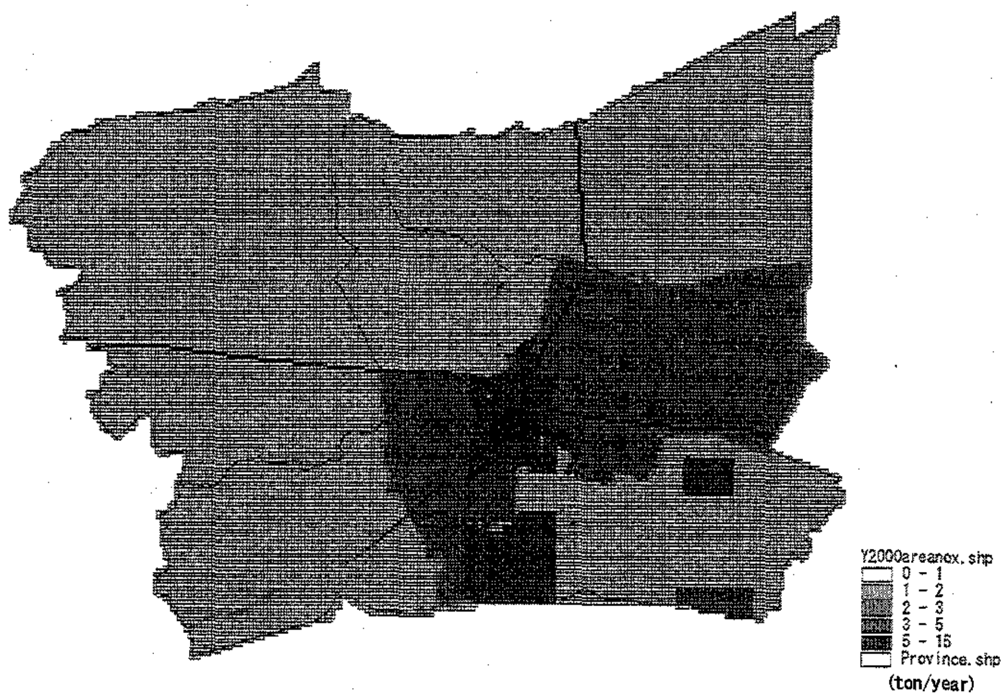


Figure 6.2.3.4 NOx Emission for the Year 2000 in the BMR (Area Source)

6.2.3.3 Line Source for the Year 2000 in the BMR

1) Traffic Data and Traffic Demand Forecast

The locations of road link maps for the year 1997 and the year 2000 are shown in Figure 6.2.3.5. Road links for the year 1997 are based on Airviro simulation data, and road links for the year 2000 are based on the traffic assignment data in the URMAP report of OCMLT. The number of road links for the year 1997 is 1116 and for the year 2000 is 7482. The number of road links for the year 2000 is approximately 7 times as many as for the 1997. Road links for the year 1997 included expressways and main roads. Road links for the year 2000 included express ways, main roads and minor roads of heavy traffic volume. Also road links for the year 1997 have one way links and road links in the year 2000 have two way information for the same road. The URMAP forecast data have precise information for each link such as traffic volumes, vehicle traveling speeds, types of roads and the number of lanes. The road links for the year 2000 are more precise than for the year 1997.

Traffic volume measurements and the URMAP are compared to check the validity of the traffic volume forecast of the URMAP data. Measurement points of traffic volume are shown in Figure 6.2.3.6. The traffic volume by vehicle type is measured at 95 points based on OCMLT and 57 points based on DOH on the main roads for the year 2000 in the BMR. The relation between the traffic assignment data in the URMAP and the measurement data of traffic volume is shown in Figure 6.2.3.7. The scatter of the traffic demand forecast and the measurement traffic volume show a good correlation.

Therefore, the new road databases in Airviro system was updated by URMAP data of year 2000.

2) General and Static Information

Some of the road sources information (Supporting Report, Chap5.2.2.2) stored is shown in Table 6.2.3.3.

Table 6.2.3.3 General and Static Information of Line Source

Items	Contents (Data Source)
Road Name	Each road link has a road name (URMAP)
Average Speed (km/h)	Vehicle travelling along the road link (URMAP)
Number of Lanes	Based on measurement data (URMAP)
Road Type	Each road link has one of road types (measurement data and year 1997 Airviro data)
Coordinate of Road Links	The coordinates of start and end points of road links (URMAP)
Correction Factor	1.0 has been used as a default

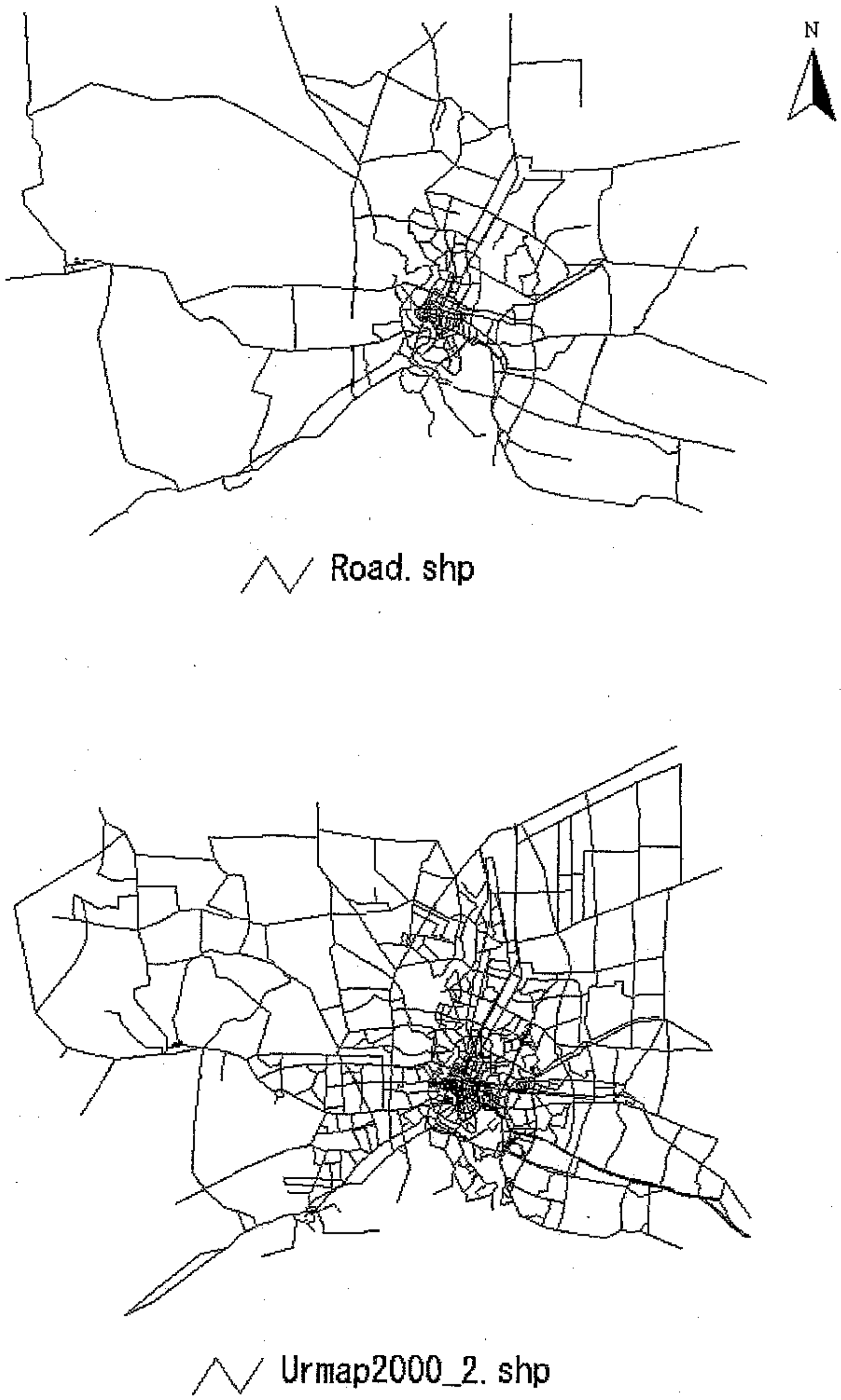


Figure 6.2.3.5 Road Links Map in 1997 (upper) and 2000 (low)

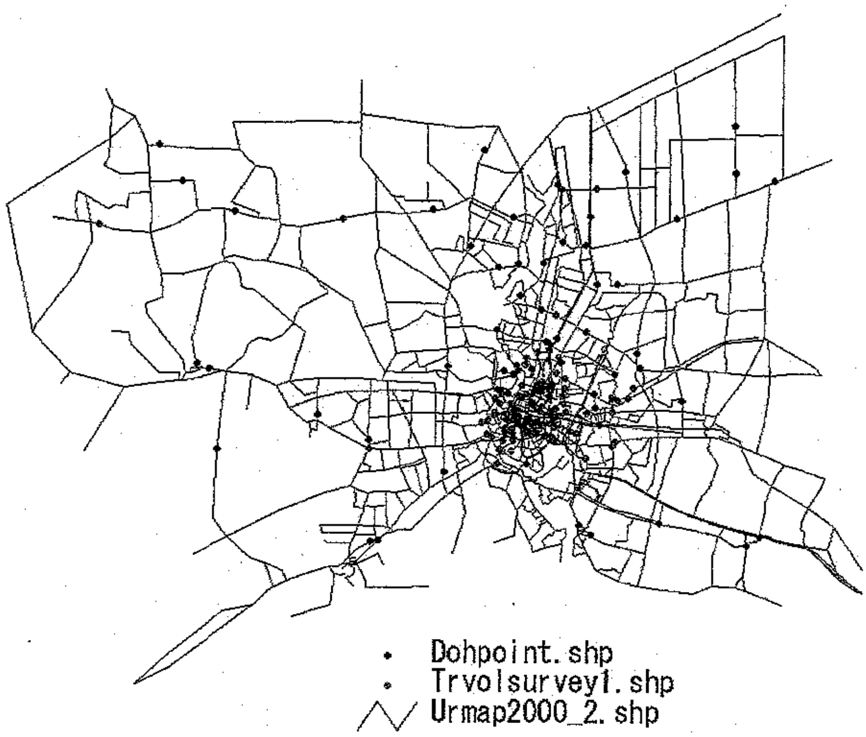


Figure 6.2.3.6 Traffic Volumes Measurement Points

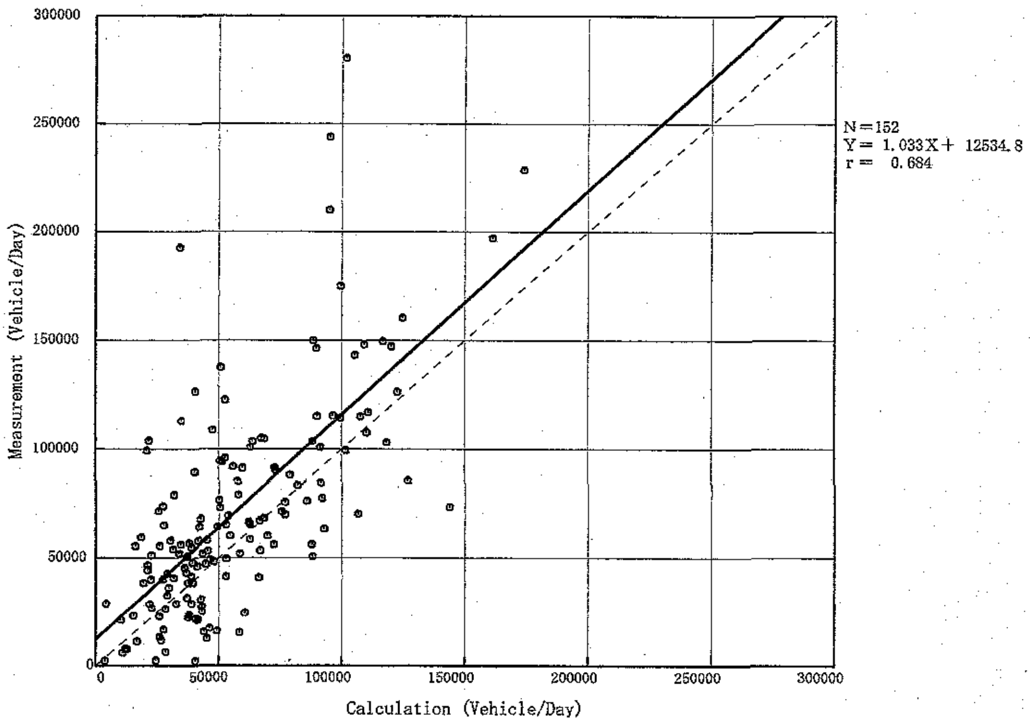


Figure 6.2.3.7 Comparison of Measurement with Traffic Forecast

3) Dynamic Information

(1) Roadtype

Each road link is linked to the roadtype database. The roadtype database and emission factor database are defined as dynamic information. The roadtype database consists of hourly patterns and the vehicle type composition of traffic volumes. Each roadtype had different composition for each vehicle type running along it. The composition is assumed to be constant throughout the day, week and year.

(2) Emission Factor

Each road link is linked to the emission factor database. Also, the emission factors database is also linked to the vehicle speed and vehicle type composition of road database. The emission factor database is shown in Table 6.2.3.4. The emission factor of the original mobile sources inventory (see Chapter4) has 20 speed ranks. However, the emission of the database of Airviro can define 11 speed ranks, so the emission factor for each substance was averaged out the original emission factors.

S02 (g/km)

Km/h	PS(G)	Taxi(G)	Taxi(L)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
0- 5	0.140	0.139	0.000	0.071	0.089	0.340	0.357	0.020	0.000
5-10	0.118	0.117	0.000	0.065	0.081	0.284	0.304	0.019	0.000
10-15	0.099	0.098	0.000	0.060	0.073	0.237	0.260	0.019	0.000
15- 20	0.083	0.083	0.000	0.055	0.067	0.198	0.223	0.019	0.000
20- 25	0.071	0.071	0.000	0.050	0.061	0.168	0.195	0.019	0.000
25- 30	0.062	0.062	0.000	0.046	0.056	0.147	0.174	0.019	0.000
30- 35	0.057	0.057	0.000	0.042	0.052	0.135	0.162	0.019	0.000
35- 40	0.054	0.054	0.000	0.039	0.048	0.129	0.155	0.018	0.000
40- 50	0.050	0.049	0.000	0.035	0.044	0.119	0.144	0.019	0.000
50- 70	0.044	0.044	0.000	0.030	0.041	0.108	0.134	0.020	0.000
70-100	0.045	0.044	0.000	0.031	0.050	0.111	0.147	0.022	0.000

NOx (g/km)

Km/h	PS(G)	Taxi(G)	Taxi(L)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
0- 5	2.074	2.005	0.633	2.602	2.446	50.843	50.843	0.063	0.400
5-10	1.960	1.908	0.601	2.360	2.220	46.129	46.129	0.062	0.400
10-15	1.862	1.825	0.574	2.142	2.020	41.916	41.916	0.062	0.400
15- 20	1.778	1.758	0.550	1.950	1.844	38.202	38.202	0.063	0.400
20- 25	1.710	1.705	0.531	1.782	1.694	34.989	34.989	0.063	0.400
25- 30	1.656	1.668	0.515	1.640	1.568	32.275	32.275	0.065	0.400
30- 35	1.618	1.645	0.504	1.522	1.468	30.062	30.062	0.066	0.400
35- 40	1.594	1.638	0.496	1.430	1.392	28.348	28.348	0.068	0.400
40- 50	1.589	1.656	0.493	1.341	1.329	26.778	26.778	0.072	0.400
50- 70	1.683	1.799	0.514	1.339	1.378	27.137	27.137	0.082	0.400
70-100	2.141	2.336	0.630	1.834	1.958	37.736	37.736	0.108	0.400

Table 6.2.3.4 Emission Factor by Vehicle Type for Airviro for the Year 2000

4) Searchkeys

The line sources of the searchkeys in the BMR are the same as the searchkeys of the point sources and area sources.

5) Vehicle Patterns

The roadtype database for the year 2000 is arranged in Figure 6.2.3.8. The road database of Airviro has static information and dynamic information. The static information is such as road name, number of lanes and road type. The dynamic information is composed of traffic volume and roadtype pattern for each road. The roadtype patterns have hourly patterns, the traffic types composition rates and the monthly variation.

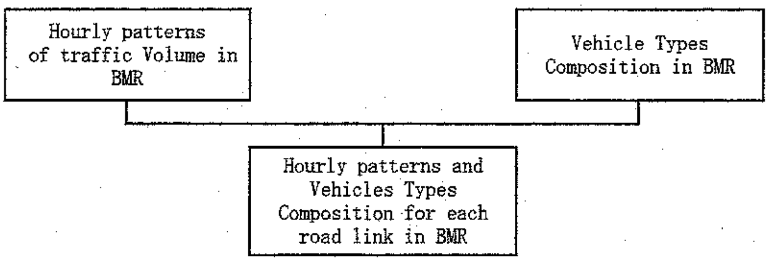


Figure 6.2.3.8 Hourly Pattern and Vehicle Type Composition

(3) Hourly Patterns of Traffic Volume in the BMR

a. Method of Setting Hourly Patterns

The OCMLT measured hourly traffic volumes at 95 roads for the year 2000 are shown in Figure 6.2.3.9. The measurement points are mainly located on main roads of central BMR. The suburbs and small roads have no data for hourly patterns of traffic vehicles in the year 2000. Measured hourly patterns of traffic volumes can not apply for all road links in the BMR. Hourly patterns for the year 1997 Airviro cover all BMR roads. Therefore, the Airviro hourly pattern of traffic vehicles in the year 2000 is prepared by the 1997 Airviro data and the measurement data prepared for the year 2000.

The method of hourly patterns of traffic vehicles is shown in Figure 6.2.3.10. The hourly patterns for year 2000 are applied to measurement roads. The hourly patterns of traffic vehicles based on 1997 Airviro are applied to the rest of the roads in the BMR.

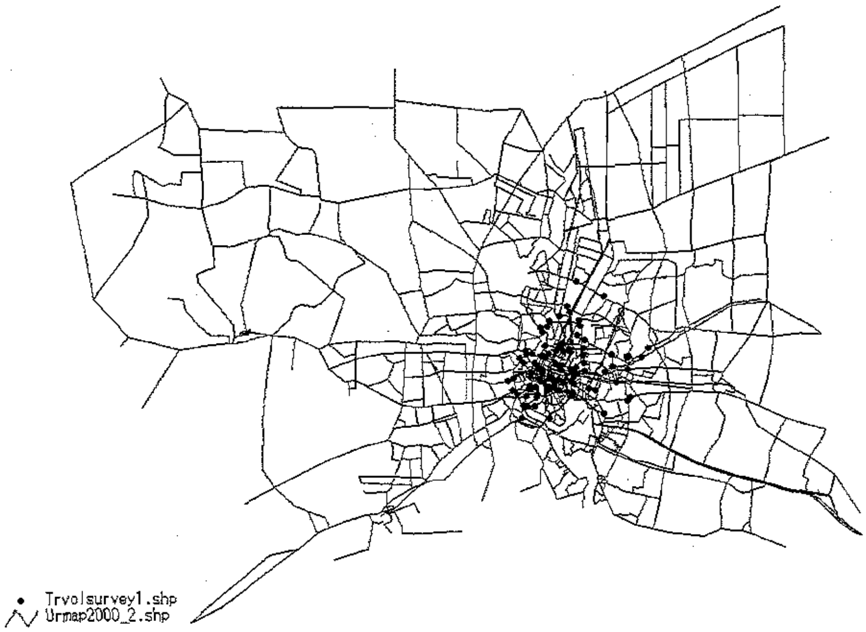


Figure 6.2.3.9 Measurement Points of Traffic Volume

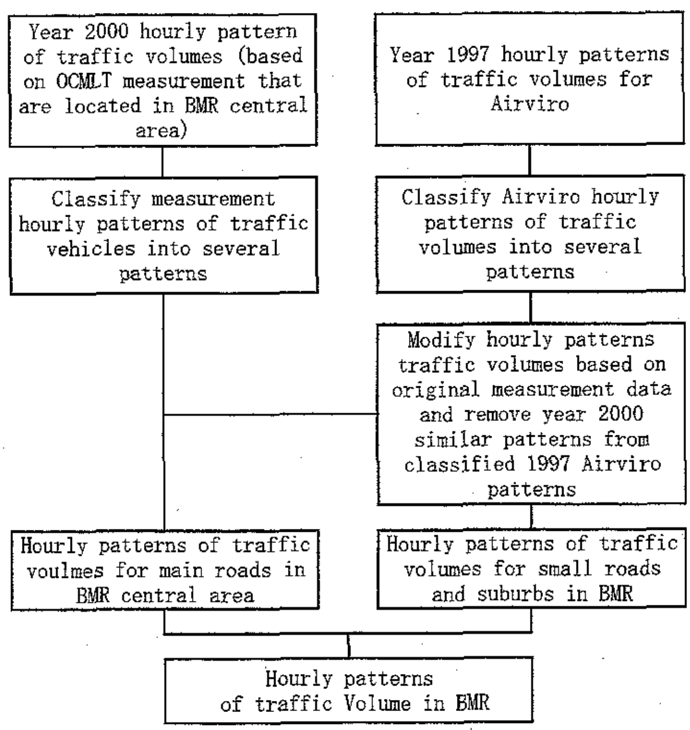


Figure 6.2.3.10 Hourly Pattern of Traffic Vehicles

b. Hourly Patterns for main roads in the BMR central area

OCMLT hourly patterns of traffic volume have 95 measurement data. The number of measurement data is too much information to link each road, and most of the measurement points are very close. Also, road types and the variation of hourly traffic road volumes can be separated by several patterns. Therefore, the measurement data can be categorized into several patterns based on the variation of hourly traffic volume. The relation between the measurement of hourly data for the year 2000 and classified hourly patterns is shown in Figure 6.2.3.11. Year 2000 hourly patterns of traffic volumes based on OCMLT data are classified into five groups such as

Type 11 : Morning High Type
Type 12 : Two Mountain Type1 (morning and evening high)
Type 13 : Evening High Type
Type 14 : Daytime High Type
Type 15 : Two Mountain Type2 (morning and midnight high).

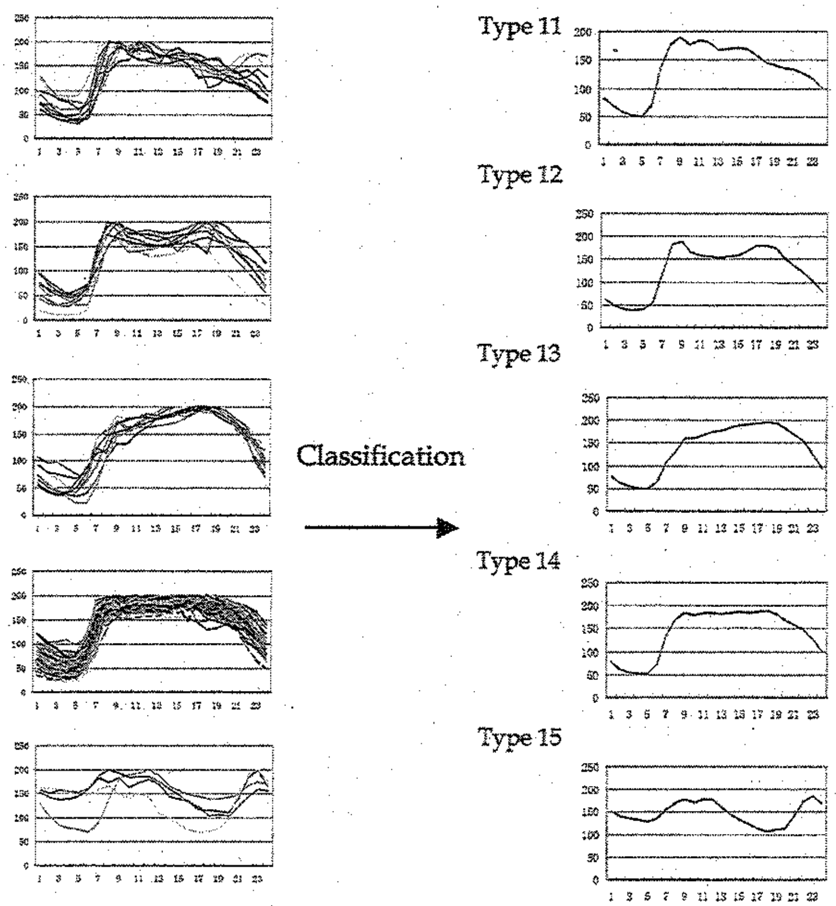


Figure 6.2.3.11 Classified Hourly Patterns in the Year 2000

c. Hourly Patterns for Small Roads of the BMR central area and Suburbs

Year 1997 Airviro has 50 hourly patterns of traffic volume. The hourly patterns of traffic volume are classified into five groups based on the variation of hourly traffic volumes using the same as categorization as for the year 2000 measurement data. However, two classified hourly patterns are used for main roads in central BMR, these two cases are removed because the year 2000 patterns are duplicated in the year 1997 Airviro patterns. Hourly patterns of traffic volumes at midnight are constant, hourly patterns of traffic volume for the year 1997 Airviro based on the OCMLT measurement data for the year 1996. Therefore, three classified patterns are modified to the OCMLT data for the year 1996 for suburbs and small roads in the BMR. The relation between the 1997 Airviro hourly patterns and classified hourly patterns are shown in Figure 6.2.3.11. The 1997 hourly patterns of traffic volumes based on the OCMLT data are classified into three types as follows.

Type1 : Small Road Type for Central BMR

Type3 : Main Road Type for Suburbs

Type4 : Small Road Type for Suburbs.

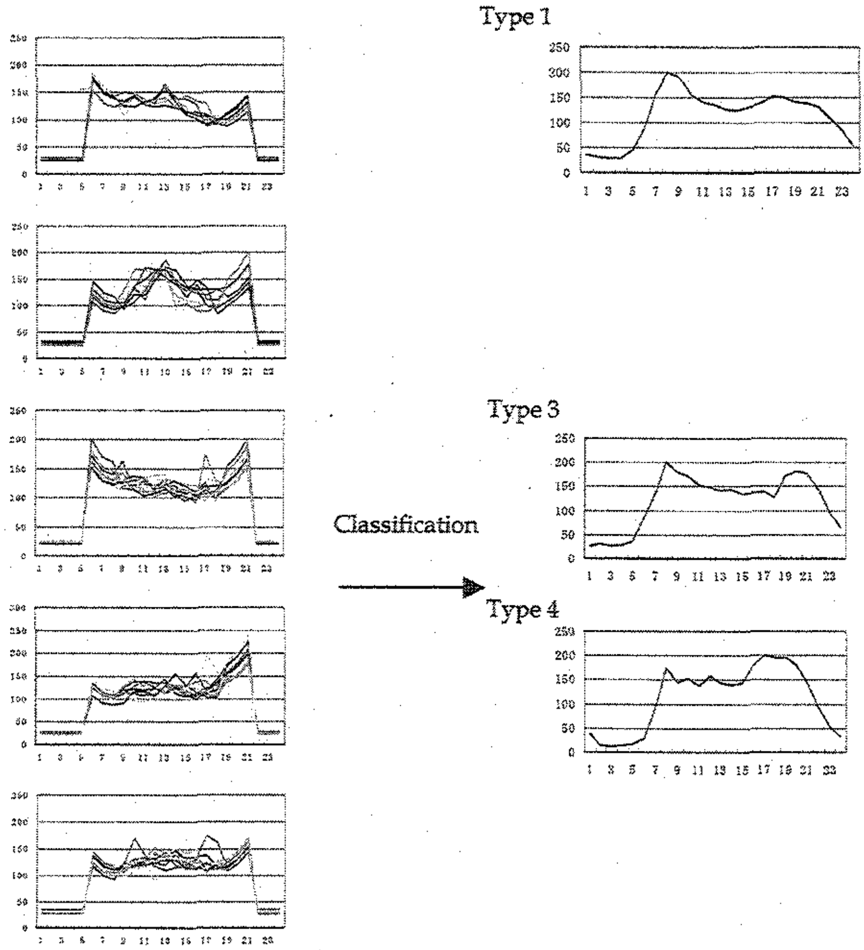
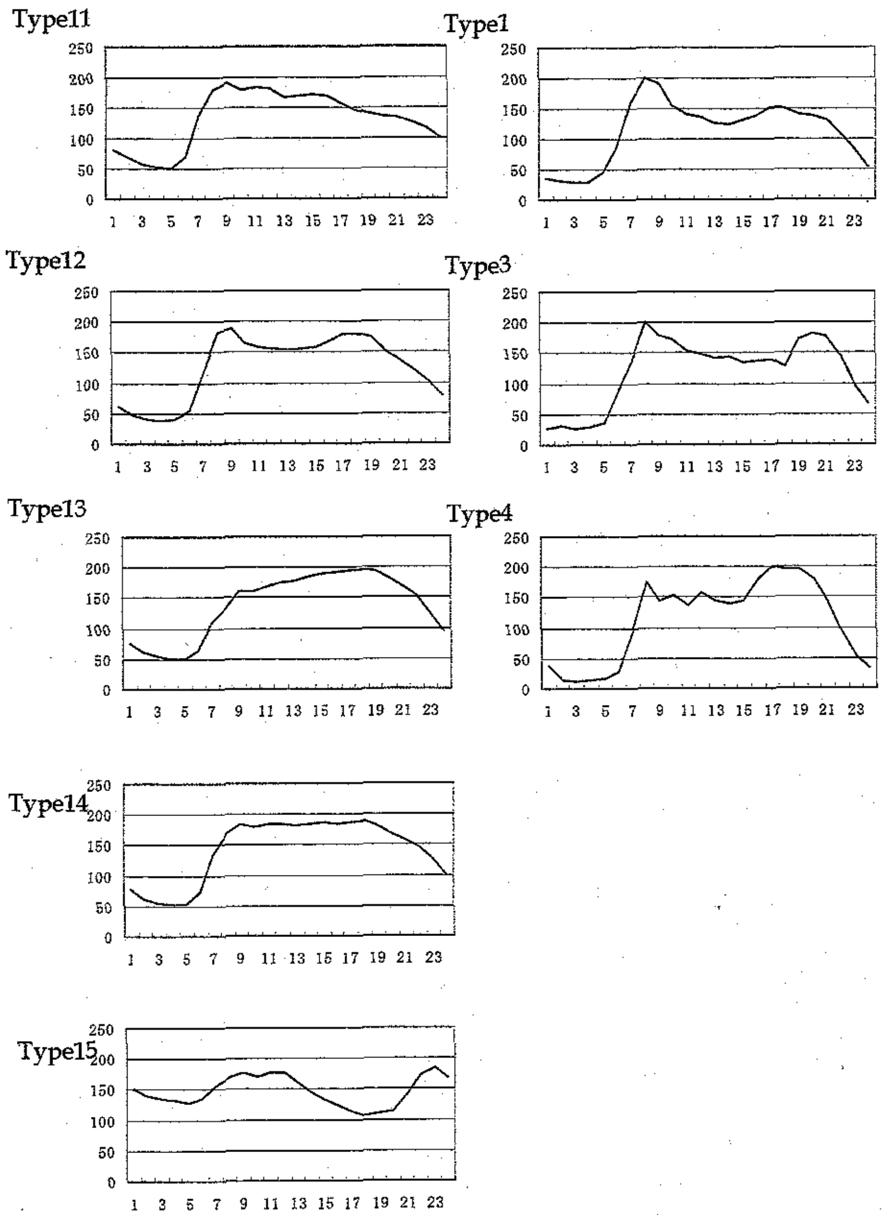


Figure 6.2.3.12 Classified Hourly Patterns in the Year 1997

d. Hourly Patterns of Traffic Vehicles for the Year 2000

All hourly patterns of traffic volumes for the year 2000 in the BMR are shown in Figure 6.2.3.13. The relation between the road links map and the hourly patterns of traffic volumes in the BMR is shown in Figure 6.2.3.14.



Main Road in Central BMR (Based on year 2000 data)

Suburbs and Small Roads (Based on year1997 Airviro)

Figure 6.2.3.13 Whole Hourly Patterns of Traffic Volumes

Figure 6.2.3.14 Relation between Road links and Hourly Patterns in the BMR

(4) Vehicle Type Composition of Traffic Volume

a. Method of Setting Vehicle Composition

The OCMLT traffic demand forecast has traffic volume data of each road link, but it does not have vehicle type composition of traffic volumes. Therefore, the vehicle type compositions are based on the composition measurement data, road types and target area. The DOH measurement of vehicle type compositions at 57 roads is shown in Figure 6.2.3.15. The measurement points are located in the whole of the BMR, but they are not sufficient measurement points for applying vehicle type composition rates to all road links.

The method of setting vehicle type compositions is shown in Figure 6.2.3.16. For the year 2000 the vehicle type composition of traffic volume is prepared by the 1997 Airviro and 2000 DOH measurement data. The vehicle types composition of the 2000 measurement data and 1997 Airviro are classified into certain patterns. Firstly the year 2000 classified vehicle types composition are applied to road links in the BMR, secondly the Airviro 1997 classified vehicle types composition rates are applied to roads links that can not be applied by the DOH measurement data for the year 2000.

Figure 6.2.3.15 DOH Measurement Points in the BMR

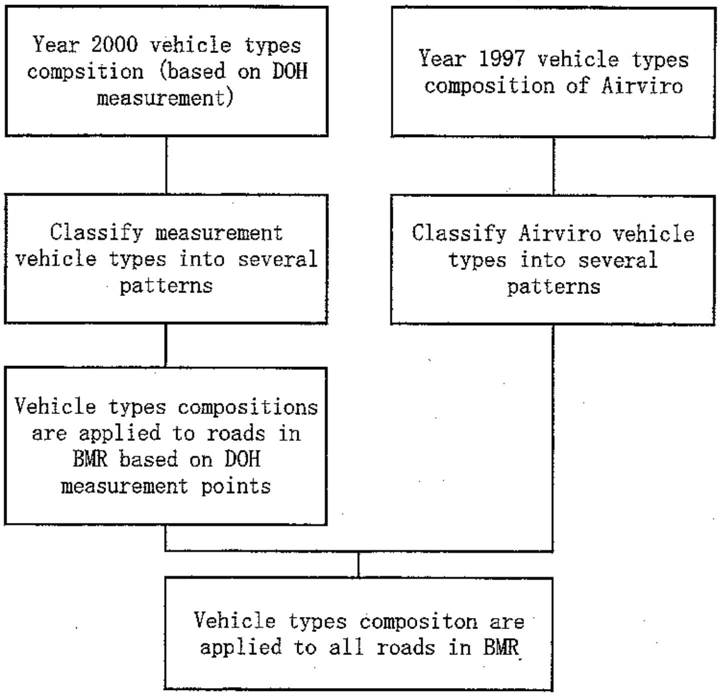


Figure 6.2.3.16 Method for Setting Vehicle Types Composition

b. Vehicle Types Composition Rates based on DOH Measurement Data

Vehicle composition rates have nine types such as PS(G), Taxi(G), Taxi(LPG), PS(D), L-TRUCK, Bus, H-Truck, MC and Tuk-Tuk. DOH measurement data of composition rates for the year 2000 are classified by road types and area. The DOH composition rates are shown in Table 6.2.3.5.

Table 6.2.3.5 Composition Rates of Vehicle Types based on DOH

	PS(G)	Taxi(G)	Taxi(LPG)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
Ptn	LDGV	Taxi(G)	Taxi(LPG)	LDDV	LDDT	HDDV	HDDV	MC	Tuk-Tuk
21	41%	1%	1%	10%	16%	10%	13%	8%	1%
22	56%	2%	1%	14%	4%	8%	7%	7%	0%
23	30%	1%	1%	7%	16%	6%	9%	28%	2%
24	24%	1%	0%	6%	23%	12%	19%	13%	1%
27	10%	0%	0%	2%	37%	3%	15%	31%	2%
Average	32%	1%	1%	8%	19%	8%	13%	17%	1%

c. Vehicle Type Composition for the Year 1997 Airviro in the BMR

The 1997 Airviro of vehicle type composition rates are shown in Table 6.2.3.6. The year 1997 Airviro has 50 types of vehicle composition data. The year 1997 Airviro of composition rates are classified based on the road types and area.

Table 6.2.3.6 Composition Rates of Vehicle Types based on the year 1997 Airviro

Ptn	PS(G)	Taxi (G)	Taxi (LPG)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
	LDGV	Taxi (G)	Taxi (LPG)	LDDV	LDDT	HDDV	HDDV	MC	Tuk-Tuk
1	50.0%	1.0%	1.0%	6.0%	16.0%	2.0%	3.0%	20.0%	1.0%
6	54.0%	2.0%	1.0%	1.0%	4.0%	7.0%	10.0%	20.0%	1.0%
7	67.0%	2.0%	1.0%	1.0%	4.0%	2.0%	2.0%	20.0%	1.0%
10	33.0%	1.0%	1.0%	9.0%	23.0%	4.0%	6.0%	22.0%	1.0%
13	37.0%	1.0%	1.0%	3.0%	7.0%	12.0%	18.0%	20.0%	1.0%
14	63.0%	2.0%	1.0%	7.0%	20.0%	3.0%	4.0%	0.0%	0.0%
15	69.0%	2.0%	1.0%	2.0%	5.0%	8.0%	13.0%	0.0%	0.0%
16	48.0%	1.0%	1.0%	3.0%	9.0%	15.0%	23.0%	0.0%	0.0%

d. Vehicle Type Composition for the Year 2000 in the BMR

All vehicle type composition rates for the year 2000 have thirteen cases. The relation between the composition rates and the distribution map is shown in Table 6.2.3.7 and Figure 6.2.3.17.

Table 6.2.3.7 Composition Rates of Traffic Vehicle for Year 2000

Ptn	PS(G)	Taxi (G)	Taxi (LPG)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
	LDGV	Taxi (G)	Taxi (LPG)	LDDV	LDDT	HDDV	HDDV	MC	Tuk-Tuk
1	50.0%	1.0%	1.0%	6.0%	16.0%	2.0%	3.0%	20.0%	1.0%
6	54.0%	2.0%	1.0%	1.0%	4.0%	7.0%	10.0%	20.0%	1.0%
7	67.0%	2.0%	1.0%	1.0%	4.0%	2.0%	2.0%	20.0%	1.0%
10	33.0%	1.0%	1.0%	9.0%	23.0%	4.0%	6.0%	22.0%	1.0%
13	37.0%	1.0%	1.0%	3.0%	7.0%	12.0%	18.0%	20.0%	1.0%
14	63.0%	2.0%	1.0%	7.0%	20.0%	3.0%	4.0%	0.0%	0.0%
15	69.0%	2.0%	1.0%	2.0%	5.0%	8.0%	13.0%	0.0%	0.0%
16	48.0%	1.0%	1.0%	3.0%	9.0%	15.0%	23.0%	0.0%	0.0%
21	41.0%	1.0%	1.0%	10.0%	16.0%	10.0%	13.0%	8.0%	1.0%
22	56.0%	2.0%	1.0%	14.0%	4.0%	8.0%	7.0%	7.0%	0.0%
23	30.0%	1.0%	1.0%	7.0%	16.0%	6.0%	9.0%	28.0%	2.0%
24	24.0%	1.0%	0.0%	6.0%	23.0%	12.0%	19.0%	13.0%	1.0%
27	10.0%	0.0%	0.0%	2.0%	37.0%	3.0%	15.0%	31.0%	2.0%

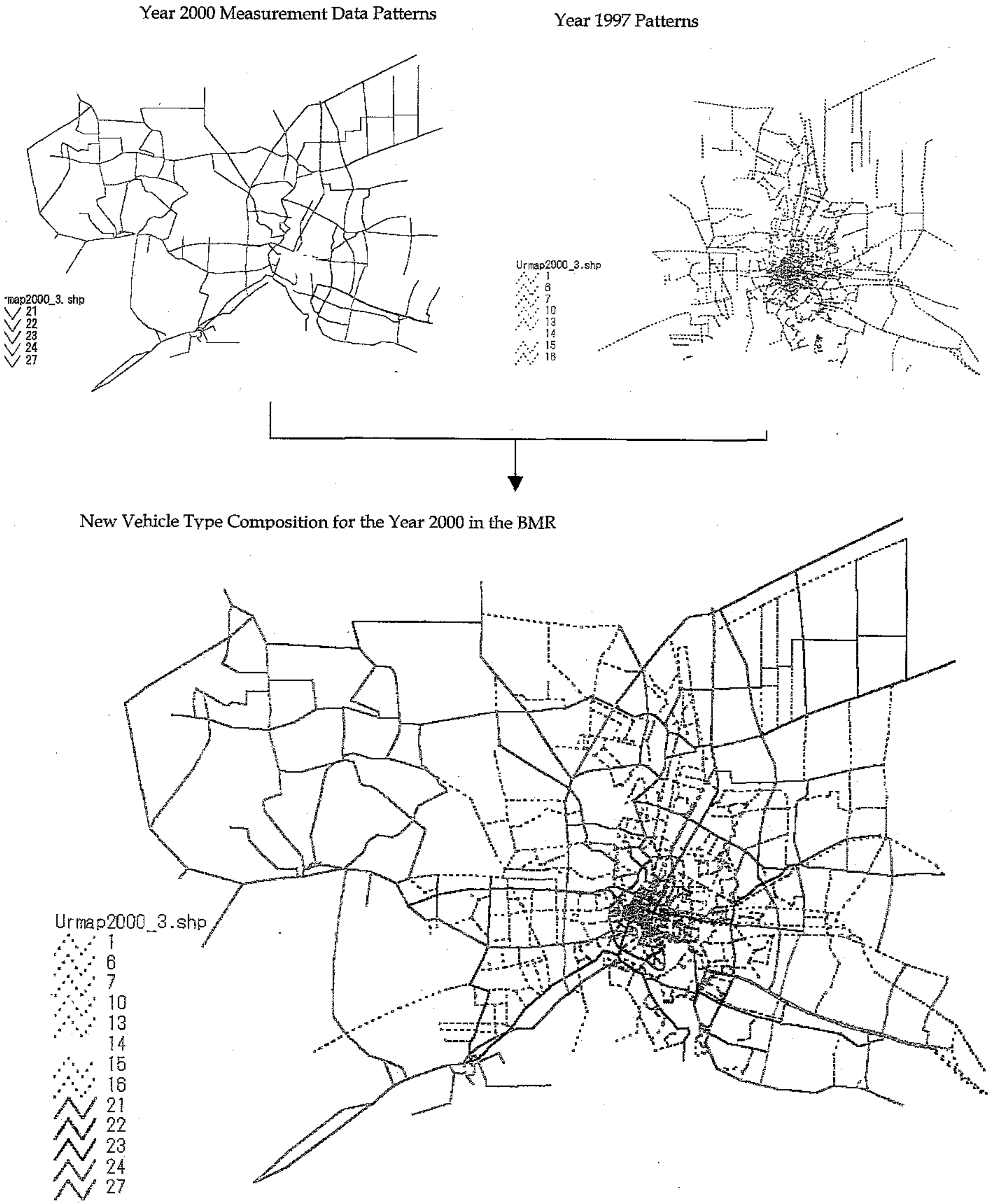


Figure 6.2.3.17 Vehicle Types Composition for the Year 2000 in the BMR

(5) All Patterns of Road Links in the BMR

The relation between the hourly patterns and the vehicle types composition in the BMR is shown in Table 6.2.3.8. Each road link has an hourly pattern and vehicle type composition. Some cases do not have any pairs of hourly pattern and composition; the total number of pairs is 64 patterns (Supporting Report, Chap5.2.2.1).

Table 6.2.3.8 Relation between Hourly Patterns and Vehicle Types Composition

Composition Patterns		AIRVIRO(1997)								DOH(2000)				
Hourly Patterns		1	6	7	10	13	14	15	16	21	22	23	24	27
AIRVIRO(1997)	1	298	54	2	34	45		12		85	5	60	2	
	3	758	76	60	63	257	1	19	7	376	43	47	100	29
	4	1277	265	44	60	218		34		267	23	159	70	312
OCMLT(2000)	11	95								1				
	12	47	6		4	37				11		7		
	13	47	22							36				
	14	576	76	14	79	56	58	357	26	440	47	69	14	
	15	112	4	1		25		-	1	43		9		

Unit : Number of Road Links

6) Emission Map for the Year 2000 for Line Sources in the BMR

The SOx and NOx emission maps for line sources in the BMR are shown in Figure 6.2.3.18 and Figure 6.2.3.19. The SOx emission of road sources has low values. The high NOx emission areas appear in the major roads of Bangkok central to the suburbs. Also, the ring roads of suburbs show higher emission than central BMR.

Figure 6.2.3.18 SOx Emission for the Year 2000 in the BMR (Line Source)

Figure 6.2.3.19 NOx Emission for the Year 2000 in the BMR (Line Source)

6.2.3.4 Point Sources and Area Sources for the Year 2011 in the BMR

1) General Information

The emission database of point sources and area sources is the same structure as for the year 2000. General information for the year 2011 is updated from the year 2000 inventory and the investigation results.

2) Static Information

The structure of the year 2011 emission inventory is the same as for the year 2000. The static information for the year 2011 emission inventory is updated from the year 2000 emission inventory.

3) Dynamic Information

The structure of dynamic information for the year 2011 is the same as for the year 2000. The formulae can describe the daily patterns and hourly patterns of the working date. The number of stationary source patterns is sixty-one types.

4) Emission Map for the Year 2011 for Point Sources and Area Sources in the BMR

Emission maps for the year 2011 for point sources and area sources in the BMR are shown from Figure 6.2.3.20 to Figure 6.2.3.23. The number of point sources for the year 2011 in the BMR is approximately 7400 factories. The number of area sources in the BMR is approximately 35000 grids. The SOx emission of point sources for the year 2011 in Bangkok province is lower than for the year 2000. High SOx emission areas of point sources are located around the Chao Phraya River in Samut Sakhon and the central area of Samut Sakhon. The SOx point source emission of Nonthaburi, Nonthaburi and Pathum Thani is the same level as for the year 2000.

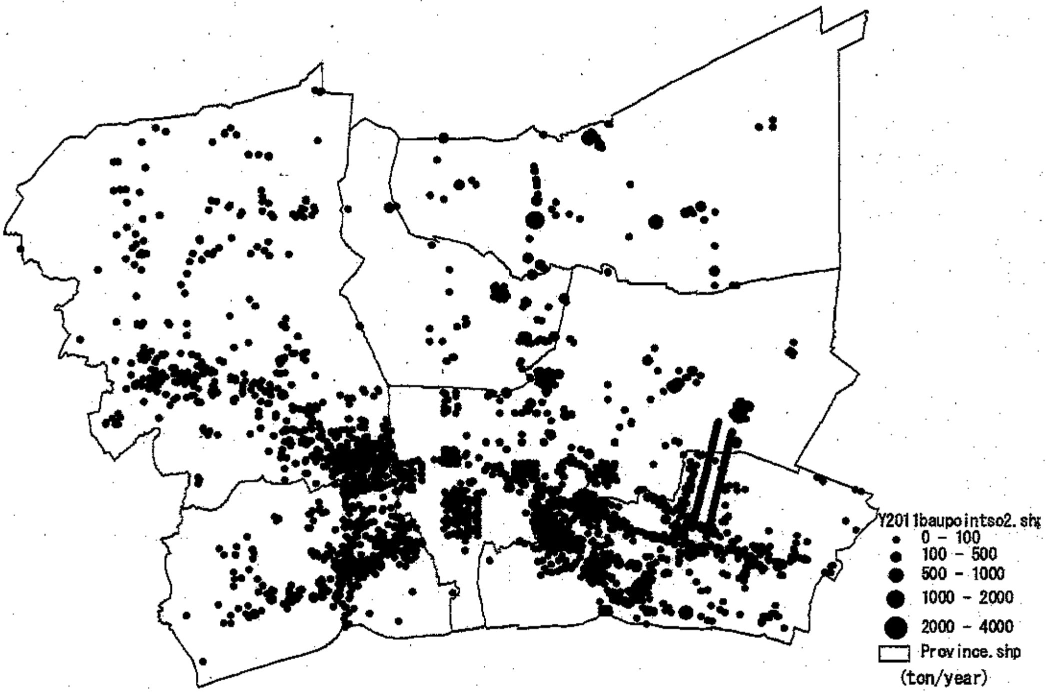


Figure 6.2.3.20 SOx Emission Map for Year 2011 Bau in the BMR (Point Sources)

Figure 6.2.3.21 SOx Emission Map for the Year 2011 Bau in the BMR (Area Source)

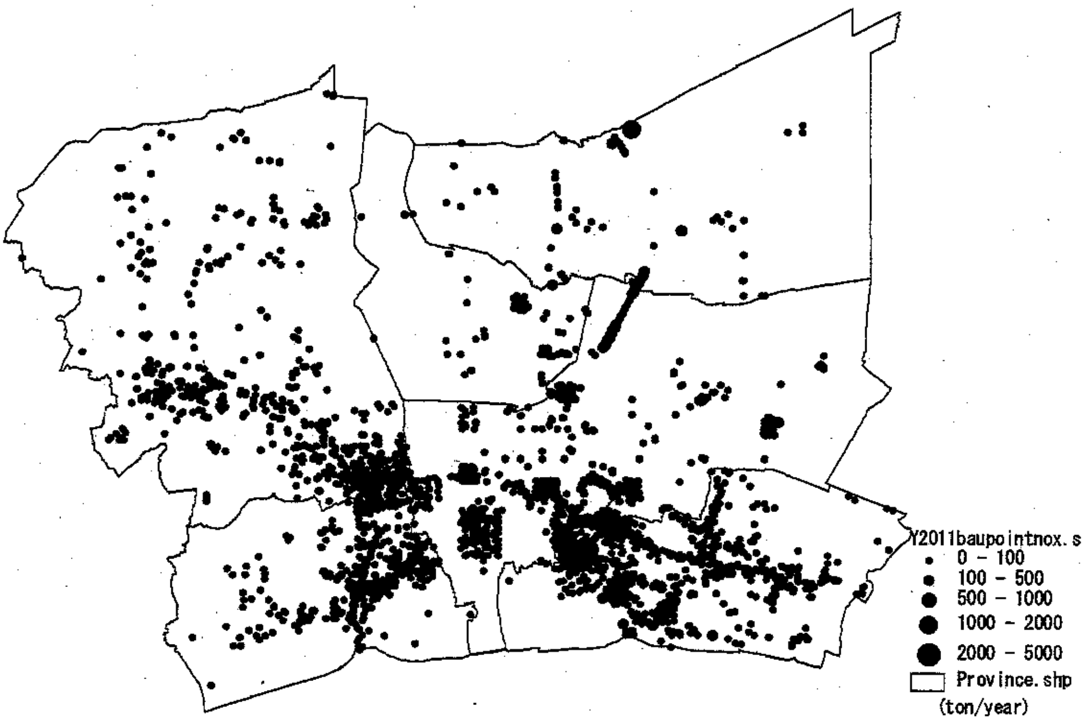


Figure 6.2.3.22 NOx Emission Map for the Year 2011 Bau in the BMR (Point Sources)

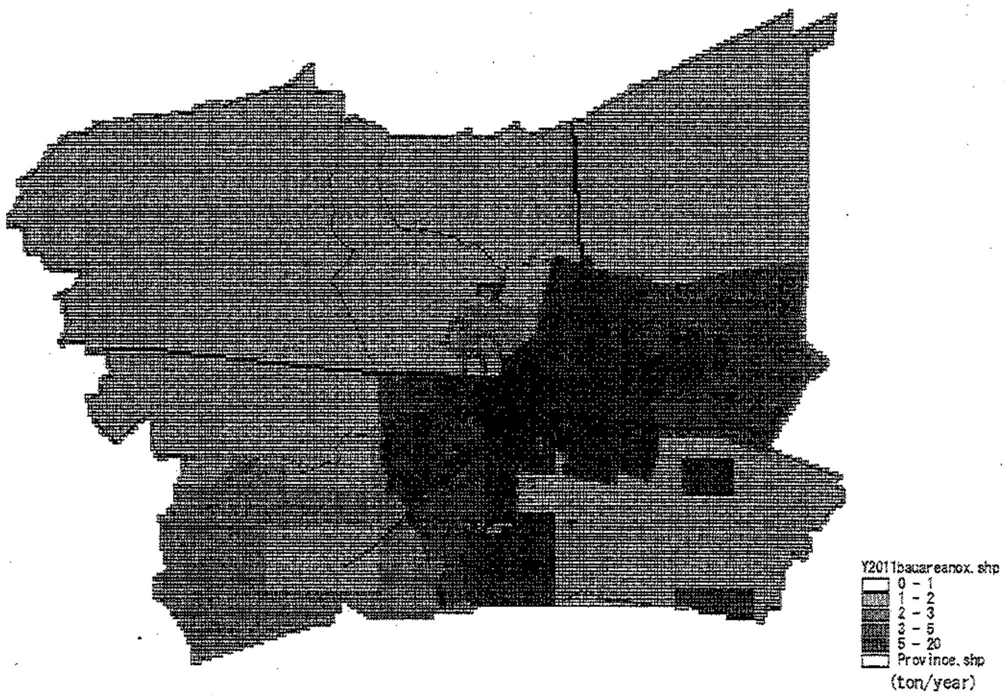


Figure 6.2.3.23 NOx Emission Map for the Year 2011 Bau in the BMR (Area Source)

6.2.3.5 Line Source for the Year 2011 in the BMR

1) Traffic Data and Traffic Demand Forecast

The location of road maps for the year 2011 is shown in Figure 6.2.3.24. The road links data is based on the URMAP report of OCMLT for the year 2011. The number of road links for the year 2011 is 8553. The number of road links for the year 2000 is 7482. The forecast data for the year 2011 is increased approximately by 1000 from the year 2000. New ring roads and express ways will be constructed by the year 2011. The URMAP forecast data for the year 2011 have precise information for each link such as traffic volumes, vehicle speed, road types and the number of lanes.

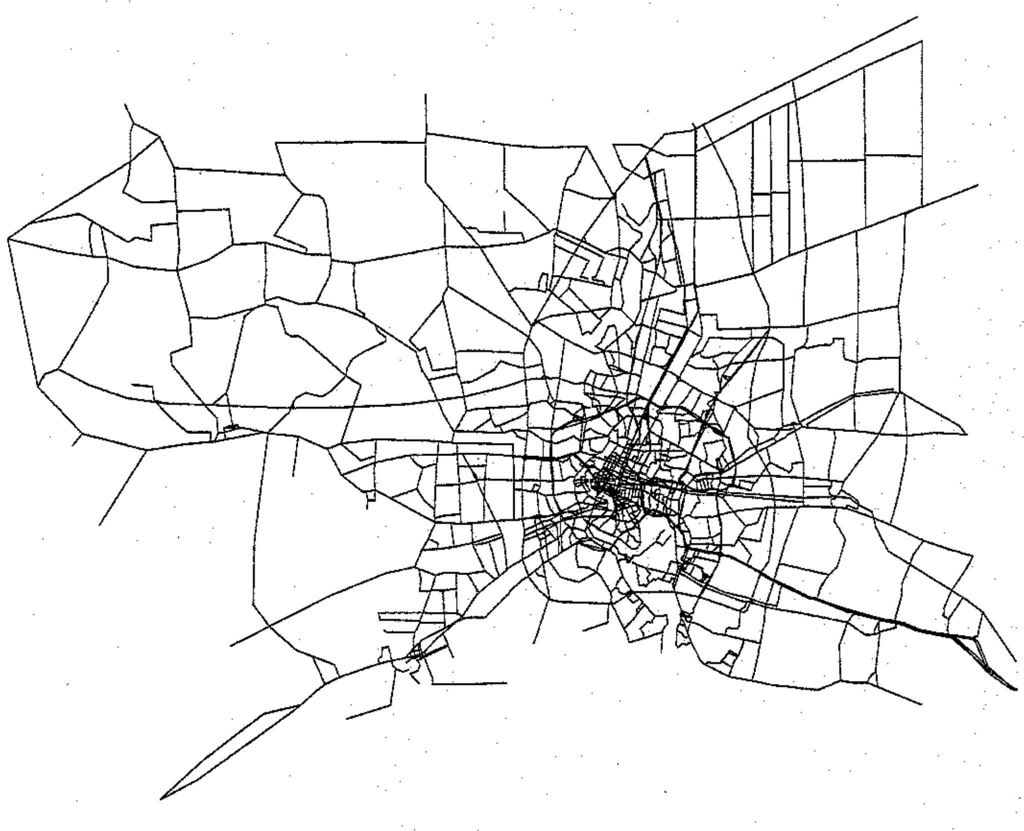


Figure 6.2.3.24 Road Links Map for the Year 2011

2) General and Static Information

General information and static information of road sources for the year 2011 is shown in Table 6.2.3.9.

Table 6.2.3.9 General and Static Information of Line Source

Items	Contents (Data Source)
Road Name	Each road link has a road name (URMAP)
Average Speed (km/h)	Forecast of vehicle travelling speed (URMAP)
Number of Lanes	Based on measurement data and forecast (URMAP)
Road Type	Each road link is linked to one of road types based on year 2011 road types
Coordinate of Road Links	The coordinates of start and end points of road links (URMAP)
Correction Factor	1.0 has been used as a default

3) Dynamic Information

(1) Roadtype

Each road link is linked to the roadtype database. The roadtype database and emission factor database are defined as dynamic information. The roadtype database consists of hourly patterns and the vehicle type composition of traffic volumes. Each roadtype had different proportions for each vehicle type running along it. The proportions are assumed to be constant throughout the day, week and year.

(2) Emission Factor

The emission factors database is also linked to the vehicle speed of the road links and the vehicle type composition of the road database. The emission factor database for the year 2011 is shown in Table 6.2.3.10.

Table 6.2.3.10 Emission Factor by Vehicle Type of Airviro for the Year 2011

S02

Km/h	PS(G)	Taxi(G)	Taxi(L)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
0- 5	0.047	0.043	0.000	0.062	0.085	0.340	0.357	0.018	0.000
5-10	0.040	0.037	0.000	0.058	0.077	0.284	0.304	0.015	0.000
10-15	0.034	0.032	0.000	0.053	0.070	0.237	0.260	0.014	0.000
15- 20	0.030	0.028	0.000	0.050	0.064	0.198	0.223	0.012	0.000
20- 25	0.026	0.025	0.000	0.046	0.058	0.168	0.195	0.010	0.000
25- 30	0.023	0.022	0.000	0.043	0.053	0.147	0.174	0.009	0.000
30- 35	0.021	0.020	0.000	0.040	0.049	0.135	0.162	0.008	0.000
35- 40	0.020	0.019	0.000	0.037	0.045	0.129	0.155	0.007	0.000
40- 50	0.018	0.017	0.000	0.034	0.041	0.119	0.144	0.008	0.000
50- 70	0.015	0.014	0.000	0.030	0.038	0.108	0.134	0.008	0.000
70-100	0.014	0.013	0.000	0.030	0.047	0.111	0.147	0.009	0.000

NOx

Km/h	PS(G)	Taxi(G)	Taxi(L)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
0- 5	1.624	0.750	0.618	1.512	1.182	27.767	27.767	0.119	0.400
5-10	1.543	0.712	0.587	1.372	1.072	25.195	25.195	0.118	0.400
10-15	1.472	0.680	0.560	1.248	0.974	22.898	22.898	0.118	0.400
15- 20	1.413	0.652	0.537	1.138	0.887	20.876	20.876	0.118	0.400
20- 25	1.364	0.630	0.518	1.044	0.812	19.129	19.129	0.119	0.400
25- 30	1.327	0.612	0.503	0.964	0.748	17.657	17.657	0.122	0.400
30- 35	1.300	0.600	0.492	0.900	0.696	16.460	16.460	0.125	0.400
35- 40	1.285	0.592	0.485	0.850	0.655	15.538	15.538	0.128	0.400
40- 50	1.284	0.591	0.482	0.806	0.617	14.705	14.705	0.136	0.400
50- 70	1.358	0.624	0.505	0.822	0.621	14.964	14.964	0.157	0.400
70-100	1.702	0.778	0.624	1.150	0.858	20.896	20.896	0.209	0.400

4) Searchkeys

Line sources of searchkeys for the year 2011 in the BMR are the same as the searchkeys for point sources and area sources.

5) Vehicle Patterns

The road database of Airviro has static information and dynamic information. The static information is such as road name, the number of lanes and road type. The dynamic information is composed of traffic volumes data and the roadtype pattern for each road. The roadtype patterns have data such as hourly patterns, traffic types composition rates and monthly variation. The roadtype database for the year 2011 is arranged in Figure 6.2.3.25.

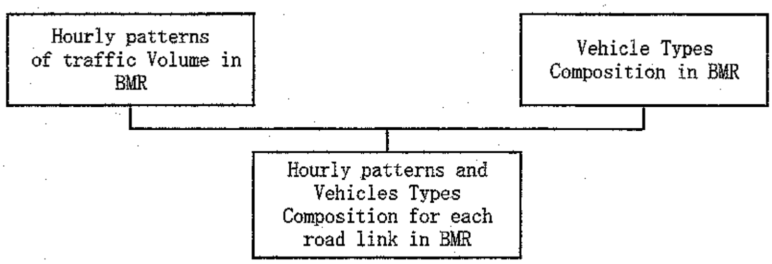


Figure 6.2.3.25 Hourly Pattern and Vehicle Type Composition

(1) Hourly Patterns of Traffic Vehicle of Year 2011

The year 2011 hourly patterns use the hourly patterns of year 2000. New road links and the year 2000 road links are updated by the type of road, the number of lanes and the vehicle speed of the URMAP in year 2011.

The relation between the map of hourly patterns of traffic volumes in the BMR and road links is shown in Figure 6.2.3.26.

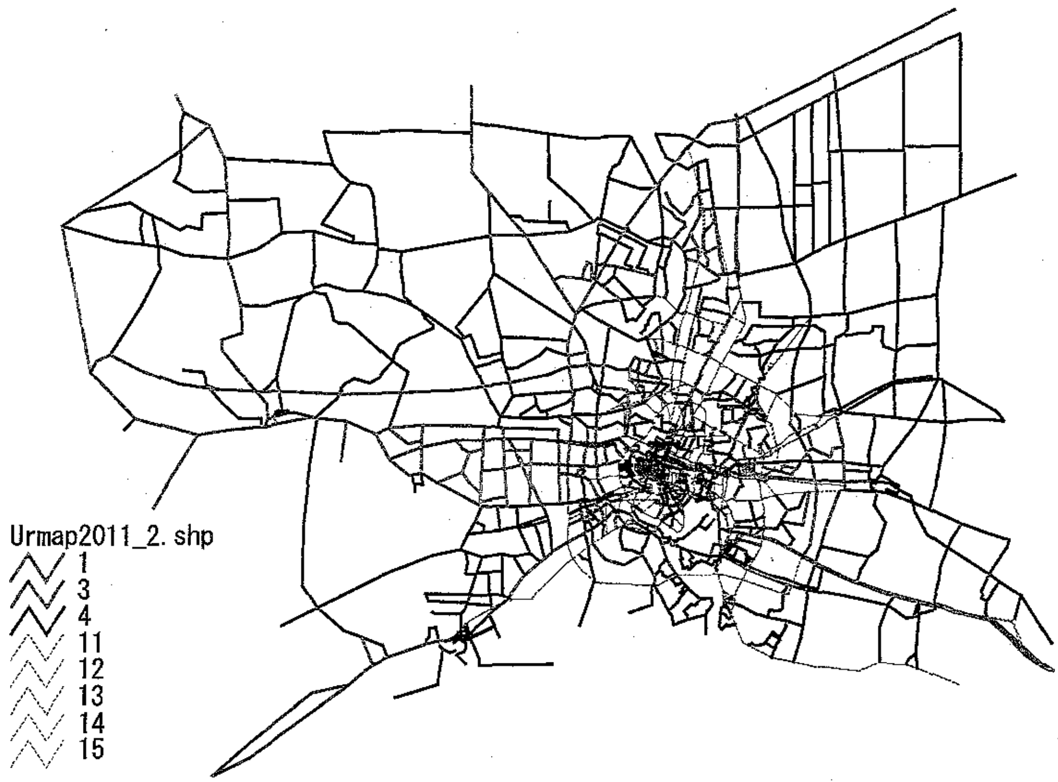


Figure 6.2.3.26 Relation between Road links and Hourly Patterns in the BMR

(2) Vehicle Type Composition Rate for the Year 2011

The vehicle type composition rates for the year 2011 are modified from the Study Team composition rates for the year 2000 and the trend for the number of registered vehicles (Land Transportation Department) from the year 2000 to 2011 in the BMR. The thirteen types for the year 2011 are shown in Table 6.2.3.11 and Figure 6.2.3.27.

Table 6.2.3.11 Composition Rates of Vehicle Types for the Year 2011

Ptn	PS(G)	Taxi(G)	Taxi(LPG)	PS(D)	L-Truck	Bus	H-Truck	MC	Tuk-Tuk
	LDGV	Taxi(G)	Taxi(LPG)	LDDV	LDDT	HDDV	HDDV	MC	Tuk-Tuk
1	49.0%	2.0%	1.0%	4.0%	17.0%	2.0%	3.0%	20.0%	1.0%
6	54.0%	2.0%	1.0%	1.0%	4.0%	7.0%	10.0%	20.0%	1.0%
7	67.0%	2.0%	1.0%	1.0%	4.0%	2.0%	2.0%	20.0%	1.0%
10	32.0%	1.0%	1.0%	6.0%	26.0%	4.0%	6.0%	22.0%	1.0%
13	38.0%	1.0%	1.0%	2.0%	8.0%	12.0%	18.0%	20.0%	1.0%
14	62.0%	2.0%	1.0%	5.0%	22.0%	3.0%	4.0%	0.0%	0.0%
15	69.0%	2.0%	1.0%	1.0%	5.0%	8.0%	13.0%	0.0%	0.0%
16	47.0%	1.0%	1.0%	2.0%	10.0%	15.0%	23.0%	0.0%	0.0%
21	44.0%	1.0%	1.0%	7.0%	16.0%	10.0%	13.0%	8.0%	0.0%
22	60.0%	2.0%	1.0%	9.0%	4.0%	8.0%	7.0%	7.0%	0.0%
23	32.0%	1.0%	1.0%	5.0%	16.0%	6.0%	9.0%	29.0%	1.0%
24	26.0%	1.0%	1.0%	4.0%	23.0%	12.0%	19.0%	13.0%	1.0%
27	10.0%	0.0%	0.0%	2.0%	37.0%	3.0%	15.0%	32.0%	1.0%

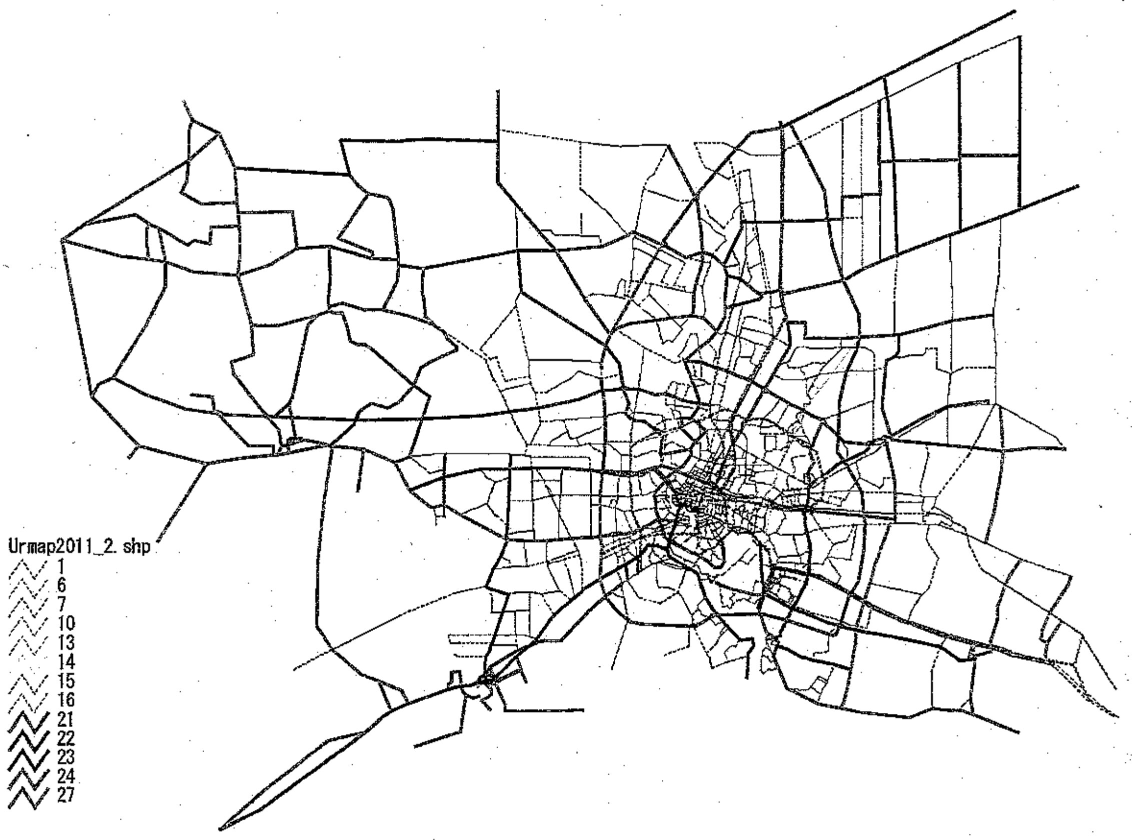


Figure 6.2.3.27 Vehicle Types Composition in the BMR

(3) Pattern of All Road Links for the Year 2011 in the BMR

The relation between hourly patterns and vehicle type composition in the BMR is shown in Table 6.2.3.12. Each road link has an hourly pattern and vehicle type composition. Some cases do not have pairs of hourly pattern and composition. The total number of pairs is 66 patterns (Supporting Report, Chap5.2.2.1).

Table 6.2.3.12 Relation between Hourly Patterns and Vehicle Types Composition

		Compostition Patterns												
		1	6	7	10	13	14	15	16	21	22	23	24	27
Hourly Patterns	1	333	56	2	34	52		10		76	5	60	2	
	3	784	86	60	72	291	4	19	9	445	43	58	92	42
	4	1411	308	45	64	239		39		272	23	175	86	376
	11	101						2						
	12	56	6		4	37				11		8		
	13	42	26							36				
	14	619	89	14	87	59	92	660	41	530	44	77	22	6
	15	123	4	1		26		1	1	42		12		

Unit : Number of Road Links

6.2.3.6 Emission Map for the Year 2011 of Line Sources in the BMR

The SOx and NOx emission map for the year 2011 in the BMR is shown in Figure 6.2.3.28 and Figure 6.2.3.29. SOx emission is lower than NOx. Comparison between year 2011 and year 2000, shows that the emissions of major roads have decreased. However, high emission areas appear in new major roads and the new ring roads of suburbs.

Figure 6.2.3.28 SOx Emission Map for the Year 2011 Bau in the BMR (Line Sources)

Figure 6.2.3.29 NOx Emission Map for the Year 2011 Bau in the BMR (Line Sources)

6.2.4 Simulation Model Description

6.2.4.1 Basic Structure of the Grid Model

1) Model Category

The Airviro Grid Model is an Eulerian three-dimensional model. The Eulerian model is adequate for the calculation of high concentrations in urban areas.

One of the grid model boxes is shown in Figure 6.2.4.1. The actual inside of the box has several types of sources, but the inside concentration of the box is assumed uniform. The Grid model of concentration for the target box is calculated from the inflow and outflow of wind and pollutants and emission pollutants the box. Compared with the trajectory model, the calculation time is longer than the trajectory model to solving the differential equation for all boxes. However, the grid model is appropriate for the simulation of the complex topography and time-dependency.

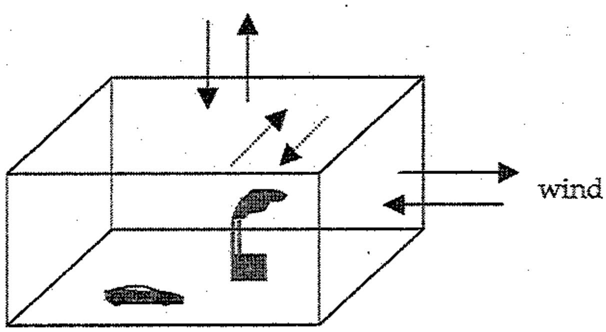


Figure 6.2.4.1 Inflow and Outflow of Pollutants in a Box

2) Simulation Target Area

- The simulation target area is 94km×70km.
  The target area covers the major emission sources in the BMR.
  The target area has all the monitoring stations in the BMR.
- The calculation height is 4m.
- Horizontal Grid
  The horizontal grid size is 500m.
  The total number of horizontal grid is 188×140.
- Vertical Layer
  The number of vertical layers is 7.
  The total number of the calculation grid is 188×140×7.

The vertical layer is calculated in each horizontal grid. The height of grid in each grid point depends on the roof height and the topographical height (ground level). The distance between ground level and the roof top is divided in to a specific number of levels. The distance from the ground of each level is distributed according to a transformation formula based on the shape of the neutral mixing length according to:

$$x = a\left(\frac{1}{k}\left(\ln\left(\frac{z}{z0}\right) + (z - zo)/l\right)\right) + 1$$

The constant a is the iterative process. z0 is the surface roughness. The equation is log-linear and gives an increased accuracy close to the ground. l is the stretching coefficient. Small l-values result in a dominating linear behavior of equation above while large l-values gives a more pure logarithmic vertical distribution.

Vertical layer parameters in the BMR are as follows.

Roof Height : 1000m

Number of Vertical Layers : 7

l : 0.6

a : 0.1601114

3) Target Pollutants

Target pollutants are SO2, NO2

6.2.4.2 Wind Field Model

1) Characteristics of the Wind Field Model

The Wind Field Model of Airviro can simulate phenomena such as efforts due to changes in atmospheric stability, land and sea breezes, and anabatic and katabatic wind.

The procedure of the wind field calculation is shown in Figure 6.2.4.2. The wind field calculation has three steps. The first step is the preparation of initial value and some parameters. The second step is the calculation of the two-dimensional wind field. The third step is the calculation of the vertical wind that is satisfied with mass continuity by using the results of the two-dimensional wind field.

Preparation of Meteorological data, physiographical data

↓

Calculation of Monin-Obukhov length, friction velocity, temperature scale, boundary layer and mixing height at master station

↓

Interpolation of all grids value

↓

Calculation of wind direction and wind speed

↓

Solution of wind field (calculation of two dimensional wind field by each layers)

↓

Calculation of vertical wind direction and wind speed

Figure 6.2.4.2 Procedure of the Wind Field Calculation

2) Characteristics of Master Station

The wind field model uses the meteorological data of one station that is called master station. The master station data are the most important factor for the wind field calculation and simulation in the BMR. The BMR has several meteorological stations. Therefore, the Study Team selected one reliable meteorological station. The name of the master station is Chatujak Bangkok (see Figure 6.2.7.1 [station code 5M]). The characterization of wind data is shown in Figure 6.2.4.3. The wind direction and wind speed of 10m height causes no calculation problems for the wind field and simulation.

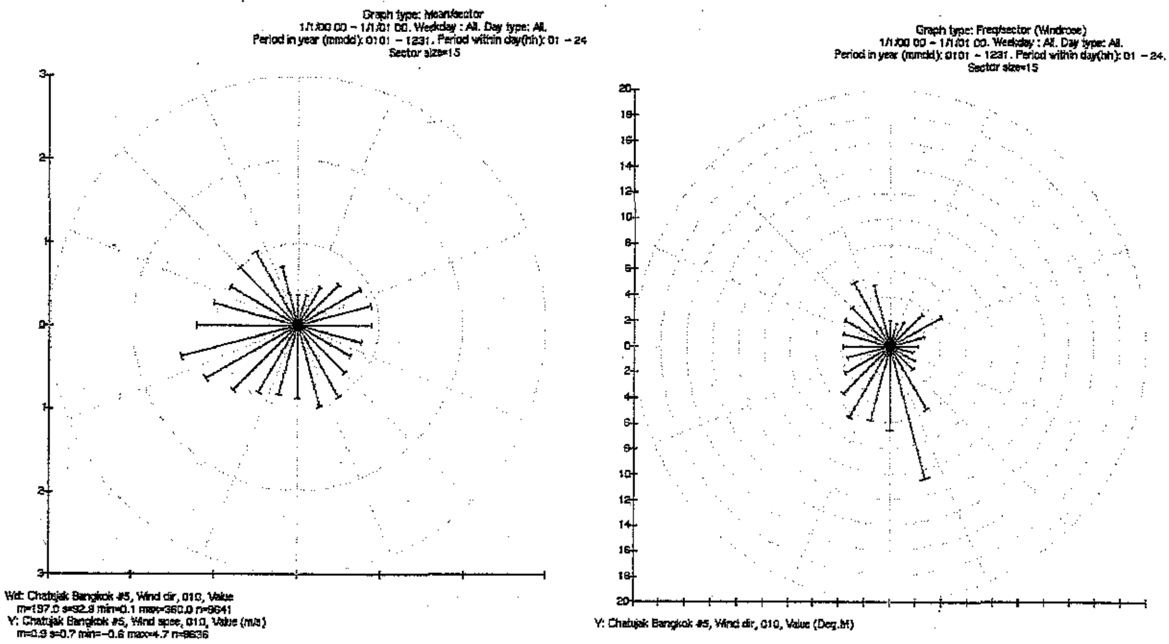


Figure 6.2.4.3 Characterization of the Wind Speed and Wind Direction of the Master Station

3) Necessary Data

Necessary data for the wind field calculation and simulation is as follows.

- Topography – Mean height in each grid cell
- Land Usage (physiography) - Mean height in each grid cell
  - Surface Roughness
  - Percentage of Water
  - Percentage of Urban Area
  - Percentage of Open Area
  - Percentage of Forests (zero percent)
  - House-height
  - Influence Zone
  - Heat Island
- Meteorological data of master station
  - 15 minutes mean value from the last quarter of each hour
    - Wind Direction (10m) – value
    - Wind Direction (10m) – standard deviation
    - Wind Speed (10m) – value
    - Vertical Wind Speed (10m) – standard deviation (optional)
    - Temperature (2m)
    - Differential Temperature (8-2m)

- Resources Files (Supporting Report, Chap5.2.3)

  Modell.par

  This file specifies the simulation size and grid size.

  Realwind.rf

  This file specifies the meteorological and analyzes of master station.

  Const_met.rf

  Const_met.rf is Airviro dispersion meteorological constant configuration file.

4) Basic Equations

The basic equations of the wind field model are as follows. The thermodynamic equation (eq6.2.2) is used to estimate the local change in the potential temperature. The pressure tendency equation (eq6.2.3) is estimated by the local pressure tendency due to temperature effects. The change in local pressure at ground level is used in the momentum equation (eq6.2.3) to estimate a wind tendency.

$$\frac{\partial V_s}{\partial t} = -V_s \cdot \nabla V_s - \left(g\nabla Z_s + RT_s \nabla \ln p_s \right) - fK \times V + F + K_m \nabla^2 V \quad \Lambda\ \Lambda\ (6.2.1)$$

$$\frac{\partial \Theta_s}{\partial t} = -V \cdot \nabla \Theta_s + K_t \nabla^2 \Theta_s + Q / C_p \quad \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ (6.2.2)$$

$$\frac{\partial \ln p_s}{\partial t} = \frac{g}{R\Theta_s T_s} \cdot \int_0^H \frac{\partial \Theta}{\partial t} dz \quad \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ \Lambda\ (6.2.3)$$

V : Horizontal Wind

Θ : Potential Temperature

F : Friction

p : Air Pressure

H : Boundary Layer Height

Each equation (6.2.1)-(6.2.3) is written in finite-different form. Starting from giving new initial values, they give new values of Θ, lnp_s, and V. After a number of time steps, the fields of these variables will evolve which represent the modifying influences of topography.

5) Initial Value Setting

(1) Monin–Obukhov length

Stability and turbulence conditions in the boundary layers are evaluated at locations of master station. Master station has information about temperature gradient and wind speed at one or two levels.

Monin-Obukhov length (L) is an important parameter for preprocessing to determine the stability, turbulence and mixing layer.

$$L = \frac{\overline{T}}{g} \cdot \frac{u_*^3 \rho c_p}{\kappa H}$$

H : Vertical heat flux

u_* : Friction velocity

$\overline{T}$: Average air temperatue

g : Gravity

κ : von Karman constant

ρc_p : Specific heat capacity

(2) Stability and Mixing Layers

Stability is categorized by the calculated Monin-Obukhov length. The Monin-Obukhov length is shown in Figure 6.2.4.4. The Monin-Obukhov length and the Coriolis parameter estimate the boundary layer (Zi).

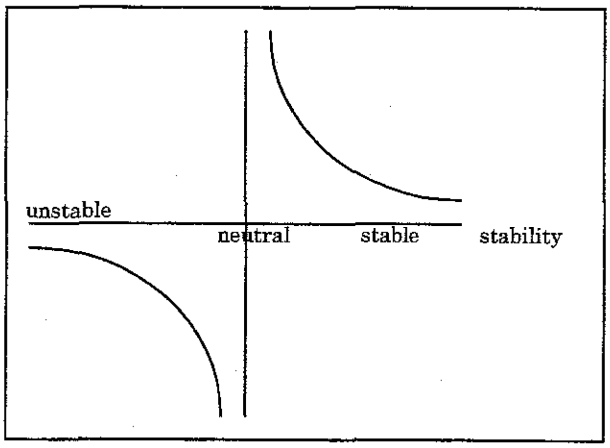


Figure 6.2.4.4 Monin-Obukhov length (L) by Stability

- Stable condition (L>0)

$$Z_i = 0.4\sqrt{\frac{u_*}{f}L}$$

f : Coriolis parameter (=2Ωsinϕ, ϕ: latitude)

- Neutral and unstable condition (L<0)

$$Z_i = 0.3\left(\frac{u_*}{f}\right)$$

(3) Mixing Height

The relation between the mixing height and boundary layers is as follows.

$$mixh = 50 + 10 \times \sqrt{Z_i + 1}$$

(4) Friction Velocity and Temperature Scale

The friction velocity (u_*) and temperature (T_*) scale is calculated by using the formula below.

$$u_* = \frac{\kappa(U_{z2} - U_{z2})}{\ln\left(\frac{z_{u2}}{z_{u1}} - \psi_{m2} - \psi_{m1}\right)}$$

$$T_* = -\frac{H}{\rho c_p u_*} = \frac{\kappa \Delta\theta}{\ln\left(\frac{z_{t2}}{z_{t1}} - \psi_{H2} - \psi_{H1}\right)}$$

ψ : Function of z/L (see Section of Integral Wind Profile)

6) Interpolation

Each grid point of wind speed (u, v) is interpolated from all observation places. The Monin-Obukhov length (L), friction velocity (u_*), temperature scale (T_*), boundary layer (Zi) and mixing height (mixh) are interpolated by the below method.

$$value(i,j) = \frac{\sum_k obs(k) \times weight(i,j,k)}{\sum_k weight(i,j,k)}$$

$$weight(i,j,k) = \frac{1}{d_k(i,j)}$$

$d_k(i,j)$: distance between the grid point(i,j) and the observation place k

7) Integral Wind Profile

(1) Free Wind

The wind speed profile is obtained from the integration between the surface and height z in the surface layer, which results in

$$U_z = \frac{u_*}{k}\left\{\ln\left(\frac{z}{z_0}\right) - \psi_M\left(\frac{z}{L}\right)\right\} \qquad (6.2.4)$$

where Uz is wind speed at height z, z_0 is the appropriate surface roughness length and ψ_M is defined by

$$\psi_M\left(\frac{z}{L}\right) = \int_0^{z/L} \frac{1-\phi_m(\xi)}{\xi} d\xi$$

Assuming that a wind speed U_1 is available at one level z_1 in the surface layer. In this case, (6.2.4) can be written as

$$U_2 = U_1 \frac{\ln\left(\frac{z_2}{z_0}\right) - \psi_M\left(\frac{z_2}{L}\right)}{\ln\left(\frac{z_1}{z_0}\right) - \psi_M\left(\frac{z_1}{L}\right)}$$

Definition of ϕ_M written as

Unstable condition (L<0)

$$\phi_m = \left(1 - 16\frac{z}{L}\right)^{-\frac{1}{4}}$$

Stable condition (L>0)

$$\phi_m = 1 + 5\frac{z}{L}$$

(2) Deflection of the Free Wind Vector

For different stabilities there are different deflections when going from the observed level up to the free wind level at mixing height. Deflection of the free wind vector is shown in Table 6.2.4.1. The first line states the number of classes. For each class three values are given. The first two are the lower and upper limits for the Monin-Obukhov length in the class followed by the deflection.

Table 6.2.4.1 Deflection of Free Wind

Class	Monin-Obukhov Length		Deflection
	Min	Max	
wnd.dir.class1:	0.	10.	11.5
wnd.dir.class2:	10.	40.	11.5
wnd.dir.class3:	40.	100.	10.3
wnd.dir.class4:	100.	200.	8.2
wnd.dir.class5:	200.	1000.	5.3
wnd.dir.class6:	1000.	3.4E+38	3.5
wnd.dir.class7:	-12.	0.	3.5
wnd.dir.class8:	-40.	-12.	3.5
wnd.dir.class9:	-200.	-40.	2.9
wnd.dir.class10:	-1000.	-200.	2.6
wnd.dir.class11:	-3.4E+38	-1000.	3.5

8) Solving the Basic Equation

(1) Scheme

The time and space differential of the equation is solved in the leap flog method. The leap flog method is solved by the time differences from the location(x) and the speed(v).

$$v\left(t + \frac{\Delta t}{2}\right) = v\left(t - \frac{\Delta t}{2}\right) - \Delta t \cdot x(t)$$

$$x(t + \Delta t) = x(t) + \Delta t \cdot v\left(\frac{\Delta t}{2}\right)$$

Δt : micro time

The advection scheme is upstream the formula.

(2) Numerical Method

When the initial conditions have been estimated, the thermodynamic equation (6.2.2) is used to estimate the local change in the potential temperature. The tendency equation (6.2.3) is then utilized in order to estimate the local pressure tendency due to temperature effects. The change in local pressure at ground level is then used in the momentum equation (6.2.1) to estimate a wind tendency. Thereafter, the slightly changed wind field is used in the surface potential temperature and so on.

By iteration in this way, the quasi-steady-state condition will usually be reached within a few time steps (10-20). According to the initial assumptions, the length of the time steps is not allowed to be larger than a few seconds, in order to have an adaptation process within a few minutes. The results of the model are not satisfied with a mass conservation.

(3) Calculation Time Step

The length of the time steps (Δt) depends on the resolution of the grid (Δs) and the wind speed of the large scale wind (Vg), i.e.

$$\Delta t = (0.125 * \Delta s)/Vg$$

Normally, for a 500*500m resolution and a typical scale wind of 5m/s. the length of the time steps would be 12 seconds. The total number of time steps has a maximum of 80. Consequently, the total adaptation period in this case is 8 minutes.

9) <u>Vertical Wind</u>

In order to create three dimensional wind fields, the vertical wind field has to be calculated at each grid cell. Above, the construction of the two dimensional wind field described, the two-dimensional wind fields are not satisfied with the mass conservation. The vertical wind component is calculated with mass continuity equation. The calculated horizontal wind fields(u,v) at each level in each grid cell and the vertical wind components are calculated with the use of a numerical formulation of the mass continuity equation as follows.

$$\frac{\partial w}{\partial z} = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

6.2.4.3 Process of Diffusion and Transportation

1) Basic Equation

Horizontal diffusion is strongly affected by quasi-diffusion. The basic equation of Airviro is not considered a horizontal diffusion coefficient. The basic equation uses the Cartesian coordinate, z uses the staggered coordinate.

$$\frac{\partial c}{\partial t}+u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}+w\frac{\partial c}{\partial z}=\frac{1}{\rho}\frac{\partial}{\partial z}\left[\rho\left(K_Z\frac{\partial c}{\partial z}+w_S c\right)\right]+\frac{Q}{\rho}$$

c : Concentration (mass of substance per unit volume/ mass of air per unit volume)

ρ : Density of Air (a function of height)

u,v,w : Wind Velocity Component

x,y,z : Cartesian Coordinates

ws : Particle Settling Velocity

Q : Sources

K_Z : Vertical Turbulent Diffusion Coefficient

2) Numerical Method

(1) Fractional Step

All terms of the basic equation are solved with much difficulty. Therefore, Airviro uses the fractional step for solving the basic equation. The fractional step is the solution method for one-dimensional equations instead of the three-dimensional equation, and it separates the solving of each term. The time step of the fractional step is set so that the wind speed × the time step does not exceed for all boxes, the terms of emission, transportation and diffusion.

The initial concentration of each substance is set to zero value, and the Grid Model starts calculating for the target period.

(2) Scheme

Transportation	Horizontal Direction	Finite Element Scheme
	Vertical Direction	Finite Difference Scheme
Time Domain	Horizontal Direction	Crank-Nicolson Method
	Vertical Direction	Implicit Time Stepping

(3) Boundary Condition

The horizontal boundaries have inflow and gradient outflow constant conditions. The concentration reflects at roof height and surface. The vertical wind speed and horizontal wind speed of ground level is set to zero value.

3) Vertical Diffusion Coefficient

(1) In the surface layer (z<0.1mixh)

Unstable (L<0 and z/L>1)

$$K_Z(z) = u_* \kappa z \Big/ \phi_h\left(\frac{z}{L}\right)$$

$$\phi_h\left(\frac{z}{L}\right) = \left(1 - 16\frac{z}{L}\right)^{-\frac{1}{2}}$$

Kz:Vertical Diffusion Coefficient

Free convection (L<0 and z/L>1)

$$K_Z(z) = w_* z$$

Stable (L>0)

$$K_Z(z) = u_* \kappa z \Big/ \phi_h\left(\frac{z}{L}\right)$$

$$\phi_h\left(\frac{z}{L}\right) = 1 + 5\frac{z}{L}$$

(2) Above the surface layer

$$K_Z(z) = K_Z(0.1mixh) + \frac{(z - mixh)^2}{(mixh - 0.1mixh)^2}\Big[K_Z(0.1mixh) - K_Z(mixh) + (z - 0.1mixh)\left(\frac{\partial K_Z}{\partial z}(0.1mixh) + 2\left(\frac{K_Z(0.1mixh) - K_Z(mixh)}{(mixh - 0.1mixh)}\right)\right)\Big]$$

mixh : Mixing Layers

L : Monin-Obukhov Length

4) Emission Height of Each Source

The point sources are treated individually. The line sources and area sources are collected together into a grid. The source strength of a line source passing through a grid square is transformed to an equivalent grid area source.

The emission height for the area sources is 2m and 1m for the line sources.

Emission heights of the point source are initially elevated by the plume rise formula until the puff radius has grown to the size of the two grid sizes.

5) Plume Rise Formula

Stack effluent gas rises up in the atmosphere due to the effects of the exhaust velocity and buoyancy caused by the high stack gas temperature. The overall rise of the stack gas final plume height (effective stack height) must be estimated and then a point source is placed at this final plume height, which is the sum of the real stack height and the rising height (see Figure 6.2.4.5). The effective stack height is calculated by the plume rise formula. The final plume height (h_e=h_s+Δh) depends on the stability condition.

The Plume Rise formulation use parameters of M_0 and F_0. M_0 is the initial momentum flux and F_0 is initial buoyancy flux. $V_0 = \pi r$ (internal stack radius)^2

$$M_0 = wV_0$$

$$F_0 = \frac{g}{T_s}(T_s - T_a)V_0$$

where w is the exhaust gas velocity, g is the gravitational acceleration, T_s is the exhaust gas temperature and Ta is the air temperature (°C).

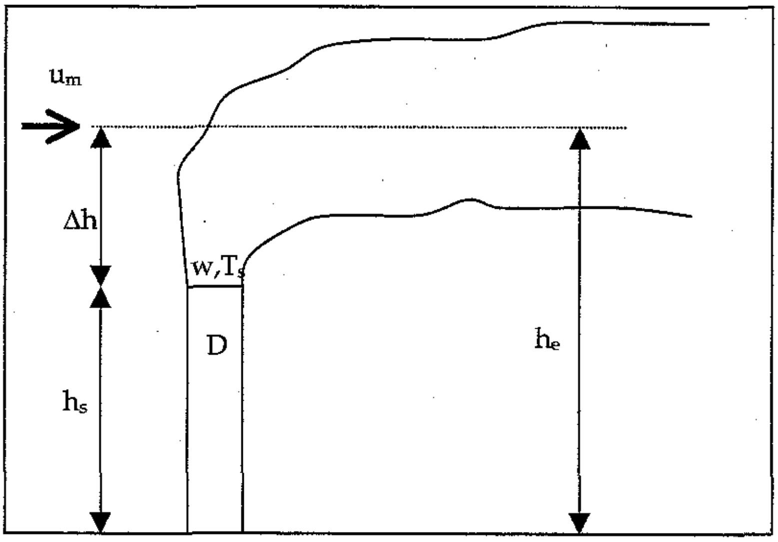


Figure 6.2.4.5 Final Plume Height and Stack Height

(1) Stable (0<L<100)

$$\Delta h = 2.6\left(\frac{F_0}{u_m s}\right)^{\frac{1}{3}}$$

where s describe the atmospheric stability:

$$s = \frac{g}{T_a}\left(\frac{\Delta T_a}{\Delta z} + 0.01\right)^{\frac{1}{3}}$$

(2) Unstable (-68<L<0)

$$\Delta h = 4.3\left(\frac{F_0}{u_m}\right)^{0.6} H_*^{-0.4}$$

$$H_* = \frac{gH}{c_p \rho T}$$

(3) Neutral and Near Neutral (L>100 or L<-68)

$$\Delta h = 1.54\left(\frac{F_0}{u_p \cdot u_m^{\;2}}\right)^{2/3} (h_s + \Delta h_d)^{1/3} + \Delta h_e + \Delta h_m$$

The plume downdraft Δh_d is:

$$\Delta h_d = -2\left(\frac{w}{u_s} - 1.5\right)D$$

for wind u_s>1.5w, D being the outer diameter of the stack. The plume entrainment is calculated as

$$\Delta h_e = -0.25\sqrt{DX_*}$$

with $X_*=6.49F_0^{2/5}\Delta h_d^{3/5}$. The initial momentum contribution is

$$\Delta h_m = 3D\left(\frac{w}{u_s} - 1\right)$$

$$h'_e = h_s + \Delta h$$

(4) Very Low Wind Speed

$$\Delta h = 5\frac{F_0^{\;0.24}}{s^{3/8}}$$

$$h''_e = h_s + \Delta h$$

where h''_e is the intermediate final plume height.

The calculated plume height is then mixed with the layer depth mixh. For a calculated plume height (h''_e) within 2 times the mixed layer depth, a fraction (frac) of the plume is reflected back below the inversion.

$$frac = \frac{mixh}{h''_e} - 0.5$$

This fraction should be treated as a plume that is dispersed within the mixed layer at a height (Δh) above the stack height (h_s). The calculated plume height then become,

$$h'_e = h_s + (0.62 + 0.38(1.0 - frac))(h''_e - h_s)$$

6) Deposition

The BMR simulation is not considered with the options of deposition.

6.2.5 Conversion Formula

6.2.5.1 Conversion of NOx into NO2 by Statistical Model

The target pollutants of the Thai Ambient Standard and the WHO Ambient Standard is NO2 concentration. However, the Grid Model can not calculate NO2 directly and the conversion method of NOx into NO2 needs to be decided. The SOx inventory include the contents of sulfate, so the SOx calculation value is of reduced contents of sulfate.

1) Concept of Statistical Model

The photochemical reactions that regulate the fractions NO and NO2 are fast and complicated. For, the conversion of NOx into NO2, the statistical model is used. This model is to solve the relation between the NOx and NO2 measurement data in the target area for the long term period. The non-linear equation considers the relation between NOx and NO2.

$$[NO2]=a[NOx]^b$$

Coefficient a and b is calculated by the least square method from the monitoring data of NOx and NO2. The formula does not include the O3 concentration directly, but the formula includes indirectly the effect of NO2 oxidation by O3.

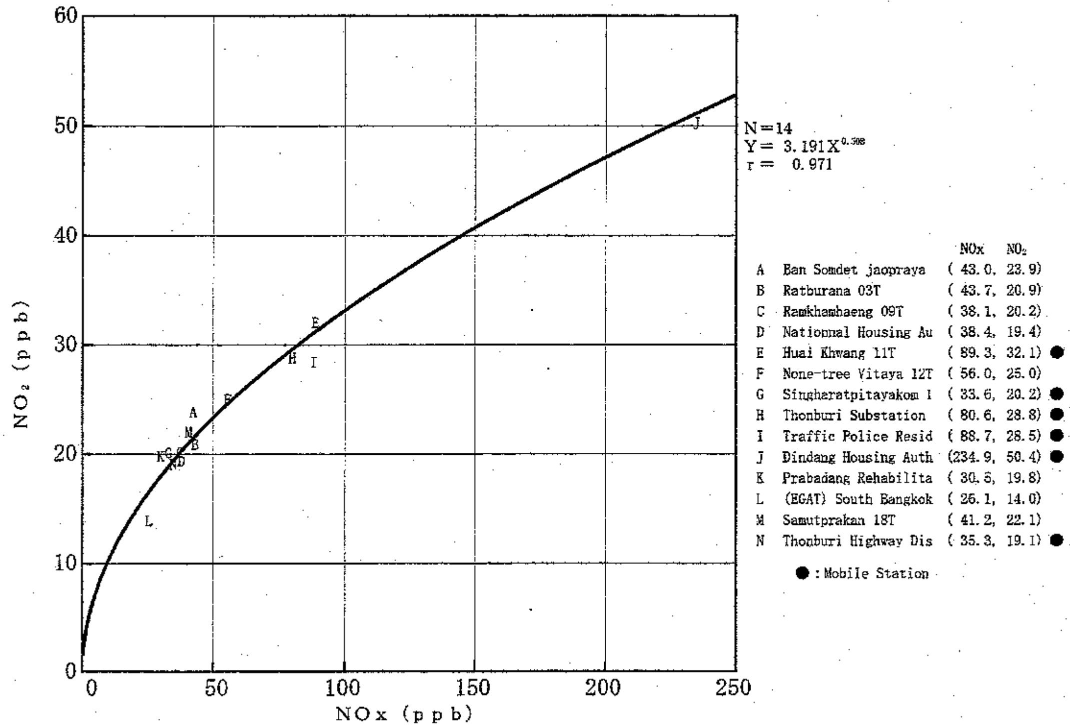
2) Conversion Formula in the BMR

In the BMR, the relation between the annual mean value and the conversion formula is shown in Figure 6.2.5.1. Fourteen monitoring stations satisfy the criteria that NOx and NO2 were measured over 80%(7028 hours) in year 2000. The NO2 conversion statistical formula in the BMR is as follows.

$$[NO2]=3.191\times[NOx]^{0.508}$$

[NO2]: NO2 Annual Mean Concentration

[NOx]: NOx Annual Mean Concentration



Relation between NOx and NO2 (Annual Mean Value)

Figure 6.2.5.1 Result of Statistical Model for Year 2000

6.2.5.2 SOx Conversion for Sulfate

The SOx inventory estimation included the sulfate contents, but the SO2 measurement data can not measure sulfate. Also, in general five percent is used as the sulfate conversion rate. Therefore, the simulation results are cut by 5% from the SOx calculation values.

$[SO2]=[SOx]^{*}\times 0.95$

*First SOx calculation value includes sulfate.

6.2.6 Target Ambient Annual Standard

6.2.6.1 Simulation Period

The Grid Model of Airviro has two types of simulation options such as the scenario base and the hourly base. The hourly base calculation simulates hourly concentration, but the simulation takes long the time for one year. Also the hourly base simulation affects the transmission from the monitoring data in the stations of the Airviro system, the simulation of the hourly base can not calculate for all cases. The scenario base calculation of the procedure involves a statistical approach. By extracting a representative sample of the joint variation of weather and emissions, the expected mean values and extreme values of air quality can be simulated based on a limited number of representative hours. The scenario base simulation sets a target period, and it can calculate the mean value and 95-99 percentile concentration. The scenario base simulation can not calculate hourly values. In addition, the annual evaluation is the most important factor for the acid deposition strategy. Therefore, the simulation target period is the annual calculation for the years 2000 and 2011. Also, the evaluation is to compare the annual simulation the scenario base with the ambient air standard.

6.2.6.2 Setting of the Target Ambient Annual Standard

The ambient air standards of Thailand and the guidelines for air quality of WHO is shown in Table 6.2.6.1. The WHO standard has the SO2 and NO2 annual standard, but the NO2 standard of Thailand does not have an annual standard. The setting of a Thailand target annual standard for NO2 is necessary. Figure 6.2.6.1 shows, the relation between the maximum hourly value and the annual mean value of the monitoring data. The target annual standard is 40ppb based on the hourly standard of Thailand and the formula that is the relation between the maximum hourly value and the annual mean value.

$$
\begin{aligned}
\text{NO2 Target Annual Standard} &= 0.335 \times \text{Hourly Standard of Thailand} - 16.98 \\
&= 0.335 \times 170(\text{ppb}) - 16.98 \\
&= 40\ (\text{ppb})
\end{aligned}
$$

Table 6.2.6.1 Ambient Air Standards of Thailand & Guidelines for Air Quality of WHO

	10 Minutes		1 Hour		24 Hours		1 Year	
	mg/m³	ppb	mg/m³	ppb	mg/m³	ppb	mg/m³	ppb
SO_2								
Thailand	——		0.78	300	0.30	120	0.10	40
WHO	0.5	175	——		0.125	44	0.05	18
NO_2								
Thailand	——		0.32	170	——		——	
WHO	——		0.2	98	——		0.04	20

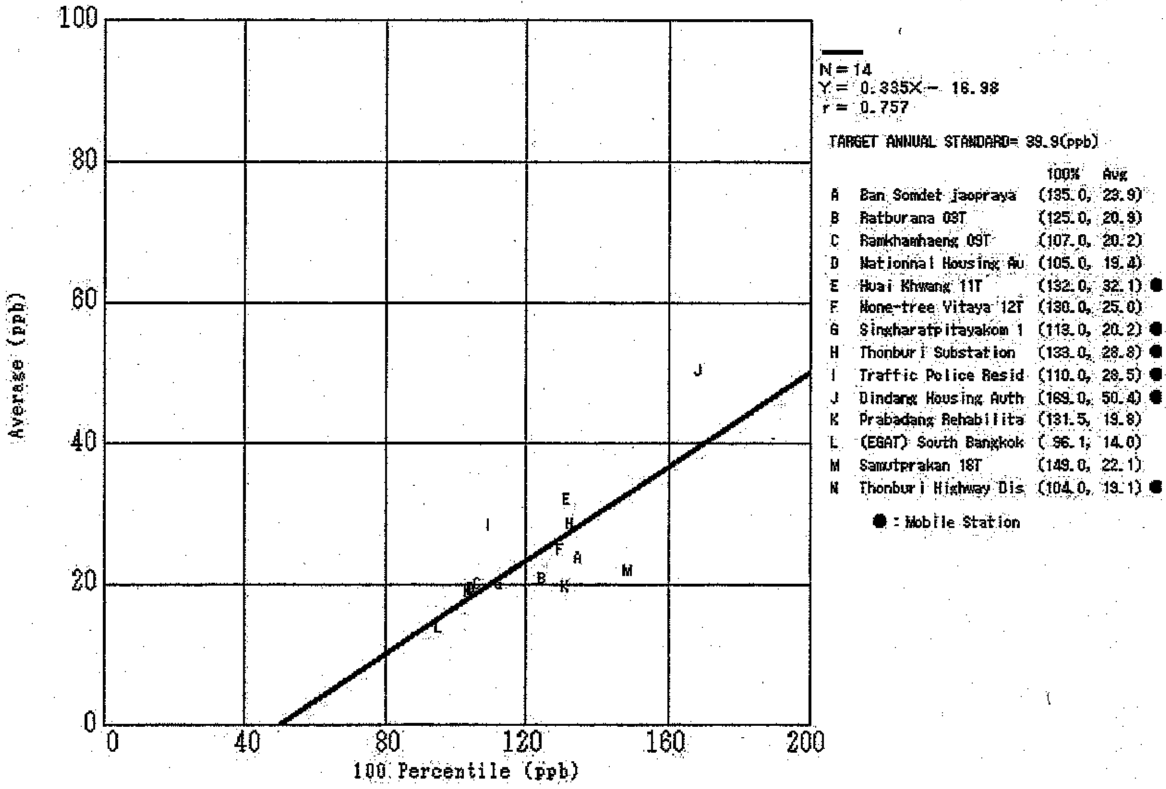


Figure 6.2.6.1 Maximum Hourly Value and Annual Mean Value of Monitoring Data

6.2.7 Monitoring Station and Monitoring Data

6.2.7.1 Type of Monitoring Station

The monitoring stations of PCD have mobile type stations and general type stations. The mobile stations are effected by major roads. The general Stations are not effected directly by the emission sources. The Study Team inspected for classification the monitoring stations in the BMR. The location map of the monitoring stations is shown in Figure 6.2.7.1. The types of monitoring stations and the SO2 and NO2 annual average are shown in Table 6.2.7.1.

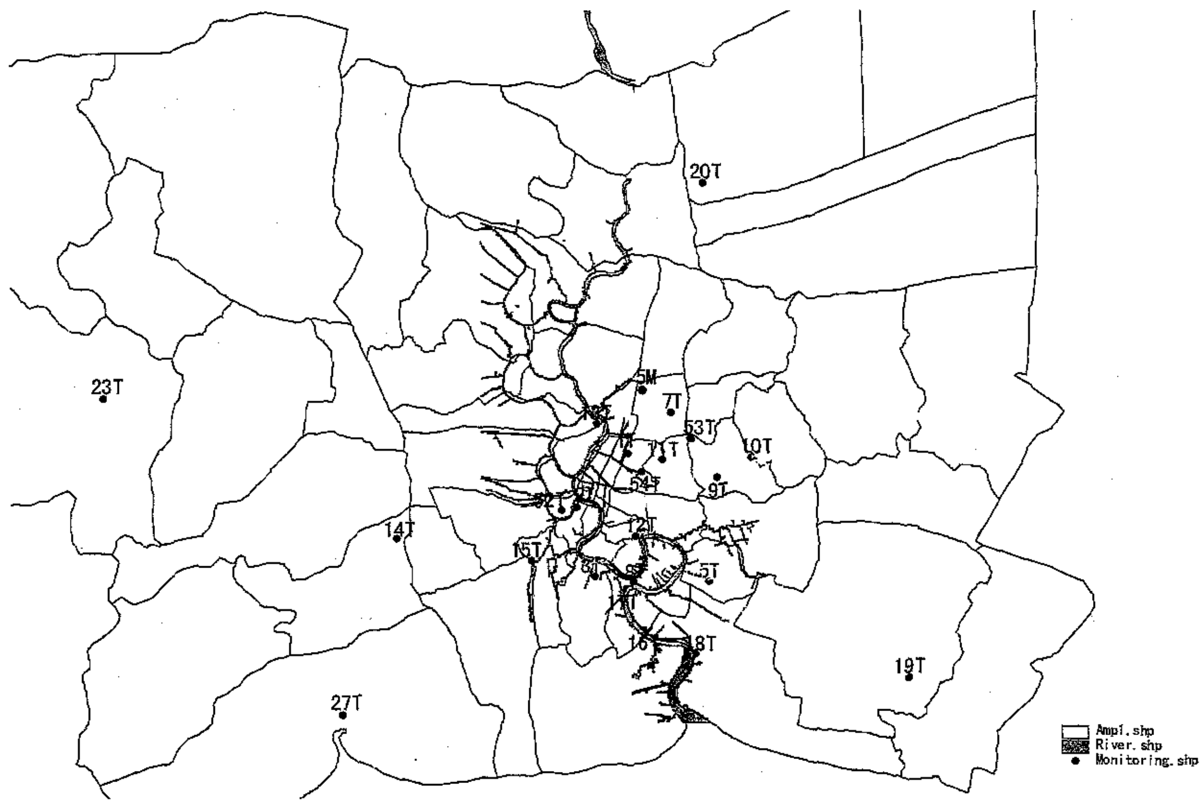


Figure 6.2.7.1 Location of Monitoring Stations

Table 6.2.7.1 Types of Monitoring Stations

Province	No.	Monitoring Stations Name	Type of Stations M:Mobile G:General ?:No Inspection	SO_2 (ppb)				NO_2 (ppb)			
				Max	Min	Ave	Measure ment hours	Max	Min	Ave	Measure ment hours
Bangkok	01T	OEPP	M	150.0	0.0	4.6	7183	125.0	0.0	32.8	1619
	02T	Bansomdat jao praya	G	94.0	0.0	2.9	8207	135.0	0.0	23.9	7703
	03T	Ratuburna	G	72.5	0.0	4.1	8135	125.0	0.0	20.9	7788
	05T	Meteorological Department	G	75.0	0.0	4.5	6590	126.0	0.0	17.7	5304
	07T	Junkasame	G	93.0	0.0	5.6	7123	136.0	0.0	20.3	4778
	09T	Ramkhamhaeng	G	161.0	0.0	10.8	7190	107.0	0.0	20.2	7856
	10T	National Housing Authority	G	113.0	0.0	7.3	7601	105.0	0.0	19.4	7687
	11T	Huai Khwang	M	136.0	0.0	7.2	7113	132.0	0.0	32.1	8248
	12T	None Tree Vittaya	G	151.0	0.0	10.8	7765	130.0	0.0	25.0	8226
	15T	Singharatpitayakom	M	85.4	0.0	7.7	7901	113.0	0.0	20.2	8282
	52T	Thon Buri Substation	M	69.0	0.0	7.0	8103	133.0	0.0	28.8	8111
	53T	Traffic Police Residence	M	85.8	0.0	9.1	7777	110.0	0.0	28.5	7761
	54T	Din Dang	M	120.0	0.0	11.8	7208	169.0	0.0	50.4	7102
Samutprakan	8T	Prabadang Rehabilitation	G	40.7	0.0	1.2	7729	131.5	0.0	19.8	7951
	16T	EGAT South Bangkok	G	138.5	0.0	7.6	7618	96.1	0.0	14.0	7486
	17T	Prabadang Mineral Resources	G	123.8	0.0	14.4	7906	149.1	0.0	20.8	6395
	18T	Samutprakan	G	104.0	0.0	6.6	8071	149.0	0.0	22.1	7810
	19T	Bangplee Housing Authority	G	43.0	0.0	2.8	7048	89.0	0.0	11.6	6040
Samut Sakhon	14T	Thonburi Highway District	M	169.0	0.0	17.3	6569	104.0	0.0	19.1	7703
	27T	Samut Sakhon	G	138.0	0.0	13.7	6212	82.0	0.0	23.8	3161
Pathum Thani	20T	Rangsit	G	123.0	0.0	4.3	6958	55.0	0.0	5.7	7140
Nonthaburi	13T	(EGAT)Department of Energy Affairs	M	130.0	0.0	5.3	7129	134.0	0.0	22.9	5786
	22T	Nonthaburi(Scothai Univ.)	?	27.0	1.8	3.7	389	121.0	5.0	16.9	906
Nakhon Pathon	23T	Sanamchan	?	32.0	0.0	4.6	3642	52.0	0.0	7.4	2980

6.2.7.2 Evaluation of the Monitoring Data and the Monitoring Stations

1) Criteria of the Monitoring Data for the Simulation Evaluation

Some of the monitoring stations could not be sufficiently measured in the year 2000. The monitoring stations of average value can not compare with the simulation results. Therefore, the criteria for the annual average are decided by those based on the relation between hourly data and the daily average. The criteria for the annual available average and the evaluation results are shown in Table 6.2.7.2.

Table 6.2.7.2 Criteria and Evaluation Results of the Monitoring Data

Item	Criteria	Evaluation Results
SO2	Hourly data of SO2 were available over 80% (7028h) in year 2000.	15 Stations are satisfied with criteria.
NOx	Hourly data of NOx and NO2 were available over 80% (7028h) in year 2000.	14 Stations are satisfied with criteria.

2) Excluding of the Monitoring Station for the Simulation Evaluation

The Airviro Grid Model can not simulate cases such as evaluation points which are located around strong intensity emission sources. Therefore, the following monitoring stations are excluded from the model evaluation.

(1) Mobile Type Station

Mobile type stations are located along major roads. The Airviro calculation concentration for one major road shows a linear interpolation of distance. The actual concentration distribution of the roadside shows a non-linear equation by distance. Therefore, the Airviro Grid Model can not simulate concentration around main roads. The monitoring stations of the Thonburi Substation, the Traffic Police Residence, the Dindaeng and the Thonburi Highway District are excluded from the SO2 and NO2 model evaluation.

(2) Quasi Mobile Type Station

Huai Khwang is located near a bus terminal, and monitoring data are affected by bus exhaust gases. Therefore, Huai Khwang is excluded from the SO2 and NO2 model evaluation.

(3) Rangsit

Rangsit is located near the upper north side of the target area. The emission inventory of this area does not include major emission sources. Therefore, the monitoring station of Rangsit is excluded from the SO2 and NO2 model evaluation.

(4) EGAT South Bangkok

The simulation result of the single emission source of SB-EGAT is beyond the measurement value at chimney location by the Airviro Grid Model. The simulation of Airviro overestimated if the monitoring stations of EGAT South Bangkok are included for the model evaluation. Therefore, the monitoring station of SB-EGAT is excluded from the SO2 and NO2 model evaluation.

(5) Prapadang Rehabilitation

The SO2 annual average of the Prapadang Rehabilitation is 1.9ppb. By comparison with the Prapadang Mineral resource which is located 1km distance from Prapadang Rehabilitation, the SO2 annual average is 14.3ppb, the Prapadang Rehabilitation is 1/10. Also, the NO2 of the Prapadang Rehabilitation is 20.8ppb and the Prapadang Rehabilitation is 19.8ppb, and their annual averages are almost the same level. The annual average of SO2 at the Prapadang Rehabilitation is extraordinarily low. The monitoring data of the Prapadang Rehabilitation do not have high reliablity so far. In addition, Prapadang Rehabilitation is inappropriate station for model evaluation. Therefore, the SO2 Prapadang Rehabilitation is excluded from the SO2 model evaluation.

(6) Ramkhanheng

The SO2 Annual Averages from 1999 to 2001 are 5.3ppb, 10.8ppb, and 6.0ppb. The year 2000 annual average is higher than other years. Also, the concentration of Ramkhanheng is affected by the parking lot in the university. Therefore, the Ramkhanheng is excluded from the SO2 model evaluation.

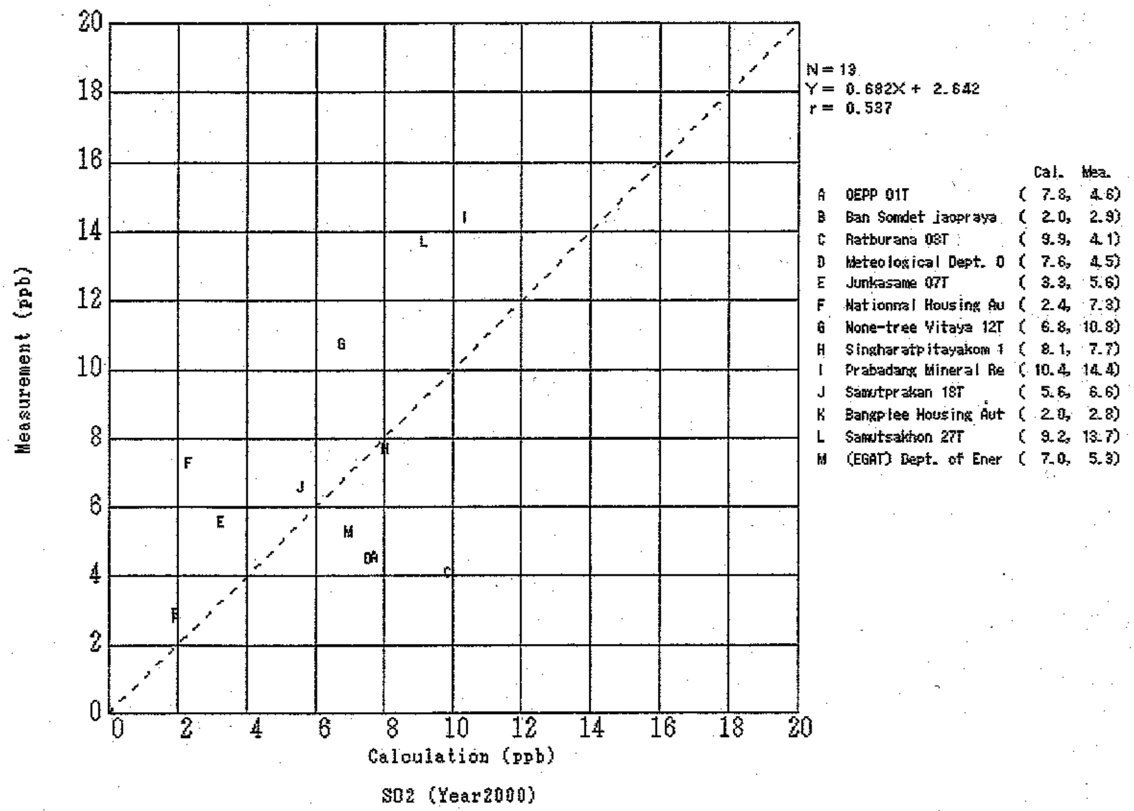
6.2.8 Model Simulation for the Year 2000

6.2.8.1 Comparison of Simulation Results with Monitoring Data

Simulation comparison with the monitoring data is shown in Figure 6.2.8.1. The SO2 calculation values of some stations are underestimated measurement values. On the whole, the SO2 correlation between the calculation and measurement shows a relatively high value. The NO2 correlation shows a very good value.

6.2.8.2 Simulation Results for the Year 2000

The SO2 and NO2 concentration maps for the year 2000 are shown in Figure 6.2.8.2 and Figure 6.2.8.3. The SO2 high concentration area is similar to the emission distribution of large point sources. SO2 high concentration areas appear around the Chao Phraya River and Samut Sakhon. The NO2 high concentration area is similar to the emission distribution of the major roads source. NO2 high concentration areas appear around the ring roads in suburbs.



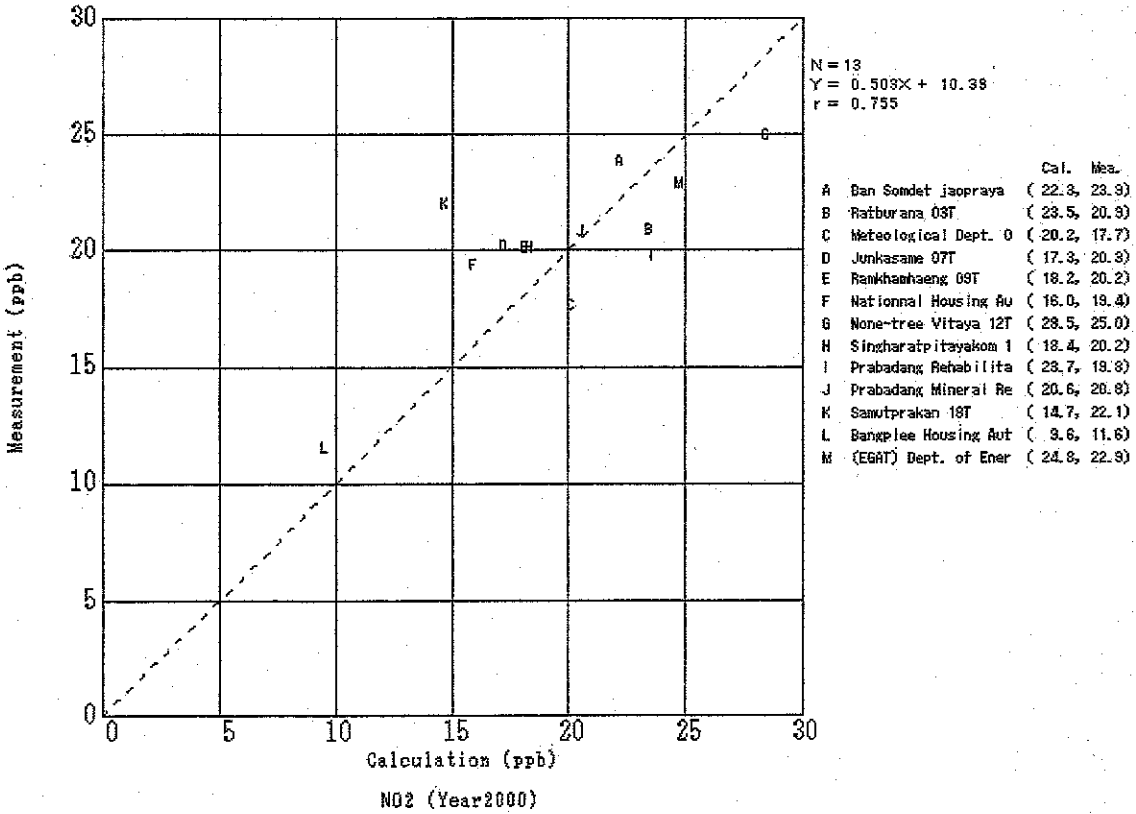


Figure 6.2.8.1 Comparison of Calculation Values and Monitoring Data