CHAPTER 3: AIR QUALITY AND POLLUTION MITIGATION

3.1 General

Seasonal monsoon winds and sea breezes prevail in Bangkok. However there are many reports and sources of information that point out the significant atmospheric pollution in Bangkok.

Particulate matter pollution, which is quite noticeable, is especially considered to be extreme and the high level of this pollution appears to be leaching the limits of endurance. The major origin of this pollutant could be attributed to construction activities and vehicles.

In order to mitigate the air pollution in Bangkok, various issues are studied, such as the numerical simulation analysis of ground level concentration of PM-10, CO, SO2 and NO2. The purpose of these simulations is to estimate the effects of various plans, such as the reduction of pollutant emissions from vehicles, transportation improvement and urban structures. The implications from selected activities and policies relating to this atmospheric pollution.

3.2 Assessment of Present Conditions

(1) Meteorology

Generally speaking, Bangkok which lies in the monsoon zone, has a typical climate. In the dry season (Nov.~Jan.), the north-easterly wind are significant and south-westerly winds prevail during the rainy season (May ~Oct.).

Air stability, which is shown in Fig. 3.1 is an influential meteorological parameter for pollutants dispersion. In Fig. 3.1, F and G represent stable and strongly stable respectively. If the condition of the air is stable, there is little vertical mixing of air, therefore the upward dispersion of pollutants is difficult. Fig. 3.1 shows that Bangkok has a fairly high ratio of F and G, particularly from December to February. Generally speaking, under such conditions, the upward dispersion of pollutants emitted from a low altitude is difficult. It can be said that the stable condition during the dry season is one of the important factors contributing to the high PM concentration and low visibility.

(2) Pollutant Sources and Amounts

In the BMR, nearly 50% of the petroleum products consumption in Thailand occurs. Through petroleum products consumption, large amount of air pollutants are emitted continuously. The annual amount of these pollutants by sector are estimated in Table 3.1 and Fig. 3.2.

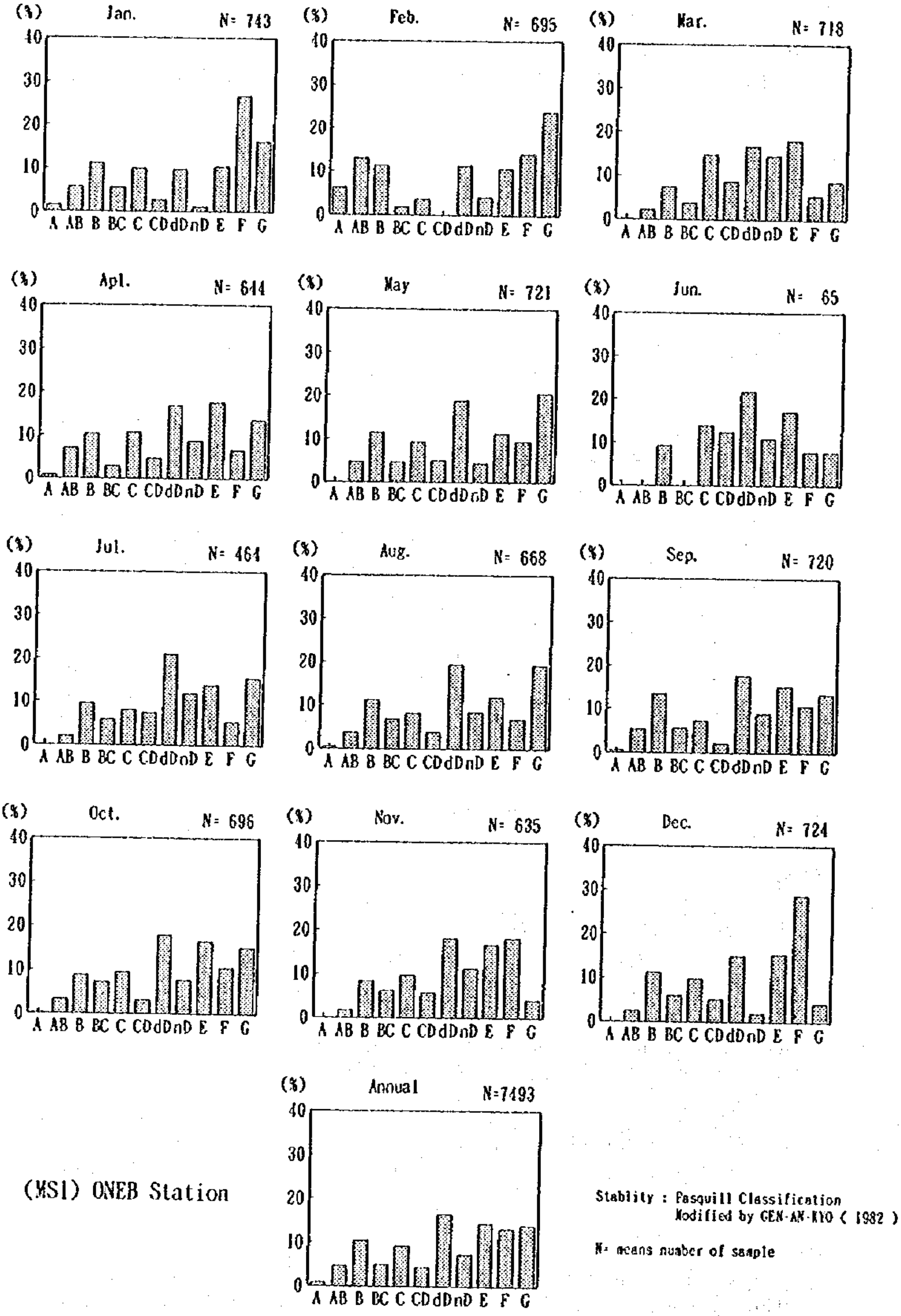
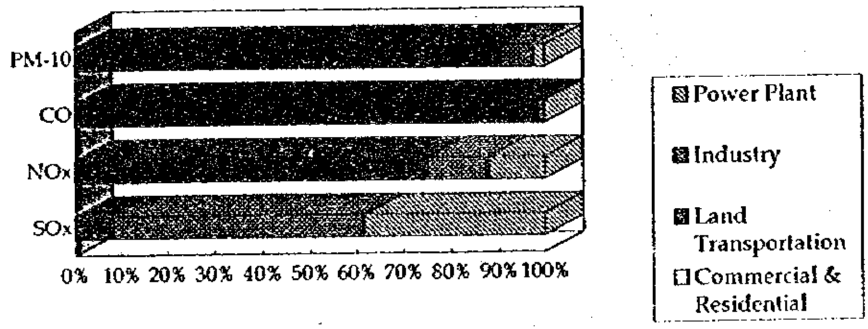


Fig. 3.1 Appearance Frequency of Atmospheric Stability 1988 (2531)

Table 3.1 Air Pollutants Emissions in BMR, by Sector, 1992 1000ton/year

Sector	SOx	NOx	CO	PM-10
Power Plant	104	23	2	4
Industry	145	24	7	12
Land Transportation	22	141	686	152
Commercial & residential	0	1	0	0

Source : Power Plant, Industry and Com. & Res. ; Air Pollution Database, 1994, PCD
Land Transportation ; JICA, BEIP Study Team



Source : Power Plant, Industry and Com. & Res. ; Air Pollution Database, 1994, PCD
Land Transportation ; JICA, BEIP Study Team

Fig. 3.2 Air Pollutants Emissions Ratio by Sector, BMR, 1992

The emissions from land transportation accounts for a very large portion of NOx, CO and PM-10. The emissions from vehicles contributes a significant, although not the highest, portion of SOx.

It is noteworthy that the emission from land transportation has a direct affect on the concentration of ground level pollutants. In addition, the stable condition of atmosphere increases the ground level concentration.

(3) Monitoring Result of Pollutants

Currently, PCD is monitoring the ambient air condition of the entire nation, with 8 stationary monitoring stations in 1994 (as shown in Fig. 3.3), and approximately 15 temporary monitoring stations in Bangkok. The Ministry of Health operates 3 stationary monitoring stations in Bangkok under the UNEP-WHO Global Environmental Monitoring System. The Department of Health, BMA, has one stationary monitoring station.

Nevertheless, the ambient air quality standard was formulated to protect people's health. It is therefore essential to review the results of the monitored ambient air condition with respect to the air quality standard.

Ambient air quality standards and the PCD's monitored ambient air condition results of 1994 is summarized in Table 3.2 . This table implies issues listed below.

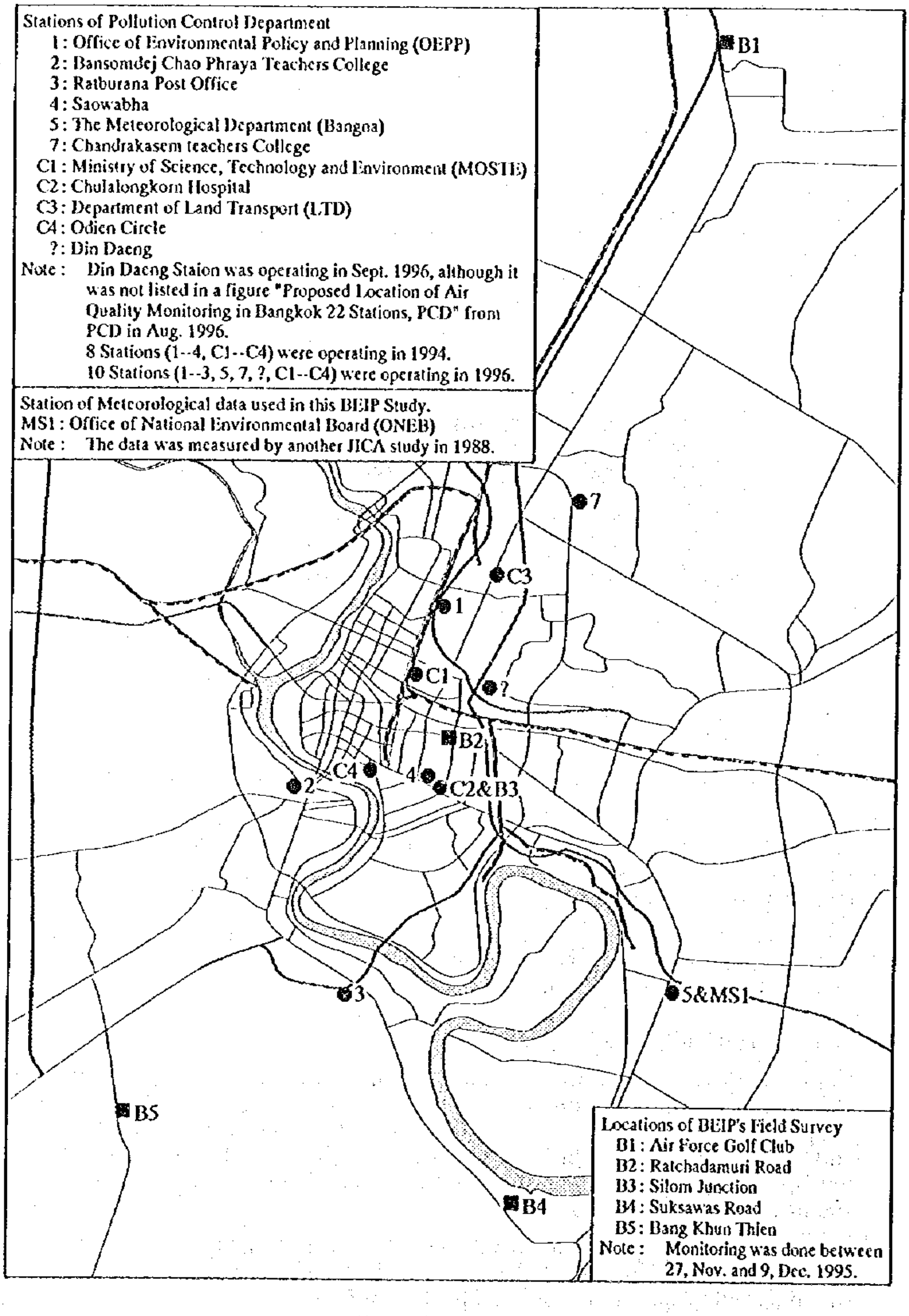


Fig. 3.3 Locations of Monitoring Stations

Table 3.2 Review of Present Situation of Atmosphere, 1994*

Pollutant	Evaluating Time	Standard Value	Roadside	General Area
CO	1 Hour	50 mg/m3	0/18	0/4
	8 Hours	20 mg/m3	2/18	0/4
NO2	1 Hour	0.32 mg/m3	---	---
SO2	1 Hour	0.78 mg/m3	---	---
	24 Hours	0.30 mg/m3	---	---
	1 Year	0.1 mg/m3	---	---
TSP**	24 Hours	0.33 mg/m3	12/15	2/4
	1 Year	0.10 mg/m3	---	3/4
PM-10***	24 Hours	0.12 mg/m3	2/2	---
	1 Year	0.05 mg/m3	---	---
O3	1 Hour	0.20 mg/m3	---	---
Lead	24 Hours	10 μg/m3	0/15	0/4

Source : Management of Air Pollution and Noise Pollution in 1993-1994, PCD
Notes : Ex. 2/15 means 2 stations value of 15 stations exceed the air quality standard.
--- column means no available data.
* Standard value were valid values as of 1994.
** Total Suspended Particulates, ***Particulates with diameters _...10/£m

First, many stations exceeded the standards of TSP and PM-10. In Fig. 3.4 and 3.5, TSP and PM-10 numerical data are graphed. Briefly, PM-10 indicates suspended dusts below 10 micron diameter and TSP indicates whole suspended dusts. For the health of the people of Bangkok, the mitigation of this high concentration of TSP and PM-10 is an urgent issue.

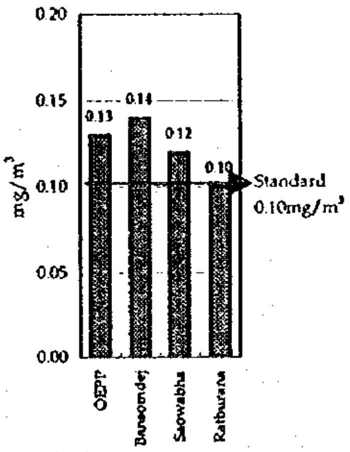


Fig. 3.4 TSP, One Year Average 1994,

General Stations

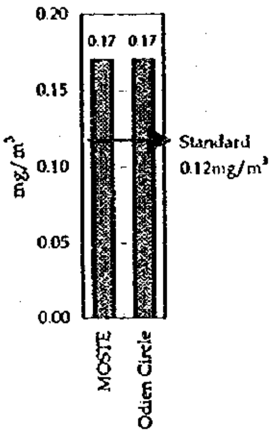


Fig. 3.5 PM-10, Max. of 24Hr Ave. 1994
Roadside Stations

It is said that PM-10 consists of two portions. One is of natural origin such as the fine matters of soil or sea-salt particulates, and the other is human activity origin matter. For human activity origin PM-10, particulate matters from vehicle exhaust pipes and factory's stacks might be typical. PM-10 is inhalable and affects human health.

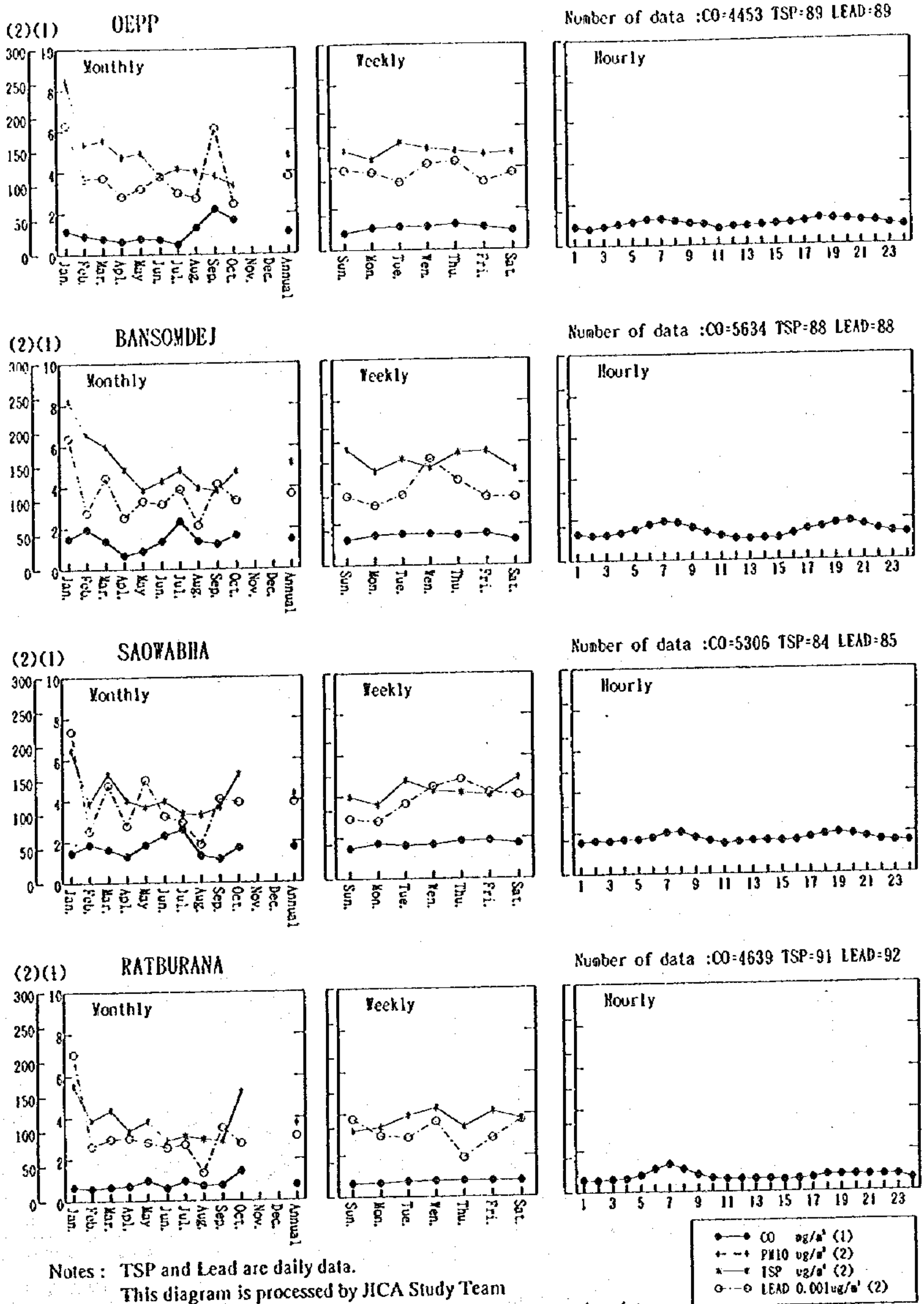
TSP consists of PM-10 and other coarse particles, exceeding 10 microns in diameter. It might be supposed that construction activities on and around roads and vehicles traveling on dusty roads are major sources of the coarse portion of TSP. In addition, peeling off dust from vehicle tires and bodies and scattering dust of truck beds might belong to coarse portion and worsen TSP concentration.

Integrated abatement measures of the above mentioned sources should be implemented urgently, not only for PM-10 but also for TSP.

Second, mitigating the level of CO is another target. One hour values are under the standard, however 8 hours average exceeds the standard at some roadside stations. Vehicles are thought to be the cause, and vehicle traffic is expected to increase in the future. Regulations with regard to CO from vehicles may be necessary.

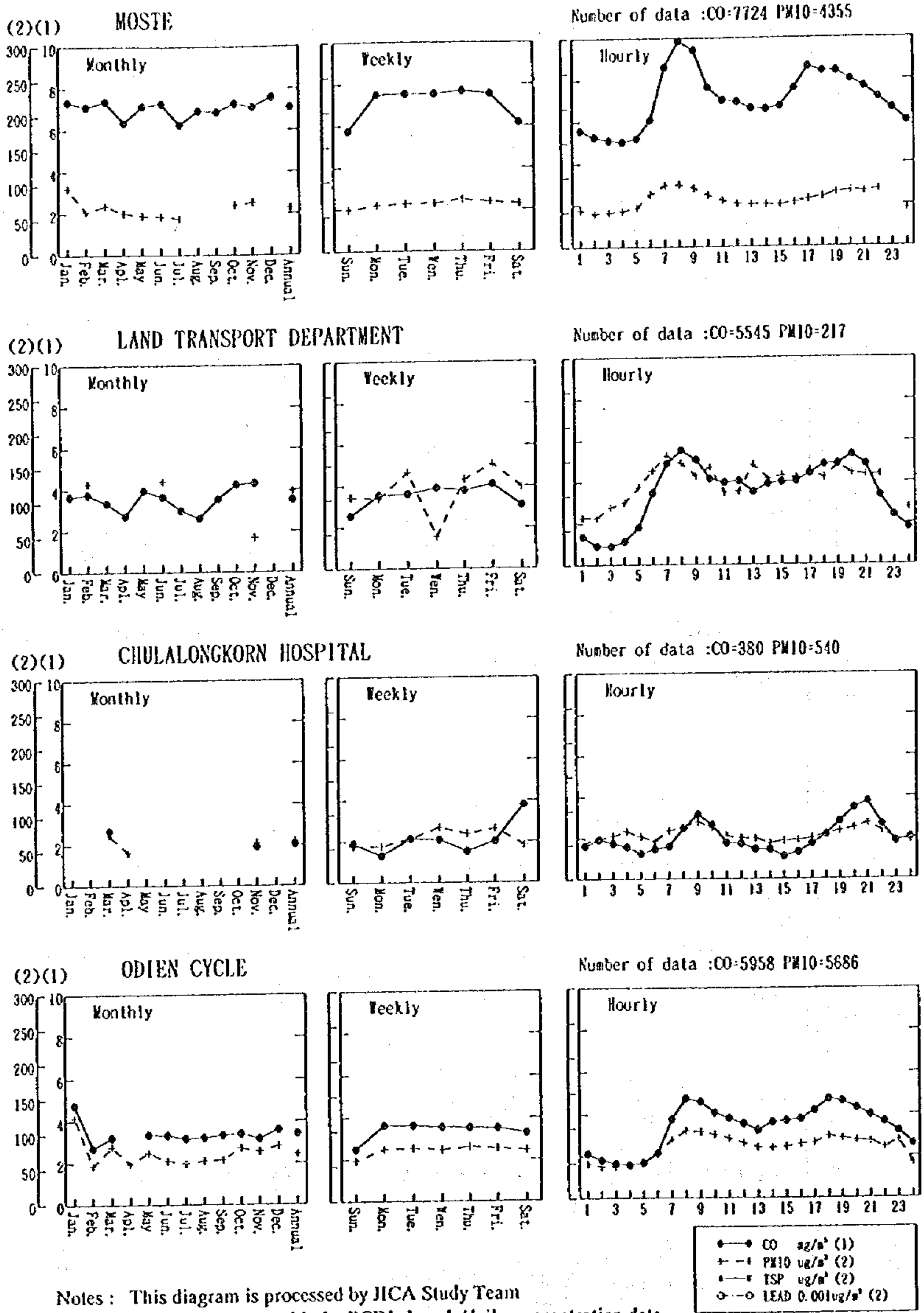
Third, there are many loopholes for reviewing the current atmospheric pollution. The monitoring activity is not sufficient. SO2 and NO2 were not monitored in 1994. PCD has already started monitoring of SO2 and NO2 mainly at residential area stations. This activity should be strengthened to monitor not only residential areas but also roadside areas. The roadside areas should be monitored as many inhabitants earn their living at roadside areas in Bangkok. In addition, PCD started monitoring O3. If these monitoring data are reviewed analytically, the significant characteristics of pollution in Bangkok could be understood.

The processing result of PCD's 1994 monitoring data by the Team are shown in Fig. 3.6 and Fig. 3.7. If this processing was done continuously, significant characteristics of air pollution in Bangkok could be found. From Fig. 3.7, hourly roadside graphs of CO and PM-10 might indicate the effect of vehicle emission. It should be noted that the lack of meteorological data, such as wind direction and speed, at each station lead to the limitation of studying and the reviewing of results. In addition, the frequent suspension of monitoring may devalue the quality of outcomes.



Notes : TSP and Lead are daily data.
This diagram is processed by JICA Study Team
with the PCD's hourly/daily concentration data

Fig. 3.6 Variations of Air Quality Concentration, 1994 (2537), General Stations



Notes : This diagram is processed by JICA Study Team with the PCD's hourly/daily concentration data

Fig. 3.7 Variations of Air Quality Concentration, 1994 (2537), Roadside Stations

Field Survey Results of the JICA BEIP Study Team

Ambient Air Quality Survey

Methodology

A ambient air quality survey was undertaken Nov. - Dec., 1995. Survey points were established along trunk roads, and their locations are shown in Fig. 18.3 in the text. Parameters of the survey were SO2, NO2 and CO using simplified methods. SO2 and NO2 were exposed for 24 hours, collected by TEA immersed filters and analyzed by ionchromatography. CO were detected directly by gas detectors. The traffic volume from 5:30 to 21:30 was studied together.

Result 1 Outside of the Central Business Zone

Table 1 shows the result of the survey outside of the central business zone. The roadside south of Bangkok showed fairly high values of SO2 and NO2. It might be worth reviewing the influence of stationary sources of this area. Other data showed low values.

Table 1 Survey outside of the central business zone

	Roadside			Approx. 100m from Roadside			Traffic PCU and HCR*	
Location	SO2 ppb	NO2 ppb	CO ppm	SO2 ppb	NO2 ppb	CO ppm	Outbound	Inbound
North (Air Force Golf Club, Route 1)	5	22	0.4	4	20	0	104,856 0.18	101,794 0.16
South (Suksawat Road)	61	80	0	12	28	0	16,395 0.22	17,142 0.24
South-West (Bang Khun Thien Road)	6	39	0	3	15	0	9,911 0.24	8,451 0.09

Note: * HCR ; heavy car ratio

Result 2 Central Business Zone

In the central business zone, intersections of Ratchadamri/Ploenchit-Rama 1 and Ratchadamri-Silom/Rama 4 were chosen for the survey. Survey results of each intersection are shown in Fig. 1 and 2.

These two figures show relatively high levels of NO2 at the roadsides of the central business zone. As the high value of NO2 could be attributed to vehicle emission, mitigation measures towards vehicles should be implemented.

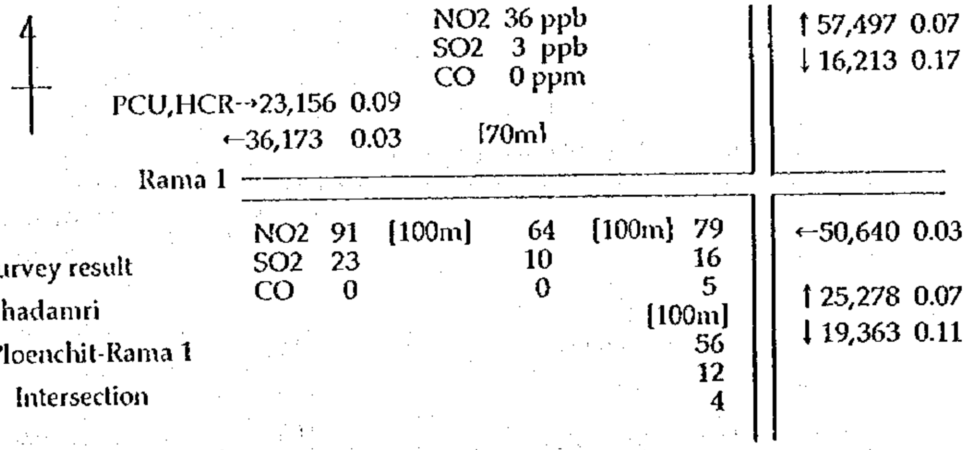


Fig. 1 Survey result
Ratchadamri
/Ploenchit-Rama 1
Intersection

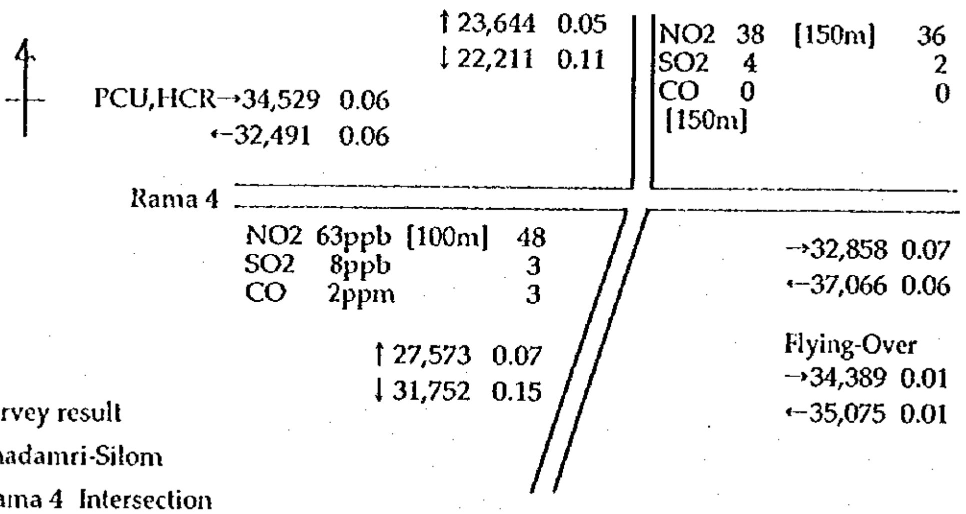


Fig. 2 Survey result
Ratchadamri-Silom
/Rama 4 Intersection

Stationary Source Survey

Stationary source sampling survey was carried out on an interview basis. Twenty-five factories and five households were selected for the sample. AS large consumers of fuel do not exist in the BMA, large exhaust gas emitters adjacent to Bangkok were chosen in addition.

The objective of this sample study is to obtain supporting data for quantitative characteristics which were found in existing reports and papers.

However data did not contradict the existing reports, the outcome from factories couldn't be considered as quantitatively sufficient. It might be supposed that the quantitative recognition of pollutants through production process of operation are not yet familiar. Presently, voluntary environmental management, such as the ISO14000 system, might start to be introduced to the private sector. The recognition of the combustion process and formation of pollutants may act substantial role at the time of the introduction and accomplishment of environmental management systems.

Health Impacts by Air Pollution

Assessing the health effect of atmospheric pollution is not easy, as various conditions affect the human health. Available health effect data appears to be scarce in Bangkok. Table 1 to 4 include available information regarding pollution-related diseases in Bangkok.

Table 1. Incidence of air pollution-related diseases in 1995

(1) Comparing Bangkok and Nakhon Sawan

	Bangkok	Nakhon Sawan
Number of samples	911	203
-All air pollution-related ailments	19%	8%
-Dust-inflicted lung inflammation	19%	7%
-Carbon monoxide poisoning	17%	0%
-Chronic lead poisoning	11%	0%

(2) Comparing inner, middle and outer Bangkok and suburb

	Inner	Middle	Outer	Suburb
Number of samples	235	236	235	205
-All air pollution-related ailments	23%	21%	17%	16%
-Dust-inflicted lung inflammation	27%	18%	15%	16%
-Carbon monoxide poisoning	22%	12%	12%	13%
-Chronic lead poisoning	14%	9%	9%	9%

Notes : Inner;Ratchathewi, Middle;Rat Burana, Outer;Lat Krabang, Suburb;Bang Phli
Source : The Pollution Control Department and the Occupational Health Medicine and Environment Association
Quoted from the Bangkok Post, Sept. 16, 1996

Table 1 may clearly show the health effects of atmospheric pollution, i.e. dust, CO and lead. While Table 2 and 3 include available data regarding the trend of respiratory system diseases in Bangkok, it has been considered that more data are needed for specific recognition.

Table 2. Number of reported cases of Pneumonia and Influenza in Bangkok

	1983	1984	1985	1986	1987	1988	1989	1990
Pneumonia	350	395	595	1763	4288	5765	5646	3384
Influenza	2286	2875	3001	2715	2733	2240	1707	874

Source : Ministry of Public Health, 1989, 1990
Quoted from Urban Air Pollution in Mega-cities of the World, WHO and UNEP, 1992

Table 3. Number of diseases of the respiratory system and total out-patients in hospitals in the BMA

	1989	1990	1991	1992	1993
Diseases of the respiratory system	809,214	729,511	778,077	742,004	779,141
Total out-patient	5,197,776	4,997,416	5,029,734	5,160,334	5,172,089
Ratio	0.16	0.15	0.15	0.14	0.15

Source : Statistical Profile of BMA 1991, 1992, 1993

Table 4 includes health impact information data by calculation. It should be noted that these impacts are not assessed empirically, but are calculated using standardized risk formulas.

Table 4. Impacts Attributed to Ambient Air Pollution in Bangkok

Pollutant	Impact
Particulate	51 million restricted activity days (including 26 million lost work days) and 1,400 excess mortalities in 1989
Carbon Monoxide	20,000 - 50,000 people at risk of increased angina pain/day ; 900,000 - 2,300,000/day at risk of minor effects such as headaches

Source : USAID, 1990 Ranking Environmental Health Risks in Bangkok, Thailand (Vols.1 and 2)

Awareness for environmental protection should be enhanced by adequate scientific information and explanation. It would be helpful for the enhancement of awareness to study the health effects of pollution and thereafter publicize the results to encourage discussion..

(4) Simulation of Air Pollution (Present Condition)

In order to review the present condition and evaluate the effects of policies in the future, the simulation analysis of air pollutants is introduced. Simulation of the present condition of air pollution is described in this chapter.

First, PM-10, CO, SOx and NOx emissions from vehicle and power plants, supposedly the major sources of pollution, and then emissions from households are examined as described in 1). Second, their ground level concentrations are computed by the BEIP diffusion model as described in 2). Third, outputs of simulation are analyzed as described in 3).

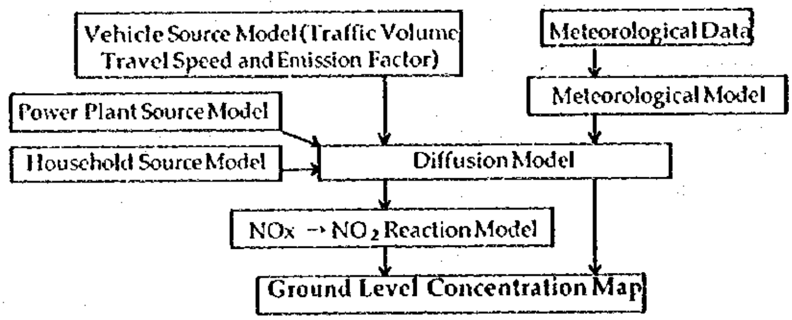


Fig. 3.8 Flow Chart of Simulation

1)Air Pollutant Sources

Emission of pollutants from sources was estimated and modeled to be applied to the dispersion simulation model. The objective pollutant sources were motor vehicles, two thermal power plants (South Bangkok Power Plant and North Bangkok Power Plant) and households.

The estimating methodology and emission amount estimated from each source are as follows:

Emission from Vehicles

Emission from vehicles were estimated for each link by using the emission factor, traffic volume and travel speed data as;

$$Q_{lz} = \sum_{t} \left(EF_t(s_{lz}) \cdot V_{lzt} \right)$$

where;

Q_{lz}: Quantity of Pollutant of each Time Zone per each Link;

$EF_t()$: Emission Factor of each Vehicle Type;

s_{lz}: Travel Speed of each Time Zone per each Link;

V_{lzt}: Traffic Volume of each Vehicle Type of each Time Zone per each Link.

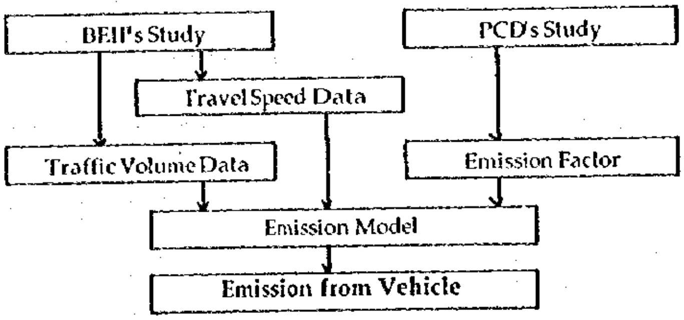


Fig. 3.9 Flow Chart to Estimate Emission from Vehicles

a.Emission Factor

The emission factors applied for estimation are quoted from "Air Emission Database of Vehicles and Industry in Bangkok Metropolitan Region 1992: PCD MOSTE" which is the most authoritative source at this time.

The objective pollutants are PM-10, CO, SO_2 and NO_X, and the emission factors are established by the average driving speed of each vehicle type as shown in Table 3.3.

The emission rate of CO is high from small vehicles and Motorcycles, and NOx and SOx is high from large vehicles.

b.Road Network, Traffic Volume and Traffic Speed

The road network and traffic volume data which were prepared for the present analysis by the traffic planning sector of the BEIP study, were applied for the pollutant load estimation. The traffic volume was classified into 9 vehicle types (Motorcycle, Samlor, Taxi, Passenger Car, Medium Bus, Heavy Bus, Light Duty Truck, Medium Duty Truck and Heavy Duty Truck). The average traveling speed on each road was also prepared.

The total amount of trip volume (vehicle·km) by vehicle type is as shown in Table 3.4.

Table 3.3 Emission Factors

Pollutants	Vehicle Type	Averaged Speed (km/h)				
		0-1	8	16	24	32
PM-10 (g/km)	Small	2.77				
	Medium	4.48				
	Large	8.34				
	MC	10.00				
CO (g/km)	Small	491.43	156.74	75.92	50.66	40.80
	Medium	11.97	3.64	2.46	1.86	1.20
	Large	28.33	20.59	14.15	10.17	7.61
	MC	152.94	71.69	38.34	27.24	22.06
SO_2 (g/km)	Small	0.53				
	Medium	0.78				
	Large	1.60				
	MC	0.20				
NO_X (g/km)	Small	5.23	2.06	1.87	1.85	1.93
	Medium	12.40	1.88	1.57	1.38	1.18
	Large	28.19	21.65	17.96	15.43	13.73
	MC	0.40	0.20	0.20	0.20	40.80

Note: Small; Passenger Car, Samlor, Taxi, Station Wagon
Medium; Van, Pickup, Medium Truck
Large; Truck, Bus, Trailer
MC; Motorcycle
Source:Air Emission Database of Vehicles and Industry in Bangkok Metropolitan Region 1992: PCD MOSTE

Table 3.4 Total amount of Trip Volume (Unit: 10^3 Vehicle-km/Day)

Type	Trip Volume	Type	Trip Volume
MC	15,047	Heavy Bus	9,433
Samlor	1,504	Light Duty Truck	18,929
Taxi	5,871	Medium Duty Truck	6,833
Passenger Car	21,638	Heavy Duty Truck	7,175
Medium Bus	6,690	Total	93,115

Source: BEIP Study Team

c.Estimated Results of Pollutants' Load Amount

The estimated results of pollutants' load from motor vehicles based on the emission factors and trip volume described above are shown in Table 3.5. These emission loads are estimated as in the year of 1995.

Table 3.5 Estimated Results of Pollutants' Load Amount (Unit: ton/y)

Type of Car	PM-10	CO	SO_x	NO_x
MC	54,915.8	173,858.3	1,098.3	1,128.8
Samlor	1,520.4	36,303.2	290.9	1,109.3
Taxi	5,935.8	133,651.2	1,135.7	4,298.9
Passenger Car	21,876.5	481,185.8	4,185.8	15,810.9
Medium Bus	20,367.1	21,647.3	3,907.4	35,492.4
Heavy Bus	28,715.1	30,347.1	5,508.9	49,926.7
Light Duty Truck	30,951.2	11,626.2	5,388.8	10,229.1
Medium Duty Truck	20,795.8	22,295.5	3,989.6	36,357.9
Heavy Duty Truck	21,842.6	23,186.6	4,190.4	38,042.3
Total	206,920.2	934,101.0	29,695.8	192,396.3

Source: BEIP Study Team

Emissions from Thermal Power Plants

Two thermal power plants, North and South Bangkok Power Plants, are included as pollutant sources for the model as the share of pollutants emitted from them is significant.

Basic data for the model were obtained from "Air Emission Database of Vehicles and Industry in Bangkok Metropolitan Region 1992: PCD MOSTE". The fuel consumption and pollutants' load from each power plant are shown in Table 3.6.

Table 3.6 Fuel Consumption and Pollutants' Load of Power Plants

Name of Power Plant	Type of Fuel	Fuel Consumption	SOx	CO	NOx	PM-10
		(ton/y)				
South Bangkok P. P.	Heavy Oil	2,340,000	108,482	1,404	15,444	2,925
North Bangkok P. P.	Heavy Oil	478,440	22,927	287	3,158	598
Total	Heavy Oil	2,818,440	131,410	1,691	18,602	3,523

Source:Air Emission Database of Vehicles and Industry in Bangkok Metropolitan Region 1992: PCD MOSTE

Emissions from Households

Emissions from households were estimated as;

$Qg = Pg \times Qp$

Qg: Quantity of pollutant from each grid

Pg: Grid population data (Source: BEIP Study Team)

Qp: Quantity of pollutant per capita

$$Qp = \frac{V}{P} \cdot EF$$

V: Annual Fuel Consumption of Residential Sector of Bangkok (PCD, 1994)

P: Total grid population of Bangkok (Source: BEIP Study Team)

EF: Emission Factor for LPG burning (Table 3.7)

Table 3.7 Emission Factors for LPG Burning (kg / 1,000 liters)

	PM-10	CO	SO_2	NOx
LPG	0.06	0.23	0.0048	1.13

Source: Air Emission Database of Vehicles and Industry in Bangkok Metropolitan Region 1992, PCD, 1994

Table 3.8 Total Emissions from Households in BMA (ton/y)

PM-10	CO	SO_2	NOx
13	50	1	246

Source: BEIP Study Team

2) BEIP Simulation Model for Air Pollution

In order to estimate the ground-level concentration distribution of pollutants in the BMA, the "BEIP Simulation Model for Air Pollution" was prepared through its parameters fitting and simulation was carried out. The outline of the simulation model is as follows and the preciseness is shown in the sector paper. Outline of simulation procedure is shown in Fig. 3.10.

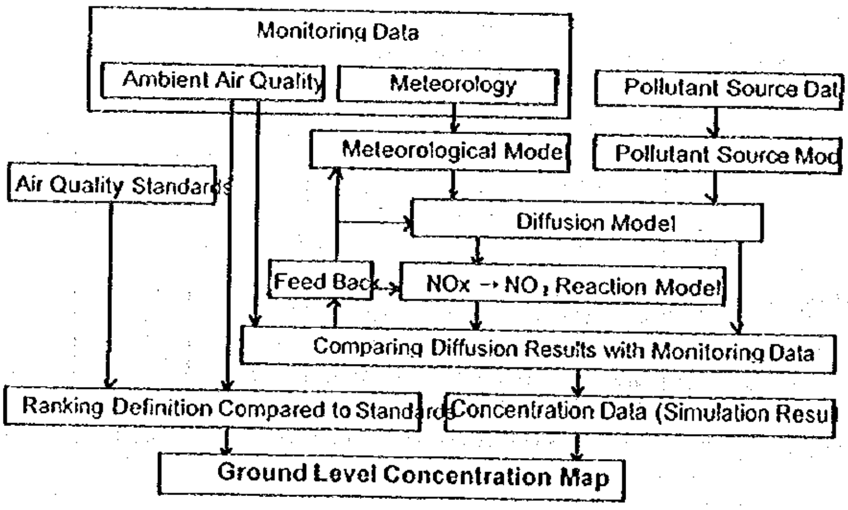


Fig. 3.10 Flow Chart of Diffusion Simulation

Targets of Simulation

The targets of the "BEIP Simulation Model for Air Pollution" are as follows:

- Simulated air pollutants are SO_2, NO_x, NO_2, PM-10 and CO;
- Computerized value is the annual arithmetic mean concentration;
- Pollutant sources are motor vehicles, thermal power plants, and households; and
- Target area of concentration calculation is BMA.

Applied Meteorological Data

Meteorological data observed at ONEB Station in 1988 by JICA is applied for the diffusion simulation model. The data were classified follows:

- Wind Direction: 16 Direction (N~S~NNW)
- Wind Speed: 8 Classes as 0~0.4m/s, 0.5~0.9, 1.0~1.9, 2.0~2.9, 3.0~3.9, 4.0~5.9, 6.0~7.9, and 8.0~)
- Air Stability: Pasquill's Stability Classification (10 Classes; A(unstable)~D(neutral)~ G(stable))

Seasons and Time Zones

One(1) year is divided into three(3) seasons and four(4) time zones as shown in Table 3.9.

The average concentration of each period is estimated, and totaled to estimate the annual concentration.

Table 3.9 Seasons and Time Zones

Season	Month
Wet Season	May to October
Dry Season	November to January
Intermediate	February to April

Time zone	Time
Morning	6:01 to 10:00
Afternoon	10:01 to 16:00
Night	16:01 to 23:00
Midnight	23:01 to 6:00

Source: BEIP Study Team

Pollutant Source Modeling

Each pollutant source is modeled for the diffusion simulation model as follows.

Table 3.10 Pollutant Source Model

Source		Type
Vehicle	Major roads	Line
	Other minor road	Area
Power Plant		Point
Household		Area

Source: BEIP Study Team

Diffusion Model

The height of the plume rise from thermal power plant stacks is estimated by CONCAWE Equation (CONCAWE, 1966) and Briggs Equation (Briggs, 1969). The concentration from each pollutant source is estimated by Gaussian Plume Equation if it is windy (Wind speed is more than or equal to 0.5m/s) and Gaussian Puff Equation if it is calm (Wind speed is less than 0.5m/s).

Reproducibility of the Diffusion Simulation Model

Reproducibility of the diffusion simulation model was checked through regression analysis using the actual monitored data of CO.

The Scatter Diagram of estimated and actual CO concentration (annual) is shown in Fig. 3.11. The model is considered to have sufficient reproducibility as the gradient of regression line is near to 1.0 and the coefficient of correlation is more than 0.9.

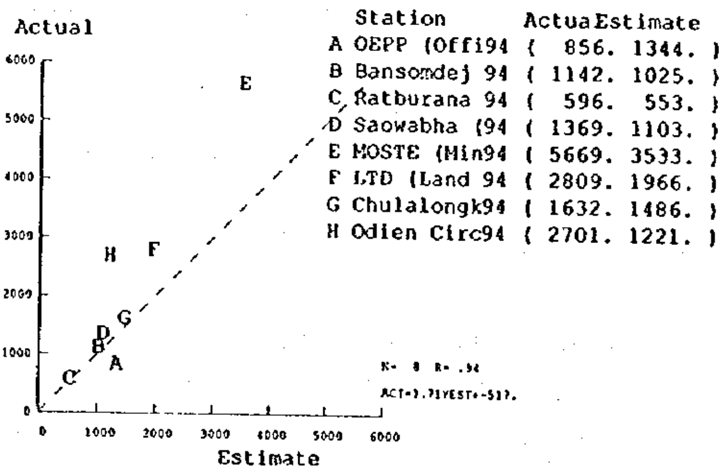


Fig. 3.11 Scatter Diagram Comparing the Simulation Result (Estimate) and the Monitoring Result in 1994 (Actual) (CO, ppb)

Comparison of Simulated Annual Average to Air Standards

Simulation results are annual arithmetic averages. For ranking these results by comparing with the standards, two types of ideas were introduced.

(1) For example, SO2 has three different standard values according to evaluating time (1 hour and 24 hours average and 1 year geometric average). The standard most difficult to attain was selected among several standards by statistical analysis.

(2) For ranking annual, arithmetic mean (simulation result) by comparing with the standards, the statistical method was also introduced.

These considerations might assure the adequacy of comparison by statistical probability. The detailed method of this analysis is described in Appendix.

Table 3.11 Ranking of Annual Arithmetic Average of Air Pollutant Concentration, compared to the ambient air standards

	PM-10 (μg/m³)	CO (ppb)	SO_2 (ppb)	NO_2 (ppb)
Much Lower than the Standard	≤ 20	≤ 722	≤ 9	≤ 9
Lower than the Standard	≤ 40	≤ 1445	≤ 19	≤ 17
Possibly Lower than the Standard	≤ 52	≤ 2131	≤ 24	≤ 21
Possibly Higher than the Standard	≤ 88	≤ 4748	≤ 36	≤ 30
Higher than the Standard	≤ 177	≤ 9496	≤ 72	≤ 60
Extremely Higher than the Standard	177<	9496<	72<	60<

Source: BEIP Study Team

3) Result of Simulation Analysis (Present Condition)

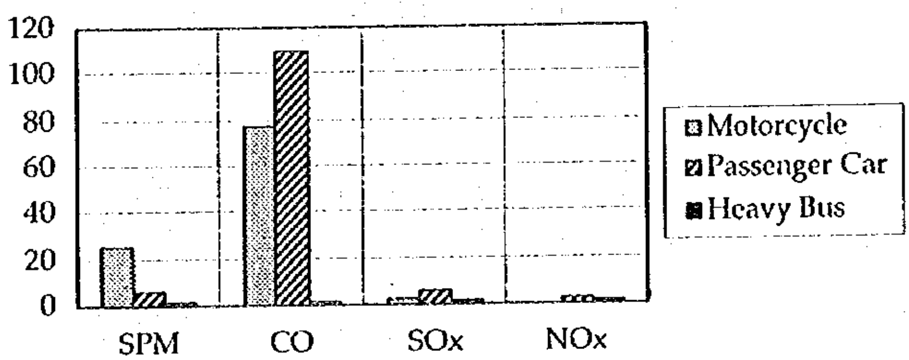
Emission per Distance per Passenger

Emission per Distance per Passenger (hereinafter, Unit Pollutant Emission, g/km/person) was computed by the BEIP Study Team, shown in Table 3.12 and Fig. 3.12. These values were calculated by using the total emission, trip volume (vehicle·km) and occupancy rate (person/vehicle) of the entire BMR.

Table 3.12 Unit Pollutant Emission (g/km/person), Average of BMR

	PM-10	CO	SOx	NOx
Motorcycle	7.14	22.6	0.143	0.147
Passenger Car	1.46	32.1	0.279	1.05
Heavy Bus	0.278	0.294	0.0533	0.483
Car/ Heavy Bus Ratio	5.25	109.	5.23	2.17

Note: Occupancy Rates are 1.4 for Motorcycle, 1.9 for Passenger Car and 30 for Heavy Bus
Source: BEIP Study Team



Source: BEIP Study Team

Fig. 3.12 Ratio of Unit Pollutant Emission (bus emission per passenger = 1.0)

Emission of motorcycles is low with regard to NOx, but extremely high for PM-10. Passenger cars show considerable SOx and NOx emissions. Buses show the lowest emissions of SOx, CO and PM-10 and the second lowest for NOx after motorcycles. The low emissions results for buses is a reflection of their high occupancy rate.

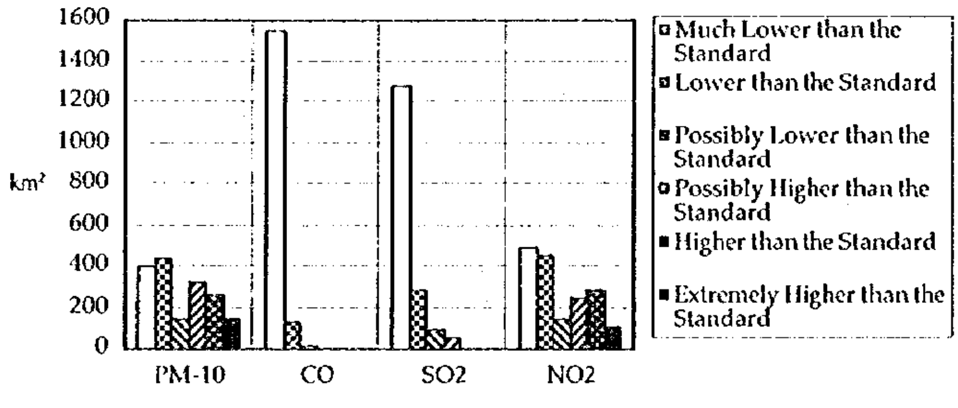
Air Pollutant Distribution

The concentration distribution of air pollutants is shown in Fig. 3.13 and the area of each ranking is shown in Table 3.13 and Fig. 3.14.

Table 3.13 Area of Each Ranking (km^2)

Rank	PM-10	CO	SO_2	NO_2
Much Lower than the Standard	395.50	1,551.75	1,275.25	485.50
Lower than the Standard	444.50	134.50	287.75	455.50
Possibly Lower than the Standard	145.00	17.50	93.25	144.50
Possibly Higher than the Standard	324.00	4.25	48.25	241.25
Higher than the Standard	263.00	0.00	3.50	283.75
Extremely Higher than the Standard	136.00	0.00	0.00	97.50

Source: BEIP Study Team



Source: BEIP Study Team

Fig. 3.14 Area of Each Ranking (km^2)

Fig. 3.13

Air Pollution Simulation

Case 1

Present Vehicle Emission Factor
Present Road Network
Present Mass Transit Network
Present Transport Demand

N W E S

SCALE 1:470000

5 0 5 10 15 20

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THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

The "Higher than the Standard" area of PM-10 covers the BMA widely, thus not contradicting the monitoring results that indicate that the majority of monitoring stations exceed the standard.

There is no area where the CO concentration is "Higher than the Standard" or "Extremely Higher than the Standard." The "Possibly Higher than the Standard" area is limited to some major roads. There is no contradiction between this simulation result and the monitoring result by PCD, i.e., exceeding CO standard points are only 2 out of 18.

The "Higher than the Standard" area of SO_2 is limited to some major roads. The influence of power plants is an important factor in SO_2 air pollution as all the grid cells are "Possibly Lower than the Standard" or "Lower than the Standard" if only air pollutants from motor vehicles are simulated.

"Higher than the Standard" covers a wide area in the NO_2 map.

Top 20 Grid Cells of High Concentration

Fig. 3.15 shows the top 20 cells of concentration. Areas along the expressways and part of the built-up area are included. Most of the areas are in the Ratchathewi district, on the First Stage Expressway from Din Daeng to Khlong Toey, and on the Second Stage Expressway from Din Daeng to Samsen.

Expressways with many lanes and heavy traffic might be the reason for the high concentration in the urbanized area.

Fig. 3.15

Air Pollution Simulation High Concentration Area (Top 5 km²)

Case 1

SCALE 1:470000

5 0 5 10 15 20

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THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

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(5) Implications from Environmental Activities

Many policies are formulated or selected for atmospheric pollution control in fields, such as land transportation, energy, education and city planning. In addition, there are various activities for atmospheric pollution control by the authorities and NGOs.

1) Significant Activities

In Bangkok, many environmental activities are developed. The following are significant regulating activities explicitly formulated:

- Regulation for new and in-use vehicles (See Boxed Item)
- Enhancement of inspection program for vehicles (See Boxed Item)
- Governmental ad hoc committee against serious pollution by particulate matter
- Regulation for stationary sources
- Regulation for lead content in gasoline
- Reformulation of fuel (See Boxed Item)
- Revision of ambient air quality standard

The following are significant activities for mitigating air pollution:

- Monitoring and its enhancement
- Review works of current situation (I/M program, Health influence by PM)
- Training for staff relating to environmental control
- Daily PR by mass media
- NGO activity in various fields
- ISO 14000 Pilot Project
- Promotion of environmental service supplier

Some activities, such as the maintenance program, experience difficulties; whereas others, such as the lead regulation, are successful. Consideration of the outcomes of these activities is important for future environmental policies. In addition, consideration of tacit existing policy is indispensable. The following topics are worth discussing with regard to further sustainable development.

2) Effects of the Vehicle Transportation System on Air Quality

Motor vehicles are used primarily for land transportation in Bangkok. This implicit public choice for use of motor vehicles will result in huge consumption of fossil fuel in the future. Such a huge consumption of fossil fuel needs to be carefully assessed with regard to its influence on air quality. For PM-10, CO, SO2 and NO2, the numerical simulation assessments of ground level concentration are described in other sections.

It might be necessary to review the effects of pollutants, such as green house gases in addition to pollutants for which the ambient air quality standard is fixed. Currently, there may not be an expectation to change to less CO2 originating fuels. If the majority of transportation needs in the future continue to be supported by motor vehicles, emission of CO2 in Bangkok could become significant, and thus result in public discussion.

Regulation for New Motor Vehicle Emission

Currently enforced latest standards and future strengthening regulation plans are as follows.

Thai Standard No.	Reference Standard	Date of Enforcement	Planned Date of Enforcement
● Gasoline Engine Vehicle			
TIS.1280-1995	ECE R 83-01(B)	24 March 96	
	Directive 93/59/EEC		1 January 97

ECE : Economic Commission for Europe, UN
EEC : European Economic Community

● Light Duty Diesel Engine Vehicle

TIS.1140-1993	ECE R 83-C	29 January 95	
TIS.1285-1995	ECE R 83-01 App. C		1 January 96
	Directive 93/59/EEC		1 January 97

● Heavy Duty Diesel Engine Vehicle

TIS.1290-1995	EURO 1		1 January 97
TIS.1295-1995	EURO 2		1 January 99

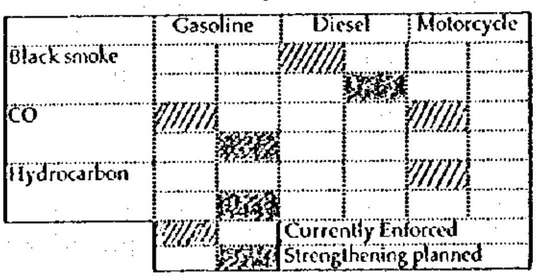
EURO 1, EURO 2 are formulated by EEC.

● Motorcycle

TIS.1185-1993	ECE R 40-01	15 March 95	
TIS.1305-1995	Thai Level 3		1 July 95
	Taiwan Level 2		Under Planning

Regulation for In-Use Vehicle Emission

For in-use vehicle, the regulations are as follows.



Inspection Program

The outlines of inspections are as follows.

● Frequency

Passenger car	Annually, after car age exceeds 10 years.
Pick up	Annually, after car age exceeds 10 years.
Motorcycle	Annually, after motorcycle age exceeds 7 years.
Truck and Bus	Annually

● Inspection Item

	Item
Gasoline Vehicle	CO
Diesel Vehicle	Smoke
Motorcycle	CO, HC

From the beginning of 1997, passenger cars and pick ups will be inspected annually after exceeding 7 years, and motorcycles after 5 years.

Reformulation of Fuels

A program of introduction of unleaded gasoline was completed in January 1996.
For high speed diesel oil, already implemented and planned measures are as follows:

Year	Items
1992	90% distillation temp. 370 to 357℃ (for mitigating particulate matter)Sulfur content to 0.5%
1996	Sulfur content to 0.25%
2000	Sulfur content to 0.05% (plan)

For the aromatic in gasoline, the current value of 50%, will be reduced to 35 % in 2000.

3) Science and Technology

To recognize and protect the environment, the scientific approach is indispensable. With scientific recognition, proper environmental policy can be established. Ambient air quality standard, monitoring, traceability, simulation analysis and accessibility to information are important components of the scientific approach.

Ambient air quality standard

The ambient air quality standard was set originally in 1981, and revised in 1995. The revised items are shown in Table 3.14 .

Table 3.14 Revised Items of Ambient Air Quality Standard, 1995

Pollutant	Evaluating time	1981 Standard	1995 Revision
CO mg/m3	1 Hour	50	34.2
	8 Hours	20	10.26
Lead μg/m3	24 Hours	10	---
	1 Month	---	1.5

Such scientific review and revision play an essential role in environmental management, and should be enhanced.

The one hour SO2 standard is 1.3 in the Mae-Moh area and 0.78 mg/m3 in another area. These values are higher than the WHO's guideline of 0.35. The different health-relating standards in the Mae-Moh area and the other area may be questioned.

Monitoring

In Bangkok, PCD of MOSTE, MOH and BMA monitors ambient air quality independently. PCD operates monitoring stations as Table 3.15, and provides almost all the available data of BMA.

Table 3.15 Monitoring Stations by PCD, Jan. to Dec. 1994

Area	Number of fixed stations	Monitoring item	Note
Roadside	4	PM-10, CO	Temporary station:approximately 15, Item:TSP, CO, Lead
General	4	TSP, CO, Lead	

Recently, the number of general stations were expanded, and stations such as Chandrakasem started monitoring SO2, NO2, meteorological conditions and others. (See Fig. 3.3)

The simulation results by the Team show high NO2 and SO2 concentration in the central zone of Bangkok. SO2 and NO2 monitoring activity should thus be enhanced.

Traceability and standard

Traceability is the essential concept for monitoring and analysis. If an analysis dose not have traceability to national and international standards, the importance of the analysis diminishes and the results cannot be compared with other analyses. PCD and BMA apply different methods for monitoring. The evaluation method and procedures with regard to standards might not therefore be clear.

Accessibility to information

Information is the basis for recognition of pollution. Through adequate exchange of information among inhabitants, NGOs and agencies, sufficient participation could be expected. There are newspaper articles regarding to pollution, but this may not be sufficient for adequate recognition. In addition, the publicity of regulation and data seems to be insufficient, resulting perhaps in indifference to a certain extent to such issues.

4) Measures for Implementation

There are various regulations, with an elaborate network of assigned authority to various agencies. Several cases are shown in Table 3.16. The network could function well if each agency has sufficient knowledge regarding the policies of relevant agencies and if administration is adequate.

Table 3.16 Network Examples of Environmental Administration

Field	Relating Agency	Function
Emission Standards for Exhaust Gas from Industry	Ministry of Industry	Establishment of Emission Standards
	Ministry of Science, Technology and Environment	If the above standard exceeds MOSTE's studied standard, the standard by MOI is modified. In a case where there is not modification, NEB decides the matter.
Reformulation of Fuels (Ex. Lead in Gasoline, Sulfur in HSD Oil)	National Energy Policy Office	Studying and Ordering to Relating Ministry
	Ministry of Commerce	Decision of Specification of Gasoline
Standards for New Vehicles (Ex. Exhaust Gas regulation)	Ministry of Science, Technology and Environment	Review and Studying Plan
	National Environmental Board	Making Proposals to the Cabinet
	Ministry of Industry	Issuance of Industrial Standards
Vehicle Inspection	Ministry of Transport and Communication	Vehicle Inspection at Laboratory and Roadside Establishment of Inspection Standard
	Ministry of Interior	Vehicle Inspection at Roadside

To implement regulations properly, it can be said that concrete plans and procedures are necessary. However, in many cases, few concrete plans and measures are applied. For example, regarding the black smoke from buses, the integrated mitigation plan is expected through such studies follows:

- Analysis of the operators' accounting situation
- Checking of the operating buses exhaust gas
- Estimation of the operating cost of well-maintained buses
- Planning the schedule of implementation together with incentives and fines

5) Responsible Body for the Integration of Urban Environmental Mitigation

Bangkok contains a huge population and undertakes economic activities which raises environmental issues. The authorities, however, have little integrating functions with regard to mitigating various environmental issues in the mega-city. With respect to current issues, such as particulate matter from construction sites, it can be said that mitigating activities are rather isolated efforts by respective agencies.

In addition, Bangkok in the future will need to cope with another aspect of environmental issues closely related to the urban structure, the vulnerable natural condition, human activities and human health, which is the people's desire for increase material comfort. An integrated viewpoint of all environmental issues is thus necessary.

3.3 Policy Directions and Planning Issues

It could be said that many people in Bangkok recognize that the level of TSP, which is particularly noticeable in Bangkok, is unacceptable. Currently a governmental ad hoc committee is dealing with this issue. The first priority is suppression of the visible particulate matter. Thus the following measures could be applicable.

- Control of dust from construction activity
- Maintenance of the pavement and curbside
- Cleaning of roads
- Suppression of dust scattering from the tires, body and bed of vehicles
- Reduction of black and white smoke from vehicle exhaust

In addition to these activities, people's awareness with regard to the environment need to be enhanced. The mitigation of TSP may be the first step towards the improvement of the environment in Bangkok.

Much of the atmospheric pollution in Bangkok is supposedly closely related to land transportation. For this study, the dispersion simulation analyses which focused on land transportation are applied, and the outcomes of the simulation are discussed.

Abatement measures are also discussed in this section. Sustainable development could materialize when various approaches to environmental policies are networked well.

(1) Mitigation of Traffic Air Pollution implicated by Simulation Analysis

1) Simulated Cases

According to the following policies and trends, 9 cases were simulated as in Table 3.17. Results of the respective cases are explained in the next section.

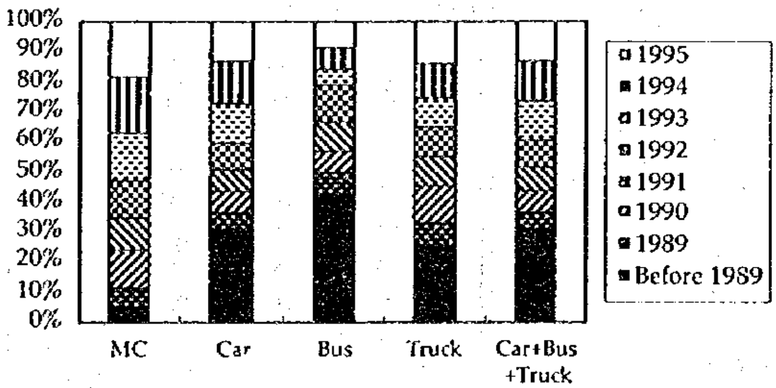
Table 3.17 Simulated Cases

*	Case 1	2	3	4	5	6	7	8	9
*	C)	P)	P)	P)	P)	P)	B)	A)	A)
C) Current Vehicle Emission	O	-	O	O	-	-	-	-	-
P) Future Vehicle Emission	-	O	-	-	O	O	O	O	O
A) Low-Emission Bus	-	-	-	-	-	-	-	-	O
C) Current Road Network	O	O	-	-	-	-	-	-	-
P) Road Construction of the 8th National Plan	-	-	O	O	O	O	O	O	O
P) Implementation of the Mass Transit Master Plan	-	-	-	O	O	O	O	O	O
A) Extreme Modal Shift	-	-	-	-	-	-	-	O	-
C) Current Transport Demand	O	O	O	O	O	-	-	-	-
P) Transport Demand in 2011 (Free Case)	-	-	-	-	-	O	-	-	-
B) In 2011 under Sub Center Development Case	-	-	-	-	-	-	O	O	O

Note: *: Conditions of the current situation are marked as C), conditions of future probable situation are P), that of BEIP recommendation are B), and other additional future conditions are marked as A).

Future Vehicle Emission under Planned Policies (P)

All new vehicles will need to meet stringent regulations after January 1999 (See Boxed Item of 3.2 (3)), as in European countries (PCD, 1996). In 2011, almost all vehicles should be new-regulation vehicles as more than 50% of the vehicles are less than 5 years old in Bangkok presently, as shown in Fig. 3.16.



Note: This graph was processed from the number of 'new vehicles registered' each year and the number of 'vehicles registered on Dec. 31, 1995,' reported in 'Road Transport Statistics' by LTD. It is assumed that cars are scrapped from the old ones. MC: MotorcycleCar: Total of Sedan (Not more than 7 passengers), Microbus & Passenger Pick up, Van & Pick up, and Urban Taxi.
Source: BEIP Study Team

Fig. 3.16 Estimated Ratio of Vehicles by the First Registered Year as of Dec. 31, 1995, BMA

All vehicles will need to adhere to the stringent regulations in 2011, although many buses that are exhausting black smoke appear not to be meeting the requirements of the regulations today.

The sulfur content of high speed diesel oil is considered to be 0.05% in 2011.

The Emission Factor was estimated with regard to these policies.

Replacement by Low-Emission Buses (A)

To further control emissions, a case is simulated that many buses are replaced by low-emission buses. The average emission factor of buses would thus be decreased by half. It could be actualized by a combination of policies, e.g., if some of the bus routes are replaced by tram or trolley buses, and the other routes are operated by CNG buses.

Road Construction of the 8th National Plan (P)

Road space will increase within the BMR by the 8th National Plan, as described in the chapter 'Traffic and Transportation.' This plan affects not only heavy traffic congestion problems but also air pollution, as the vehicles in heavy traffic emit more pollutants than those in normal traffic.

Implementation of Mass Transit Master Plan (P)

The implementation of the Mass Transit Master Plan, as described in the chapter 'Traffic and Transportation,' is also effective to alleviate air pollution problem. The traffic volume of buses, passenger cars and motorcycles will be decreased and thus the emission of air pollutants will also decrease. Moreover, the improvement of the traffic flow is also effective for air pollution.

Extreme Modal Shift (A)

In order to consider further control of air pollution, an 'Extreme Modal Shift' case was simulated. The aim of this case was to obtain a numerical effect of the modal shift. The simulated setting is so tentative that all small sized vehicles except taxis and samlors shifted to buses.

Transportation Demand in 2011 (Free Case) (P)

The transportation demand will be increased by the growth of the economy, population, and urbanization. Air pollution under transportation demand in 2011 was simulated.

Transport Demand in 2011 under Sub Center Development (B)

Traffic demand and emission from traffic sources will be dispersed if the urban structure is scattered. Transportation demand under Sub Center Development, proposed by this BEIP Study Team, was also applied to simulation.

2) Simulation Results

Results of all cases are shown in Table 3.18 and Fig. 3.17 ~ Fig. 3.18, and Air Pollutant Distribution of selected cases are shown in Fig. 3.19 ~ Fig. 3.21

Table 3.18 Emission from Vehicle and Area of Each Ranking by Cases

Case Settings:

	Case:	Case 1 (C)	Case 2 (P)	Case 3 (P)	Case 4 (P)	Case 5 (P)	Case 6 (P)	Case 7 (B)	Case 8 (A)	Case 9 (A)
(C)	Current Vehicle Emission	O	-	O	O	-	-	-	-	-
(P)	Future Vehicle Emission	-	O	-	-	O	O	O	O	O
(A)	Low-Emission Bus	-	-	-	-	-	-	-	-	O
(C)	Current Road Network	O	O	-	-	-	-	-	-	-
(P)	Road Construction of 8th National Plan	-	-	O	O	O	O	O	O	O
(P)	Implementation of the MRT	-	-	-	O	O	O	O	O	O
(A)	Extreme Modal Shift	-	-	-	-	-	-	-	O	-
(C)	Current Transport Demand	O	O	O	O	O	-	-	-	-
(P)	Transport Demand in 2011 (Free Case)	-	-	-	-	-	O	-	-	-
(B)	In 2011 under Sub Center Development Case	-	-	-	-	-	-	O	O	O

Emission from Vehicle (BMR, ton/y):

Case:	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
SPM	206,920	33,353	204,062	179,492	33,918	87,870	78,325	32,069	77,641
CO	934,101	233,741	870,281	705,268	172,370	718,508	607,239	497,118	592,454
SOx	29,696	4,031	27,182	24,101	3,514	8,918	8,034	5,767	7,307
NOx	192,396	75,123	155,684	138,844	53,961	153,462	137,412	133,703	110,750

Concentration (Annual Average): Area of Each Rank (km^2):

Pollutant	Rank	Concentration	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
PM-10	1	<=20	395.50	1,413.75	415.00	466.25	1,373.50	777.75	853.50	1,334.50	855.50
(mikro g/m^3)	2	<=40	444.50	217.00	404.00	441.50	258.50	432.75	437.25	298.00	437.25
	3	<=52	145.00	41.50	163.75	168.25	46.50	158.50	144.00	52.25	144.50
	4	<=88	324.00	32.50	339.25	343.00	28.25	228.75	198.00	23.00	196.00
	5	<=177	263.00	3.25	291.25	237.75	1.25	104.75	72.25	0.25	71.75
	6	177<	136.00	0.00	94.75	51.25	0.00	5.50	3.00	0.00	3.00
CO	1	<=722	1,551.75	1,705.25	1,598.00	1,658.75	1,708.00	1,629.50	1,660.50	1,689.25	1,661.25
(ppb)	2	<=1445	134.50	2.75	102.25	48.25	0.00	69.75	44.75	17.25	44.00
	3	<=2131	17.50	0.00	6.00	1.00	0.00	7.50	2.25	1.50	2.25
	4	<=4748	4.25	0.00	1.75	0.00	0.00	1.25	0.50	0.00	0.50
	5	<=9496	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	9496<	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO_2	1	<=9	1,275.25	1,509.25	1,312.50	1,354.75	1,523.25	1,473.75	1,481.25	1,501.50	1,483.25
(ppb)	2	<=19	287.75	190.75	302.50	287.25	176.50	220.75	214.75	196.75	213.25
	3	<=24	93.25	8.00	77.75	60.25	8.25	13.50	12.00	9.75	11.50
	4	<=36	48.25	0.00	15.25	5.75	0.00	0.00	0.00	0.00	0.00
	5	<=72	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	72<	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO_2	1	<=9	485.50	1,148.50	656.75	786.50	1,499.00	715.75	829.25	832.00	905.00
(ppb)	2	<=17	455.50	347.00	508.75	532.75	207.75	492.50	499.50	510.25	502.50
	3	<=21	144.50	82.75	171.75	156.00	1.25	171.25	140.00	129.50	121.25
	4	<=30	241.25	102.50	218.00	161.25	0.00	194.50	165.00	162.25	136.00
	5	<=60	283.75	27.25	152.25	71.50	0.00	133.50	74.25	74.00	43.25
	6	60<	97.50	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00

Source: JICA Study Team

Note: Rank 1: Much Lower than the Standard
Rank 2: Lower than the Standard
Rank 3: Possibly Lower than the Standard
Rank 4: Possibly Higher than the Standard
Rank 5: Higher than the Standard
Rank 6: Extremely Higher than the Standard

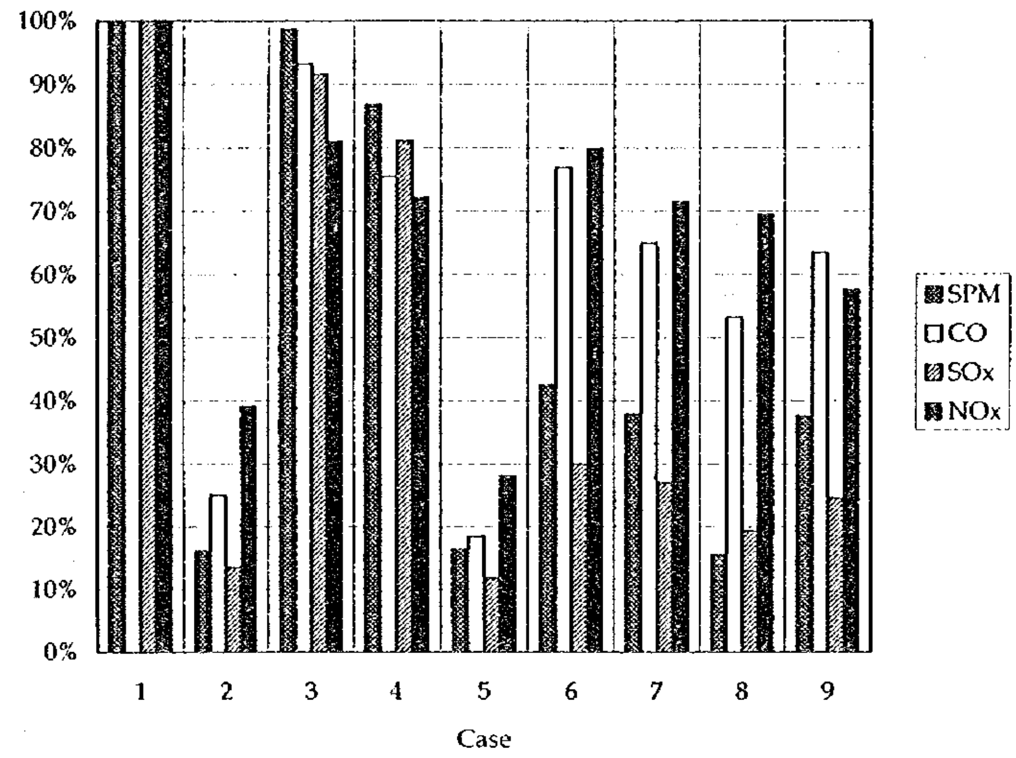


Fig. 3.17 Emission from Vehicle, Compared with Case 1

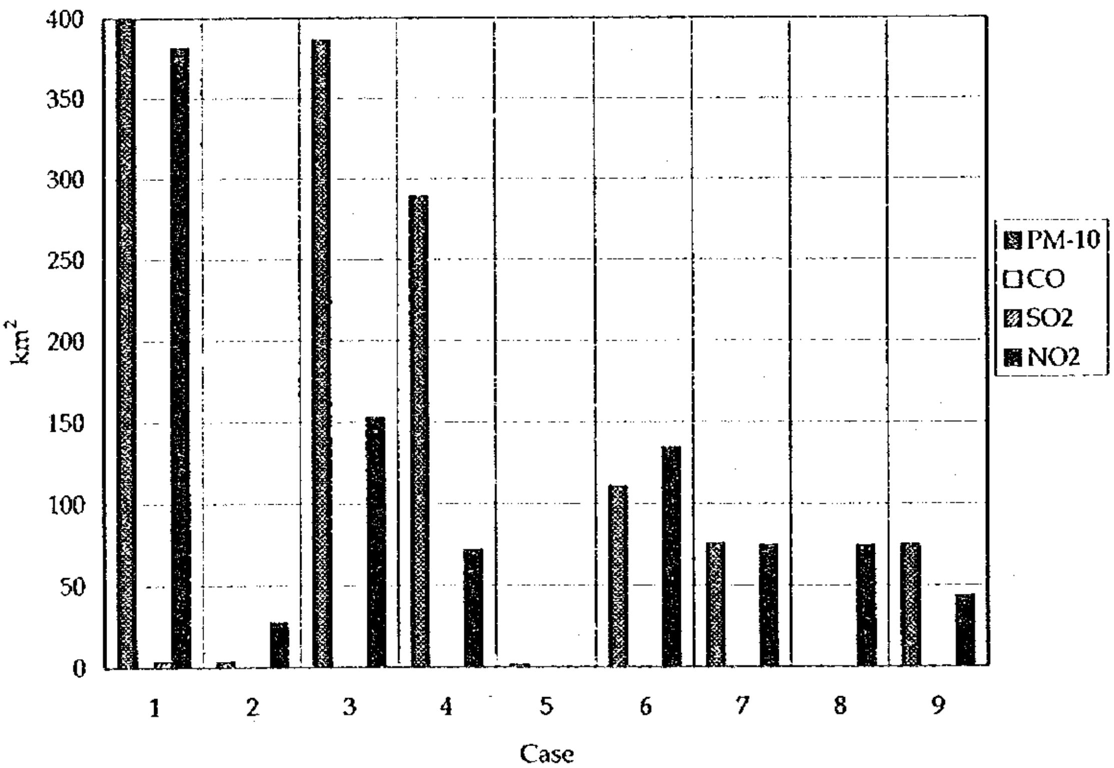


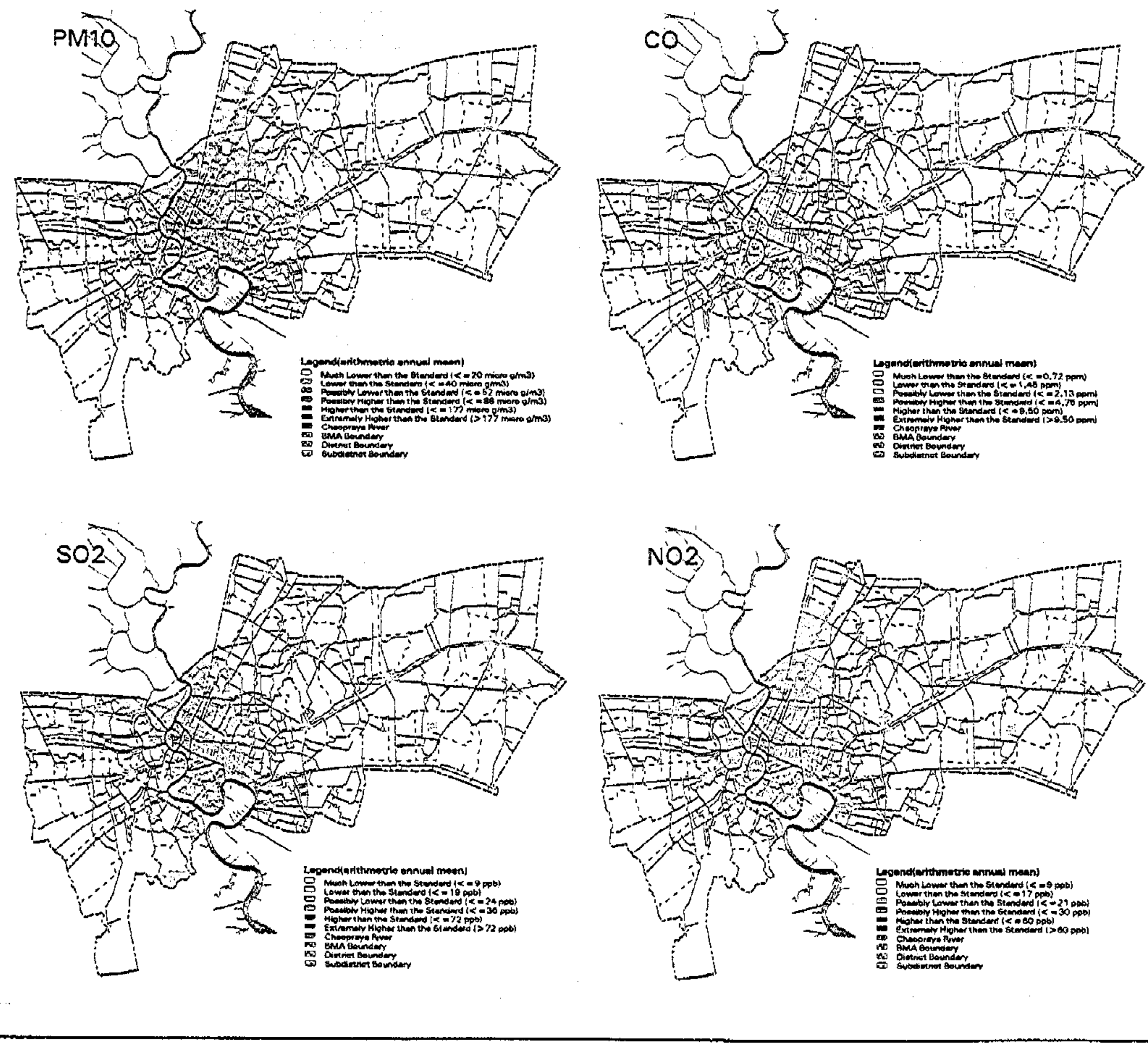
Fig. 3.18 Area of Higher than the Standard (Rank 5 + Rank 6)

Fig. 3.19

Air Pollution Simulation

Case 5

Future Vehicle Emission Factor
Future Road Network
Future Mass Transit Network
Present Transport Demand



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THE STUDY
ON
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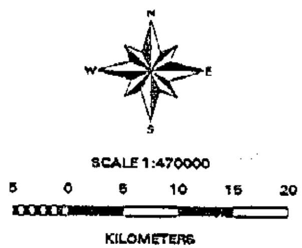
Fig. 3.20

Air Pollution Simulation

Case 6

Future Vehicle Emission Factor
Future Road Network
Future Mass Transit Network
Future Transport Demand



THE STUDY
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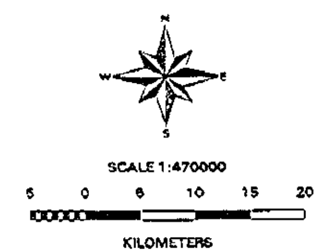
Fig. 3.21

Air Pollution Simulation

Case 7

Future Vehicle Emission Factor
Future Road Network
Future Mass Transit Network
Future Transport Demand with Sub Center Development



THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

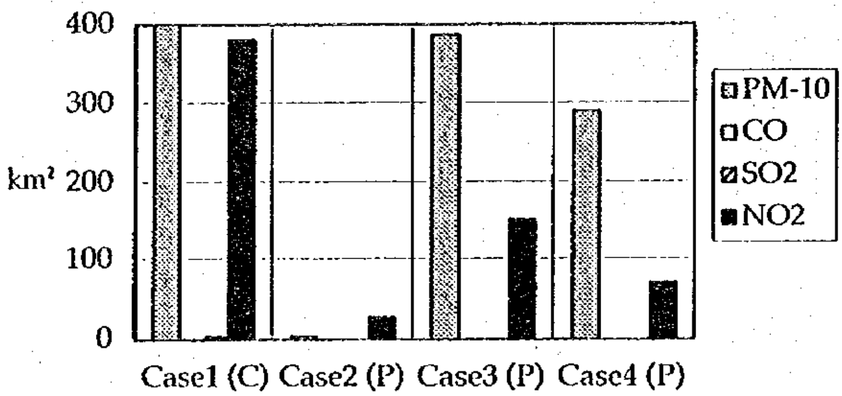
Comparison of Future Probable Policies (P)

According to the simulation results of Case 2 to Case 4 as shown in Fig. 3.22, exhaust gas regulations are most effective. Air pollution in Bangkok would be almost acceptable if the exhaust gas regulations were implemented already, as shown in Case 2. Both New and In-Use Vehicle Regulations are indispensable.

Table 3.19 Case Settings of Case 1 to Case 4

*	Case 1 C)	Case 2 P)	Case 3 P)	Case 4 P)
C) Current Vehicle Emission	O	-	O	O
P) Future Vehicle Emission	-	O	-	-
C) Current Road Network	O	O	-	-
P) Road Construction of the 8th National Plan	-	-	O	O
P) Implementation of the Mass Transit Master Plan	-	-	-	O
C) Current Transport Demand	O	O	O	O

Note: *: See Table 3.17



Source: BEIP Study Team

Fig. 3.22 Area of "Higher than the Standard" and "Extremely Higher than the Standard" of Case 1 to Case 4 (km^2)

The second effective policy is implementation of the Mass Transit Master Plan. (Case 4).

Road construction reflected in the as 8th National Plan is not so effective for PM-10 problem, although it is effective for NO_2 air pollution (Case 3).

Recommendations for Future Vehicle Emission (P)

New regulations can be actualized as the vehicle manufacturers have already developed vehicles meeting the EC regulations. However, actualization of in-use regulations seems to be difficult.

The inspection system, which may include the only major existing regulations for in-use vehicles, has already been applied to all buses. However, the inspection system is apparently not enough as there are many buses that do not meet the In-Use Vehicle Regulations, although all vehicles would have passed the inspection several months before. For example, 3,291 buses were fined for violating the standards in 1995 (Bangkok Post, Apr. 29, 1996) although the number of registered buses was only 24,364 at Dec. 31, 1995 (LTD, 1996). The problem might be that many vehicles are badly maintained even if they have been checked at inspection time.

A daily maintenance program should be strengthened first. An exhaust gas checking program should be applied more frequently than the checking which is carried out under the existing inspection system, and the fine system should also be strengthened.

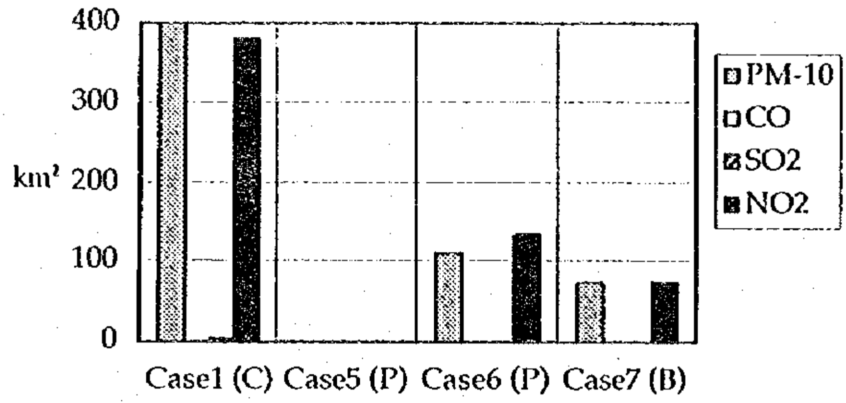
Future Probable Policies (P) vs Future Transport Demand in 2011 (P)

Most of the points in Bangkok would not be rated as "Higher than the Standard" nor "Extremely Higher than the Standard" if all the policies already discussed were implemented by this time (Case 5, shown in Fig. 3.19 and Fig. 3.23). However, Case 6, shown in Fig. 3.20 and Fig. 3.23, shows that even if all these policies were introduced, the situation in Bangkok would not improve sufficient by 2011. The increase of the transport demand would cancel the effect of the mitigation policies. There will still be over-standard areas even under the sub center development (Case 7, shown in Fig. 3.21 and Fig. 3.23), proposed by this BEIP Study Team. Further policies for controlling air pollution are required.

Table 3.20 Case Settings of Case 1 and Case 5 to Case 7

	Case			
	1	5	6	7
*	* C)	P)	P)	B)
C) Current Vehicle Emission	O	-	-	-
P) Future Vehicle Emission	-	O	O	O
C) Current Road Network	O	-	-	-
P) Road Construction of the 8th National Plan	-	O	O	O
P) Implementation of the Mass Transit Master Plan	-	O	O	O
C) Current Transport Demand	O	O	-	-
P) Transport Demand in 2011 (Free Case)	-	-	O	-
B) 2011 under Sub Center Development Case	-	-	-	O

Note: *: See Table 3.17



Source: BEIP Study Team

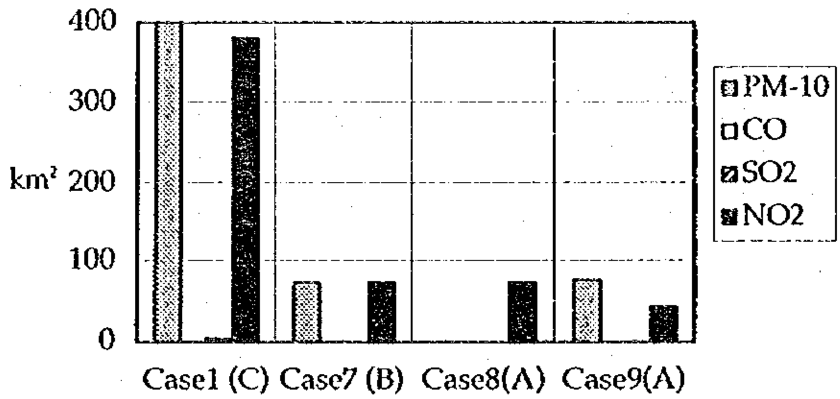
Fig. 3.23 Area of "Higher than the Standard" and "Extremely Higher than the Standard" of Case 1 and Case 5 to Case 7 (km^2)

To evaluate the sensitivity of additional future policies under Case 7, two hypothetical policies were simulated. Case 8 shows that the PM-10 problem of Case 7 can be almost solved by the Extreme Modal Shift to buses as shown in Fig. 3.24, although this shift requires a strong administrative initiative and complete change of transport network. Case 9 shows that the increase of low-emission buses such as the CNG type might be effective for pollution mitigation as shown in Fig. 3.24.

Table 3.21 Case Settings of Case 1 and Case 7 to Case 9

	Case			
	1	7	8	9
*	C)	B)	A)	A)
C) Current Vehicle Emission	O	-	-	-
P) Future Vehicle Emission	-	O	O	O
A) Low-Emission Bus	-	-	-	O
C) Current Road Network	O	-	-	-
P) Road Construction of the 8th National Plan	-	O	O	O
P) Implementation of the Mass Transit Master Plan	-	O	O	O
A) Extreme Modal Shift	-	-	O	-
C) Current Transport Demand	O	-	-	-
P) Transport Demand in 2011 (Free Case)	-	-	-	-
B) In 2011 under Sub Center Development Case	-	O	O	O

Note: *: See Table 3.17



Source: BEIP Study Team

Fig. 3.24 Area of "Higher than the Standard" and "Extremely Higher than the Standard" of Case 1 and Case 7 to Case 9 (km^2)

3) Other Recommendations by Simulation Analysis

There is another problem even if case 7 could be realized by 2011. All of these policies require a considerably longer time in order to change the situation regarding air pollution, and there would not be obvious efficacy within a few years.

First, vehicle regulations need to be implemented as soon as possible. TIS.1295-1995 (New vehicle regulation for Heavy Duty Diesel Engine Vehicle as EURO II) is planned to be enforced on Jan. 1, 1999. Therefore 42% of buses and 24 % of trucks will not meet this regulation by Jan. 2006, that is 7 years after 1999, if the ratio of vehicles older than 7 years is the same as the present ratio as shown in Fig. 3.16.

Second, replacement of vehicles by those under the New Vehicle Regulation should be accelerated.

4) Implications from the Simulation Analysis

As mentioned above, important factors to improve air pollution are as follows;

- New Vehicle Regulations, starting as soon as possible:
- In-Use Vehicle Regulations, with effective measures such as sufficient maintenance programs, exhaust gas checking programs conducted more frequently than the existing inspection system and an incentive/fine system;
- Implementation of the Mass Transit Master Plan;
- Road construction of the 8th National Plan;
- Demand control by Sub Center Development proposed by the BEIP Study Team;
- Further air pollution mitigating plans, e.g., the modal shift to low-emission vehicles such as the CNG buses.

(2) Reduction of Pollutants from Buses

1) Overview of City Buses

There are many Bangkok Mass Transit Authority (BMTA) city buses and joint-service companies contracted to the BMTA in Bangkok as listed in Table 3.22. BMTA is, a state enterprise within the category of public utility and service, under the jurisdiction of the Ministry of Communications, established on Oct. 1, 1976. A great number of people utilize city buses as listed in Table 3.23.

Table 3.22 Number of Buses, in Sep. 1995

		BMTA	Joint Service	Total
Regular		3,588	1,474	5,062
Air-conditioned	Standard & Articulated	1,164	319	1,483
	Micro buses	-	766	766
	Sub Total	1,164	1,085	2,249
Mini	On Main Roads	-	1,770	1,770
	On Feeder Roads	-	2,497	2,497
	Sub Total	-	4,267	4,267
Total		4752	6,826	11,578
	(NGV of Total)	82		
	(EURO I Vehicles of Total)	282		

Source: Annual Report 1995, BMTA

Table 3.23 Number of Daily Passengers for Fiscal Years 1991 -- 1995

	1991	1992	1993	1994	1995
Air-conditioned	207,220	253,605	426,440	483,886	548,453
Regular	3,847,064	3,802,278	3,360,663	3,022,395	2,831,131
Total	4,054,284	4,073,883	3,787,103	3,506,261	3,379,584

Source: Annual Report 1995, BMTA

2) Maintenance of City Buses

The maintenance of BMTA buses are undertaken mainly by contract. The existing maintenance program of BMTA directly relating to air pollution is listed in Table 3.24.

For joint-service buses run by companies on contract to BMTA, it was remarked by a BMTA official that the maintenance situation was not satisfactory because of the obsolescence of many buses and the irregularity of their maintenance(Bangkok Post, Apr.29, 1996).

Table 3.24 Existing Maintenance Program for Air Pollution

	2 weeks	Every Month	Year
To change the machine oil	-	O	O
To change the oil filter	-	O	O
To change the cylinder head	-	-	O
To adjust the valve and to check the injector	-	O	-
To change the injector	-	-	O
To change the injector pump	-	-	O
To check the injecting pipe	-	-	O
To change the fuel filter	-	-	O
To check the joint of the oil pump and the cover of the fuel filter	-	-	O
To check the exhaust system	-	O	-
To set the ID valve for exhaust gas	-	-	O
To clean the exhaust pipe	-	O	-
To wash the exhaust pipe	-	-	O
To clean the air filter and to check the condition	O	-	O
To clean the bus both inside and outside	-	O	-

Note: These items are selected from BMTA's bus maintenance checking sheet.

In 1995, 3,291 buses were fined for violating the standard (Bangkok Post, Apr.29, 1996), and this number corresponded to 14% of the total registered bus in this region(LTD, 1996)

3) Financial State of BMTA

According to Table 3.25, BMTA is in heavy debt. To conform with EURO1 regulations for exhaust gas, air-conditioned buses may cost 4 to 5 Million Bahts per bus. This financial situation might not enable BMTA to purchase low emission new buses.

According to Annual Report 1995, BMTA, it is said that the loss could be derived from the imbalance of fares and cost and the mass transit operation is considered to be an important public service by the government for people in the low-to-middle income segment. The fare level corresponding to cost, according to BMTA, is listed in Table 3.26.

4) Activities by BMTA

According to reports, BMTA has been undertaking various measures for air pollution mitigation.

BMTA introduced 82 compressed natural gas vehicles(NGV) in 1994 using government budget funds. All of the new 282 buses introduced in fiscal year 1995 met the EURO1 emission standard with ozone-friendly non-CFC air conditioning(Annual Report 1995, BMTA)

Table 3.25 Profit and Loss of BMTA (Bath)

	Fiscal Year 1995	Fiscal Year 1994
Operating Revenues	5,658,929,047.69	5,629,077,724.93
Operating Expenses		
Expense of operating buses	4,096,756,840.87	3,760,781,116.47
Maintenance expenses	1,584,916,003.26	1,516,057,791.13
Interest	848,482,764.21	548,076,700.97
Total	7,717,667,116.01	6,755,650,077.18
Operating Profit (Loss)	(2,058,738,068.32)	(1,126,572,352.25)
Net Profit (Loss)	(1,692,888,866.41)	(898,764,466.48)
Accumulated Loss	14,526,176,736.12	12,833,287,869.71

Source: Annual Report 1995, BMTA

Table 3.26 Fare Levels Sufficient to Cover Operating Costs for Fiscal Year 1995

	Adequate Fare (Baht)	Actual Fare (Baht)
Regular Buses (Off-white-Red)	4.7163	3.5
Regular Buses (Off-white-Blue)	4.8433	3.5
Air-conditioned Buses	10.2366	6~

Note: These values are for operating costs including all types of expenditures.
Source: Annual Report 1995, BMTA

However an earlier plan to buy 2,000 new buses(in conformity with EURO1 emission standards) has been suspended by the cabinet, and there are no other plans to introduce the new fleet within the next two years(Bangkok Post, Apr. 29, 1996).

5) Improvement of City Buses

Buses are environmental friendly mode of transportation as unit pollutant emission (g/km/person) is much lower than that for motorcycles and passenger cars, as shown in Table 3.27. The modal shift to buses from personal vehicles should thus be enhanced.

Improvement of bus emission is also very important. The number of registered buses is small, but the emission ratio is significant as shown in Table 3.28. The reduction of pollutants from buses might be an applicable policy as the number subject to policy is small, and BMTA is the main operator.

In addition to the expansion of low-polluting buses, the maintenance program of the BMTA buses and joint-service buses needs to be strengthened. The current BMTA and joint-service's maintenance program for air pollution appears not to be enough to improve the air pollution in Bangkok. Improvement measures could include regular inspections implemented by the owner whenever buses return to their depots (Bangkok

Post, Apr. 29, 1996). Moreover, the maintenance contract could include incentives and penalties relating to the compliance of regulations for in-use vehicles.

Table 3.27 Unit Pollutant Emission (g/km/person), Average of BMR

	PM-10	CO	SOx	NOx
Motorcycle	7.14	22.6	0.143	0.147
Passenger Car	1.46	32.1	0.279	1.05
Heavy Bus	0.278	0.294	0.0533	0.483
Car/ Heavy Bus Ratio	5.25	109.	5.23	2.17

Note: Occupancy Rates are 1.4 for Motorcycle, 1.9 for Passenger Car and 30 for Heavy Bus
Source: BEIP Study Team

Table 3.28 Pollutants from Bus (Case 1) Ton / Year

	Registered Number	PM-10	CO	SOx	NOx
Bus(Med.+Hvy.)	24,364	49,082	51,994	9,416	85,419
Total of Vehicles	3,241,081	206,920	934,101	29,696	192,396
Bus Ratio	0.8%	23.7%	5.6%	31.7%	44.4%

Source: BEIP Study Team

Total emission from transportation will be reduced by the modal shift from private cars to public buses. This emission will be reduced further by the systematic replacement of high-emission buses to low-emission buses. To enable this replacement, the financial situation, reflecting various views, should be studied.

(3) Perspective of Energy Consumption and Its Effects

It might be essential for the making of environmental policies to consider the trend of energy consumption. The consideration of development in terms of energy is a significant current issue.

1) Energy consumption trend in Thailand

The trend of primary energy consumption per GDP has not shown a declining tendency in the 1990s as reflected in the following Table 3.29.

Table 3.29 Primary Energy Consumption per GDP of Thailand TOE/Million $

1980	1985	1990	1991	1992	1993
361	357	426	430	439	452

Source : IEA Energy Statistics and Balances of Non-OECD Countries, World Bank World Tables

The trend of the transportation sector final energy consumption/national final energy is listed in Table 3.30. According to these figures, the transportation energy ratio to that of the whole nation does not show a significant declining tendency.

Table 3.30 Final Energy Consumption in Thailand **Consumption : Million TOE**

	1980	1985	1990	1991	1992	1993
Whole Nation	9	12	21	23	25	29
Transportation Sector	4	6	11	12	12	14
Transportation sector / Whole Nation	0.44	0.50	0.52	0.52	0.48	0.48

Source : IEA Energy Statistics and Balances of Non-OECD Countries

Table 3.29 and Table 3.30 imply that the national transportation energy consumption might increase with the economic growth at present.

2) Transportation energy trend in Bangkok and the surrounding region

Petroleum products supply all the energy for transportation. For Bangkok and its surrounding regions (Nonthaburi, Pathum Thani and Samut Prakan), the petroleum products consumption is listed in Table 3.31. Also in Bangkok and its surrounding regions, it can be said that the transportation energy ratio (excluding aviation fuel) does not show a clear declining tendency as in Table 3.31.

Table 3.31 Petroleum Products Consumption in Transportation Sector, Bangkok*
Consumption : KTOE

	1987	1990	1991	1992	1993
Petroleum Consumption**	4,836	8,029	8,020	9,322	10,291
Consumption in Transportation Sector***	2,487	3,829	3,875	4,135	4,558
Ratio	0.51	0.48	0.48	0.44	0.44

Source : Thailand in Figures, 1995 - 1996, Processed by JICA, BEIP Study Team
Note : * Bangkok, Nonthaburi, Pathum Thani and Samut Prakan
** Including power plants, excluding aviation fuel
*** Excluding aviation fuel

3) CO2 emission in Bangkok

Currently the transportation energy elasticity in Bangkok and its surrounding regions does not show a clear declining tendency. There may also not be sufficient expectation to shift to less CO2 originating fuels such as natural gas. In Bangkok, CO2(the major portion of the greenhouse-effect gas) emission will be significant.

If the worldwide increase of CO_2 results in global warming, it will cause a 0.49m rise in the sea level in 2100 (IPCC 1995). This estimation has implications worthy of study for Bangkok, which is located at the lower reach of Chao Phraya and has the flooding and land subsidence problem.

4) Perspective

The existing urban structure of Bangkok invites huge fuel consumption mainly in the transportation sector. This consumption will increase almost proportional to the growth of GDP, and therefore air pollution will increase. In addition to this, it is a matter for verification whether an insufficient transportation infrastructure could afford the basis for economic development.

No matter how strongly exhaust gas from vehicles is regulated, the increase of fuel consumption by vehicles might cancel out the effect of the regulations. In particular, the mitigation of PM-10 and NO_2 might be expected to be long-range issues. Particulate matters from diesel engine may be discussed by the public further. Also, CO_2 may be further discussed.

Summing up these issues, it could be inferred that the introduction of a mass transportation system to Bangkok would become an inevitable issue. This finding would be supported by a transportation study.

(4) Administration based on Science and Technology

1) Enhancement of monitoring and application of simulation analysis

The monitoring activity by PCD can be said to provide the majority of the information regarding the atmospheric pollution situation in Bangkok. This monitoring activity is being enhanced with the increase of monitoring stations, and the addition of the monitoring parameters of SO_2, NO_2 and others.

It should be pointed that roadside monitoring should be expanded in order to analyze SO_2, NO_2, HC and O_3, as many inhabitants earn their living by the roadside. It should also be pointed out that the adequacy of the distribution of stations in Bangkok might be reviewed through various monitoring data and numerical simulation analyses of mobile sources and stationary sources.

If monitoring data are processed carefully, the outcome can provide various information for policy-making. This information is a starting point for initiating pollution mitigation measures.

To direct policy-making appropriately, proper simulation analyses are indispensable, especially with regard to the atmosphere. In Bangkok, monitoring data could be applied to validate simulation model. After this procedure, the simulation in terms of one-year averages is very useful. Monitoring network systems are equipped rapidly in Thailand, and one hour on-line data can be gathered nationwide. This database would provide a good ground for policy-making.

2) Monitoring of other chemical substances

Current monitored parameters do not cover all materials relating to human health. It may be advisable to widen the monitoring parameters to include, for examples, asbestos and organochroline compounds.

The monitoring may be processed by chemical analysis, and thus may not be able to be undertaken by only one agency. The co-operative study of government and university laboratories should be planned and implemented.

3) Traceability and standard for analysis

Traceability carries out a vital role in monitoring and analyzing activity. Monitoring and analysis of the atmosphere should depend on the traceable method. All types of enforcement should be reviewed by the traceable method. It should be recommended that the standardization agency in Thailand should set up standard sampling procedures and analyzing methodology, and that every monitoring laboratory should adopt the standardized method and use traceable machines. In addition regulations should refer to and be based on the relating traceable method.

4) Development of capability

Energy saving is a major issue for pollution abatement, and this activity is supported by proper recognition and understanding of manufacturing processes. The introduction of ISO 14000, i.e. voluntary environmental management, depends on the capability of the management and the operation with regard to production control.

Pollutants are formed through scientific processes. To control and/or minimize this formation is a matter for science. Accordingly, scientific capability is indispensable for environmental mitigation. Scientific capability would thus be indispensable for assuring sustainable development.

Appraisal, qualification and incentive systems might accomplish the development of a capability for pollution control together with education and training.

5) Recognition and decisions based on scientific information

It is beyond doubt that the human five senses approach provides the most vital basis for environmental issues. If the scientific approach joins forces with this approach, the outcome of such cooperation would result in swift environmental mitigation.

In 1995, the ambient air quality standard was revised through the review of scientific knowledge. Because this standard is the touchstone of scientific environmental policy, it should be reviewed and revised whenever necessary with the widening and deepening of scientific knowledge.

Scientific information includes cause and effect, dose and response. Publicity of scientific facts would form an adequate basis of recognition and decision. The more the people understand scientific information, the more participation towards environmental mitigation might be expected. Continuous publicity may therefore develop people's awareness to the environment.

(5) Lessening Air Pollutants from Stationary Sources

The awareness of people in Bangkok that the major origin of air pollution is attributed to traffic should be accepted fully. Based on this recognition, influences of pollutants from stationary sources, and other major sources, must be assessed scientifically.

Black smoke from various stacks are easily noticed. They clearly publicize energy inefficiency and emission of unnecessary atmospheric pollutants.

The structure of measures to lessen pollutants from stationary sources should involve many activities:

- Management : Environmental consciousness should be built into the management scheme of business. This is the point of the ISO 14000 system. The ISO 14000 system is a voluntary and might be an unavoidable tool especially for export-oriented industries.

- Operation : The scientific approach is essential for the operation. This approach can for example, reduce black smoke substantially, and can result in significant energy saving.
- Monitoring : Source monitoring is as important as ground level concentration monitoring. Utilizing this monitoring outcome coupled with the scientific operation, emission of pollutants can be controlled to an acceptable level. It might be said that this monitoring should be accomplished by adequate role assignment among administration, industry and private laboratories.
- Incentive : The incentive method is effective. Under this policy, fuel conversion to lower pollution fuels such as LPG and/or LNG and the setting up of environmental measures could become smooth and extensive.
- Enforcement : The introduction of various types of enforcement are useful, i.e. source emission standards, and compulsory appointments of registered staff for large capacity boilers. For enforcement, fairness to all sectors and clear publicity are vital.
- Education and PR : The above-mentioned measures are in vain, unless supported by people who are well-informed and educated with regard to environmental issues.

(6) Integrating Activity for Urban Environmental Mitigation

Bangkok is the only mega-city in Thailand. Its population is approximately 30 times larger than the second largest city in Thailand. This large difference between the populations of cities in one country is unusual. A target for Bangkok could be to establish the prosperous hub of south-east Asia through sustainable development. Environmental policies for Bangkok should be established deliberately for supporting this target. This could not be attained only through the laissez-faire attitude and without adequate growth management,.

Bangkok has many environmental issues relating to the urban structure, natural condition, transportation activity, prevailing noise and human health. The necessity of a specific environmental policy would apply in particular to Bangkok, rather than to other regions in Thailand.

In the future, it could be imagined that more complicated issues regarding the environment will appear in this mega-city. Sufferers may also be polluters and vice versa. The people's desire for material comfort and an increase in the standard of living will increase. To cope with such problems in the future, integrating activity with regard to environmental issues will need to be introduced.

3.4 Planning Targets and Proposed Measures

(1) Mitigation Targets and Proposed Activities

Thailand's ambient air standard is formulated in Table 3.32. Some pollutants show different values according to the different evaluating time. These values are the target of mitigation policies.

It is stressed that the essential target should be the mitigation of air pollution up to a level where health can be protected. Numerical target provide means for policy-making.

Table 3.32 Thailand Ambient Air Standard, 1995 (2538), compared with WHO's Guideline and Japanese Standard

Pollutants		1 Hour mg/m^3	1 Hour ppm	8 Hours mg/m^3	8 Hours ppm	24 Hours mg/m^3	24 Hours ppm	1 Month mg/m^3	1 Month ppm	1 Year mg/m^3	1 Year ppm	Measuring method in Thailand
CO	Thailand	34.2	30	10.26	9							Non-Dispersive Infrared Detection
	WHO	30		10								
	Japan				20		10					
NO_2	Thailand	0.32	0.17									Chemi-luminescence
	WHO	0.4				0.15						
	Japan						0.04-0.06					
SO_2	Thailand	0.78	0.3			0.30	0.12			0.1*	0.04*	UV-Fluorescence
	WHO	0.35				0.15						
	Japan		0.1				0.04					
TSP	Thailand					0.33				0.10*		Gravimetric-High Volume
	WHO					0.15-0.23				0.04-0.06		
PM-10	Thailand					0.12				0.05		Gravimetric-High Volume
	WHO					0.07						
	Japan	0.20				0.10						
O_3	Thailand	0.20	0.1									Chemi-luminescence
	Japan		0.06									
Lead	Thailand							1.5(μg/m^3)				Atomic Absorption Spectrometer
	WHO									0.5-1(μg/m^3)		

Note: * : Geometric mean value
Source: JICA Study Team

It may be appropriate to study environmental targets and measures with regard to the following;

First, the lessening of pollutants should be considered. Pollutants from motor vehicles in Bangkok are thought to represent significant portion of the pollutants. The lessening of pollutants from motor vehicles is therefore one of the major concrete measures for mitigation and the first priority area for policy-making.

Second, environmental administration and policy direction should be considered for Bangkok. The environmental administration brings various policies into effect, however, they may be limited in power. To achieve sustainable development, the choice of policy direction is important. Energy issues can be closely related to environmental policy direction.

(2) Policies for Motor Vehicles

1) Necessity of Powerful Countermeasures

Policy choices for motor vehicles are described in 3.3 (1) 1), and its effects are simulated in 3.3 (1) 2). According to simulation results, attaining air quality standards by 2011 will not be an easy task. Therefore almost every possible mitigating policy should be introduced for Bangkok.

Integrating effectively the following activities, the traffic pollution management plan for Bangkok should be established and implemented in order to mitigate severe atmospheric pollution as soon as possible.

2) Regulations for Motor Vehicles

The following regulations are essential for motor vehicles:

- Emission regulation for new cars according to the latest plan;
- Emission regulation for in-use cars according to the latest plan; and
- Inspection and maintenance system to satisfy emission regulations according to the latest plan.

It should be noted that these regulations could be supported by current available engine technologies.

3) Transportation Policies

In addition to regulations for motor vehicles, the following transportation policies should be implemented:

- Improvement of the road network according to the 8th National Plan;
- Implementation of the Mass Transit Master Plan;
- Enhancement of the modal shift to bus transportation; and
- Systematic introduction of buses appropriate to the latest regulation.

It might be important for the modal shift that the bus operation management be improved and that bus priority road traffic management be introduced to attract people to change from using private cars to buses.

4) Development and Introduction of Low-Emission Vehicles

Low emission vehicles will play an important role from now on. Such activities as the expansion of the CNG bus network and the development of electric cars could be important measures. It may be necessary to establish a research center for developing low emission vehicles and for studying environmentally-sound transportation policies.

(3) Environmental Administration

Bangkok has complicated environmental issues. For adequate mitigation of these issues, the environmental administration should be strengthened based on the scientific approach.

1) Monitoring and Review

Monitoring is an indispensable tool for information acquisition. Emission source concentration as well as ground level concentration should be monitored.

The monitoring parameter should be expanded systematically, as various substances which affect the health are formed and emitted into the atmosphere.

To further implement the monitoring of ground level and emission source concentration, the promotion of private laboratories might be encouraged. The standardization of monitoring and analyzing methods needs also to be addressed.

The monitoring data should be analytically reviewed and processed, and the outcome of the monitoring should be publicized periodically.

2) Enhancement of Voluntary Activities by the Private Sector

Environmental issues cannot be managed by the public sector only, therefore the voluntary activities of the private sector play an essential part. According to the ISO14000 system, management policy, monitoring, recording, auditing and reviewing are important elements for the management of environmental issues. It is therefore essential to encourage the private sector to carry out such activities.

3) Public Qualification System

In relation to the private sector's activities, the development of human power can be another important issue. The introduction of a public qualification system for the appraisal of environmental management capabilities and low pollution emitting operations are influential measures for the development of manpower.

4) Public Relations

Environmental awareness may be enhanced through constant public relations, which may lead to participation of the public towards pollution mitigation. Scientific data could provide powerful support for public relations.

(4) Long-term Policies for Sustainable Development

1) Energy Saving and Fuel Efficiency

Many environmental issues are closely related to energy consumption. Many pollutants are emitted through fuel consumption. Consequently, energy saving mitigates emission of pollutants in many cases. In order to lessen greenhouse gas, which is considered to cause the rise in the sea level, energy saving and fuel efficiency of vehicles are significant.

2) Shift to Clean Energy

The introduction and shift to low pollutant emission energy, such as LNG, can be a major environmental issue. Further reformulation of fuel for industry and vehicles should be considered.

3) Urban Growth Management

The urban structure itself has a great influence on the urban environment. Generally speaking, motor-vehicle-oriented big cities suffer from more pollutants. An appropriate urban growth management system is of especial importance in order to lessen the environmental pollutant loads in the city as a whole.

(5) Proposed Projects and Programs

Summing up the above discussions for the pursuance of atmospheric pollution mitigation, projects and programs are proposed as follows:

1) Urgent Actions

AR11:Environmental Administration Enhancement Program, including:

Extension of Monitoring Stations and Equipment for Meteorology;

Establishment of Monitoring of Chemical Substances;

Establishment of Epidemiological Surveillance System; and

Training and Technology Transfer of Analytical Techniques.

AR12:Establishment of Traffic Pollution Management Plan, including:

Regulations for New and In-use Vehicles;

Planning of Promotion of Modal-shift and Its Facility;

Consideration of Water and Air Transportation; and

Planning for Noise Reduction.

AR13:Improvement of Vehicle Inspection and Maintenance System Program, including:

Standardization and Technical Guidelines for Emission Inspection;

Training and Qualification System for Inspector / Mechanics;

Public Relation System and Institution Building, etc.

AR14:Implementation of "Fresh and Clean Air Program for Public Buses", including:

Checking System of Maintenance and Exhaust Gas; and

Low-Pollution Bus Replacement (Expansion of CNG Bus) Program.

AR15:Establishment of a Transportation Research Center, focused on:

Study for Environmentally Sound Transportation Policies;

Research for Low-emission-vehicles; and

Research for Transportation Technology Suitable to South East-Asia.

AR16:Public Campaign for the Promotion of People's Awareness of Vehicle Maintenance and Dust Reduction by Construction.

2) Medium-term Projects/Programs

AR21:Implementation of the Extended Environmental Administration Enhancement Program (following-up AR11)

AR22:Enhancement of Voluntary Activity by the Private Sector, including:

Introduction of a Voluntary Environmental Management System;

Promotion of Private Laboratories and Monitoring Activities;

Establishment of a Public Qualification System for Environmental Engineers/Managers; and

Introduction of the ISO14000 System

AR23:Implementation of the Extended Vehicle Inspection and Maintenance System Improvement Program (following-up AR13)

AR24:Implementation of the "Energy Saving Policy", including:

Incentive Provision for Shifting to Cleaner Energy/Fuel; and

Institutional Support for Fuel Efficiency Improvement

AR25:R & D Support Program for Less Polluting Vehicle Production (Hybrid Electric Vehicle, CNG Vehicle, etc.)

AR26:Study of Energy Perspective in View of Environment, including:

Analysis of Environmental Influence by Future Energy Trend;

Shift to Cleaner Energy; and

Further Reformulation of Fuels.