CHAPTER 4 FUEL AND EMISSION STUDIES

4.1 Outline

Investigation of pollution sources is one of the most important tasks in air pollution management planning. The primary purpose of source investigation in the Study was to estimate quantities of air pollutant emissions to prepare a "source model" as an essential part of the air simulation model (Section 6.2).

The target sources and pollutants are sulfur oxides (SOx), nitrogen oxides (NOx) and particulate matter (PM). Target pollutants by source are shown in Table 4.1.1. Pollutant emissions from sources unlisted in this table (such as open burning activities, earthworks, and natural phenomenon) were not estimated in this Study. The estimated pollutant emissions are only those emitted from stacks of factories and establishments (hereinafter refereed to as "factories"), ships, households, tail pipes of automobiles, and engines of aircraft.

Table 4.1.1 Targeted Sources and Pollutants

Pollution Sources	Pollutants				
	SOx	NOx	PM	CO	HC
Factories and Establishments	O	O	O		
Households	O	O	O		
Automobiles	O	O	O	O	O
Ships	O	O			
Aircraft	O	O			

To estimate current (the year 1995) air pollutant emissions from various sources, BAPEDAL and the Team conducted the surveys shown in Table 4.1.2.

Table 4.1.2 Survey Items in the Study

Survey Item	Factories	Automobiles	Households
Questionnaire survey	O		
Emission measurement	O		
Traffic volume survey		O	
Travel speed survey		O	
Simple emission test		O	
Fuel consumption pattern			O
Fuel analysis	O	O	O
Analysis of unburned coal	O		

This chapter describes the results of surveys and estimate of the pollutant emissions. The Team submitted Pollution Source Study Guidelines for Stationary and Mobile Sources to BAPEDAL.

The estimated total annual fuel consumption in Jabotabek in 1995 is shown in Table 4.1.3.

Table 4.1.3 Estimated Total Annual Fuel Consumption in Jabotabek in 1995

Source	Fuel	Unit	Estimated Consumption Rate in JABOTABEK
Stationary Sources	Kerosene	kl/year	2,227,140
	High Speed Diesel	kl/year	1,520,070
	Industrial Diesel Oil	kl/year	763,825
	Marine Fuel Oil	kl/year	498,109
	Coal	ton/year	1,647,263
	Natural gas	$1,000m^3$/year	4,741,679
	LPG	ton/year	233,161
Automobiles	Premium	kl/year	2,477,500
	Solar	kl/year	1,480,700

Table 4.1.4 shows the share of factories and households in the total consumption of kerosene and LPG. These fuels are used mainly by households.

Table 4.1.4 Share of Factories and Households in Consumption of Kerosene and LPG

Fuel	Factories	Households	Total
Kerosene (kl/year)	17,475	2,209,665	2,227,140
LPG(ton/year)	77,171	155,990	233,161

The estimated total air pollutant emissions in 1995 are summarized in Table 4.1.5. The total emission in 1995 is 56,000 tons for SOx, 144,000 tons for NOx, and 24,000 tons for PM. CO and HC emissions by automobiles are 564,000 tons for CO and 98,000 tons for HC.

Table 4.1.5 **Estimated Air Pollutant Emissions by Source in Jabotabek (1995)**

(Unit : ton/year)

		SOx	NOx	PM	CO	HC
Stationary Sources	Factories	42,697	36,832	13,581		
	Households	4,220	4,962	642		
	Sub-total	46,917	41,794	14,223		
Mobile Sources	Automobiles	8,142	98,738	9,563	564,292	97,971
	Ships	808	1,960			
	Aircraft	91	1,026			
	Sub-total	9,041	101,724	9,563	564,292	97,971
Total		55,958	143,518	23,786	564,292	97,971

4.2 Fuel Study

BAPEDAL and the Team collected existing data on fuels used in Jabotabek and analyzed the components of common fuels used by factories, automobiles, and households. The fuel consumption data were used to estimate the current fuel consumption in Jabotabek. The fuel analysis result was used to estimate emission factors and exhaust gas volumes from stacks.

4.2.1 1995 Fuel Consumption in Jabotabek

Fuel consumption by factory, household and automobile was estimated from statistical data and the results of questionnaire survey. The estimating procedure is shown in Appendix 3.1.

(1) Factories

Main fuels used in Jabotabek by factories are High Speed Diesel (Minyak solar), Industrial Diesel Oil (Minyak diesel), Marine Fuel Oil (Minyak bakar) , natural gas and coal. The estimated consumption of the main fuels in 1995 is shown in Table 4.2.1. This table also shows the coverage rate of the fuel consumption by factories responded to the questionnaire survey to the total fuel consumption in Jabotabek. The consumption of MFO and coal is fully covered by the questionnaire factories. However, the coverage rates of HSD, IDO, kerosene and LPG are low at less than 20%. Table 4.2.2 and Figure 4.2.1 show the share in energy of each fuel (calorific value is shown in Table 4.2.5). The share of natural gas is highest at 51%, followed by HSD (18%), and coal (16%).

Table 4.2.1 Total Fuel Consumption by Factories and Coverage Rate by Factories under Questionnaire Survey

Fuel	Unit	Consumption by questionnaire factories	Total consumption in Jabotabek	Coverage rate (%)
Kerosene	Kl/year	894	17,475	5.1
HSD	Kl/year	295,886	1,520,070	19.5
IDO	Kl/year	153,021	763,825	20.0
MFO	Kl/year	498,109	498,109	100.0
Coal	ton/year	1,647,263	1,647,263	100.0
Natural gas	1,000m^3/year	4,059,741	4,741,679	85.6
LPG	ton/year	559	77,171	0.7

Table 4.2.2 Total Fuel Consumption by Factories and Their Energy Share in Jabotabek in 1995

Fuel	Total annual consumption	Total energy (10^{12} kcal)	Energy share (%)
Kerosene	17,475 (kl/year)	0.2	0.2
HSD	1,520,070 (kl/year)	12.8	17.6
IDO	763,825 (kl/year)	6.4	8.7
MFO	410,190 (kl/year)	3.9	5.4
Coal	1,647,263 (ton/year)	11.6	16.0
Natural gas	4,741,679 (1,000m^3/year)	37.1	51.0
LPG	77,171 (ton/year)	0.9	1.3
Total		72.8	100.0

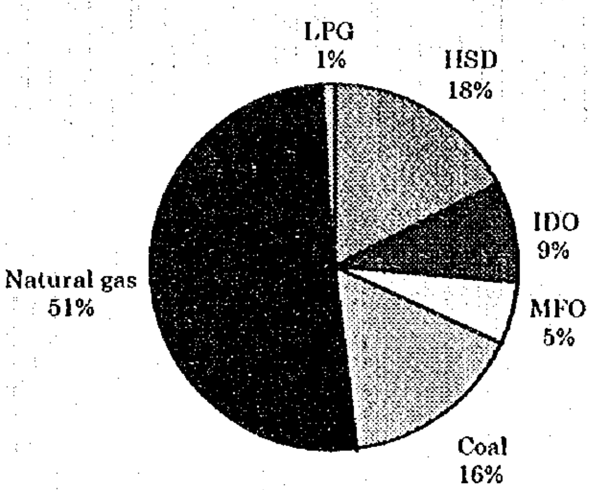

Figure 4.2.1 Shares of Fuels in Industry in 1995

(2) Households

Major fuels used by households in Jabotabek are kerosene and LPG. Table 4.2.3 shows fuel consumption by households in 1995. Energy shares are 91% for kerosene and 9% for LPG.

Table 4.2.3 Fuel and Energy Consumption by Households in 1995

Fuel	Total annual consumption*	Total energy (10^{12} kcal)	Energy share (%)
Kerosene	2,209,665 (kl/year)	19.7	91.4
LPG	155,990 (ton/year)	1.8	8.6
Total		21.6	100.0

(3) Automobiles

In Jabotabek, Solar is used by diesel vehicles and main fuel for gasoline vehicles is Premium gasoline. The estimated consumption of Premium and Solar is summarized in Table 4.2.4. The estimated annual consumption in 1995 is 2.5 million kl for Premium and 1.5 million kl for Solar.

Table 4.2.4 Annual Fuel Consumption of Vehicles in Jabotabek in 1995

Fuel	Total consumption (kl/year)
Solar	1,480,700
Premium	2,477,500

4.2.2 Fuel Analysis

Fuels used in Jabotabek were analyzed to estimate air pollutant emissions and exhaust gas volumes from stacks. Sulfur content of liquid fuels was analyzed at EMC. Other properties of liquid fuels and gas fuels were analyzed at LEMIGAS. Coal and its unburned residue were analyzed in Japan.

(1) Fuel Characteristics

Table 4.2.5 shows the analysis results of liquid, solid and gas fuels. The main items analyzed for fuels for stationary sources include contents of S, C, H, N, gross heating value, and specific gravity. The items of fuel analysis for automobiles include contents of S and lead and specific gravity. Tables 4.2.6 and 4.2.7 show average sulfur contents for stationary sources and automobiles respectively. For the fuels used by factories, sulfur content of MFO is highest at 2.23%, followed by coal (0.95%) and IDO (0.54%). With the fuels for automobiles, sulfur in Solar is high at about 0.4% while that of gasoline is less than 0.02%.

Table 4.2.5 Characteristics of Fuels Used in Jabotabek (1/2)

(Fuels used by factories and households)

Fuel	No.	wt% S	C	H	N	O	F (*1)	H_2O	Ash	Gross heating value (kcal/kg)	Specific gravity
Kerosene	1	0.09	85.79	13.97	0.12			0.10		10,296	0.867
	2	0.12									
HSD	1	0.19	85.54	13.44	0.09					10,352	0.813
	2	0.40									
	3	0.24									
	4	0.23									
IDO	1	0.54	85.44	13.56	0.01					10,410	0.800
	2	0.55									
	3	0.52									
MFO	1	2.46	84.56	13.45	0.17			0.20	0.03	10,160	0.947
	2	1.94									
	3	2.36									
	4	2.14									
Waste oil	1	0.56	73.06	11.01	0.21			12.50	3.35	10,565	0.934
IDO and MFO	1	1.60									
MFO and Black liquor	1	0.34	84.51	12.92	0.12				0.01	10,543	0.830
Coal	1	1.27	66.76	5.56	1.17	10.74	168	2.40	12.10	6,810	
	2	0.97	66.51	5.63	1.26	11.27	134	2.90	11.46	7,050	
	3	0.97	69.67	5.72	1.26	12.40	168	3.10	6.88	7,330	
	4	0.49	71.74	4.70	1.47	8.82	168	2.00	10.78	7,070	
	5	1.06	68.52	5.60	1.25	11.10	123	3.50	8.97	7,060	
Natural gas	1	<100 ppb	72.57	23.60	0.95	2.85		0.03		11,264	0.695(*2)
LPG	1	41 ppb (*3)	82.53	16.44	<0.01			0.05		11,848	0.559
	2	41 ppb (*3)	81.98	16.36	<0.01			0.04		11,846	0.559

Note : (*1) unit is mg/kg, (*2) unit is kg/m^3, and (*3) data source is PERTAMINA.

Table 4.2.5 Characteristics of Fuels Used in Jabotabek (2/2)

(Fuels used by automobiles)

Fuel	No.	S (wt%)	Specific gravity	Reid vapor pressure	Lead metal g/l
Premium	1	0.011	0.735	7.4	0.09
	2	0.032			
	3	0.008			
	4	0.008			
Premix	1	0.026	0.737	7.8	0.27
	2	0.012			
Super TT	1	0.012	0.735	6.9	<10ppb
	2	0.004			
Solar	1	0.398	0.848		
	2	0.391	0.852		
	3	0.398	0.846		

Table 4.2.6 Average Sulfur Content of Fuels for Stationary Sources

Fuel	Average sulfur content (wt%)
Kerosene	0.11
HSD	0.27
IDO	0.54
MFO	2.23
Coal	0.95

Table 4.2.7 Average Sulfur Content of Fuels for Motor Vehicles

Fuel	Average sulfur content (wt%)
Premium	0.015
Premix	0.019
Super TT	0.008
Solar	0.396

(2) Unburned Residue of Coal

Analysis results of unburned residue of coal are shown in Table 4.2.8. The fact that unburned carbon remains at more than 10% of the total residue shows coal boilers are not operated efficiently.

Table 4.2.8 Analysis Results of Unburned Residue of Coal

Sample No.	(wt%)			Gross heating value (kcal/kg)
	C	H	S	
1	13.1	0.9	0.2	1,470
2	17.3	0.9	0.1	1,440
3	9.9	0.4	0.1	604

4.3 Emission from Stationary Sources

4.3.1 Questionnaire Survey

(1) Outline of the Survey

There are about 2,000 factories in Jabotabek as listed in "Indonesian Manufacturer Directory, 1993/1994" (Ref. 93). Their breakdown by industry type and by district is shown in Table 4.3.1. The main industries by number in Jabotabek are textiles, chemicals and machinery.

Table 4.3.1 Number of Factories in Jabotabek (1993/1994)

Code	Industry	DKI Jakarta	Bogor	Tange-rang	Bekasi	Total
31	Food, beverages and tobacco	97	38	36	19	190
32	Textiles, clothing and leather	229	76	156	73	534
33	Wood and wood products including furniture	53	15	41	17	126
34	Paper and paper products, printing and publishing	29	3	33	17	82
35	Chemicals, petroleum, coal, rubber and plastic products	228	81	141	70	520
36	Non metallic mineral products, except petroleum and coal products	21	20	21	9	71
37	Basic metals	13	1	3	1	18
38	Fabricated metal products, machinery and equipment	220	58	119	68	465
39	Other manufacturing industries	20	6	16	13	55
40	Total	910	298	566	287	2061

Source : Indonesian Manufacturer Directory, 1993/1994 (Ref. 93)

BAPEDAL and the Team jointly selected from the above directory and other sources about 300 factories (manufacturing, electricity supply, hotels, and office buildings) and sent them a set of questionnaire sheets (see Appendix 3.2.1). The questionnaire items included facility type and its capacity, fuel type and its consumption, raw material and its consumption, yearly, monthly and daily operation duration, stack height, diameter and location, exhaust gas volume and temperature ,and exhaust gas treatment unit.

(2) Response to the Survey

Ninety one factories responded to the questionnaire survey. Table 4.3.2 shows the regional distribution of the responding factories by industrial type. By region, DKI Jakarta accounts for 48 (53%), Bogor 14 (15%), Tangerang 13 (14%), and Bekasi 16 (18%). By industry type, the top three are textiles (10), hotels (9), and drinks (8).

Table 4.3.2 Regional Distribution of Responding Factories by Industry Type

Industry	DKI Jakarta	Bogor	Tangerang	Bekasi	Total
Foods	0	1	1	2	4
Drinks	6	1	0	1	8
Textile	1	4	3	2	10
Pulp and paper	0	1	4	2	7
Pesticide	1	0	0	0	1
Plastics	1	1	0	1	3
Chemical	1	1	2	0	4
Medicine	4	1	0	1	6
Cosmetics	5	0	1	0	6
Shoes	0	0	0	2	2
Glass and ceramics	3	1	2	1	7
Cement	0	2	0	0	2
Iron and steel	5	0	0	1	6
Assembling	1	0	0	3	4
Battery	2	1	0	0	3
Electricity supply	2	0	0	0	2
Hotel	9	0	0	0	9
Office building	7	0	0	0	7
Total	48 (53)	14 (15)	13 (14)	16 (18)	91

Note : Figures in brackets are % values.

The ratio of responding manufacturing factories to the questionnaire by industrial type is shown in Table 4.3.3. The ratio of non metallic mineral products industry is the highest at 33%, followed by chemicals (13%), and paper (9%).

Table 4.3.3 Number of Responding Factories by Industrial Type

Industry		Response	Total	Ratio (%)
Manufac-turing	Food, beverages and tobacco	12	190	6.3
	Textiles, clothing and leather	10	534	1.9
	Wood and wood products including furniture	0	126	0.0
	Paper and paper products, printing and publishing	7	82	8.5
	Chemicals, petroleum, coal, rubber and plastic products	22	520	4.2
	Non metallic mineral products, except petroleum and coal products	9	71	12.7
	Basic metals	6	18	33.3
	Fabricated metal products, machinery and equipment	7	465	1.5
	Other manufacturing industries	0	55	0.0
	Sub total	73	2061	3.5
Energy	Electricity supply	2		
Services	Hotel	9		
	Office building	7		
Total		91		

(3) Results of Questionnaire Survey

1) Facility Type

The 91 responding factories have a total of 309 air polluting facilities as shown in Table 4.3.4. There are many kinds of facilities such as boiler (147), generator (86), melting furnace (18), and burning kiln (17). Boiler and generator are the major facilities and their combined share is 75% of the total.

2) Boiler Capacity

Table 4.3.5 gives the distribution of general boilers (excluding those for power generation) by steam capacity. Boilers in Jabotabek are generally small and those with a capacity of less than 5 tons/h account for 49% of the total.

3) Generator Capacity

Table 4.3.6 shows the distribution of generators by power generation capacity. They are, in general, small and those with a capacity of less than 3,000 kVA account for 83% of the total.

Table 4.3.4 Numbers of Facilities in Responding Factories

Facility	Usage	Number	Share (%)
Boiler	utility	5	1.6
	general	142	46.0
	subtotal	147	47.6
Generator	utility	86	27.8
Diesel engine	fire pump	1	0.3
Gas turbine	utility	4	1.3
Combined cycle	utility	1	0.3
Electric furnace	iron scrap	3	1.0
Melting furnace	glass	10	3.2
	zinc	5	1.6
	aluminum	1	0.3
	lead	2	0.6
	subtotal	18	5.8
Reheating furnace	billet	4	1.3
Heat treating furnace	glass	1	0.3
	aluminum	1	0.3
	subtotal	6	1.9
Absorption facility	sulfuric acid	2	0.6
Burning kiln	cement	11	3.6
	tile	2	0.6
	ceramic ware	4	1.3
	subtotal	17	5.5
Oven	food	4	1.3
	plastic materials	4	1.3
	subtotal	8	2.6
Dryer	paint banking	7	2.3
	detergent	2	0.6
	clay	2	0.6
	subtotal	11	3.6
Industrial waste incinerator	waste	4	1.3
	sludge	1	0.3
	subtotal	5	1.6
Total		309	100.0

Table 4.3.5 **Distribution of Boilers by Steam Generating Capacity**

Capacity (ton/h)	Number	Rate (%)
0 - 1	12	8.5
1 - 2	23	16.2
2 - 3	16	11.3
3 - 4	16	11.3
4 - 5	2	1.4
subtotal	(69)	(48.6)
5 - 6	10	7.0
6 - 7	12	8.5
7 - 8	2	1.4
8 - 9	4	2.8
subtotal	(28)	(19.7)
10 - 11	17	12.0
11 -12	3	2.1
12 -13	5	3.5
subtotal	(25)	(17.6)
15 -16	2	1.4
26 -27	1	0.7
30 -31	4	2.8
subtotal	(7)	(4.9)
Total	142	100.0

Table 4.3.6 Distribution of Generators by Power Generation Capacity

Capacity (kVA)	Number	Rate (%)
<500	19	22
<1,000	20	23
<2,000	33	38
<3,000	8	9
<4,000	1	1
<5,000	0	0
<6,000	0	0
<7,000	5	6
TOTAL	86	100

4) Fuel Consumption

Table 4.3.7 shows the main fuel consumption by facility type. The annual consumption is 296,000 kl for HSD, 153,000 kl for IDO, 498,000 kl for MFO, 1,650,000 tons for coal, 4,060 million m^3 for natural gas, and 600 tons for LPG. Utility boilers use MFO and natural gas. General boilers use various kinds of fuels. Main fuel of generator is HSD. Glass melting furnace uses MFO. Main fuel of cement kiln is coal.

Table 4.3.7 Main Fuel Consumption by Facility Type

Facility	Usage	HSD (kl)	IDO (kl)	MFO (kl)	Kerosene (kl)	Coal (ton)	Natural gas (1,000m^3)	LPG (ton)
Boiler	utility			357,413			748,333	
	general	20,406	77,303	50,201	744	9,400	157,023	
	subtotal	20,406	77,303	407,614	744	9,400	905,356	
Generator	utility	273,124	21,237					
Diesel engine	fire pump							
Gas turbine	utility						1,992,418	
Combined cycle	utility						978,858	
Electric furnace	iron scrap		1,800				1,680	
Melting furnace	glass			90,496				
	zinc		625					
	aluminum	532						15
	lead							366
	subtotal	532	625	90,496				381
Reheating furnace	billet		26,406				3,120	
Heat treating furnace	glass						3,486	
	aluminum	266						
	subtotal	266						
Absorption facility	sulfuric acid							
Burning kiln	cement		25,650			1,637,863	36,317	
	tile						720	
	ceramic ware						108,785	
	subtotal		25,650			1,637,863	145,822	
Oven	food	156			150		1	
	plastic materials						1,000	
	subtotal	156			150		1,001	
Dryer	paint baking	295						178
	detergent	1,058						
	clay						28,000	
	subtotal	1,353					28,000	178
Industrial waste incinerator	waste	5						
	sludge	44						
	subtotal	49						
Total		295,886	153,021	498,109	894	1,647,263	4,059,741	559

Table 4.3.8 shows the main fuel consumption by industry type. Electricity supply industry is the main user of MFO and natural gas. Cement industry is the dominant user of coal.

Table 4.3.8 Main Fuel Consumption by Industry Type

Industry	HSD (kl)	IDO (kl)	MFO (kl)	Kerosene (kl)	Coal (ton)	Natural gas (1,000m^3)	LPG (ton)
Foods	729	192		150		5,848	
Drinks	11,976	2,284	2,112			12,016	
Textile	232,246	74,426	15,734		8,500	33,336	
Pulp and paper	14,280	7,764	14,000	715	900	98,135	
Chemical	1,822		1,150				
Medicine	1,602						
Cosmetics	812	75	1,632	29			
Pesticide	17						
Plastics		10,343				5,000	
Shoes	8,168						
Glass and ceramics	578		90,496			140,991	
Cement		25,650			1,637,863	36,317	
Iron and steel	312	28,206				5,000	
Battery	461	625					366
Assembling	16,808		15,573				193
Electricity supply			357,413			3,719,609	
Hotel	3,272	3,456				3,490	
Office building	2,804						
Total	295,886	153,021	498,109	894	1,647,263	4,059,741	559

5) Stack Height

Table 4.3.9 shows distribution of stack heights of the surveyed factories. They are generally low. Of the total number of 385 stacks, 159 stacks are lower than 10 m and 133 stacks are between 10 m and 20 m high. Stacks lower than 20 m account for 76% of the total.

Table 4.3.9 Distribution of Stack Heights from the Ground

Height (m)	Number	Rate (%)
0 - 10	159	41.3
10 - 20	133	34.5
20 - 30	36	9.4
30 - 40	15	3.9
40 - 50	8	2.1
50 - 60	9	2.3
60 - 70	9	2.3
70 - 80	7	1.8
80 - 90	0	0.0
90 - 100	3	0.8
100 - 110	4	1.0
110 - 120	2	0.5
Total	385	100.0

6) Treatment Units

A total number of 22 facilities are equipped with dust treatment units (Table 4.3.10). Utility boilers (electricity supply) have cyclones. Electric (arc) furnaces and cement kilns are furnished with baghouses and electric precipitators respectively.

Table 4.3.10 Facilities and Treatment Units

Facility	Usage	Cyclone	Scrubber	Baghouse	Electric precipitator	Total
Boiler	Utility	5				5
Boiler	General	1				1
Electric furnace	Billet			2		2
Burning kiln	Cement				11	11
Dryer	Detergent	1		1		2
Incinerator	Industrial Waste		1			1
Total		7	1	3	11	22

7) Coverage Rate of Fuel Consumption

The coverage rate of fuel consumption by the surveyed factories to the total fuel consumption by factories in Jabotabek was examined in Section 4.2.1. The coverage rate of MFO and coal is 100%, which means their major consumers responded to the questionnaire. The coverage rate of natural gas is fairly high at 86% because the electricity supply industry is its dominant user. However, coverage rates of HSD, IDO, kerosene and LPG are below 20%, which shows many other factories are using these fuels.

4.3.2 Emission Measurement

To know the air pollutant emission and combustion condition of air polluting facilities in Jabotabek, BAPEDAL and the Team conducted a total of 36 emission measurements. The numbers by industry type are shown in Table 4.3.11. The measurement items and methods are shown in Table 4.3.12.

Table 4.3.11 Numbers of Measured Facilities by Industry Type

Type of Industry	Facility Code No.	Total
Foods	21, 34, 35	3
Drinks	9, 11, 12, 13, 14, 15	6
Textile	18, 26, 27, 28, 31	5
Pulp and Paper	2, 3, 4, 6, 19, 22, 30	7
Chemical	20	1
Medicine	17, 23	2
Cosmetics	16	1
Plastics	36	1
Glass and Ceramics	5, 29	2
Cement	7, 8	2
Iron and Steel	1	1
Battery	25	1
Assembling	24	1
Electricity Supply	32, 33	2
Hotel	10	1
Total		36

Table 4.3.12 Measurement Items and Methods

Item	Measurement Method
Dust, etc.	JIS Z 8808 Method of measuring dust density in exhaust gas
SOx	JIS K 0103 Method of analyzing SOx in exhaust gas
NOx	JIS K 0104 Method of analyzing NOx in exhaust gas
O_2	Automatic measurement by (galvani) battery type
CO	Automatic measurement by fixed potential electrolysis type
CO_2	Automatic measurement by heat conduction degree operation type

(1) Measurement Results

The measurement results by facility and fuel are shown in Table 4.3.13. The results are summarized below:

1) Facility Kind

The facilities measured include 21 general boilers, 2 utility boilers (power plants), 6 generators, 2 cement kilns, 3 melting furnaces, 1 electric arc furnace and 1 drying tower.

2) Dust Concentration

Concentration of dust ranges from 0.00061 to 0.93 g/m^3N. The big differences in concentration are due to differences in their facility kinds. Definitions of PM and Dust are shown in Appendix 2.3.

3) SOx Concentration

Concentration of SOx is from 25 to 1,100 ppm in boilers, from 87 to 100 ppm in cement kilns, from 37 to 250 ppm in generators, from Non Detection (N.D.). to 690 ppm in utility boilers, and from N.D. to 1,100 ppm in melting furnaces. The SOx levels in boilers using natural gas, electric arc furnaces and drying towers are under the detection limit.

4) NOx Concentration

Concentration of NOx is from 22 to 162 ppm in boilers, from 105 to 107 ppm in cement kilns, 18 ppm in drying tower, from 50 to 410 ppm in generators, from 105 to 188 ppm in utility boilers, and from N.D. to 370 ppm in melting furnaces. The level in electric arc furnaces is under the detection limit.

5) O_2

O_2 concentration is from 3.0 to 16.7% in boilers, from 10.2 to 12.0% in cement kilns, 18.4% in electric arc furnaces, 19.5% in drying towers, from 8.1 to 15.1% in generators, from 5.2 to 5.5% in utility boilers, and from 8.3 to 20.3% in melting furnaces.

Table 4.3.13 Emission Measurement Results by Facility and Fuel Type (1/3)

Boiler (* : 4 main industries subject to BAPEDAL emission regulations)

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
2. Paper*	0.18	1,100	147	4.5	13,000	11,300	MFO	1,500 l/h
9. Beer	0.074	390	162	6.0	3,100	2,800	MFO	320 l/h
13. Milk	0.017	350	113	6.1	10,600	9,300	MFO	708 l/h
26. Textile	0.038	660	98	9.3	10,400	9,200	MFO	458 l/h
30. Paper*	0.12	430	67	12.8	59,200	51,600	MFO	1,470 l/h
31. Textile	0.25	1,100	143	6.9	3,800	3,400	MFO	145 l/h

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
4. Paper*	0.012	170	62	9.2	7,400	6,400	IDO	271 l/h
6. Paper*	0.17	57	40	11.5	8,100	6,700	IDO	500 l/h
10. Hotel	0.088	73	36	16.7	9,000	8,400	IDO	56 l/h × 3 units
15. Beer	0.021	37	72	7.9	2,100	1,900	IDO	162 l/h

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
16. Cosmetics	0.015	82	51	3.0	830	730	HSD	85 l/h
17. Medicine	0.0039	N.D	22	11.0	1,100	1,000	HSD	90 l/h
23. Medicine	0.012	98	24	6.9	4,300	3,900	HSD	390 l/h
24. Mobile	0.0048	37	146	6.3	3,500	3,200	HSD	132 l/h
35. Food	0.023	93	61	10.4	1,200	1,100	HSD	50 l/h

Table 4.3.13 Emission Measurement Results by Facility and Fuel Type (2/3)

Boiler

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
18. Textile	0.39	62	53	14.2	15,300	14,300	Coal	833 kg/h
19. Paper*	0.27	99	106	11.1	9,700	8,900	Coal	240 kg/h

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
21. Instant Noodle	0.0037	N.D	43	7.7	2,400	1,800	NG	780 m^3/h
27. Textile	0.0050	N.D	54	8.1	4,800	3,600	NG	486 m^3/h
34. Instant Food	0.00073	N.D	59	8.3	5,300	4,300	NG	520 m^3/h
22. Paper*	0.00061	25	37	10.1	3,200	2,900	Kerosene	167 L/h

Cement Kiln

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
7. Cement*	0.12	100	105	10.2	561,000	470,000	Coal	22,000 kg/h
8. Cement*	0.039	87	107	12.0	328,000	281,000	Coal	12,063 kg/h

Electric Arc Furnace

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
1. Steel*	0.11	N.D	N.D	18.4	23,000	21,200	-	-

Drying Tower

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas		Kind of Fuel	Fuel Consumption
					Wet (m^3_N/h)	Dry (m^3_N/h)		
20. Washing Soap	0.013	N.D	18	19.5	15,300	14,000	HSD	110 l/h

Table 4.3.13 Emission Measurement Results by Facility and Fuel Type (3/3)

Generator

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas Wet (m^3_N/h)	Amount of exhaust gas Dry (m^3_N/h)	Kind of Fuel	Fuel Consumption
3. Paper*	0.37	250	410	15.1	6,500	5,900	HSD	450 l/h
11. Milk	0.012	37	341	9.0	2,400	2,200	HSD	144 l/h
12. Milk	0.60	98	140	10.2	3,300	3,000	HSD	150 l/h
14. Milk	0.93	79	150	8.1	1,900	1,700	HSD	75 l/h
28. Textile	0.029	81	82	13.9	5,800	5,400	HSD	164 l/h × 4 units
36. Plastic & Leather	0.051	42	50	13.1	2,200	2,000	HSD	115 l/h

Power Plant

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas Wet (m^3_N/h)	Amount of exhaust gas Dry (m^3_N/h)	Kind of Fuel	Fuel Consumption
32. Power Plant	-	690	188	5.5	977,000	874,000	MFO	26,000 l/h
33. Power Plant	0.0040	N.D	105	5.2	1,185,000	1,000,000	NG	47,500 m^3/h

Melting Furnace

Type of Industry	Dust (g/m^3_N)	SO_x (ppm)	NO_x (ppm)	O_2 (%)	Amount of exhaust gas Wet (m^3_N/h)	Amount of exhaust gas Dry (m^3_N/h)	Kind of Fuel	Fuel Consumption
5. Glass	0.13	370	370	8.3	60,800	54,700	MFO	1,200 l/h
25. Battery	0.017	N.D	N.D	20.3	1,300	1,200	-	-
29. Glass Sheet	0.35	1,100	91	10.2	61,400	52,700	MFO	11,600 l/h

(2) Comparison with the National Emission Standards

During the Study, spot data, one datum for one facility, were obtained through cooperative efforts of the Indonesian counterparts and the Team members. Although the stipulations of Decree KEP-13/MENLH/3/1995 request continuous or substantially frequent measurements of all parameters including particulates, the comparison with the emission standards is carried out on spot data. The comparison ratios obtained are given in Table 4.3.14. Generators (Gener) found in factories and offices of Jabotabek are classified as Power Boiler Sources in the table.

Calculation of the ratio is straightforward, assuming that all gases concerned comply with the Ideal Gas Law. Following are equations applied to calculate the ratios.

Gas Z ppm to Y mg/m^3_S at O_{2M} : $Y = Z \times MW \times 273 / (22.4 \times 298)$

$MW = 64$ for SO_2, and 46 for NOx

$_S$: Gas @ 25℃, 1 atm.A

$_N$: Gas @ 0℃, 1 atm.A

TSP X mg/m^3_N at O_{2M} to W mg/m^3_S at O_{2M} : $W = X \times 273 / 298$

Oxygen correction : Y' (or W') mg/m^3_S at $O_{2D} = Y(\text{or } W) \times (21 - O_{2D}) / (21 - O_{2M})$

O_{2M} : O_2 %vol when measured

O_{2D} : O_2 %vol specified in the Decree

Where no O_2 correction given in the Decree: Y' (or W') = Y (or W)

Ratio = Y' (or W') ÷ Maximum Limit specified in the Decree (mg/m^3)

As shown in Table 4.3.14, 3 facilities for SO_2 and 1 facility for NOx of the 7 facilities in pulp & paper industries have concentrations exceeding the national emission standards. Also 2 facilities for TSP and 4 facilities for SO_2 among the 26 facilities in all other industries have concentrations exceeding the emission standards.

Table 4.3.14 Ratios of Measured Data to the National Emission Standards

(Ratio over 1.0 = exceeding the standards; Only one spot measurement)

Iron and Steel Industries

Facility No.	Sources	TSP	SO_2	NOx
1	E.A.F.	0.168	-	-

Pulp and Paper Industries

Facility No.	Sources	TSP	SO_2	NOx	Facility No.	Sources	TSP	SO_2	NOx
2	Boiler	0.412	2.036	0.168	3	Gener	0.339	1.295	1.307
4	Boiler	0.027	0.440	0.099	6	Boiler	0.574	0.183	0.079
19	Boiler	0.618	0.305	0.201	22	Boiler	0.001	0.070	0.064
30	Boiler	0.469	1.602	0.154					

Coal Fired Steam Power Plants - No applicable data available

Cement Industries

Facility No.	Sources	TSP	SO_2	NOx	Facility No.	Sources	TSP	SO_2	NOx
7	Kiln	0.95	0.226	0.143	8	Kiln	0.37	0.236	0.174

All Other Industries - (Without O_2 correction)

Facility No.	Sources	TSP	SO_2	NOx	Facility No.	Sources	TSP	SO_2	NOx
5	Melt.F	0.328	0.712	0.451	9	Boiler	0.169	0.681	0.179
10	Boiler	0.202	0.127	0.040	11	Gener	0.027	0.065	0.377
12	Gener	1.374	0.171	0.155	13	Boiler	0.039	0.611	0.125
14	Gener	2.130	0.138	0.166	15	Boiler	0.048	0.065	0.079
16	Boiler	0.034	0.143	0.056	17	Boiler	0.009	0.000	0.024
18	Boiler	0.893	0.108	0.059	20	Dryer	0.030	0.000	0.020
21	Boiler	0.008	0.000	0.048	23	Boiler	0.027	0.170	0.026
24	Boiler	0.011	0.065	0.162	25	Melt.F	0.039	0.000	0.000
26	Boiler	0.087	1.152	0.108	27	Boiler	0.011	0.000	0.060
28	Gener	0.066	0.141	0.091	29	Melt.F	0.802	1.920	0.101
31	Boiler	0.573	1.920	0.158	32	Boiler	0.000	1.204	0.208
33	Boiler	0.009	0.000	0.116	34	Boiler	0.002	0.000	0.065
35	Boiler	0.053	0.162	0.068	36	Gener	0.117	0.073	0.055

(3) Major Findings from the Emission Measurement

According to the results of the above-mentioned measurement, some emission tendencies related to stationary sources in Jabotabek could be generally summarized as below.

Fuels for boilers can be classified into MFO, IDO, HSD, coal and NG. The larger-scale boiler facilities have significant adverse impacts on air, since they usually not only use MFO containing much sulfur but also consume it to a great extent. In particular, concentrations of dust and SOx are high. On the other hand, the boiler facilities in smaller scales have given low concentrations of dust and SOx, as they use HSD.

As for the facilities consuming NG, concentration levels of dust and SOx are low so that their impacts on the air are considerably small. However, an appropriate management for fuel combustion control is still desirable for these facilities. It is because their NOx-concentration levels largely differ depending on applied combustion methods although the results from the current measurement do not indicate such large concentration figures.

High dust/NOx-concentrations are found for the facilities with diesel generators, even though they use HSD as fuel. This is because their combustion systems are different from those of the boiler facilities.

The glass melting furnaces show high concentration levels of dust and SOx, since they also use MFO.

4.3.3 Air Pollutant Emissions from Factories

(1) Outline of Estimating Method

BAPEDAL and the Team obtained responses from 91 factories to the questionnaire. However, as shown in Section 4.2, consumption of HSD, IDO, kerosene, natural gas and LPG by the responding factories did not fully cover their total consumption by all the factories in Jabotabek. Emissions from "unsurveyed factories" by combustion of the remaining amounts of these fuels were estimated as shown in Figure 4.3.1.

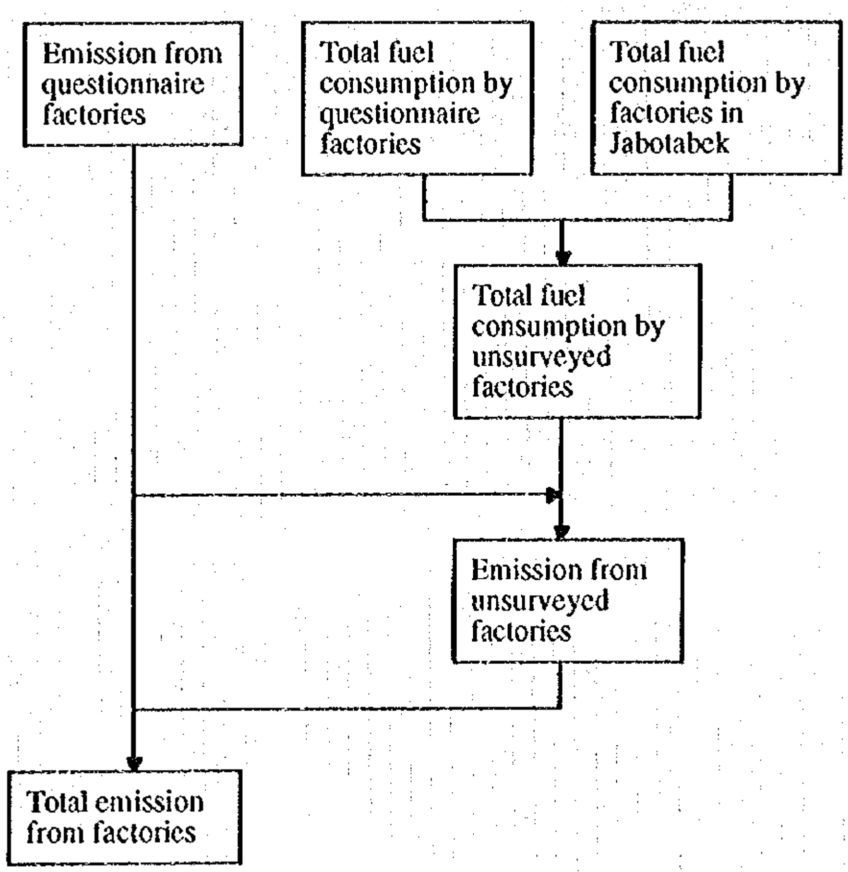

Figure 4.3.1 Procedure for Estimating of Total Emission from Factories in Jabotabek

(2) Estimate of Emissions from Factories Responding to Questionnaire Survey

1) Setting of Emission Factors

Emission factors were determined from the results of the flue gas measurement and published emission factors in USA and Japan. The results of the fuel analysis were also used. The emission factors for SOx, NOx and PM are shown in Appendix 3.2.3.

2) Estimated Air Pollutant Emission

Estimated emissions from factories of SOx, NOx and PM by facility type are shown in Table 4.3.15. For SOx, boiler (mainly utility boiler) is the biggest polluter. For NOx, gas turbine, cement kiln, combined cycle and utility boiler are the major polluting facilities. For PM, cement kiln, generator and electric furnace are the major contributors.

Table 4.3.16 shows emissions by industry. For SOx and NOx, electricity supply industry is the biggest polluter. For PM, cement, iron and steel and textile industries are the main contributors.

Table 4.3.15 Air Pollutant Emissions by Facility Type

(Unit : ton/year)

Facility	Usage	SOx	NOx	PM before treatment	PM after treatment
Boiler	utility	15,096	3,627	690	207
	general	3,171	659	292	272
	subtotal	18,267	4,286	982	479
Generator	utility	1,427	1,495	1,507	1,507
Diesel engine	fire pump	0	0	0	0
Gas turbine	utility	0	11,038	371	371
Combined cycle	utility	0	5,423	182	182
Electric furnace	iron scrap	16	41	8,344	1,483
Melting furnace	glass	4,969	644	468	468
	zinc	5	1	0	0
	aluminum	2	1	0	0
	lead	0	1	0	0
	subtotal	4,976	647	468	468
Reheating furnace	billet	228	50	9	9
Heat treating furnace	glass	0	4	0	0
	aluminum	1	1	0	0
	subtotal	1	5	9	9
Absorption facility	sulfuric acid	515	8	0	0
Burning kiln	cement	6,379	5,740	40,183	2,009
	tile	0	0	0	0
	ceramic ware	0	11	3	3
	subtotal	6,379	5,751	40,186	2,012
Oven	food	1	0	0	0
	plastic materials	0	1	0	0
	subtotal	1	1	0	0
Dryer	paint baking	1	0	0	0
	detergent	5	5	6	1
	clay	0	46	47	47
	subtotal	6	51	53	48
Total		31,817	28,796	52,102	6,560

Table 4.3.16 Air Pollutant Emissions by Industry Type

(Unit : ton/year)

Industry	SOx	NOx	PM	
			before treatment	after treatment
Foods	5	9	1	1
Drinks	163	82	52	52
Textile	2,506	1,493	1,418	1,398
Pulp and paper	873	310	148	148
Chemical	572	20	9	6
Medicine	7	4	3	3
Cosmetics	73	10	7	4
Pesticide	0	0	0	0
Plastics	89	49	42	42
Shoes	37	14	1	1
Glass and ceramics	4,972	707	521	521
Cement	6,379	5,740	40,183	2,009
Iron and steel	245	91	8,353	1,492
Battery	8	2	0	0
Assembling	734	144	103	103
Electricity supply	15,096	20,088	1,242	760
Hotel	45	16	5	5
Office building	13	14	14	14
Total	31,817	28,796	52,102	6,560

(3) Total Air Pollutant Emissions in Jabotabek

1) Air Pollutant Emissions from Unsurveyed Factories

As shown in Section 4.2.1, there are many unsurveyed factories. As a result, consumption of HSD, IDO, kerosene, natural gas and LPG in Jabotabek was not fully covered by the questionnaire survey. Here, in this Study, emissions from unsurveyed factories were estimated by using the ratio of fuel consumption between unsurveyed and surveyed factories (excluding electricity supply and cement industries). The estimated emissions from unsurveyed factories are 11,000 tons for SOx, 8,000 tons for NOx and 7,000 tons for PM (Table 4.3.17).

Table 4.3.17 Estimated Air Pollutant Emissions from Unsurveyed Factories

Fuel		Surveyed					
		HSD (kl/year)	IDO*1 (kl/year)	Kerosene (kl/year)	Natural*2 gas (1,000m³/year)	LPG (ton/year)	Total
	(A)	295,886	127,371	894	303,815	559	
Emission (ton/year) (B)	SOx	1,347	1,100	1.70	0	0	2,449
	NOx	1,429	299	1.24	256	0.67	1,986
	PM	1,403	214	0.01	56	0.47	1,673
Fuel		Unsurveyed					
		HSD	IDO	Kerosene	Natural gas	LPG	Total
	(C)	1,224,184	610,804	16,581	681,938	76,612	
Emission (ton/year) (D)	SOx	5,573	5,275	32	0	0	10,880
	NOx	5,912	1,434	23	575	92	8,036
	PM	5,805	1,026	0	126	64	7,021

Note : D = C/A * B

*1 IDO excludes consumption by cement industry

*2 Natural gas excludes consumption by cement and electricity supply industries

2) Total Emissions from Factories in Jabotabek

Total emissions by three industrial types (electricity supply, cement and other industries) are shown in Table 4.3.18. The annual total emissions from factories in Jabotabek are 43,000 tons for SOx, 37,000 tons for NOx and 14,000 tons for PM.

Table 4.3.18 Total Emissions from Factories in Jabotabek (1995)

(Unit : ton/year)

	SOx	NOx	PM
Electricity Supply	15,096	20,088	760
Cement	6,379	5,740	2,009
Other	21,222	11,004	10,812
Total	42,697	36,832	13,581

Figures 4.3.2~4.3.4 show the shares of electricity and cement industries to the total emissions. For SOx, the share of electricity supply industry is 35% and that of other industries is 50%. For NOx, electricity supply industry's share is 54% and that of other industries is 30%. For PM, the share of cement industry is 15% and that of other industries is 79%.

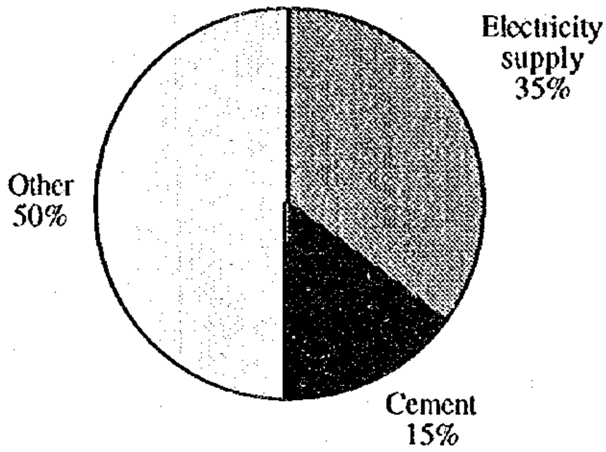

Figure 4.3.2 Shares by Industry to Total SOx Emissions

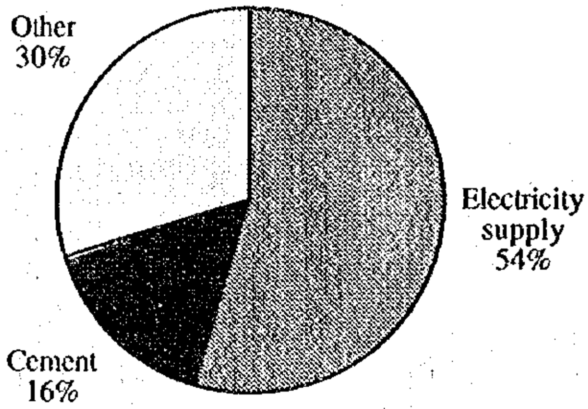

Figure 4.3.3 Shares by Industry to Total NOx Emissions

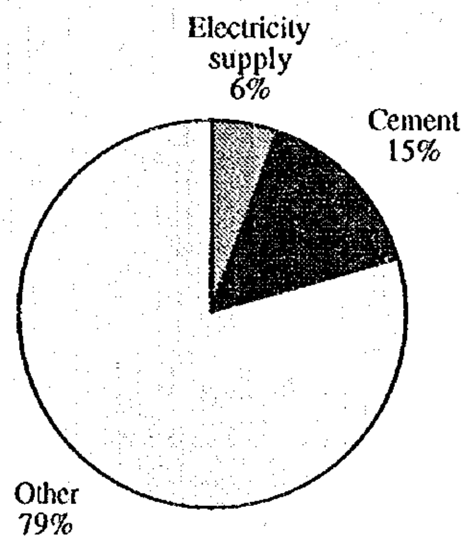

Figure 4.3.4 Shares by Industry to Total PM Emissions

3) Regional Distribution of Air Pollutant Emissions from Factories

Regional distribution of the emissions from factories was estimated by the procedure shown in Figure 4.3.5. In this Study, emissions from unsurveyed factories were evenly apportioned in Jabotabek area because of insufficient data on industrial zones in Botabek and factory distribution in Jabotabek. It should be noted that emissions from commercial activities were included in those from factories. Basic data on factories necessary for air dispersion simulation are shown in Appendix 3.2.4.

The estimated regional emissions of SOx, NOx and PM are shown in Table 4.3.19. The share of each district to the total emission is shown Table 4.3.20 and Figures 4.3.6. to 4.3.8. For SOx, the share of DKI Jakarta is the highest at 49%, followed by Bogor (30%). For NOx, DKI Jakarta's share is the highest at 58% followed by Bogor (27%). With PM, Bogor's share is high at 41% and that of the other districts is about 20%.

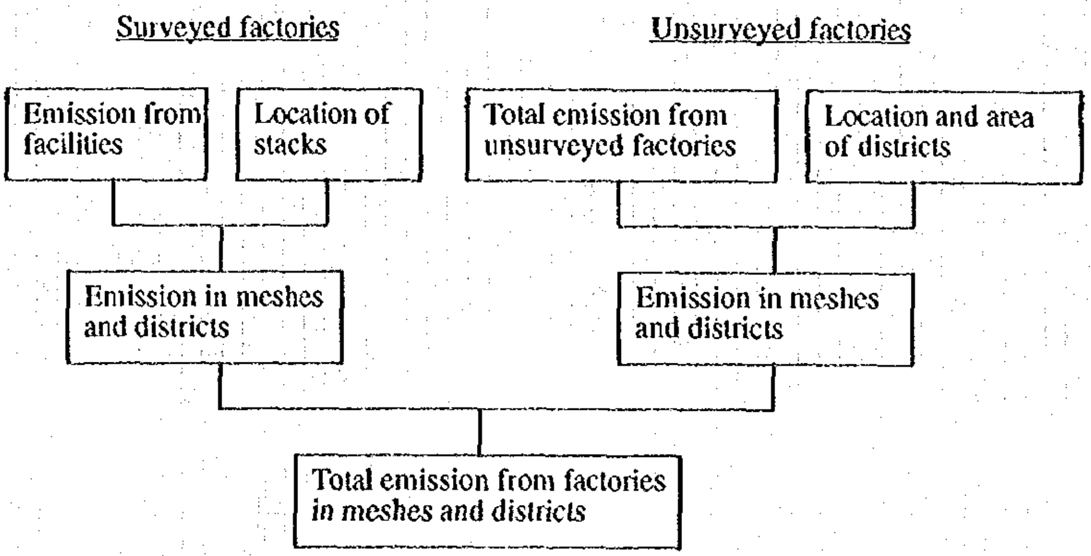

Figure 4.3.5 Procedure for Calculation of Regional Pollutant Emissions from Factories

Table 4.3.19 Air Pollutant Emissions from Factories by District (1995)

(ton/year)

District	Sources	SOx	NOx	PM
DKI Jakarta	Questionnaire	19,820	20,720	1,649
	Unsurveyed	1,055	779	681
	subtotal	20,875	21,499	2,330
Bogor	Questionnaire	7,413	5,971	2,168
	Unsurveyed	5,139	3,796	3,316
	subtotal	12,552	9,767	5,484
Tangerang	Questionnaire	2,545	1,538	1,421
	Unsurveyed	2,182	1,612	1,408
	subtotal	4,727	3,150	2,829
Bekasi	Questionnaire	2,039	567	1,321
	Unsurveyed	2,504	1,850	1,616
	subtotal	4,543	2,417	2,937
Jabotabek	Questionnaire	31,817	28,796	6,559
	Unsurveyed	10,879	8,036	7,021
	Total	42,697	36,833	13,580

Table 4.3.20 Shares by District to Total Emissions from Factories (1995)

(%)

District	SOx	NOx	PM
DKI Jakarta	48.9	58.4	17.2
Bogor	29.4	26.5	40.4
Tangerang	11.1	8.6	20.8
Bekasi	10.6	6.6	21.6

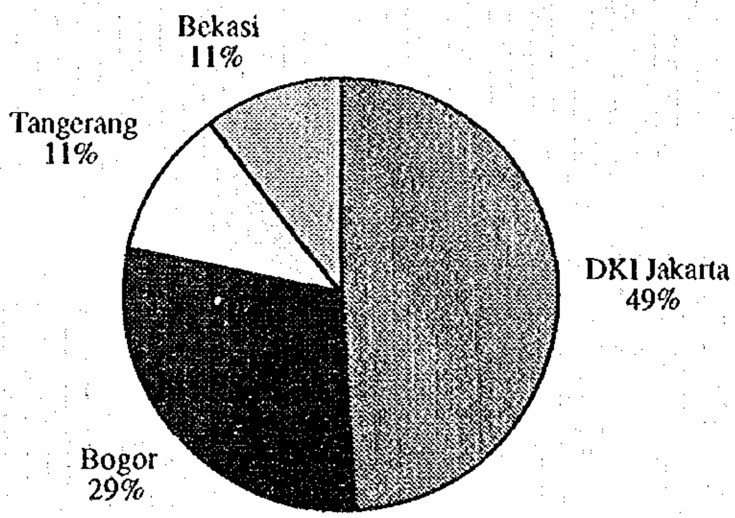

Figure 4.3.6 Shares by District to Total SOx Emissions from Factories

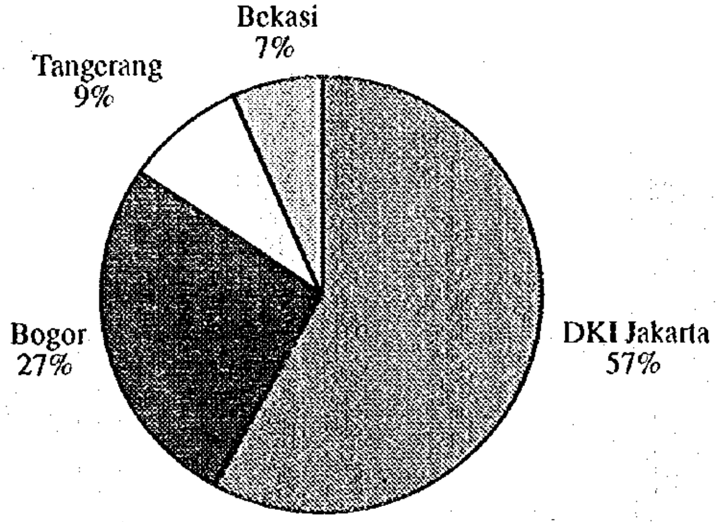

Figure 4.3.7 Shares by District to Total NOx Emissions from Factories

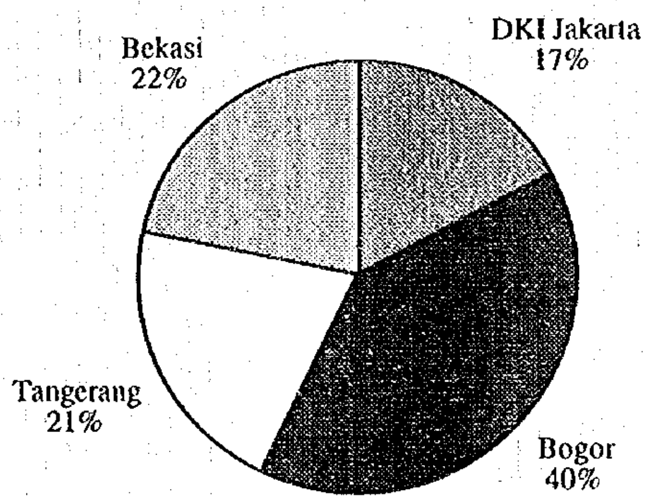

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Figure 4.3.8 Shares by District to Total PM Emissions from Factories

4.3.4 Air Pollutant Emissions from Households

(1) Population

Table 4.3.21 and Figure 4.3.9 give the regional population of Jabotabek. Total population is 20 million and 45% of them live in DKI Jakarta. These figures were estimated from "Proyksi Penduduk Indonesia per kabupaten/kotamadya 1990-2000" (Ref. 209) and "Kabupaten Bekasi Dalam Angka 1994" (Ref. 154).

(2) Fuel Consumption

Total fuel consumption by households in Jabotabek in 1995 is shown in Table 4.3.22. Total annual fuel consumption is 2.2 million kl for kerosene and 156,000 tons for LPG (see Section 4.2).

Table 4.3.21 Regional Population of Jabotabek in 1995

(Unit : 1,000 persons)

District		1995
DKI Jakarta	Barat	2,143.3
	Pusat	962.1
	Utara	1,558.8
	Selatan	2,019.6
	Timur	2,378.7
	Sub-total	9,062.5
Bogor	Kota	287.4
	Kabu	4,477.1
	Sub-total	4,764.5
Tangerang	Kota	1,190.1
	Kabu	2,404.9
	Sub-total	3,595.0
Bekasi	Central (*1)	898.9
	Other	1,839.6
	Sub-total	2,738.5
Jabotabek	Total	20,160.5

Note : *1 Central part of Bekasi includes Timur, Selatan, Barat, and Utara.

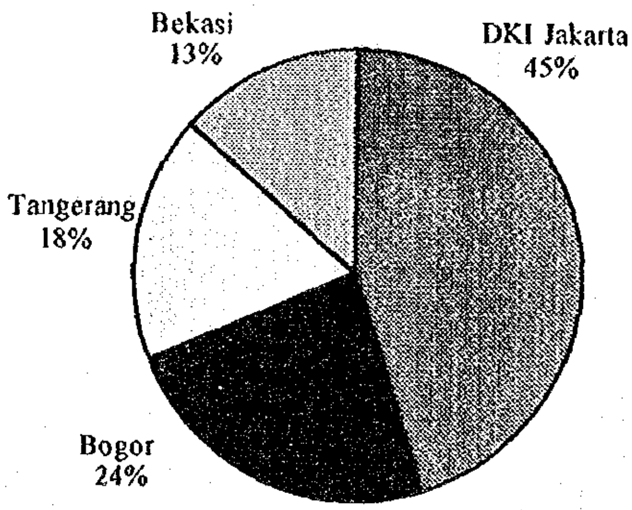


Figure 4.3.9 Regional Population and Emission Distribution in Jabotabek in 1995

Table 4.3.22 Annual Fuel Consumption by Households in Jabotabek (in 1995)

Fuel	Annual consumption
Kerosene	2,209,665 kl
LPG	155,990 tons

(3) Daily Fuel Consumption Pattern

Survey on daily fuel consumption pattern in a week was conducted on 11 families each with more than 4 persons in BAPEDAL. Figure 4.3.10 shows their average consumption pattern in a day. There are 3 peak time zones: 7 a.m. (40 minutes), 1 p.m. (25 minutes) and 6 p.m. (30 minutes).

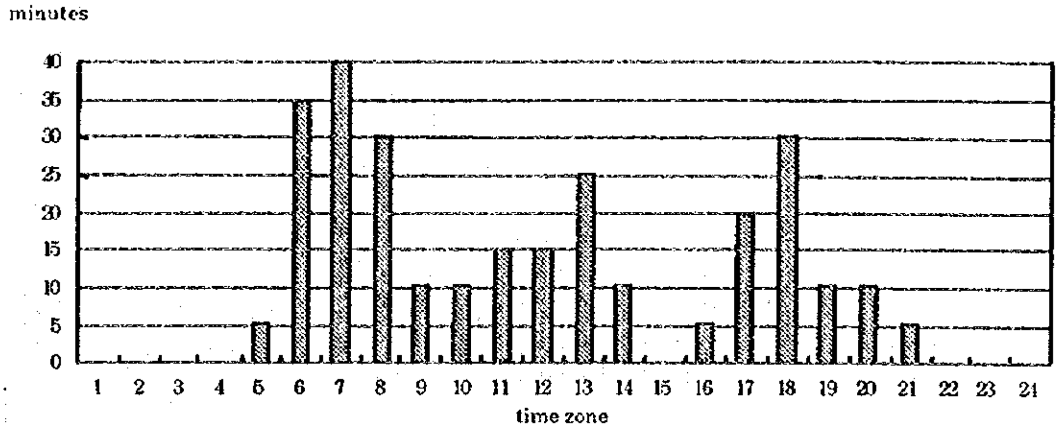


Figure 4.3.10 Daily Fuel Consumption Pattern (Non - Ramadan Period)

(4) Estimate of Air Pollutant Emissions from Households

The emission factors used for SOx, NOx and PM are shown in Table 4.3.23.

Table 4.3.23 Emission Factors for Households

	SOx	NOx	PM		Source
kerosene	1.91	2.10	0.286	kg/kl	Fuel analysis
LPG	0.0	2.06	0.062	kg/t	USA(*1)

Note : (*1) Source : COMPILATION OF AIR POLLUTANT EMISSION FACTORS
Volume 1 : Stationary Point And Area Sources (Ref. 208)

The emissions from households as calculated from the values given in Tables 4.3.22 and 4.3.23 are shown in Table 4.3.24. Total annual emissions from households are 4,000 tons for SOx, 5,000 tons for NOx and 600 tons for PM.

Table 4.3.24 Total Emissions from Households (1995)

(Unit : ton/year)

	SOx	NOx	PM
kerosene	4,220	4,640	63
LPG	0	321	10
Total	4,220	4,962	642

(5) Regional Distribution of Air Pollutant Emissions from Households

Figure 4.3.11 shows the procedure for estimating the regional air pollutant emissions from households. Table 4.3.25 gives emissions by district. The share of DKI Jakarta in the total emission is 45% for each pollutant (refer to Figure 4.3.9). Basic data on households necessary for air dispersion simulation are shown in Appendix 3.2.4.

Table 4.3.25 Regional Air Pollutant Emissions from Households (1995)

(Unit : ton/year)

District		SOx	NOx	PM
Jakarta	Barat	449	527	68
	Pusat	201	237	31
	Utara	326	384	50
	Selatan	423	497	64
	Timur	498	585	76
	Sub-total	1,897	2,230	288
Bogor	Kota	60	71	9
	Kabu	937	1,102	142
	Sub-total	997	1,173	152
Tangerang	Kota	249	293	38
	Kabu	503	592	77
	Sub-total	753	885	114
Bekasi	Central*	188	221	29
	Other	385	453	59
	Sub-total	573	674	87
Jabotabek	Total	4,220	4,962	642

Note : Central part of Bekasi includes Timur, Selatan, Barat, and Utara

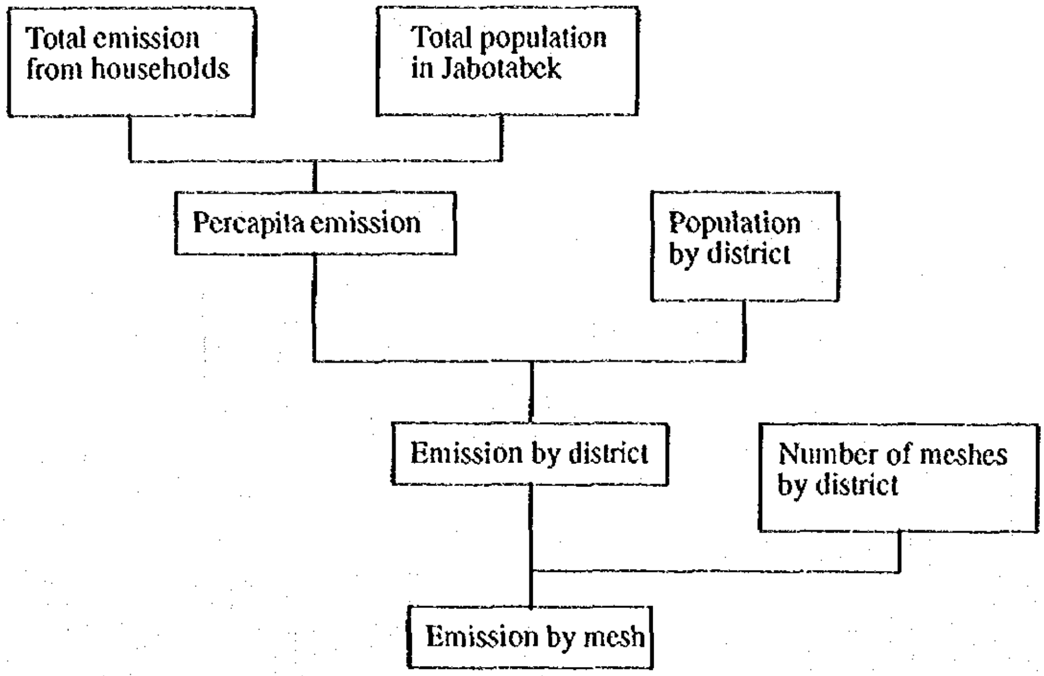


Figure 4.3.11 Procedure for Calculating Regional Air Pollutant Emissions from Households

4.4 Emission from Mobile Sources

4.4.1 Air Pollutant Emissions from Automobiles

(1) Outline of Air Pollutant Load Estimate

The procedure of estimating air pollutant emissions from automobiles is schematized in Figure 4.4.1. The estimate of air pollution load from automobiles is divided into two categories, major roads and minor roads. The basic concept of estimating air pollutant load is common for both categories and is as follows:

Pollutant Emission Load = Running Kilometers × Emission Factors

Influencing parameters for emission factors are traveling speed, engine type composition and so on. The running kilometers are estimated by the following equation for the major road traffic.

Running Kilometers = Traffic Volume × Road Length

The OD data-based method was used in this Study for estimating running kilometers on minor roads. In the estimate of air pollution emissions, the existing data and information and results of some supplemental field surveys were fully utilized. Most of the existing data were especially collected for this Study. The major basic data and their sources are listed below.

- Traffic Volume:	Original Data and Existing Data of Binkot
- OD data:	Existing Data of the other JICA Study
- Road Network:	Original Data made from existing maps
- Emission factors:	Existing Data in Japan and the USA (Data of Indonesia for check and comparison)
- Traveling Speed:	Original Data and existing data of the other JICA Study
- Engine Type Composition:	Existing Data form GAIKINDO, PASMI, and others

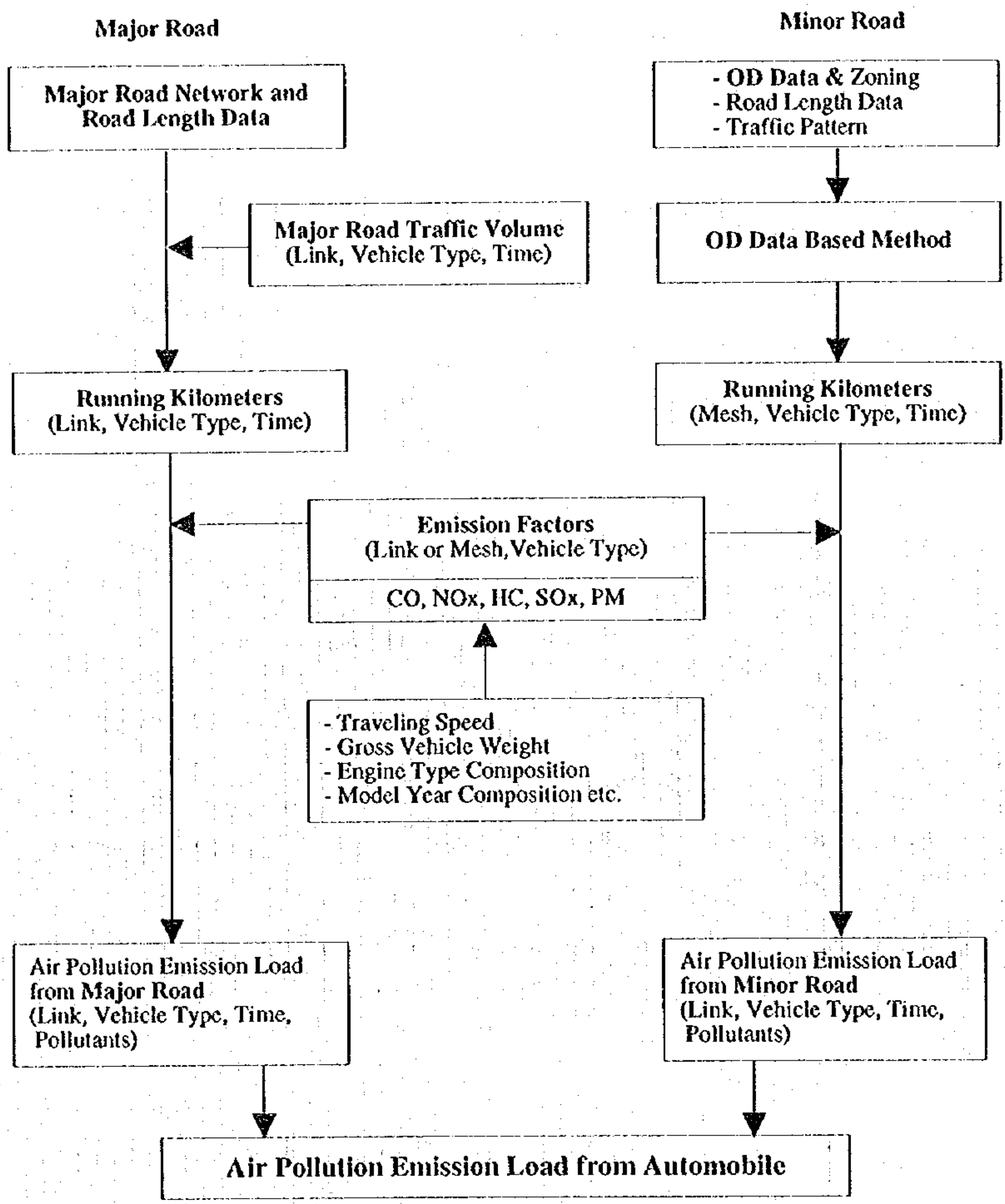


Figure 4.4.1 Procedure for Estimation of Pollutant Emission from Automobile

(2) Field Surveys

The following surveys were conducted in this Study.

- Traffic Volume Survey
- Traveling Speed Survey
- Simple Emission Test

Traffic volume survey and traveling speed survey were conducted to obtain the basic information for the pollutant emission estimate, and simple emission test to check the current situation of vehicle emission at idling.

1) Traffic Volume Survey

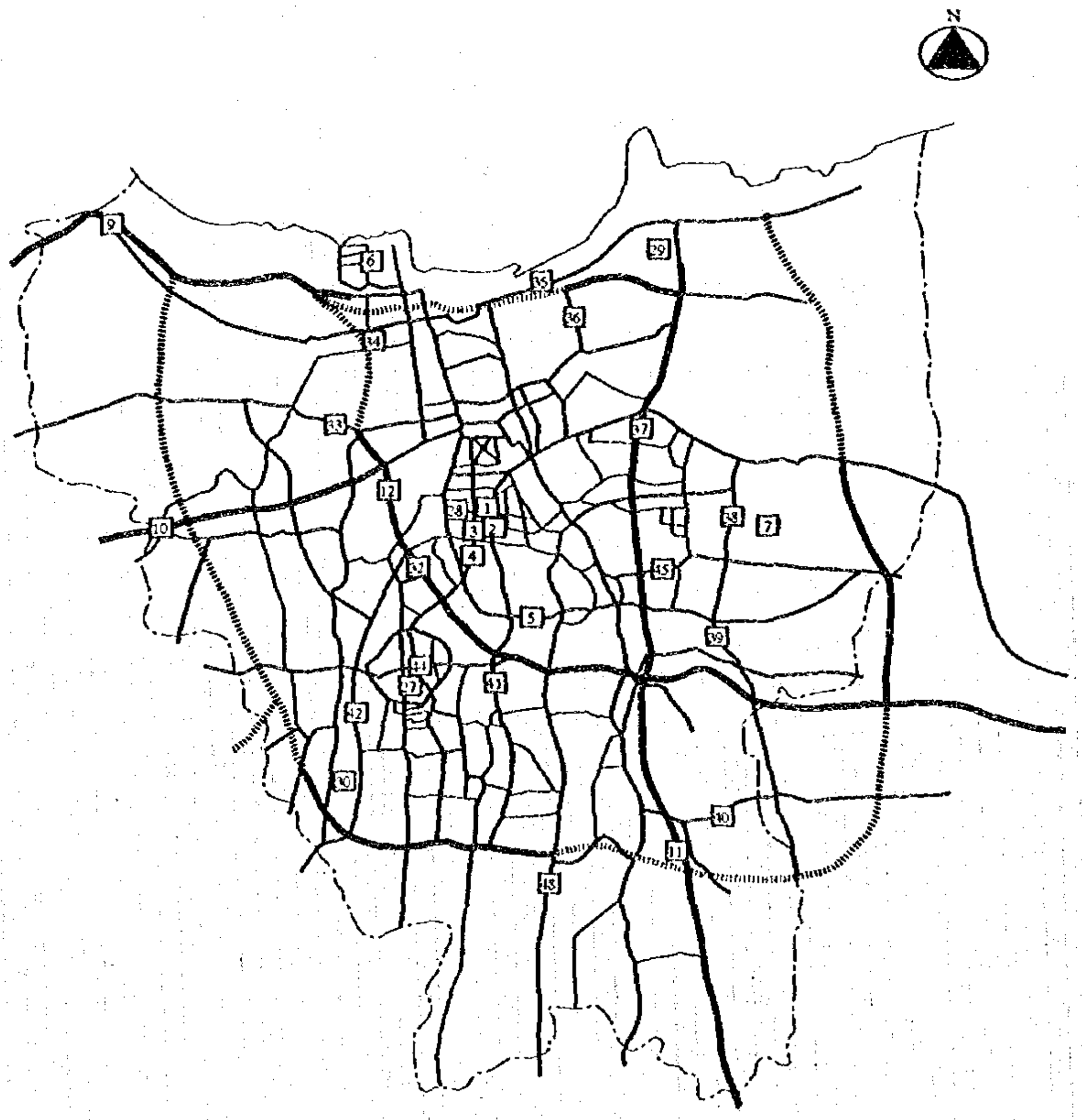
Contents and Specification

Traffic counting was conducted at 50 points as shown in Figures 4.4.2 and 4.4.3 to determine traffic volume by time, point, and vehicle type. These points were divided in the following three groups:

- 30 points on major roads in daytime (6:00 - 22:00) on one weekday
- 10 points on major roads in a whole day (6:00 - 6:00) on one weekday and one holiday
- 10 points on minor roads in daytime (6:00 - 22:00) on one weekday

The following 10 categories of vehicle types were used for this Study and subsequent estimate of pollutant emission :

- Motorcycle & Three wheeler
- Passenger car
- Taxi
- Microbus
- Bus
- Van
- Pick-up truck
- 2-axle truck
- 3-axle or more truck & Trailer
- Other (with engine)

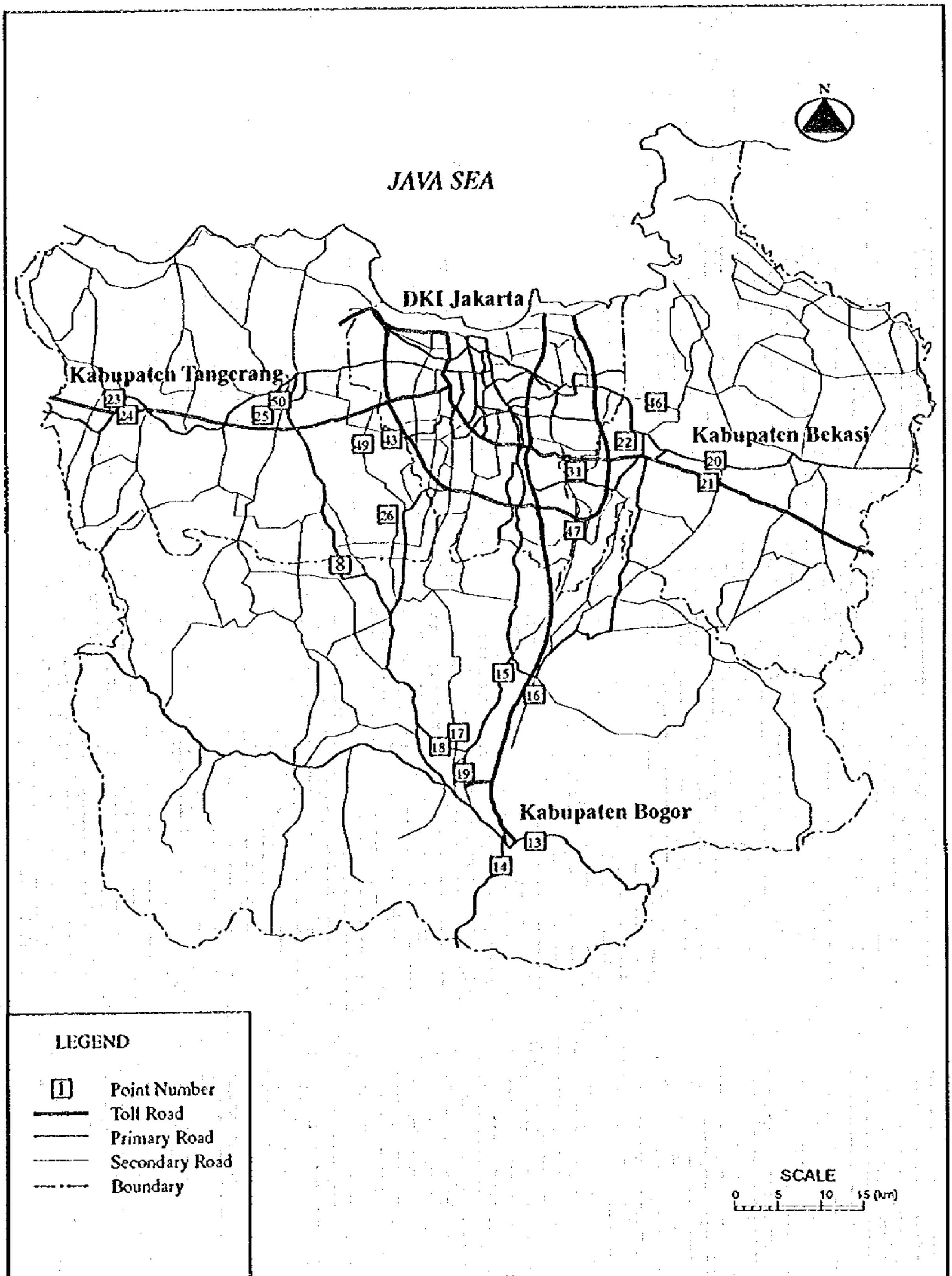


LEGEND

[1] Point Number
Toll Road
Toll Road (Planned or Under Construction)
Arterial Road
Other Major Road
Boundary

SCALE
0 1 2 3 4 5 km

THE STUDY ON THE INTEGRATED AIR QUALITY MANAGEMENT FOR JAKARTA METROPOLITAN AREA IN THE REPUBLIC OF INDONESIA	**Figure 4.4.2 Location of Traffic Volume Survey Points (DKI Jakarta)**



THE STUDY ON THE INTEGRATED AIR QUALITY MANAGEMENT FOR JAKARTA METROPOLITAN AREA IN THE REPUBLIC OF INDONESIA

Figure 4.4.3 Location of Traffic Volume Survey Points (BOTABEK)

Characteristics of Traffic in Jabotabek

Total traffic volumes by point are shown in Table 4.4.1. The traffic volume on Jend. Sudirman (Point 4) is highest with nearly 200,000 vehicles within 16 hours on a weekday. The traffic volumes on M. H. Thamrin (Point 3) and Casablanca (Point 5) are also more than 100,000 vehicles.

Survey points are classified into six groups according to the administrative areas and road classification. Figure 4.4.4 gives the vehicle composition by group.

- Share of microbuses is as high as 25.8%, while shares of motorcycles and passenger cars are 17.3% and 14.6% respectively in Bogor.

- Share of taxis is as high as 8.3% on major roads in DKI Jakarta.

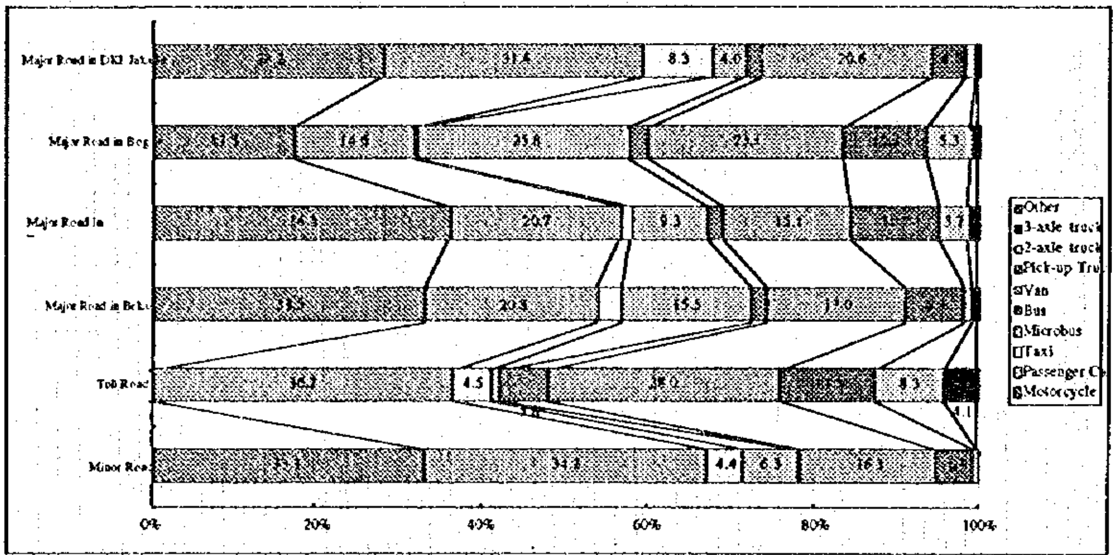


Figure 4.4.4 Vehicle Composition

Hourly fluctuation of traffic by point is given in Appendix 3.3.1. Since 24-hour traffic counting was conducted at 10 points, the ratio of 24-hour traffic versus 16-hour can be calculated from them. Ratios are in the range of 1.07 to 1.20 and the average ratio is 1.12.

Fluctuation of traffic was calculated from traffic counting results on weekdays and on holidays. Ratios of traffic volume on a holiday versus that on a weekday are in the range of 0.54 to 0.95. Those in the core area along the roads M.H. Thamrin and Casablanca are less than 0.6.

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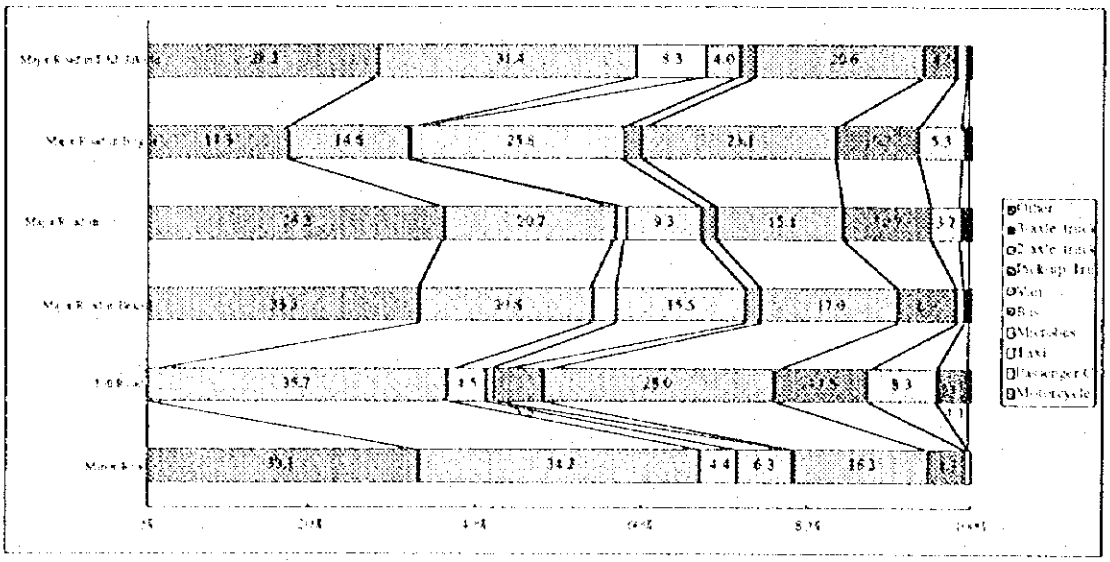

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Table 4.4.1 Traffic Volume by Point (1/2)

Point	Road Name	Place Name (Kecamatan/Kabupaten)	Traffic Volume (Veh.) Weekday-16h	Weekday-24h	Holiday-24h
1	Sutan Syahrir+Prof. Moch.Yamin	Menteng/Jakarta Pusat	22,501		
2	Imam-Bonjol	Menteng/Jakarta Pusat	26,142		
3	M.H.Thamrin	Menteng/Jakarta Pusat	133,809	148,184	86,004
4	Jend. Sudirman	Tanah Abang/Jakarta Pusat	194,452		
5	Casablanca	Setia Budi/Jakarta Selatan	104,913	112,194	60,238
6	Pluit	Penjaringan/Jakarta Utara	11,809		
7	Pulo Buaran	Cakung/Jakarta Timur	10,742		
8	Serpong Raya	Serpong/Tangerang	12,774		
9	Tol Prof. Sediyatmo	Penjaringan/Jakarta Utara	26,699		
10	Tol Jakarta-Merak	Kembangan/Jakarta Barat	53,778		
11	Tol Jagorawi	Makasar/Jakarta Timur	69,236		
12	Tol Jen. S. Parman	Palmerah/Jakarta Barat	96,632	103,672	80,738
13	(Cipayung)	Cisarua/Bogor	24,374		
14	(Ciawi)	Ciawi/Bogor	21,616		
15	Bogor Raya	Cibinong/Bogor	28,829		
16	(Karangasem Tim.)	Citeureup/Bogor	12,162		
17	Pajagalan	Semplak/Bogor	5,560		
18	(Sukaresmi)	Semplak/Bogor	24,198	27,142	25,855
19	Sencang Blok AII	Bogor Tengah/Bogor	8,712		
20	Ir. H. Juanda	Tambun/Bekasi	24,506	29,378	26,171
21	Tol Jakarta-Cikampek	Tambun/Bekasi	54,120		
22	Komodo	Bekasi Selatan/Bekasi	6,933		
23	Serang Raya	Balaraja/Tangerang	17,156		
24	Tol Jakarta-Merak	Balaraja/Tangerang	11,620		
25	Palem	Jatiuwung/Tangerang	6,640		
26	Aria Putra	Ciputat/Tangerang	15,948		
27	Melawi	Kebayoran Baru/Jakarta Selatan	28,252		
28	Kebon Kacang	Tanah Abang/Jakarta Pusat	16,405		
29	Kebon Bawang I	Tanjung Priok/Jakrta Utara	1,580		
30	Kartika Utama	Kebayoran Lama/Jakarta Selatan	14,891		
31	Jatipura	Pondok Gede/Bekasi	7,181		
32	Gatot Subroto	Tanah Abang/Jakarta Pusat	74,778		
33	Daan Mogot	Grogol Petamburan/Jakarta Barat	51,553		
34	Dr. Latumeten	Tambora/Jakarta Barat	99,710		
35	R. E. Martadinata	Pademangan/Jakarta Utara	41,246	46,045	30,304
36	Danau Sunter Barat	Tanjung Priok/Jakarta Utara	24,099		
37	Jend. Achmad Yani	Cempaka Putih/Jakarta Pusat	83,308	93,235	80,628
38	Bekasi Raya	Pulo Gadung/Jakarta Timur	39,981		
39	Pahlawan Revolusi	Duren Sawit/Jakarta Timur	36,147		
40	Pondok Gede Raya	Cipayung/Jakarta Timur	36,763	41,857	34,474

Table 4.4.1 Traffic Volume by Point (2/2)

Point	Road Name	Place Name (Kecamatan/Kabupaten)	Traffic Volume (Veh.) Weekday-16h	Weekday-24h	Holiday-24h
41	Mampang Prapatan	Mampang Prapatang/Jakarta Timur	89,273		
42	Arteri Kebayoran Lama-Pondok Indah	Kebayoran Lama/Jakarta Selatan	59,879		
43	Ciledug Raya	Ciledug/Tangerang	39,027		
44	Sultan Hasanuddin	Kebayoran Baru/Jakarta Selatan	60,634		
45	Bekasi Timur Raya	Jatinegara/Jakarta Timur	81,087	89,785	73,726
46	(Harapan Jaya)	Bekasi Utara/Bekasi	32,163		
47	Hankam Raya	Jati Sampurna/Bekasi	14,108		
48	Tanjung Barat+Lenteng Agung	Jagakarsa/Jakarta Selatan	75,081		
49	Jombang	Ciledug/Tangerang	15,006		
50	Karawaci Raya	Tangerang/Tangerang	14,813	16,337	14,302

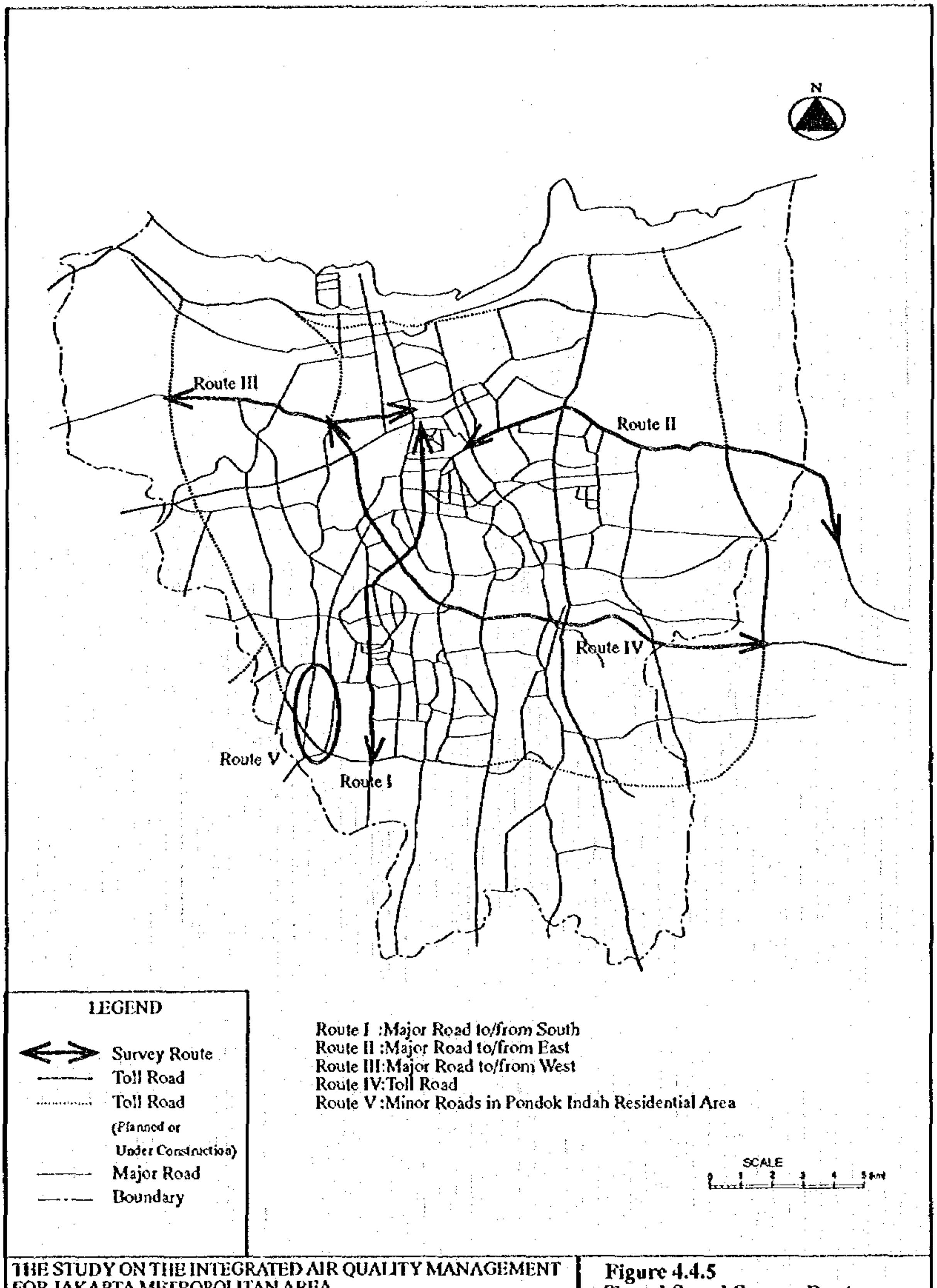
Table 4.4.2 Characteristics in Traffic Volume

Point	Road Name	Area	Traffic Volume (Veh.) Weekday 16h	Weekday 24h	Holiday 24H	Ratio 24h/16h	Holiday/Weekday
3	M.H. Thamrin	DKI Jakarta	133,809	148,184	86,004	1.11	0.58
5	Casablanca		104,913	112,194	60,238	1.07	0.54
35	R.E. Martadinata		41,246	46,045	30,304	1.12	0.66
37	Jend. Achmad Yani		83,308	93,235	80,628	1.12	0.86
40	Pondok Gede Raya		36,763	41,857	34,474	1.14	0.82
45	Bekasi Timur Raya		81,087	89,785	73,726	1.11	0.82
12	Tol. Jen. S. Parman	DKI (Toll Road)	96,632	103,672	80,738	1.07	0.78
18	(Sukaresmi)	Bogor	24,198	27,142	25,855	1.12	0.95
50	Karawaci Raya	Tangerang	14,813	16,337	14,302	1.10	0.88
20	Ir. H. Juanda	Bekasi	24,506	29,378	26,171	1.20	0.89

2) Travel Speed Survey

Contents and Specification

Since the average travel speed is one of the factors determining the emission amount of motor vehicles in operation, travel speed survey has been conducted along the five typical routes in the Jabotabek Area (Figure 4.4.5). The survey was done three times (morning, daytime, and evening) on one weekday and once in daytime on a holiday per direction and route.



THE STUDY ON THE INTEGRATED AIR QUALITY MANAGEMENT FOR JAKARTA METROPOLITAN AREA IN THE REPUBLIC OF INDONESIA

Figure 4.4.5 Travel Speed Survey Routes

Characteristics of Travel Speed in Jabotabek

Results of travel speed survey are given in Appendix 3.3.2 and summarized in Table 4.4.3. Characteristics observed by the travel speed survey are described below:

- In the morning, travel speeds on major roads from all directions (Bogor, Tangerang and Bekasi) to the core area of Jakarta are less than 20 km/h.
- In the daytime, travel speeds on major roads to/from all directions except to Bekasi are less than 20 km/h.
- In the evening, travel speeds on major road from the core area of Jakarta to all directions are less than 20 km/h.
- Travel speeds are more than 60 km/h on toll roads free from congestion.
- Average travel speeds on a holiday are higher than those on a weekday.

Table 4.4.3 Summary of Travel Speeds

Route		Direction	Average Travel Speed (km/h)			
			Weekday			Holiday
			Morning	Daytime	Evening	Daytime
I	Major Road to/from South (M.H. Thamrin, Jend. Sudirman etc.)	To South	23.1	14.8	9.3	26.1
		From South	15.1	17.2	22.6	22.2
II	Major Road to/from East (Bekasi Raya etc.)	To East	22.3	22.7	16.3	27.6
		From East	13.5	19.8	21.2	24.7
III	Major Road to/from West (Daan Mogot etc.)	To West	19.9	18.9	17.7	22.8
		From West	14.1	12.5	12.4	20.7
IV	Toll Road (Cawang-Tomang, Jakarta-Cikampek)	To East	63.3	53.9	40.6	68.1
		From East	41.1	60.3	25.2	67.4
V	Minor Roads in Pondok Indah		-	31.0	-	30.8

3) Simple Emission Test

Contents and Specification

To investigate the state of maintenance of existing vehicles, a simple emission test was conducted on vehicles with gasoline engines and diesel engines. Carbon monoxide (CO) and Hydrocarbon (HC) were measured for gasoline engines and Black Smoke was measured for diesel engines.

To collect enough samples, the measurement was conducted for seven days at parking lots and inspection places with the cooperation of the counterpart staff from BAPEDAL and LLAJR. During these periods, 142 gasoline engines and 135 diesel engines were measured in all. Vehicle gas meter and diesel smoke meter are provided by courtesy of EMC. The detailed results are given in Appendix 3.3.3.

The Indonesian and Japanese standards for existing vehicles are shown in Table 4.4.4.

Table 4.4.4 Indonesian and Japanese Standards for Existing Vehicles

Items	Indonesian Standards	Japanese Standards
CO	Up to 4.5 %	Up to 4.5 %
HC	Up to 3,000 ppm (2-Wheel, 4-Stroke) Up to 2,400 ppm (2-Wheel, 2-Stroke) Up to 1,200 ppm (4-Wheel)	Up to 1,200 ppm (4-Wheel, 4-Stroke) Up to 7,800 ppm (4-Wheel, 2-Stroke)
Black Smoke	No more than 50 %	No more than 50 %

Results and Findings

Measurement data were compared with the above standards. No inspection was conducted for motorcycles in Japan and the standard of HC for motor vehicles with 2-stroke engines and the standards of CO were applied as a reference. The category of motorcycles includes bajaj, bemo and scooter. The category of passenger cars includes sedan and van for passenger use. The trucks equipped with engines of more than 4,000 cc are included in the category of large trucks.

The findings from the simple emission test are as follows:

- 50 % of gasoline vehicles exceed the CO standards.
- Around 20% or 30 % of gasoline vehicles exceed the HC standards and especially motorcycles and small/medium buses have a high HC value.
- Around 20 % of diesel vehicles exceed the Black Smoke standard with buses and passenger cars having a relatively higher level compared with trucks.

Table 4.4.5 Vehicles Exceeding the Standards

Vehicle Types	CO	HC	Smoke	Number
Indonesian Standards				
Vehicle Types	CO	HC	Smoke	Number
Motorcycle	11/22(50.0)	18/22(81.8)	-----	22
Passenger Car	40/71(56.3)	10/71(14.1)	2/7(28.6)	78
Small/Medium Bus	9/25(36.0)	16/25(64.0)	16/46(34.8)	71
Bus	-----	-----	7/27(25.9)	27
Small/Medium Truck	11/24(45.8)	5/24(20.8)	4/36(11.1)	60
Large Truck	----	-----	2/19(10.5)	19
Total	71/142(50.0)	49/142(34.5)	31/135(23.0)	277
Japanese Standards				
Vehicle Types	CO	HC	Smoke	Number
Motorcycle	11/22(50.0)	**10/22(45.5)**	-----	22
Passenger Car	40/71(56.3)	10/71(14.1)	2/7(28.6)	78
Small/Medium Bus	9/25(36.0)	16/25(64.0)	16/46(34.8)	71
Bus	-----	-----	7/27(25.9)	27
Small/Medium Truck	11/24(45.8)	5/24(20.8)	4/36(11.1)	60
Large Truck	----	-----	2/19(10.5)	19
Total	71/142(50.0)	**31/142(21.8)**	31/135(23.0)	277

Note: Fractional number indicated ratio of exceeding the standard within total samples and figure in the bracket indicated its percentage.
Bold figures indicate the differences between the Indonesian and Japanese standards.

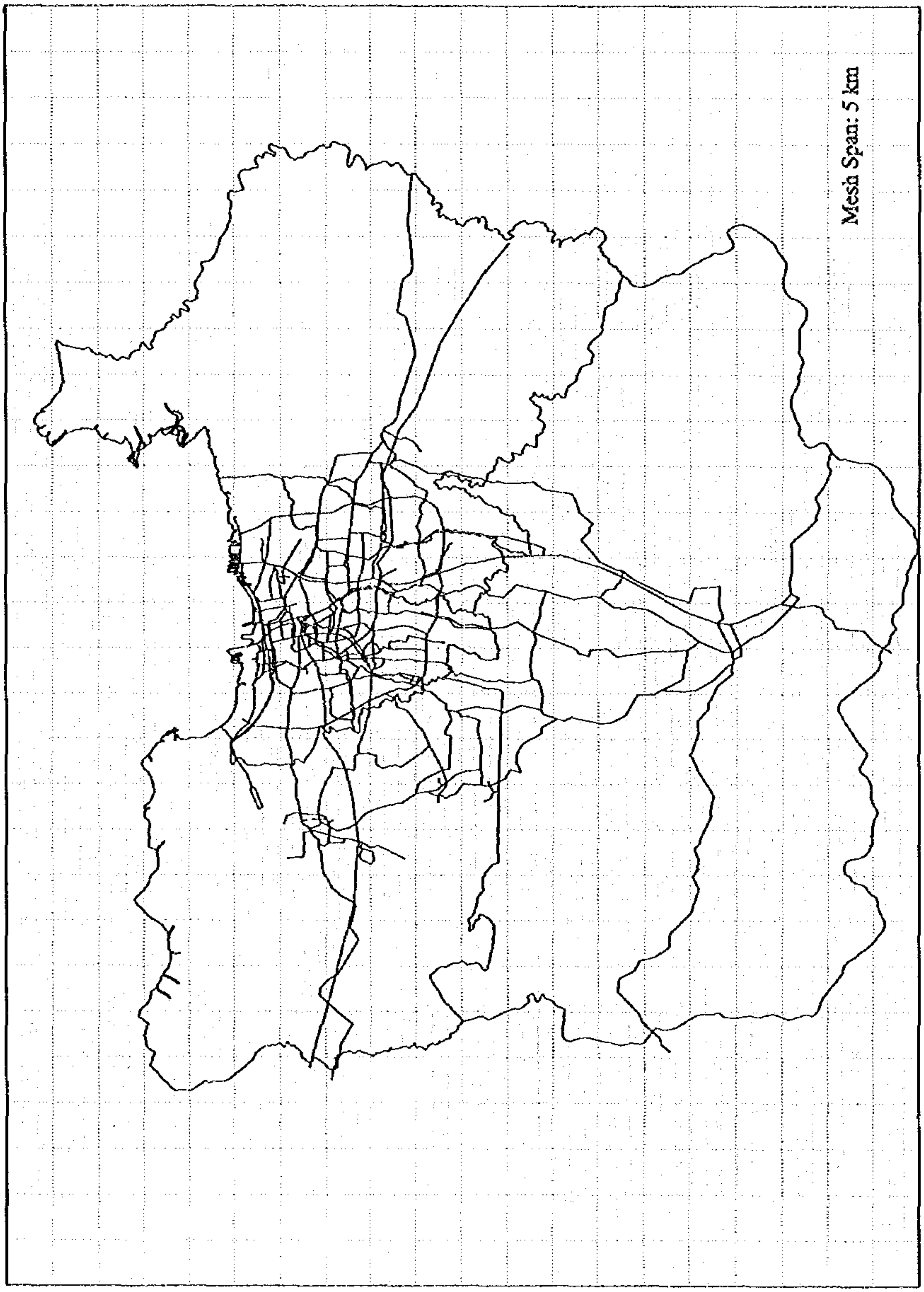
(3) Estimate of Automobile Air Pollutant Loads on Major Roads

1) Road Network

The major road network used for estimating pollutant loads is shown in Figure 4.4.6.

2) Traffic Volume

The traffic count data of this Study, covering 50 points on weekdays and 10 points on holidays, and Binkot data covering 110 points on weekdays were used. Based on the analysis of JICA and Binkot data, the traffic volume data for each hour and 10 vehicle types on a weekday and on a holiday in 1995 were estimated for 50 JICA survey points and 110 Binkot survey points. The traffic volume data during nighttime (from 22:00 to 6:00) were estimated for 16-hour survey points of JICA study to obtain 24-hour traffic data on weekdays. Then, the 24-hour traffic data on holidays were estimated using the holiday/weekday ratio. The 24-hour traffic data of Binkot survey were converted to 10 vehicle types of JICA study in 1995. Then, the 24-hour traffic data on holidays were estimated


Mesh Span: 5 km

using the 1995. Then, the 24-hour traffic data on holidays were estimated using the holiday/weekday ratio. A comparison of contents of the two surveys is shown in Appendix 3.3.4.

Correction by Year

The Binkot traffic data of 1993 were converted to the ones of 1995 using a factor of 1.268, which is the increasing factor from 1993 to 1995 based on the DKI Jakarta related traffic data of Jasa Marga.

Taxi Fraction

11 vehicle types of Binkot were converted to 10 vehicle types of JICA. The "Sedan" type of Binkot is divided into "Passenger car" and "Taxi" of JICA using the taxi fraction derived from the analysis of the 16-hour data of JICA survey at 40 points. The taxi fraction, Taxi/(Taxi + Passenger Car), is 0.161.

Hourly Traffic Volume during the Nighttime

The hourly fraction by area and road type during nighttime was obtained from the analysis of 24-hour survey points, 10 points of JICA survey and 110 points of Binkot (Appendix 3.3.4). This fraction was used for estimating the hourly nighttime traffic volume from the hourly daytime (16 hours) traffic volume.

Holiday/Weekday Ratio

The holiday/weekday ratios by road type and area in daytime and the nighttime were set based on the analysis of the holiday and weekday data at 10 points of JICA study (Table 4.4.6).

Table 4.4.6 Holiday/Weekday Ratios

Road Type & Area	Holiday/Weekday Ratio		
	Day	Night	All Day
Toll Road	0.75	1.24	0.78
Jakarta	0.68	0.86	0.69
Botabek	0.89	0.88	0.89

Estimate of Traffic Volume to Each Link

The traffic volumes at JICA and Binkot survey points were used to calculate traffic volumes to the links including or continuing to the corresponding survey points. The "Traffic Assignment Method" was adopted to estimate the traffic volumes to the links without traffic counting data in the DKI Jakarta area (Appendix 3.3.5), and the traffic volumes in the Botabek area were estimated considering the road types and areas.

3) Emission Factors

Targeted pollutants are CO (Carbon Monoxide), HC (hydrocarbon), NOx (Nitrogen Oxides), SOx (Sulfur Dioxide), and PM (Particulate Matter). Economy of gasoline and diesel is also analyzed. The emission factors were set based on the following reports and books.

Material 1 : "Automobile Emission Factors under Actual Driving Condition", Japan Environment Agency, January 1994 (for CO, HC, NOx excluding Motorcycles) (Ref. 238)

Material 2 : "Report on Emission Condition Study from Uncontrolled Vehicles", Japan Environment Agency, October 1995 (for CO, HC, NOx of Motorcycles) (Ref. 239)

Material 3 : "Total Emission Control Manual for Nitrogen Oxides (revised)", Japan Environment Agency, August 1993 (for SOx and Fuel Economy) (Ref. 217)

Material 4 : "Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources", U.S. Environmental Protection Agency, September 1985 (Ref. 240)

Emission Factors for CO, HC, and NOx

CO, HC, and NOx emission factors (except for motorcycles) are based on the above Reference 238. The emission factors given in the material are categorized by engine type and gross vehicle weight. Therefore, it is necessary to set engine type fractions according to traffic vehicle types and gross vehicle weight information for the Jabotabek area.

Gasoline/diesel fractions by traffic vehicle type were based on the country report presented by S.M. Lubis of BAPEDAL (Ref. 241) and the sales data from GAIKINDO (Table 4.4.7).

Table 4.4.7 Engine Type Composition by Traffic Vehicle Type

(Unit : %)

Traffic Vehicle Type	Gasoline	Diesel
Motorcycle	100	0
Passenger Car	80	20
Taxi	65	35
Microbus	50	50
Bus	0	100
Van	80	20
Pick Up Truck	50	50
Truck, 2 axles	0	100
Truck, 3 axles	0	100

Emission factors and fuel economy of heavy duty vehicles are proportional to gross vehicle weight. The gross vehicle weight by traffic vehicle type was set based on Reference 238 and "Japanese Motor Vehicle Guidebook" (Ref. 242) (Table 4.4.8).

Table 4.4.8 Gross Vehicle Weight by Traffic Vehicle Type

(Unit : ton)

Traffic Vehicle Type	Gasoline	Diesel
Microbus	3.50	5.50
Bus	11.00	11.00
Van	1.30	2.00
Pick-up Truck	1.40	2.30
Truck, 2 axles	8.00	8.00
Truck, 3 axles	18.00	18.00

Then, the vehicle types of JICA study were linked with the engine types of Reference 238 (Appendix 3.3.4), and emission factors by traffic vehicle types were determined considering the gross vehicle weight and the composition of engine types (Table 4.4.11). Six classes of traveling speed were defined as specified in Reference 238: 5 to 10 km/h, 10 to 15 km/h, 15 to 25 km/h, 25 to 40 km/h, 40 to 60 km/h, and 60 to 80 km/h.

Emission factor equations by vehicle speed in Reference 239 were used for motorcycles (Appendix 3.3.4), and the emission factors were determined for the above mentioned six speed classes. The composition of 2/4 stroke engines and exhaust gas categories was based on the sales data of PASMI (Table 4.4.9).

Table 4.4.9 Motorcycle Fraction by Engine Type and Exhaust Gas Volume

Category Number	Engine Type	Exhaust Gas Volume	Fraction
1	2 / 4 Stroke	More than 250 cc	0.
2	2 Stroke	From 126 cc to 250 cc	0.1155
3	4 Stroke	From 126 cc to 250 cc	0.1441
4	2 Stroke	From 51 cc to 125 cc	0.1647
5	4 Stroke	From 51 cc to 125 cc	0.2055
6	2 Stroke	Less than or equal to 50 cc	0.1647
7	4 Stroke	Less than or equal to 50 cc	0.2055

Fuel Economy and SOx Emission Factor

SOx emission factors are derived from fuel economy with sulfur content of the fuels.

$$\mathrm{SOx\ (g/km)} = \mathrm{(Fuel\ Consumption : liter/km)} \times \mathrm{(S\ contents : \%)} / 100 \times \mathrm{(Specific\ Gravity : g/cm^3)} \times 64/32 \times 1000$$

Sulfur content and specific gravity in Indonesia are given in Table 4.4.10. Regression equations by vehicle types for fuel economy in the Reference 217 were used (Appendix 3.3.4). Engine type composition and gross vehicle weight are the same as shown in Tables 4.4.7 and 4.4.8.

Table 4.4.10 Fuel Specification in Indonesia

Fuel Type	S content (%)	Specific Gravity
Gasoline	0.015	0.735
Diesel	0.396	0.849

PM Emission Factor

PM emission factors for particles under 10 micrometer diameter were based on Reference 240. The PM emission factors of Reference 240 were composed of lead salt, organic/sulfate (Gasoline vehicle), diesel particle (Diesel vehicle), and brake/tire wear. The lead salt portion was obtained from fuel economy and lead content in the fuels, and the lead content of gasoline fuel was set as 0.106 grams/liter. Furthermore, a conversion factor of 0.7474 from lead content in the fuel to emission was used considering under 10 micrometer fraction, emitted fraction, and conversion ratio from lead to lead salt. Vehicle types for traffic and PM emission factor are also given in Table 4.4.11.

Compilation of Emission Factors

CO, HC, NOx, SOx, and PM emission factors in the speed range from 15.0 km/h to 25.0 km/h are compiled in Table 4.4.11 and full compilation of emission factors are included in Appendix 3.3.4. The emission factors were comparable with the existing emission factors in Indonesia (Ref. 243 and 244).

Table 4.4.11 Compilation of Emission Factors

(Unit : g/km/vehicle)

Pollutant / Vehicle Type	CO	HC	NOx	SOx	PM
Motorcycle	13.18	4.57	0.09	0.01	0.01
Passenger Car	18.71	2.44	2.24	0.13	0.17
Taxi	13.07	1.73	2.00	0.21	0.22
Microbus	30.31	3.70	6.21	0.56	0.80
Bus	18.65	4.08	11.73	2.09	1.40
Van	19.98	2.44	2.95	0.10	0.17
Small Truck	17.98	2.22	2.83	0.23	0.27
Truck, 2 axles	3.22	1.89	7.21	1.52	1.40
Truck, 3 axles	6.90	4.05	15.45	3.42	1.40

Traveling Speed

Because emission factors are function of traveling speed as stated above, the traveling speed at each link is necessary for estimating emission factors. Traveling speed was set for each link based on the results of this Study and another JICA study conducted in the past (Section 4.4.5).

This Study investigated five routes while earlier study investigated other ten routes. The traveling speed on each route investigated was based on the individual result, and the traveling speeds at other links were set as given in Table 4.4.12.

Table 4.4.12 Traveling Speed Index

Road Types	Area	Hours																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Major Road	Jakarta	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4
	Botabek	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5
Toll Road	Jakarta	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6
	Botabek	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Note: Traveling Speed Index Class, 1: 5 to 10 km/h, 2: 10 to 15 km/h, 3: 15 to 25km/h, 4: 25 to 40 km/h, 5: 40 to 60 km/h, and 6: 60 to 80 km/h

4) Estimation of Air Pollutant Emission

Air pollutant emission load (CO: Carbon Monoxide, HC: Hydrocarbon, NOx: Nitrogen Oxide, SOx: Sulfur Oxide, and PM: Particulate Matter) and running kilometer were estimated in as given in Table 4.4.13.

Table 4.4.13 Estimated Air Pollutant Emission Loads and Running Kilometers of Major Roads

Vehicle Type	Air Pollution Emission (ton/year)					Running km (10^6km/year)
	CO	HC	NOx	SOx	PM	
Motorcycle	68,461.8	22,924.3	504.9	54.4	54.4	5,439.9
Passenger Car	121,303.2	16,105.9	17,130.9	868.6	1,230.6	7,395.2
Taxi	14,740.7	1,976.5	2,495.5	241.1	271.1	1,234.9
Microbus	43,772.9	5,406.3	10,859.2	875.2	1,361.2	1,752.8
Bus	8,529.2	1,875.1	6,189.4	1,047.9	791.0	565.0
Van	61,811.0	7,276.9	11,139.3	290.0	574.5	3,489.9
Small Truck	19,454.9	2,305.7	3,795.6	248.5	335.8	1,243.9
Truck, 2 axles	2,449.8	1,380.3	5,670.9	1,184.5	1,239.2	885.1
Truck, 3 axles	2,110.9	1,189.4	4,921.8	1,073.9	500.1	357.2
Total	342,634.2	60,440.5	62,707.3	5,884.2	6,358.0	22,364.6

Estimated air pollutant loads from major road traffics in Jabotabek are around 340,000 tons/year for CO, 60,000 tons/year for HC, 63,000 tons/year for NOx, 5,800 tons/year for SOx, and 6,300 tons/year for PM.

(4) Estimate of Automobile Air Pollutant Loads in Minor Roads

To estimate running kilometers for minor road traffic, the "OD Data-based Method" was used. The basic concept of this method is expressed below :

Running Kilometers (R) = OD traffic volume (Q) x Average Trip Length (L)

The average trip length (L) is calculated by the following equations.

For inter-intra and intra-inter traffic in urban area :

$$L = \frac{a}{LT} + \frac{a}{4P}$$

where, a : Area Size of Zone (km^2)

LT : Total Road Length of Major Road (km)

P : Total Road Length of Minor Road (km)

For inter-intra and intra-inter traffic in suburb area :

$$L = \frac{S \cdot P}{4LT}$$

where, S : Minor Roads Intervals

LT : Total Road Length of Major Road (km)

P : Total Road Length of Minor Road (km)

For intra-intra traffic :

$$L = \sqrt{\frac{a}{\pi}}$$

a : Area Size of Zone (km^2)

π : pi

The OD data were based on "The Feasibility Study on Urban Arterial Road System Development Project in Jakarta Metropolitan Area (UARSDP)" (Ref.173), and explained in Appendix 3.3.4. The emission factors used for estimating pollutant emission are the same as those for major roads, and the travel speed is based on the traveling speed survey for minor road. As a result, the air pollutant emissions for minor road traffic were estimated as shown in Table 4.4.14.

Table 4.4.14 Estimated Air Pollutant Emission Loads and Running Kilometer on Minor Roads

Vehicle Type	Air Pollution Emission (ton/year)					Running km (10^6km/year)
	CO	HC	NOx	SOx	PM	
Motorcycle	51,540	15,378	466	47	47	4,660
Passenger Car	75,752	10,386	12,701	565	903	5,645
Taxi	6,554	915	1,384	112	154	699
Microbus	24,656	3,094	6,840	527	871	1,146
Bus	3,576	806	2,610	459	365	261
Van	44,519	5,063	8,349	189	431	2,693
Small Truck	14,706	1,691	2,898	188	267	989
Truck, 2 axles	286	158	633	138	151	108
Truck, 3 axles	69	38	152	35	17	12
Total	221,658	37,530	36,031	2,258	3,205	16,212

(5) Air Pollutant Emission Loads from Automobiles

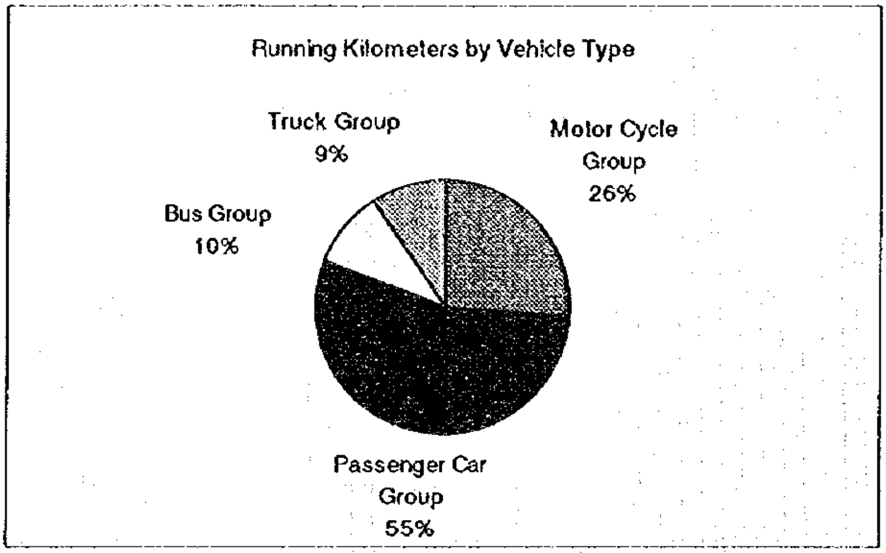
Total pollutant emissions from automobiles (major and minor roads) are shown in Table 4.4.15. Consumptions of gasoline and diesel are 2,375.9 and 1129.2 × 10^6 liter per year, respectively and fuel consumption statistics are 2,643.7 (Premium+Premix) and 1,223.9 (excluding consumption by ships) respectively. Therefore, cover ratios of fuel consumption for automobiles in Jabotabek are 90% and 92%. Pollutant emissions of CO from automobiles are calculated at 560,000 tons/year, HC at 98,000, NOx at 99,000, SOx at 8,100, and PM at 9,600. Shares by vehicle type for each pollutant are shown in Figure 4.4.7. In the figures, summarized vehicle groups are used.

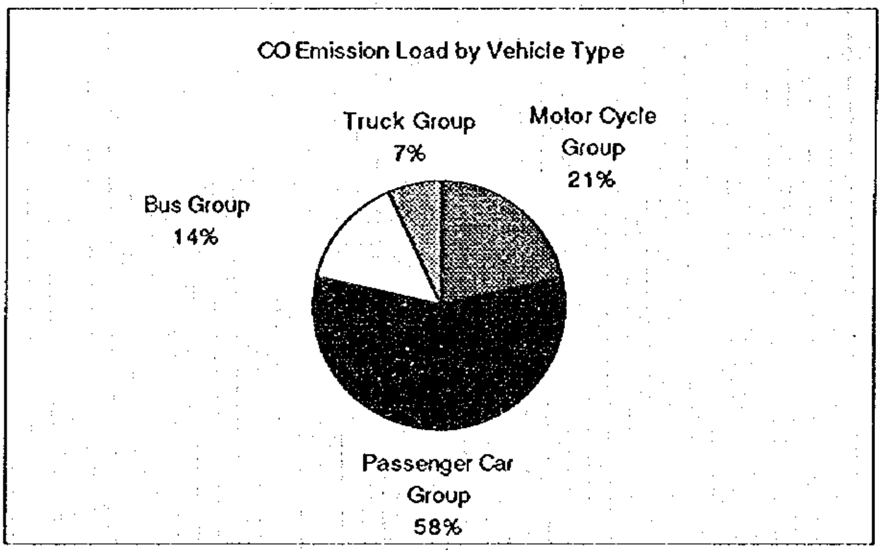
Motorcycle Group ---------- Motorcycle
Passenger Car Group -------- Passenger Car, Taxi, Van
Bus Group ------------------- Microbus, Bus
Truck Group ---------------- Small Truck, Truck 2 axles, Truck 3 axles

More than 50% of CO are emitted from the passenger car group and around 20% from motorcycles. Passenger car group and motorcycles occupied around 40% of HC emission load, respectively. More than 50% of NOx are emitted from the passenger car group, and around 30% from buses. SOx and PM emissions are almost equally shared by passenger cars, buses and trucks.

Table 4.4.15 Estimated Air Pollutant Emission Loads and Running Kilometers from Automobiles in Jabotabek

Vehicle Type	Air Pollution Emission (ton/year)					Running km (10^6km/year)
	CO	HC	NOx	SOx	PM	
Motorcycle	120,002	38,302	971	101	101	10,100
Passenger Car	197,055	26,492	29,832	1,433	2,134	13,040
Taxi	21,295	2,892	3,879	353	425	1,934
Microbus	68,429	8,500	17,699	1,402	2,232	2,899
Bus	12,105	2,682	8,799	1,507	1,156	826
Van	106,330	12,340	19,488	479	1,005	6,183
Small Truck	34,161	3,997	6,693	436	603	2,233
Truck, 2 axles	2,736	1,538	6,304	1,322	1,390	993
Truck, 3 axles	2,180	1,227	5,074	1,109	517	369
Total	564,292	97,971	98,738	8,142	9,563	38,577





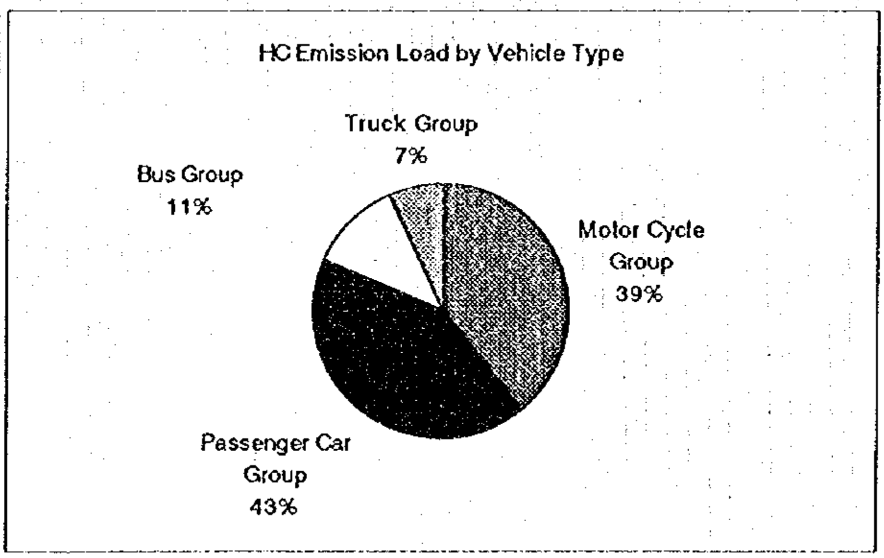
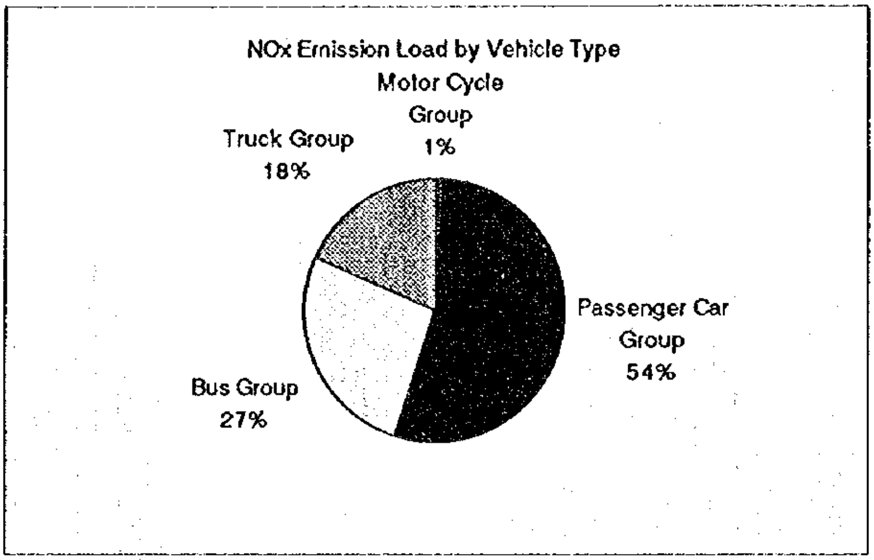
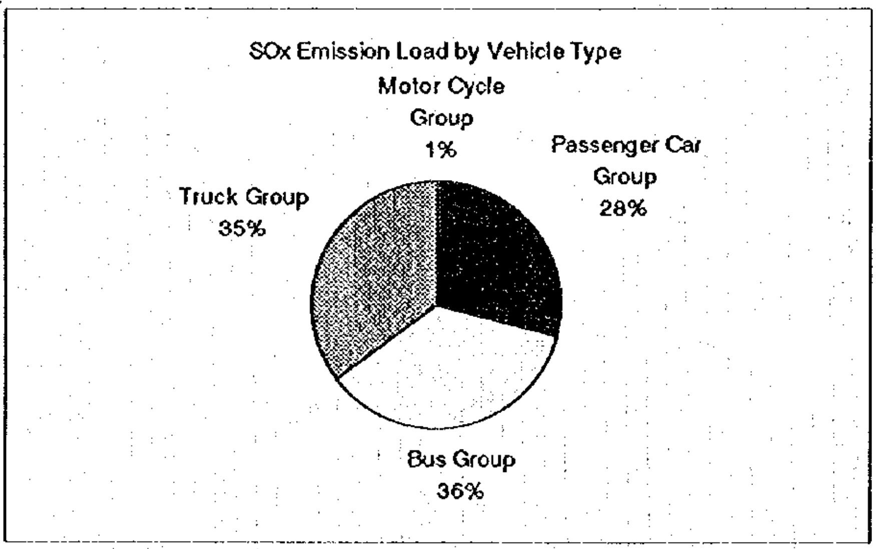


Figure 4.4.7 Emission Shares by Vehicle Type (1/2)
(for Running Kilometers, CO and HC)





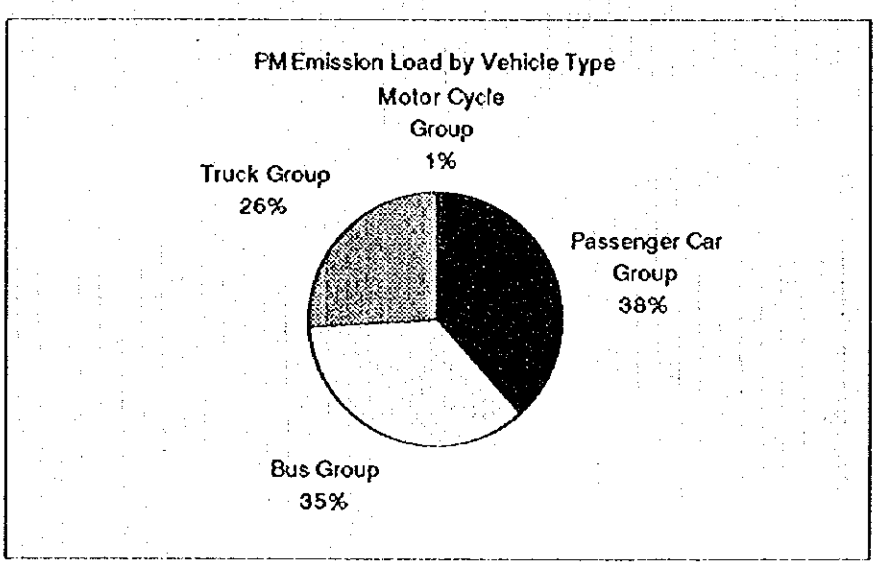


Figure 4.4.7 Emission Shares by Vehicle Type (2/2)
(for NOx, SOx, and PM)

4.4.2 Air Pollutant Emissions from Ships

(1) Outline of Air Pollutant Load Estimate

The procedure of estimating air pollutant emissions from ships is schematized in Figure 4.4.8. Basic equations for calculation of emission factors and fuel consumption are based on "Total Emission Control Manual for Nitrogen Oxides" (Ref. 217) and included in "Pollution Source Study Guideline for Mobile" (JICA Study Team, August 1996). These equations are defined for each engine type, and functions of gross tonnage, engine load etc. The amount of pollutant emission from one vessel, is calculated first, then multiplied by the number of ship calls, and distributed spatially based on the information on cruising routes and mooring points. Details of pollutant emission estimate are given in Appendix 3.3.6.

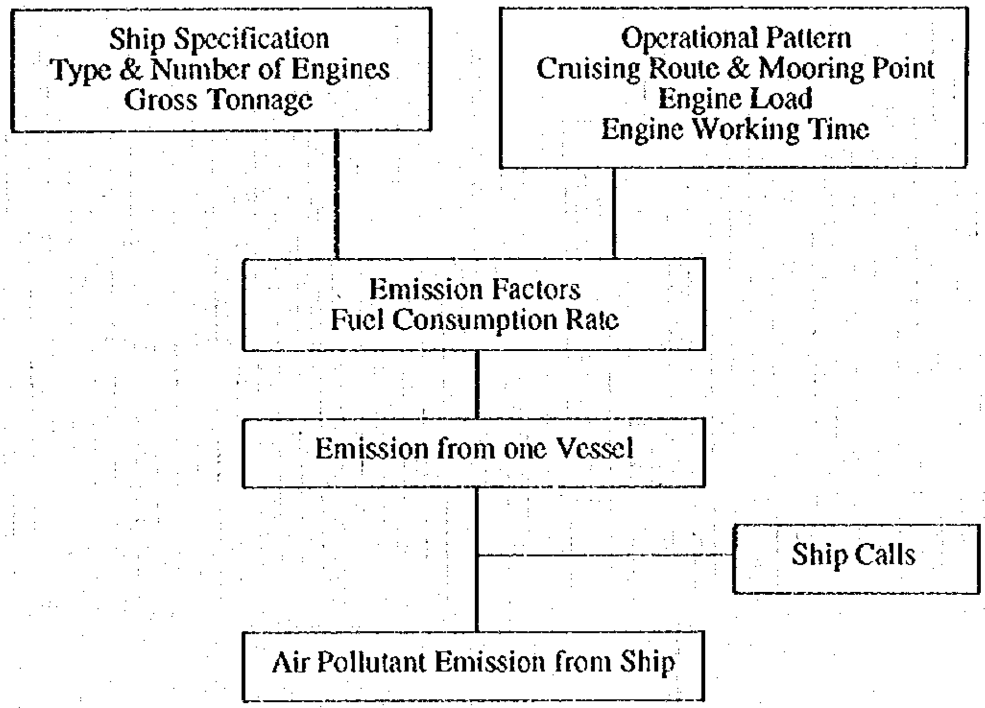


Figure 4.4.8 Procedure of Estimating Pollutant Emissions from Ships

(2) Estimate of Air Pollution Loads from Ships

Pollutant emissions from ships at Tanjung Priok Port were estimated from information such as number of ship calls, gross tonnage, etc. There were 13,649 ship calls at Tanjung Priok in 1995 as shown in Table 4.4.16.

Table 4.4.16 Ship Calls and Gross Tonnage at Tanjung Priok

Ship Category	Ship Calls	Average Gross Tonnage
Ocean Going	2,341	7,450
Container	1,682	9,667
Inter Island	7,396	2,055
Tanker	517	10,419
Offshore	1,713	1,563

Source: Information from Tanjung Priok Port Authority

Experimental equations for estimating the rated power of engines, fuel consumption, and emission factor of pollutant were compiled by ship type. Definition of ship types for each ship category is also necessary. All ocean going ships were estimated as cargo ships, and 1,049 ship calls within the inter-island category were estimated as passenger ships and the remainders as cargo ships. The equations for containers and tankers were also included in the material, and the 'Others' category was used for offshore ships.

SOx emission factor was estimated from the fuel consumption and sulfur contents in the fuel in the same manner as applied in the calculation for automobiles. Then, sulfur content and specific gravity were estimated from the fuel consumption statistics for ships and the fuel analysis results in this Study. Sulfur content was calculated at 0.595% and specific gravity at 0.831 g/cm^3. Pollutant emissions were estimated under the conditions of mooring at berth, mooring offshore, and cruising between the port and ocean as shown in Table 4.4.17.

Table 4.4.17 Estimated of Air Pollutant Emissions from Ships

SO_x (ton/year)	Mooring at Berth	570.1
	Mooring Offshore	175.4
	Cruising	62.6
	Total	808.2
NO_x (ton/year)	Mooring at Berth	1,270.5
	Mooring Offshore	360.7
	Cruising	328.3
	Total	1,959.6

4.4.3 Air Pollutant Emissions from Aircraft

(1) Outline of Air Pollutant Load Estimate

The procedure of estimating air pollutant emissions from aircraft is schematized in Figure 4.4.9. Basic equations for calculating of emission factors and fuel consumption are based on "Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources" (Ref. 240) and included in "Pollution Source Study Guideline for Mobile". These emission factors were defined for engine types and modes, namely idling, take-off, climb-out, and approach. The amount of pollutant emission from one flight was calculated first, then multiplied by the number of flights, and distributed spatially based on the information on runways and flight routes. Details of pollutant emission estimate are given in Appendix 3.3.8.

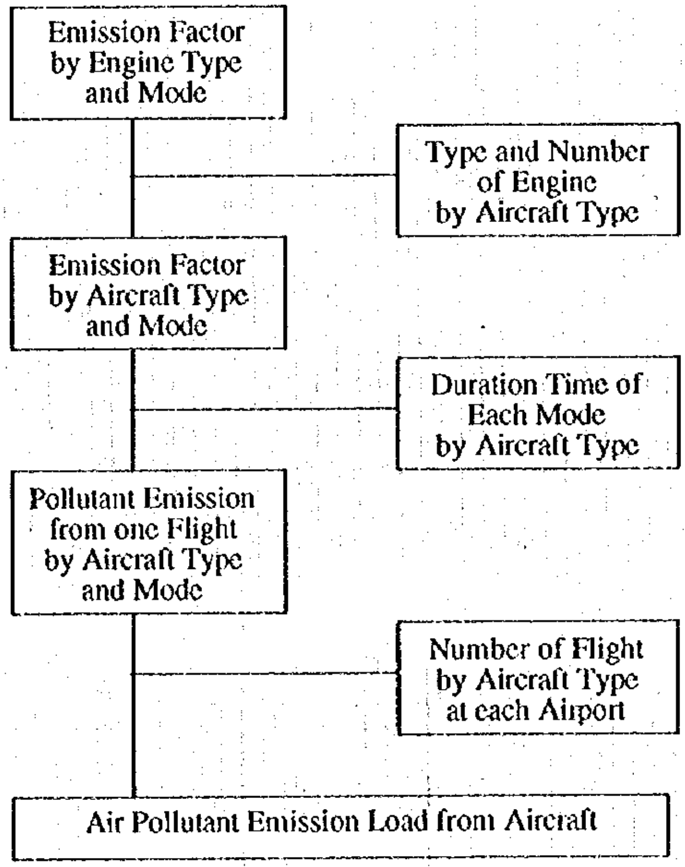


Figure 4.4.9 Procedure of Estimating Loads from Aircraft

(2) Estimate of Air Pollution Loads from Aircraft

In 1995, 149,748 and 66,142 arrival and departure flights at the Soekarno-Hatta and Halim-Perdanakusuma airports respectively, where are located in Jabotabek, were reported respectively, as shown in Table 4.4.18.

Table 4.4.18 Number of Flights at Soekarno-Hatta and Halim-Perdanakusuma Airports

Airport	Flight Category	Number of Flights
Soekarno-Hatta	International	37,268
	Domestic	112,020
	Local	460
	Total	149,748
Halim-Perdanakusuma	International	2,483
	Domestic	37,700
	Local	25,959
	Total	66,142

Source : Statistik Angkutan Udara, Tahun 1995 (Ref. 245)

Frequencies of flights by aircraft type are shown in Appendix 3.3.7, and type and number of engines were investigated from "World Aircraft Yearbook". Emission factors and landing/departure cycles by aircraft type are included in "Pollution Sources Study Guidelines for Mobile". Pollutant emissions were estimated by modes of idling, take-off, climb-out and approach, as shown in Table 4.4.19.

Table 4.4.19 Estimation of Air Pollutant Emission from Aircraft

SOx (ton/year)	Idling	39.3
	Take-off	9.8
	Climb-out	25.5
	Approach	16.7
	Total	91.3
NOx (ton/year)	Idling	103.1
	Take-off	257.3
	Climb-out	534.7
	Approach	130.6
	Total	1,025.7

4.5 Analysis of Air Pollutant Loads

Table 4.5.1 presents a summary of air pollutant emissions from factories, households, automobiles, ships, and aircraft in Jabotabek. The estimated total annual emissions in 1995 are 56,000 tons for SOx, 144,000 tons for NOx, and 24,000 tons for PM. CO and HC emissions from automobiles are 564,000 tons and 98,000 tons respectively.

The share of each source in the total emission is shown in Figures 4.5.1. to 4.5.3. SOx share is 76% for factories, 15% for automobiles, and 8% for households. NOx share is: automobiles: 69%, factories: 26% and households: 3%. PM share is: factories: 57%, automobiles: 40%, and households: 3%.

Regional SOx distributions of stationary, mobile and total sources are shown in Figures 4.5.4 to 4.5.6 respectively. All the meshes with total SOx emission at more than 500 ton/year (Figure 4.5.6) are attributed to emission from stationary sources (factories). Generally SOx emission in each mesh from automobiles are less than 10 ton/year (Figure 4.5.5). While, SOx emission from ships in each mesh of north part of DKI Jakarta exceeds 100 ton/year (Figure 4.5.5).

Regional NOx distributions of stationary, mobile and total sources are given in Figures 4.5.7 to 4.5.9 respectively. All the meshes with total NOx emission at over 1,000 ton/year (Figure 4.5.9) are attributed to stationary sources (factories) (Figure 4.5.7). Most of the NOx emission in the meshes in DKI Jakarta, with NOx emission at between 200 and 1,000 ton/year (Figure 4.5.9) are from automobiles (Figure 4.5.8).

Table 4.5.1 Total Emission from Stationary and Mobile Sources in Jabotabek (1995)

(ton/year)

		SOx	NOx	PM	CO	HC
Stationary Sources	Factories	42,697	36,832	13,581		
	Households	4,220	4,962	642		
	Sub-total	46,917	41,794	14,223		
Mobile Sources	Automobiles	8,142	98,738	9,563	564,292	97,971
	Ships	808	1,960			
	Aircraft	91	1,026			
	Sub-total	9,041	101,724	9,563	564,292	97,971
Total		55,958	143,518	23,786	564,292	97,971

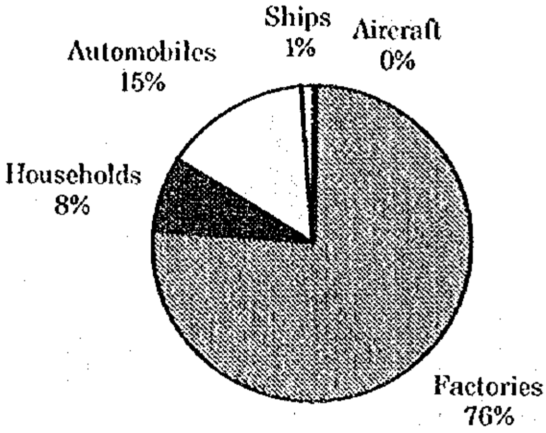


Figure 4.5.1 Shares of Sources in Total SOx Emission (1995)

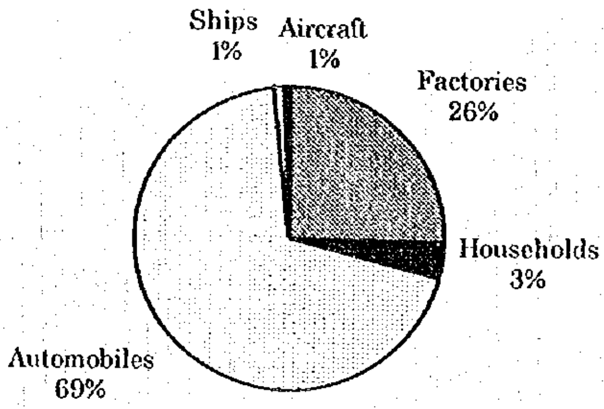


Figure 4.5.2 Shares of Sources in Total NOx Emission (1995)

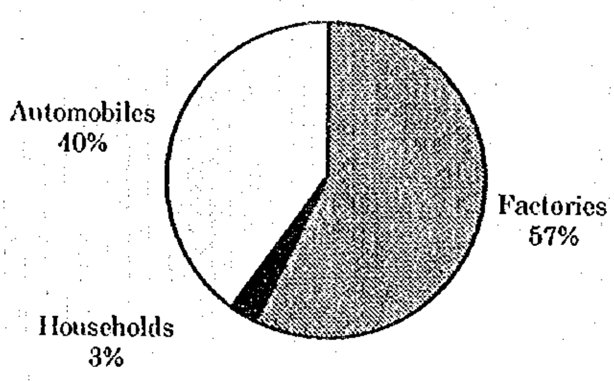


Figure 4.5.3 Shares of Sources in Total PM Emission (1995)

Several studies estimated air pollutant emission in Jabotabek and DKI Jakarta. They are given in Appendix 3.4. Total Jabotabek emission of the Team ranges from one half to two and half of that of JUDP III. These two different estimates are roughly in same order.

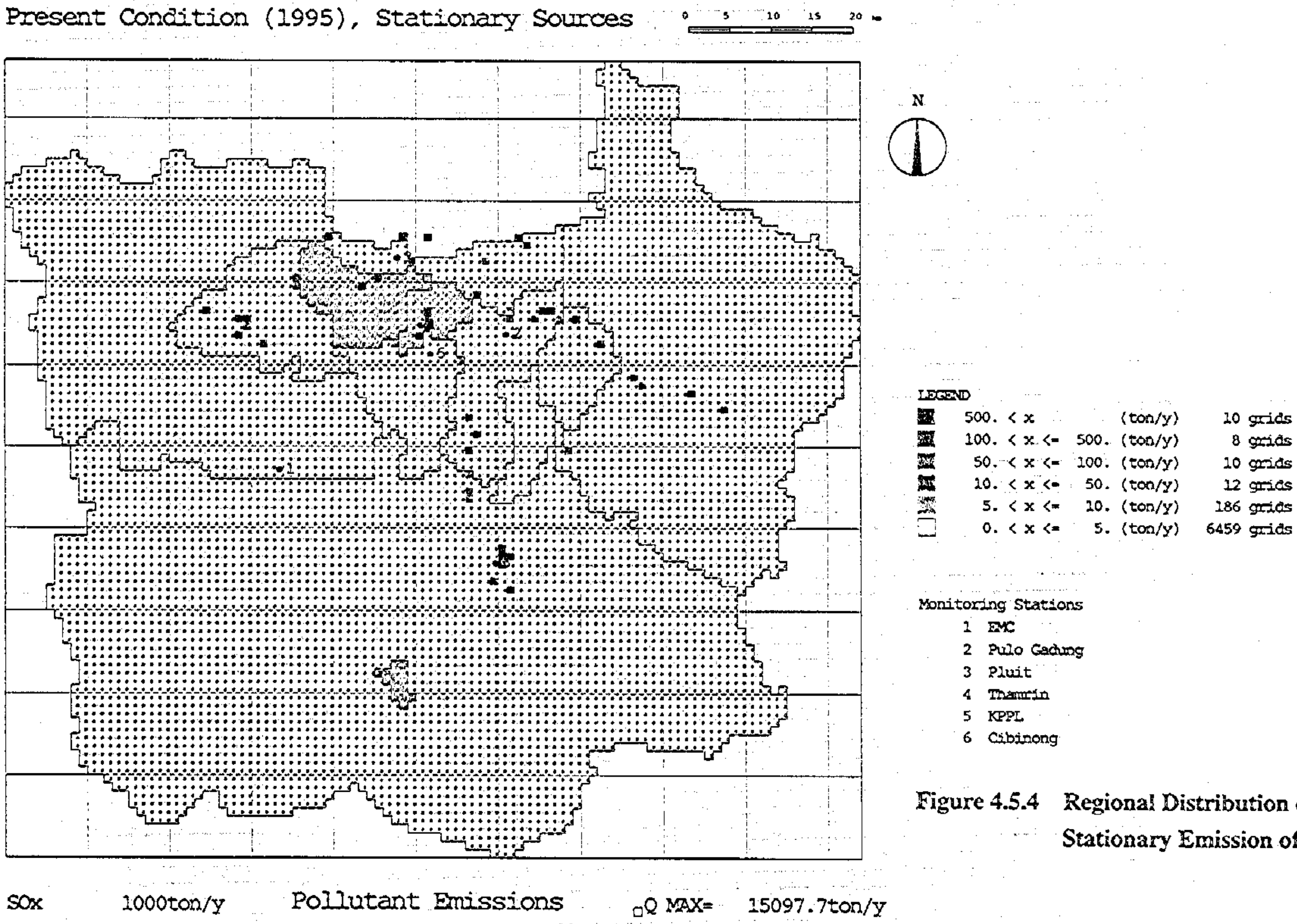
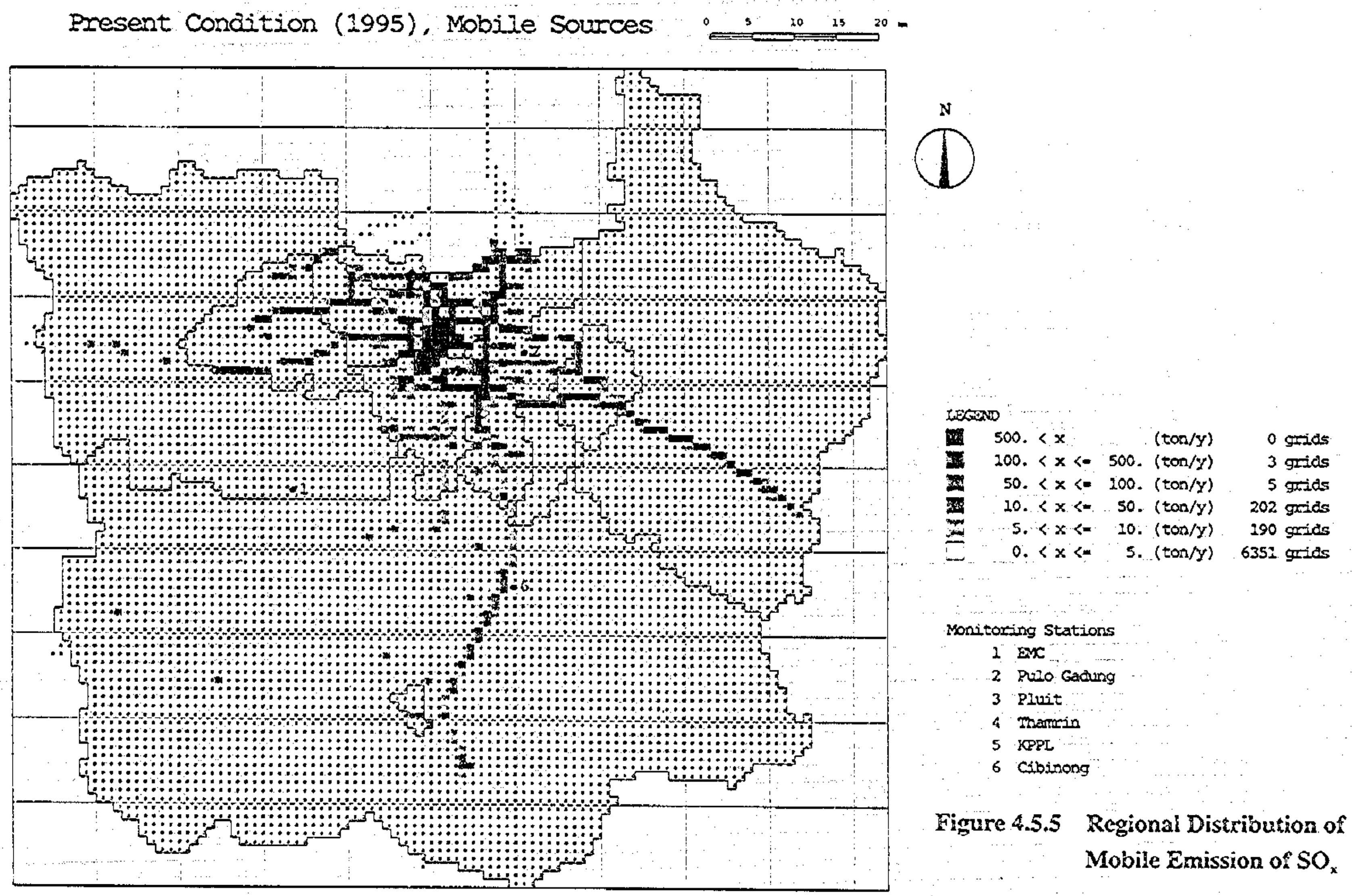


Figure 4.5.4 Regional Distribution of Stationary Emission of SO_x

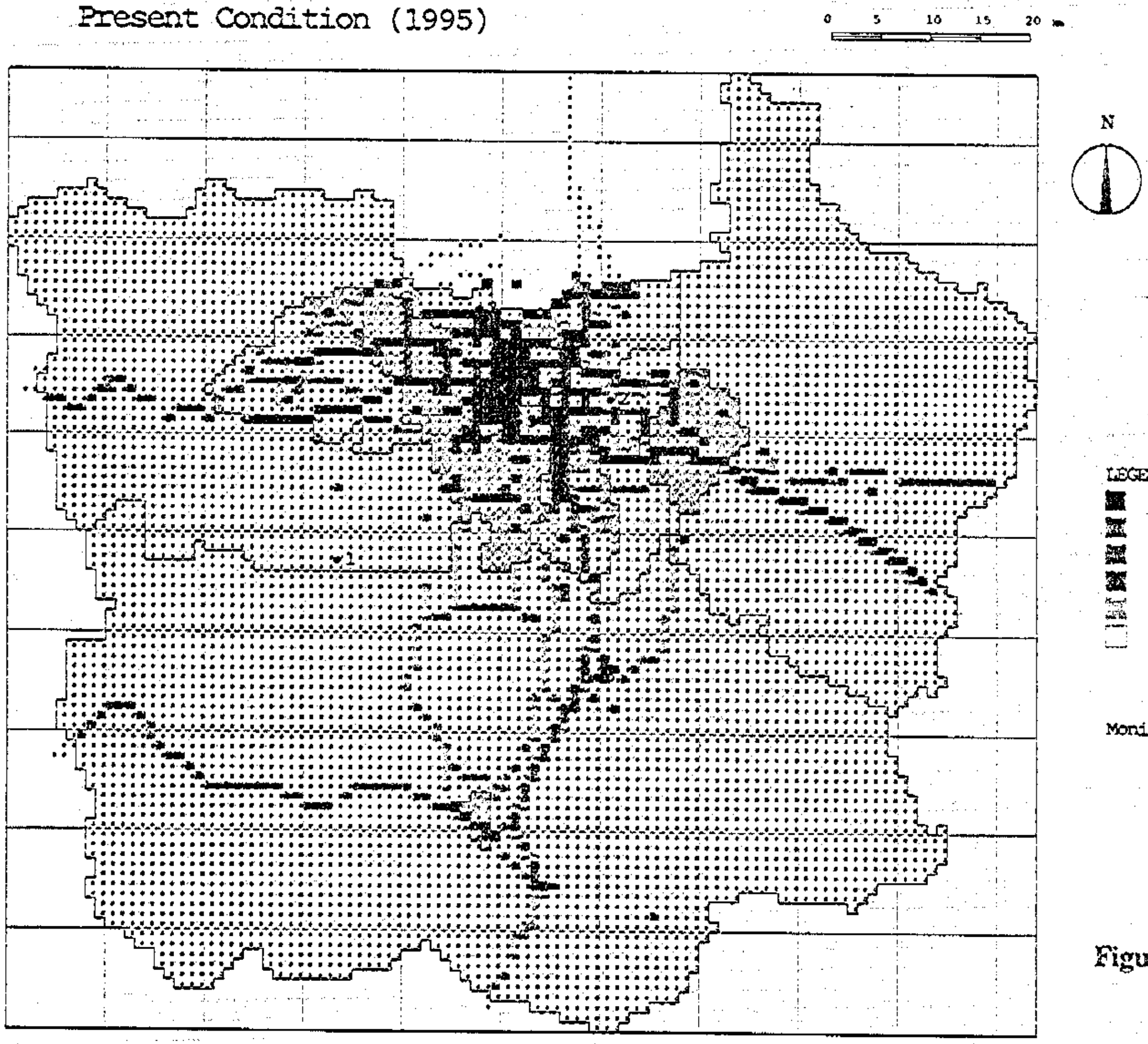
Present Condition (1995), Mobile Sources



SOx 10ton/y Pollutant Emissions □Q MAX= 154.3ton/y

Figure 4.5.5 Regional Distribution of Mobile Emission of SO_x

Present Condition (1995)



LEGEND

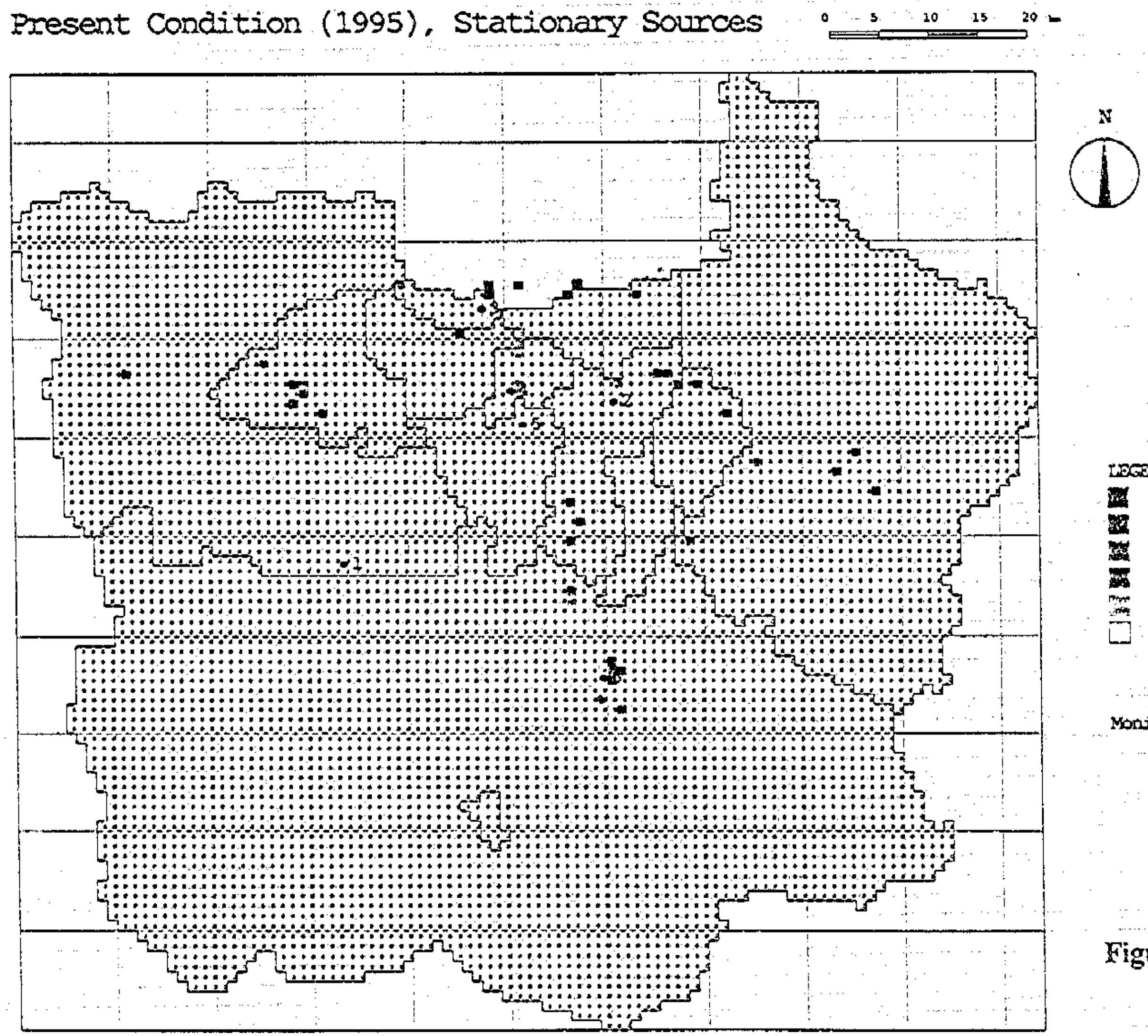
500. < x		(ton/y)	10 grids
100. < x <=	500.	(ton/y)	12 grids
50. < x <=	100.	(ton/y)	15 grids
10. < x <=	50.	(ton/y)	332 grids
5. < x <=	10.	(ton/y)	632 grids
0. < x <=	5.	(ton/y)	5753 grids

Monitoring Stations
1 EMC
2 Pulo Gadung
3 Pluit
4 Thamrin
5 KPPL
6 Cibinong

SOx 1000ton/y Pollutant Emissions □Q MAX= 15097.7ton/y

Figure 4.5.6 Regional Distribution of Total Emission of SO_x

Present Condition (1995), Stationary Sources



LEGEND

1000. < x		(ton/y)	8 grids
200. < x <=	1000.	(ton/y)	3 grids
100. < x <=	200.	(ton/y)	5 grids
20. < x <=	100.	(ton/y)	12 grids
10. < x <=	20.	(ton/y)	14 grids
0. < x <=	10.	(ton/y)	6645 grids

Monitoring Stations

1 EMC
2 Pulo Gadung
3 Pluit
4 Thamrin
5 KPPL
6 Cibinong

NOx 100ton/y Pollutant Emissions ▫Q MAX= 6848.2ton/y

Figure 4.5.7 Regional Distribution of Stationary Emission of NO_x

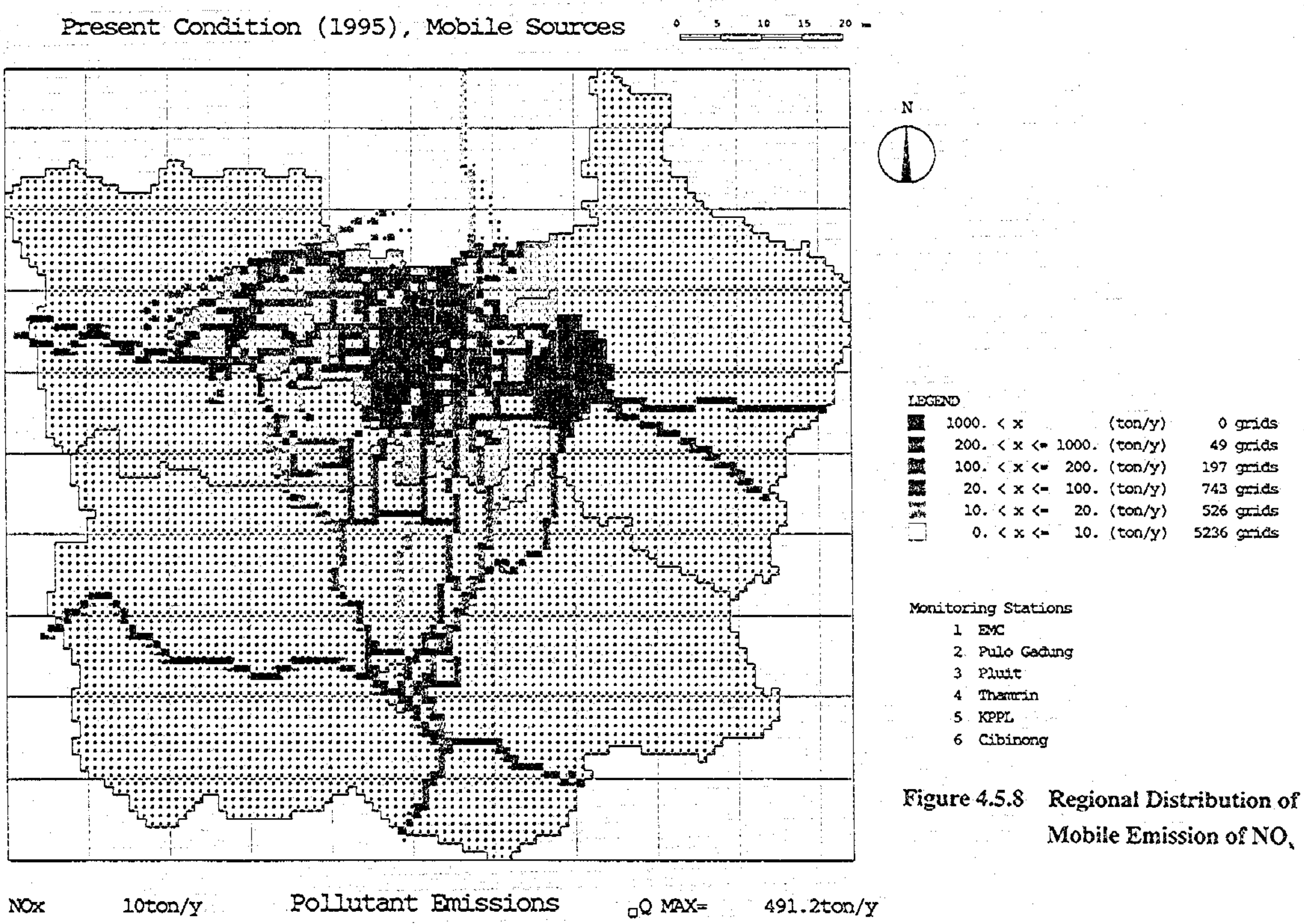


Figure 4.5.8 Regional Distribution of Mobile Emission of NO_x

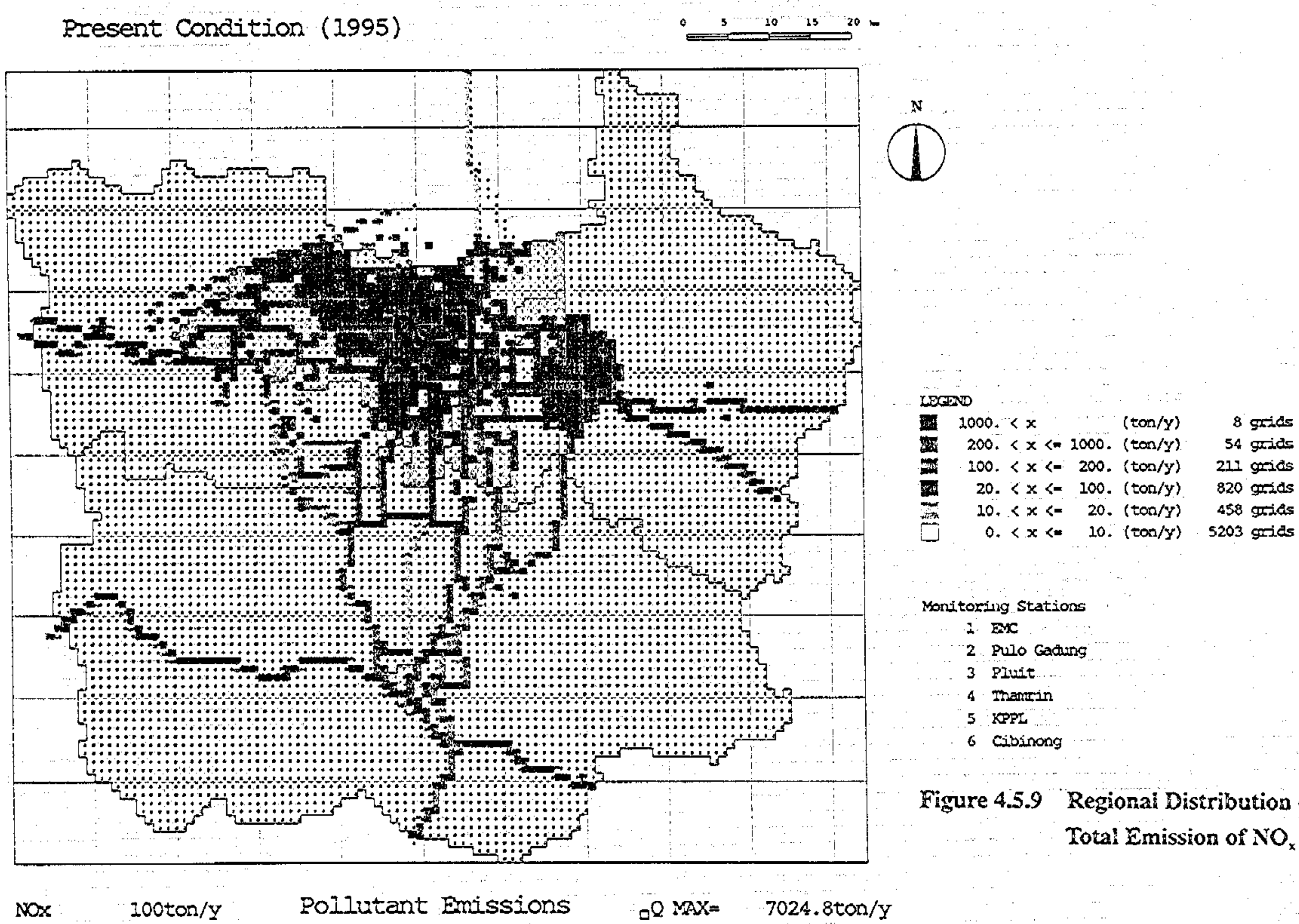


Figure 4.5.9 Regional Distribution of Total Emission of NO_x