BEIP

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)
BANGKOK METROPOLITAN ADMINISTRATION(BMA)
THE GOVERNMENT OF THE KINGDOM OF THAILAND

THE STUDY ON URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM IN BANGKOK METROPOLITAN AREA

FINAL REPORT

VOLUME 3: SECTOR PLANS AND TECHNICAL STUDIES

February 1997

PACIFIC CONSULTANTS INTERNATIONAL
SUURI-KEIKAKU CO., LTD.

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The exchange rates applied in this Study are:

US$ 1.00	=	Baht 25.42
US$ 1.00	=	Japanese Yen 110.65
Baht 1.00	=	Japanese Yen 4.35

(as of September 1996)

Preface

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct "The Study on Urban Environmental Improvement Program in Bangkok Metropolitan Area" and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to the Kingdom of Thailand a study team headed by Dr. Katsuhide NAGAYAMA, Pacific Consultants International, and composed of members of Pacific Consultants International, and Suuri-Keikaku Co.,Ltd., four times between August 1995 and December 1996.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Kingdom of Thailand for their close cooperation extended to the team.

February 1997

Kimio Fujita
President
Japan International Cooperation Agency

February 1997

Mr. Kimio FUJITA

President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to formally submit herewith the final report of "The Study on Urban Environmental Improvement Program in Bangkok Metropolitan Area".

This report compiles the results of the Study which was undertaken in the Kingdom of Thailand from August 1995 through December 1996 by the Study Team, organized jointly by Pacific Consultants International and Suuri-Keikaku Co., Ltd.

We owed a lot to many people for the accomplishment of the Study. First, we would like to express our sincere gratitude and appreciation to all those extended their kind assistance and cooperation to the Study Team, in particular, relevant officials of Bangkok Metropolitan Administration, the Thai counterpart agency.

We acknowledge all the officials of your agency, the JICA Advisory Committee, Embassy of Japan in Thailand and Ministry of Foreign Affairs.

We wish the report would be able to contribute really to appropriate polices and measures for the Bangkok environmental improvement to be formed by the Thai Government.

Very truly yours,

Dr. Katsuhide NAGAYAMA

Team Leader,
The Study Team for the Study on
Urban Environmental Improvement
Program in Bangkok Metropolitan
Area

THE STUDY ON URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM

IN BANGKOK METROPOLITAN AREA

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Abbreviation

BEIP	The Study on Urban Environmental Improvement Program in Bangkok Metropolitan Area
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Mass Transit Authority
BOD	Biological Oxygen Demand
CBD	Central Business District
CO	Carbon Monoxide
DO	Dissolved Oxygen
DOH	Department of Highways, Ministry of Transport and Communications
DTCP	Department of Town and Country Planning
EEC	European Economic Community
ERTC	Environmental Research and Training Center
ETA	Express Transit Authority of Thailand
FAR	Floor Area Ratio
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GIS	Geographic Information System
GPP	Gross Provincial Product
HBE	Home Based Education Trip
HBO	Home Based Others Trip
HBW	Home Based Work Trip
IDE	Institute of Developing Economies
IPCC	Intergovernmental Panel on Climate Change
JEA	Japan Environmental Agency
JICA	Japan International Cooperation Agency
LTD	Land Transport Department
MOF	Ministry of Finance
MOH	Ministry of Health
MOI	Ministry of Interior
MOID	Ministry of Industry
MOSTE	Ministry of Science, Technology and Environment
MOTC	Ministry of Transport and Communications
MRR	Middle Ring Road

MRTA	Metropolitan Rapid Transit Authority of Thailand
MSL	Mean Sea Level
MWA	Metropolitan Waterworks Authority of Thailand
NEPO	National Energy Policy Office
NESDB	National Economic and Social Development Board
NHA	National Housing Authority
NHB	Non-Home Base Trip
NO	Nitrogen Monoxide
NO2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPV	Net Present Value
OCMRT	Office for Commission of Management for Road Transport
OEPP	Office of Environmental Policy and Planning
ORR	Outer Ring Road
PCD	Pollution Control Department
PCU	Passenger Car Unit
PM	Particulate Matter
PM-10	Particulate Matter Smaller than 10 μ
PPP	Polluter-Pay-Principle
PWD	Public Works Department, Ministry of Interior
RID	Royal Irrigation Department
SO2	Sulfur Dioxides
SOx	Sulfur Oxides
SPM	Suspended Particulate Matter
TDRI	Thailand Development Research Institute
TOE	Ton Oil Equivalent
TSP	Total Suspended Particulate
UNEP	United Nation for Environmental Program
UTDM	Urban Transport Database Management Project
VAT	Value Added Tax
WHO	World Health Organization
WMA	Wastewater Management Authority

CHAPTER 1: URBAN LAND USE

1.1 General

Bangkok Metropolitan Area is located on the deltaic lowland which is formed by the Chao Phraya River. Topographically, elevation of this lowland is showing from 1 to 2 m above sea level and the climatic condition of this area is belonging to the tropical monsoon which has clear rainy and dry season. These physical background of the Bangkok city greatly affects on the urban development and management.

Urbanized area of Bangkok city has been greatly changed and extended in these ten years because of the remarkable growth of Thai economy. Construction rush of many high-rise buildings and new highway networks and housing development have taken place. Growth of the urban area is still continuing year by year towards suburbs of Bangkok and potentially high productive agricultural land has been changed to housing, industrial estate and urban infrastructure development.

Urban environmental problems such as air pollution derived mainly from traffic jam, degradation of water quality of river and canals, ground subsidence and flooding in the urbanized area and so on, have became important subjects to be solved. These environmental problems are taking place in Bangkok within relatively short time and each phenomena is thought to be originated from the huge concentration of population and economic activities.

Urban and related environmental problems are usually caused as an overlapped manner by each other. Degradation process of the environmental quality needs a long time for the accumulation of pollutants, however , the phenomena appears suddenly and critically. These urban environmental problems sometimes take a form of disaster and affect even on the human life directly.

Therefore, well coordinated and organized preparation for the urban land use planning for Bangkok city should be discussed to protect and improve the existing urban environmental conditions. In this chapter, specifically, characteristics of urban land use in BMA are described.

1.2 Existing Conditions

(1) Extension of Urbanized Area in Bangkok

Thai Government has prepared many regulations for the proper development, building and land use control for the BMA in these 20 years to direct and manage the urban development. According to the historical data, urbanized area of Bangkok was less than 100 km^2 only at the end of 1950s. At the beginning of the 1970s, urban area extended to about 200 km^2 and it became 345 km^2 in 1980.

Existing land use map of the whole BMA area was compiled by Mapping Division of City Planning Department in 1995 based on interpretation of aerophotography which was taken in 1993. This map which was classified into thirteen(13) land use items was digitized and stored into the BEIP-GIS as one of the digital files. After the completion of data input, area of each land use categories are measured and listed by district in table format (see Table 1.1). According to this data, total built-up area(or urbanized area) of BMA in 1993 is calculated at 541 km^2. This means that 34 % area of total BMA is covered by urban land use. On the contrary, BMA still has a sizable area of natural type land use. Agricultural area is occupied totally 1,038 km2(66 %) of BMA.

(2) Intensification of Urban Land use of Bangkok

Intensification of urban land use in Bangkok city has been taking place mainly since 1990s according to the building permission data prepared by City Planning Division and Building Control Division of BMA.

Building data of 1980-1987 is showing that number of buildings of 8-12 floors are 257, 13-20 floors are 135, 21-30 floors are 36 and over 31 floors are 6. Total number of high-rise buildings at 1987 was 434 sites. On the other hand, building permission data during 1990-1995 provided by Building Control Division is showing that number of high-rise building permission of 8-12 floors are 2092, 13-20 floors are 541, 21-30 floors are 543, and over 31 floors are 333 sites. Total number of permissions are 3509. It is very clear that these high-rise buildings having more than 31 floors have been constructed or being constructing within these 5 or 6 years. The main type of use of these buildings are condominium, office use, and hotel and so on. Construction of the large size building in the central area of Bangkok city is one of the factors of congestion.

(3) Road and Soi Ratio

Existing road network data based on 1:20,000 and 1:50,000 topographical map is also digitized and stored into BEIP-GIS and district boundary data is overlayed on this road network map. Total length and density of the existing road by district are calculated and listed in Table.

Total length of the road in BMA measured by BEIP-GIS is 7,770 km including every type of road such as expressway, secondary or tertiary road and soi. In Bangkok, soi network which is connected with major road is densely developed in the urbanized area and total length of soi is calculated at 6,180 km. This figure means that approximately 80 % of the total length of the existing road is occupied by soi.

Road density is calculated by each district and sub-district dividing total length of road by area of district or sub-district. In general, Din Daeng has the highest value of road density at 158 m/ha, and Pom Prap Sattruphai has the next high value at 137 m/ha and so on. On the contrary, the lowest value of road density is seen in Nong Chok at 9 m/ha and the second lowest is seen in Ratburana.

Mean value of the road density in Bangkok is 49.2 m/ha and these data are shown in the last column of the Table

(4) Distribution of Natural Constraints

Flooding and land subsidence are the main natural constraints for urbanization in BMA. In BEIP-GIS, flooded area by 1983 flood and simulated land subsidence map are digitized respectively as a basic data. Administrative boundary data is overlayed on these maps and flooded area and simulated land subsidence area by depth are calculated by each district. Results of calculation are listed in Table 1.2.

- Total flooded area by 1983 flood in BMA is calculated at 424 km^2 and those districts such as Phra Khanong, Lat Phrao, Suan Luang, and Bang Kapi are inundated more than 80 % area of the district. Khlong Toei, Huai Khwang, Jomtong and Prawet district were inundated 54%-68% area of their district.

Table 1.1 Land Use Statistics

DISTRICT NAME	HIGH DENSITY	MID DENSITY	LOW DENSITY	COMM-ERCIAL	INDUS-TRIAL	WARE-HOUSE	GOVERN MENTAL	AGRI-CULTUR	CONSER-VATION	PARK	SCHOOL	RE-LIGION	WATER BODY	TOTAL
Bang Kapi	1.354	14.175	10.415	2.905	0.398	0	0.610	13.434	0	1.584	0.199	0	0	45.074
Bang Khen	0	7.300	8.077	0.836	0	0	8.399	53.256	0	0	0.037	0.438	0	78.343
Bang Kho Laem	0	5.434	0.151	0.552	0.090	0.388	0.115	0.312	0	0.130	0.033	0.100	1.153	8.458
Bang Khun Thian	0	9.663	10.963	0.187	0.910	0.040	0.018	134.339	0	0.011	0.116	0.103	0.203	156.553
Bang Phlat	0	4.089	4.222	0.959	0.038	0	0.016	1.454	0	0	0.085	0.048	0.947	11.858
Bang Rak	0	0.036	0	3.372	0	0	0.274	0	0	0.014	0.205	0.017	0.126	4.044
Bang Sue	7.435	1.289	0.851	0.746	0.693	0	0.161	1.211	0	0	0.091	0.012	0.596	13.085
Bangkok Noi	0.615	3.315	3.379	1.179	0	0	0.882	1.983	0	0	0.168	0.210	0.566	12.297
Bangkok Yai	0.085	3.680	0.157	0.864	0.128	0	0.137	0.653	0	0	0.173	0.175	0.189	6.241
Bung Kum	0.985	18.177	7.535	0.389	0.849	0	0.051	33.332	0	1.736	0.065	0	0	63.119
Chatu Chak	3.519	16.606	2.219	1.368	0.212	0	4.720	0.732	0	2.678	0.419	0	0.005	32.478
Din Daeng	0	6.493	0	1.025	0	0	0.483	0	0	0.128	0.349	0	0	8.478
Don Muang	0.035	15.245	6.451	0.525	0	0	15.586	20.284	0	0	0.447	0	0	58.573
Dusit	0.138	2.674	0.018	0.272	0.144	0	5.185	0	0.897	0.824	0.280	0.119	0.749	11.300
Huai Khwang	0	5.693	3.397	1.227	0	0	0.060	5.925	0	0	0.048	0	0	16.350
Jomtong	0.011	7.869	3.347	0.906	0.393	0	0.050	10.359	0	0	0.097	0.283	0.439	23.754
Khlong San	0	3.900	0	0.984	0.171	0.047	0.138	0.016	0	0	0.124	0.056	0.579	6.015
Khlong Toei	2.309	16.533	0.285	3.147	0.058	0.872	2.590	0.544	0	0.319	0.348	0	0.949	27.954
Lat Phrao	0.521	10.175	5.936	0.620	0.066	0	0.050	11.114	0	0	0.062	0	0	28.544
Latkrabang	0.153	2.314	7.012	0	2.088	0	0	116.979	0	0	0.027	0.020	0	128.593
Minburi	0.052	3.323	7.202	0.529	1.907	0	0.107	163.895	0	0	0.254	0	0	177.269
Nong Chuk	0	0.452	5.656	0	0	0	0	234.948	0	0	0.000	0	0	241.056
Nong Khaem	0	5.071	9.530	0.143	0.746	0.012	0.490	30.622	0	0	0.138	0.203	0	46.955
Pathumwan	0.120	0.375	0.024	3.093	0	0	1.709	0.073	0	1.265	1.355	0	0.066	8.080
Phasi Charoen	0.006	16.748	3.523	1.467	0.436	0.196	0.101	33.286	0	0	0.430	0.254	0.175	56.622
Phaya Thai	0	7.989	0	0.289	0	0	0.529	0	0	0.112	0.061	0	0.093	9.073
Phra Khanong	1.424	23.853	0.767	0.789	0.239	1.356	0.332	3.738	0	0	0.520	0	0.924	33.942
Phra Nakhon	0.196	0.244	0.066	2.065	0.017	0	0.778	0	0.294	0.360	0.333	0.442	0.601	5.396
Pom Prap Sattrupha	0.181	0.054	0	1.569	0	0	0.240	0.017	0	0	0.154	0.171	0.058	2.444
Prawet	0	13.125	11.399	0.921	0.814	0	0	38.497	0	0.579	0.024	0	0.117	65.476
Ratburana	0.387	10.048	2.129	0.993	0.546	0.464	0.279	30.235	0	0.083	0.248	0.187	1.126	46.725
Ratchathewi	0.495	1.375	0.466	1.467	0	0	2.605	0.167	0	0.140	0.453	0	0.057	7.225
Samphanthawong	0	0	0	1.033	0	0	0.055	0	0	0	0.026	0.123	0.172	1.409
Sathon	0.003	5.020	0	0.814	0.140	0.098	0.594	0.096	0	0.018	0.298	0.039	0.131	7.251
Suan Luang	0	9.272	4.201	0.492	0.025	0	0.017	6.090	0	0.121	0.247	0	0.276	20.741
Taling Chan	0	5.435	15.712	0	0	0	0.026	65.153	0	0	0.221	0.300	0.755	87.602
Thonburi	0.143	5.202	0.107	1.348	0.072	0.114	0.140	0.200	0	0	0.136	0.194	0.477	8.133
Yan Nawa	1.166	6.957	0.229	0.595	0.087	0.879	0.214	0.526	0	0.025	0.099	0.054	1.574	12.405
Total	21.333	269.203	135.426	39.670	11.267	4.466	47.741	1013.470	1.191	10.127	8.370	3.548	13.103	1578.915

Unit : km

Table 1.2 Subsidence Statistics by District

District	< -50 (cm)	-50 to -75 (cm)	-75 to -100 (cm)	-100 to -125 (cm)	-125 to -150 (cm)	-150 < (cm)	Total
Bang Kapi	0	13.084	20.942	11.051	0	0	45.076
Bang Khen	0	47.539	30.802	0	0	0	78.341
Bang Kho Laem	0	0	8.459	0	0	0	8.459
Bang Khun Thian	0	72.876	27.185	14.735	36.267	5.490	156.552
Bang Phlat	0	0	8.652	3.205	0	0	11.857
Bang Rak	0	0	2.197	1.846	0	0	4.043
Bang Sue	0	1.140	11.947	0	0	0	13.087
Bangkok Noi	0	0	0.743	11.555	0	0	12.299
Bangkok Yai	0	0	0	6.241	0	0	6.241
Bung Kum	0	62.773	0.346	0	0	0	63.119
Chatu Chak	0	1.438	31.040	0	0	0	32.478
Din Daeng	0	0	3.499	4.979	0	0	8.478
Don Muang	0	31.659	26.911	0	0	0	58.571
Dusit	0	0	9.305	1.998	0	0	11.303
Huai Khwang	0	0	1.833	14.517	0	0	16.350
Jomtong	0	0.984	15.992	6.776	0	0	23.752
Khlong San	0	0	0.325	5.691	0	0	6.015
Khlong Toei	0	0	9.832	18.122	0	0	27.954
Lat Phrao	0	13.643	14.901	0	0	0	28.543
Latkrabang	0	13.660	36.739	77.555	0.637	0	128.593
Minburi	14.862	119.990	21.023	19.414	1.979	0	177.268
Nong Chok	133.243	62.370	39.318	6.126	0	0	241.056
Nong Khaem	0	0.462	6.414	11.996	28.087	0	46.959
Pathumwan	0	0	5.996	2.084	0	0	8.079
Phasi Charoen	0	0	3.175	15.076	38.370	0	56.621
Phaya Thai	0	0	9.009	0.064	0	0	9.074
Phra Khanong	0	0	21.272	7.417	5.253	0	33.941
Phra Nakhon	0	0	0	5.394	0	0	5.394
Pom Prap Sattruphai	0	0	0	2.445	0	0	2.445
Prawet	0	28.534	20.413	12.430	4.098	0	65.476
Ratburana	0	0	19.247	16.766	8.073	2.636	46.722
Ratchathewi	0	0	4.496	2.727	0	0	7.223
Samphanthawong	0	0	0	1.409	0	0	1.409
Sathon	0	0	7.106	0.142	0	0	7.249
Suan Luang	0	3.629	14.321	2.792	0	0	20.742
Taling Chan	0	0	25.294	48.262	14.047	0	87.603
Thonburi	0	0	1.322	6.812	0	0	8.133
Yan Nawa	0	0	12.263	0.142	0	0	12.405
Total	148.105	473.780	472.318	339.769	136.811	8.126	1578.910

- According to the simulated land subsidence data by the year 2017, area of less than 50 cm is calculated at 148 km^2 (9.3%), and this area is located in the north-eastern part of BMA such as Minburi and Nong Chok. Area of 50 cm-100 cm subsidence is calculated at 946 km2 (60%) and area of more than 100 cm subsidence is 485 km^2 (31%) of BMA. More than 85% district area of the Bangkok Yai, Khlong San, Bangkok Noi. Phasi Charoen, Huai Khwang and Nong Khaem is covered by over 100 cm contour line of subsidence.
- IN BEIP-GIS, these flood and subsidence data map are overlayed again and compiled as a natural constraints map. Based on this map, it is pointed out that Huai Khwang, Khlong Toei, Bangkok Noi and Phra Khanong districts are the area of both higher potentiality of land subsidence and flooding.

1.3 Urbanization Potentiality by Open Space vs Built-up Ratio

Area of existing land use type by district and sub-district is calculated and compiled into table format. Open space ratio is calculated from the existing land use map and listed in Table 12.2 and 3 of Chapter 12. Population data, transportation data such as bus service or accessibility to road network and so on that are showing the existing conditions of the urban facilities in BMA are also input into BEIP-GIS. Based on these basic data, especially on open space/vs build-up ratio and population density by sub-district, future urbanization potentiality is described rather qualitatively.

(1) Sub-district group of more than 90 % built-up ratio with limited open space

This group of sub-districts are mainly distributed in old urbanized area in Bangkok. In these area, accessibility to the main road network or commercial center is excellent and basic services of urban facilities are also excellent.

Average population density in this group is 352 person/ha and this value is almost equal to the density of built-up area such as 365 person/ha.

In extremly populated area is showing the density more than 900 person/ha. Another characteristics of this group is that the sub-district area is relatively narrow. For the instance, area of Si Phraya is 0.76 km^2, Maha Phuttharam is 0.65 km^2, and Thung Phaya Thai is 2.51 km^2 and so on. Because of the high density of population and limited open space ratio, urbanization potentiality seems to be limited. In these area, future direction of urbanization should be a combination of intensification of land use and improvement of urban environment by redevelopment.

(2) Sub-district group of 76-89 % built-up ratio

This sub-district group are distributed almost the same district mentioned above and the basic characteristics of the population density, accessibility to the urban facility services and road network are almost the same level. Area of these sub-districts are also very narrow and the potentiality of future urbanization is also limited.

(3) Sub-district Group of 51-75 % built-up ratio

In this group, population density is showing the average level of total BMA. Population density of the thirteen(13) sub-district in this group is 148 person/ha.

Average density of those sub-district which have enough space such as Thong Song Hong and Hua Mak are 103 and 143 persons/ha respectively in built-up area. Accessibility to the urban facilities in this group is showing less low level and future urbanization potentiality seems to be high in several sub-districts like Hua Mak and Thong Song Hong.

(4) Sub-district group of less than 50 % built-up ratio with enough open space

This group of sub-districts are distributed in the fringe area of existing urbanized area. Area of each sub-district is relatively large and the average population density is 146 person/ha in built-up area and 49 person/ha in total. Accessibility to the urban facilities is also relatively low level in general, however, those sub-district such as Chim Phli, Khlong Thanon, Khanna Yao, Saphan Sung, Bang Khae Nua, Minburi and Nong Khang Phlu are not only having enough space but also higher potentiality of urbanization. In these area , detail urban infrastructure development plan should be prepared as a guideline to keep the higher standard of future urbanization.

1.4 Policy Directions and Planning Issues

(1) Necessity of Basic Data Preparation

It is, first to point out that the accessibility and availability of the most up to dated map data and information for land use analysis in the study area were relatively difficult. Especially the availability of the large scale topographical map is quite limited. For this study, 1:4,000 scale map was provided to Study Team by PWD, however, the contents of this map series were already out of date because of this maps were compiled in 1987 by JICA technical assistance Program. For the detail planning, management and control of urban land use, basic information on building construction and use, floor area ratio and coverage ratio, land titles, and location of urban facilities such as pipeline network of water supply and so on, should be prepared based on the most up to dated large topographical map as the baseline data. In addition to those data, another thematic maps on the latest land use , infrastructure distribution and natural condition etc., should be prepared by relevant agencies in most appropriate map scale. Basic data survey and preparation of the urban development planning of BMA should be carried out in well coordinated manner, and accessibility to those data should be guaranteed for comprehensive understandings of the urban conditions among relevant agencies.

(2) Measures for Water Management

Treatment of both surface and ground water in BMA area is a key issue to keep the higher environmental quality for living. From the land use planning point of view, it must be necessary to fully consider how to take a harmony with water.

As the concentration of large population and rapid expansion of urbanized area in Bangkok, deltaic lowland that is basically utilized for agriculture and fish ponds have been altered to artificial land use such as buildings, roads, housings and industrial estate. These land uses always cover the land surface by pavement. This alteration of natural condition directly effects on the run-off ratio of the surface water. As a result of these change of environmental condition, heavy rainfalls in rainy season are sometimes causing flood in the relative lowland area and flood water takes the form of stagnation.

Construction of flood protection dike, watergate and pumping station for drainage of flood water was the major issues of metropolitan area of Bangkok in past years and sizable investment have been made for the development of those infrastructures. Extensive flooding has not caused in Bangkok since 1983 due to the effects of flood protection facilities. But in 1995, Thonburi area and outside area of flood protection dike in eastern part of Bangkok were suffered from severe flood disaster. Because of the limitation of available financial resource for the flood mitigation facilities, priority area to be protected or limitation area of urbanization should be discussed. At present, 17,000 ha of non-urbanized area or open space area is distributed between the Kings Dike and Inner Dike. If this area is developed by 147 person/ha which is an average density in eastern part of Bangkok, another 2,500,000 persons can be accepted. In the western bank area of Chao Phraya River, 30,800 ha of open space is measured based on existing land use map of BMA. BMA still has an enough land resource at this moment, therefore, urbanization area should be controlled within flood free area. Enough space should be designated for the development of urban road network, park, drainage canal and so on.

(3) Land Subsidence and Affection by Global Change in Environment

Attention should be also paid on changes of environment in the long term point of view. The "Green House Effect"caused by increase of CO_2 will raise the sea level at the rate of 0.5 to 1.0 cm annually. It is forecasted that the present sea level will raise 0.5 to 1.0 m globally. The raise of sea level will make serious damages in the deltaic area of lower Chao Phraya River.

Another important factor related with the change of sea level is land subsidence. The area and volume of subsidence are already mentioned in previous section. These land subsidence and sea level raise will intensify the flood disaster. In Bangkok, 320 ha of 0 m area in elevation had already recognized in 1987 and these low lying area must be extended due to the land subsidence in these ten years.

These inter-related phenomena should be well considered to seek necessary and effective measures for future urbanization of Bangkok.

(4) Preparation and Up-dating of Regulations for Land Use Control

Existing regulations for land use control should be improved and updated to regulate the urban development. The land use zoning system is the basic gudeline for land use, however, methodology for zoning system should be improved based on the detail data analysis which is supported by modern information technique such as GIS.

Chapter 2 : ENVIRONMENT-INITIATIVE TRANSPORT SYSTEM

2.1 Transport Planning Issue: Escape From A Vicious Circle in Car Oriented Society

In 1996, one of the critical environmental problems in Bangkok is poor air quality, especially that along the major roadsides. The air pollutant emission at roadsides is dependent on volume and speed of the vehicular traffic. Emission factors of vehicle become significantly increase due to decrease of speeds. Rapidly increasing vehicular traffic, with their low speeds, is contributing to a massive increase of total amount of pollutant air. Accordingly, the people in Bangkok would have a common understanding that the heavy traffic jam on roads is the main cause of the environmental problem.

It is true that road transport is a major contributor to poor air quality in Bangkok, however, it was found in the BEIP study that traffic congestion itself is not a root cause of the environmental problem. We should address more fundamental issues forming the present society towards the next transport plan. The policy of "environment initiative transport system" discussed in Chapter 10.4 of Volume 2 should be a guideline for our future planning activities.

First, it should be recognized that we have been enjoying urban economic growth and urban life of Bangkok based on a "Car-Oriented Society" for these two decades. In the car-oriented society, mobility of cars is given the highest priority rather than mobility of the people. Due to this principle (car first), development of urban and road infrastructure have been proceeded. That is, where road traffic congestion is identified, more road spaces have been provided to accommodate vehicular traffic demand. But, this is a too simplistic approach. It needs to be recognized that we will no longer able to enjoy them based on the car-oriented society.

It is recognized that there is a vicious circle in the car-oriented society of Bangkok as described in figure 2.1. Given more road space, people will be encouraged to own their private cars and motorcycles along with up-lifting of their income levels (this phenomenon is clearly shown in the transport simulation of case 2 and 8). Therefore, another traffic congestion will be added to the road segments. This eventually causes negative impacts on traffic flow of public transport (especially on buses) as well. For example, high occupancy vehicles (HOV) have been allowed to enter the bus lanes recently in peak hours. This type of policy is depriving an advantage of public transport. Then, again people are encouraged to have their private vehicles.

This vicious circle has been further worsened by some sub-social system shown in Figure 2.1. Among the sub-social systems, there are government subsidy to the bus operator, infrastructure development in the past (for example, high standard motorway of radial type such as FES and Dong Muang tollway), and several technical problems such as signal controlling.

For example, urban growth in the past has been led by transport infrastructure development e.g. the urban development at the end of the second stage expressway or the ribbon development along major road corridors, which have been adding longer vehicular trips on the major corridor.

In summary, there exists a unorganized energy-consuming cycle in the car-oriented society of Bangkok. In this context, planning issues should be found in "How to escape from this vicious circle" and/or "How to change the "Car-oriented Society" into a deferent system.

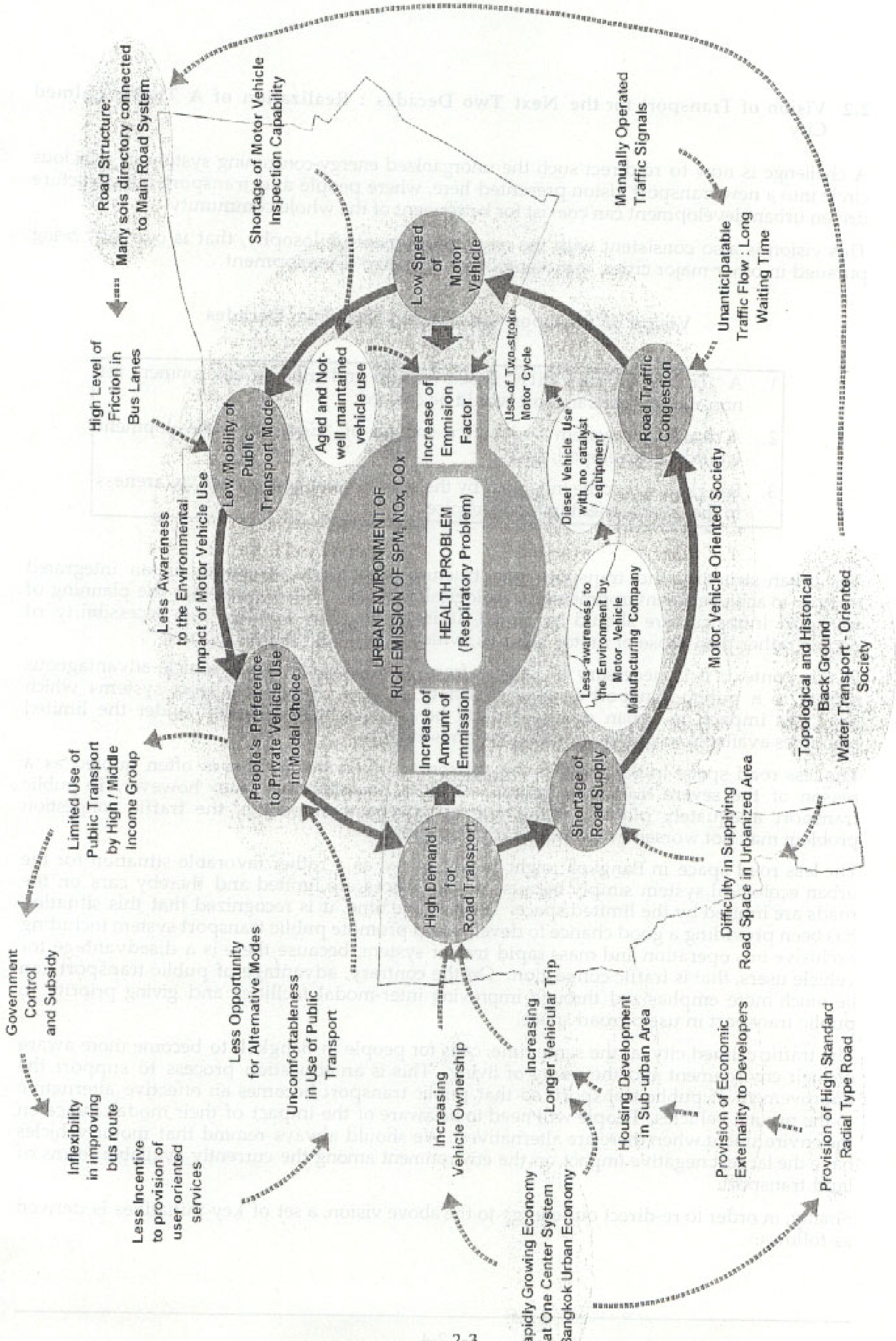


Figure 2.1 Vicious Circle of Car-Oriented Society

2.2 Vision of Transport for the Next Two Decades : Realization of A Traffic Calmed City

A challenge is now to re-direct such the unorganized energy-consuming system in a vicious circle into a new transport vision presented here, where people and transport infrastructure driven urban development can coexist for betterment of the whole community.

This vision is also consistent with the city development philosophy, that is currently being pursued in other major cities, represented by "Eco-City" Development.

Vision of Transport towards the Next Two Decades

1. A "Traffic Calmed City" based on safe and friendly environment for non-motorized transport would be created;
2. A transport system supportive enough of "Eco-city" development would be developed; and
3. Bangkok would be inhabited by the people having improved awareness to the environment in modal choice.

The urban structure and transport infrastructure need to be developed in an integrated manner to achieve an environmental / ecological balance. This implies that the planning of transport infrastructure should be aimed at improving the mobility and accessibility of people rather than those of motor vehicles, which is termed "Traffic Calming ".

In this context, it is necessary to change from a motorized-private-vehicle-advantageous society to a public-transport-orientated society at first. Public transport systems which have less impact on urban ecology should be given a higher priority under the limited resources available to spend on transport infrastructure.

The less road space in Bangkok in comparison to other major cities is often quoted as a reason of the severe traffic congestion. This is partially the case, however, if public transport adequately plays a larger role in movement of people, the traffic congestion problem may not worsen even under such a condition.

The less road space in Bangkok might be recognized as a rather favorable situation for the urban ecological system simply because paved spaces are limited and thereby cars on the roads are limited by the limited space. At the same time, it is recognized that this situation has been providing a good chance to develop and promote public transport system including exclusive bus operation and mass rapid transit system, because there is a disadvantage for vehicle users, that is traffic congestion. On the contrary, advantage of public transport can be much more emphasized through improving inter-modal facilities and giving priority to public transport in use of road space.

The traffic calmed city, at the same time, calls for people in Bangkok to become more aware of their environment and their way of living. This is an education process to support the improvement of public transport, so that public transport becomes an effective alternative to the private vehicles. People will need to be aware of the impact of their modal choice on the environment when there are alternatives. We should always remind that motor vehicles have the largest negative impact on the environment among the currently available forms of land transport.

Finally, in order to re-direct our energy to the above vision, a set of key initiatives is derived as follows:

Key Strategic Initiatives towards the Transport Vision of Bangkok in 2011

For Vehicle Owners:

1 Reduce need and use of private vehicles in urban life

2 Promote ridership of public transport systems including buses and MRTs and mom-motorized modes

For Commuters:

3 Improve or develop Inter-modal facilities among those systems;

4 Restrict private vehicle use in CBD where public transport modes are readily available

For All Residents

5 Create a safe environment for non-motorized mode users, pedestrians and residents

2.3 Goals Reflecting The Transport Vision : Environment - Initiative Transportation System in 2011

(1) Modal Share of Public Transport

Applying a mixed-policy suggested by the simulation analyses (Case 7, 9, 10), approximately 70% of all peak hour person travel will be able to be made by public transport mode. This is the most ideal situation to be the planning target. At present, about 40 % of daily person trips are made by public transport mode and 45% of those are made by private modes (car and motorcycle). Assuming the target figure of 70% is realized today, more than 60 % (4.6 million person trips a day within BMA) of private-vehicle-trip must be shifted to public transport mode. If these 4.6 million trips are accommodated by only bus transport services, the target seems to be very difficult to achieve. A simple calculation : "40 person x 10 times operation a day x 11,500 buses = 4.6 million person trips" indicates that at least the number of buses needs to be doubled now. In this context, **the Mass Rapid Transit Master Plan system should be promised in the year 2011.**

(2) Multi Modal Corridor

Through developing the sub-centers, a "Multi Nucleus" System will be created in Bangkok. In order to efficiently induce the multi nucleus system, the "Multi Modal Corridor" System, consisting of multiple transportation facilities such as major arterial roads, medium / mass transportation, and expressways, is required. The Multi Modal Corridor should have important functions as follows;

- The system gives the outlying activity centers (sub-centers and major local activity centers) direct and reliable accessibility to the central area
- The system gives alternatives to the people in modal choice
- The system gives higher priority to public transport users

(3) Integrated Public Transport System and Quality Pedestrian Environment

Special emphasis needs to place on the integrated improvement of public transport system, being consist of MRTs, public and private buses, waterways and taxis. Development of inter-modal facilities is a key for encouraging the people to use public transport modes.

Recently the new Mor Chit bus terminal project has been proceeded by a private company, where three deferent public transport systems come across : BERTS, BTSC, and Buses. Even there exist deference among the implementation schedule of each transport system, this type of facility should be designed in an integrated manner to have functions as follows;

- The facility should have enough capacity for future transfer demand and should provide high and quality access between deferent systems;
- The facility itself can be an attraction center such as a shopping center, an aquarium, and a theater to ensure vital financial performance for private sectors. These attractions are important initiators to generate trips on holidays, contributing financial performance of public transport system.

(4) Road System

A simple "More Roads" policy should, of course, be explored. However, there is an important planning view, that is "How the new road construction will improve or contribute to better public transport system in Bangkok".

Necessity of "secondary road" has been discussed in the context of solution for so-called "Super Block" problem. In BEIP, however, new road construction addition to the 8th plan project will be allowed only when those are beneficial to promotion of public transport modes and development of the sub-center. Necessary spaces should be reserved for these type of road construction.

Besides, of the 8th Plan Project, the Outer Ring Road will be effective to make the movement of freight in and around Bangkok more efficient and more rational. And, a new arterial ring road to be formed with the ETA expressway should be facilitated to provide a structural backbone of future urbanization and land use policies in Bangkok.

(5) Traffic Management

Recently introduced Area Traffic Control (ATC) system should be fully operated as soon as possible. The system has been working in night-time when the traffic congestion is not severe, but not be allowed to operate in day-time. By this time, the most of capability of the ATC has not been made. Instead of the ATC, many policemen are allocated at the intersections to control the traffic. This is simply meaning a double investment. Enacting the ATC, policemen should be re-allocated to other function such as watching vehicles on exclusive bus lanes.

In summary, target for transport sector in the year 2011 is established as follows:

Bangkok Transport Target in 2011

- 70% of all peak hour person travel by public transport in the year 2011
- Much Development of Quality Pedestrian Facilities
- Completion of Mass Transit Master Plan
- Development of Multi Modal Corridor
- Development of Integrated Public Transport System
- Development of Hierarchical Road System which is supportive of Sub Center development and use of the MRTs
- Implementation of the full ATC and Area Restraint

2.4 How do we get there ? : Concepts of Strategic Projects / Actions towards the Goal

In order to achieve the target, eight (8) key strategic projects / actions are proposed in addition to the 8th Plan Projects. Integrated efforts should be made to implement them in coordination with relevant agencies.

Strategic Project 1: Roads for Pedestrians

Access to public transport

The "soi" is an unique resource for re-organizing Bangkok as a pedestrianized city. As they are connected to major arterial roads, they can be developed as good access roads when public transport systems are facilitated along the major roads.

Exclusive space for pedestrians

There are many examples in cities where several roads be closed to create open space exclusively for pedestrians and revitalize the areas. This policy may be applied for the areas Silom Rd. between Soi Convent for example and the new road along Khlongs.

These pedestrian roads projects should be beneficial for public transport users and residents, thereby creating favorable circumstances for a "public transport - oriented society".

Strategic Project 2: Improvement of Mobility in Urban Activity Centers

Once people enter centers by public transport, they need to also use public transport again or walk for the next trip within the center. Without such convenient modal facilities in the central busy areas, it will fail to attract people to use public transport. **Both of "Accessibility to the central busy areas" and "Mobility in the central busy area" should be realized at the same time.**

Additional secondary roads are necessary to create public transport priority area where buses and MRTs are to be given advantages. Improvement of major- and minor-secondary roads is very important to encourage people to use public transport through providing convenient access to MRT stations, job places, among others.

Strategic Project 3: Revitalization of Water Transport with Green -Water Network

Currently, the water transport in Bangkok has a small modal share in Bangkok. However, in the morning peak hour, "express river boats" are full. The limitation for increasing the service level is not the number of boats but rather the capacity of piers. Piers should be improved together with inter-modal facilities. At the same time, the landscape along Khlongs is a very unique resource of Bangkok. This should be restored to be more natural and friendly system.

Strategic Project 4: "Eco-Street" Development for Non Motorized Transport

Throughout Bangkok, there is a water system of small khlongs. Providing paths along the khlongs, they are capable of function as a network for bicycle paths and walkways. Bangkok is a very flat city, thereby it is ideal for the development of this system. A comfortable Non Motorized-transport System with beautiful scenes should be restored in the unique city and for the next generation.

Strategic Project 5: Give Priority to Buses : Enforcement of Exclusive Bus Lane

Contra bus lane and bus priority lane system, which is enacted in part of the central area, should be enhanced. At present, buses are obstructed by cars (HOV and cars coming from "soi") and motorcycles coming into the bus lane even on bus priority lanes. This situation should be improved urgently rather than making efforts on controlling traffic signals.

There are several corridors connecting between sub-urban areas and the central area, which are heavily used by commuters. These corridors should be focused on first. Even on the tollways, exclusive bus lanes can be introduced.

In the central busy area, minor modification such as bus bay will be effective to avoid inter-obstruction between buses. Besides, selected secondary roads are necessary to be created as better routes for public transport services (feeder service) where buses and MRTs are to be given traffic advantage.

Strategic Project 6: Area Road Pricing System : Create disadvantageous environment for private vehicle users in selected areas

The area inside Middle Ring Road would be studied for applying this policy after the completion of MRT Master Plan. There are some 20 interfaces (major roads) on the Ring Road. Appropriate measures to functionalize the area restraint system need to be explored.

Strategic Project 7: Support Metropolitan Sub-center Development

Transport system and urban development should be inter-related to economize and rationalize the investments. Well-coordination among all relevant agencies is necessary to link the transport development together with a view to the Sub-center Development.

Strategic Project 8: Environmental Education and Enlightenment

The majority of Bangkok people are already the environment-conscious. But, further educational and enlightening activities are necessary to improve awareness to the environment in their way of living. Some form of environmental education should be provided from the beginning of the formal education, or elementary school.

2.5 Bangkok Urban Transport Structure Plan : BEIP Proposal

In line with the concept of strategic plans discussed in the previous section, A Structure Plan of Bangkok Urban Transport System in 2011 and several specific plans / programs were prepared (BEIP proposal). The fundamental of the BEIP proposal is almost all the transport projects proposed for the 8th National Development Plan by each relevant agency (BMA, DO, PWD, and ETA). Thus, BEIP proposal should be understood as an additional idea towards achieving the goals set forth

(1) Assumptions : Urban Structure

As discussed in Chapter 9, the three sub-center development: Min Buri-Lad Krabang Sub-center, Talling Chan Sub-Center, and Bang Khunthian Sub-Center, are proposed in order to create a multi nucleus system in BMA. These three sub-centers should be accommodated by good transport system.

The area inside the Middle Ring Road plus part of Khlong Toey, Huay Khwang and Bang Kapi is defined as the core area. Within the core area, quite good mobility of people will be ensured by the mass transit system. Thus, the core area is recognized as a "public transport advantageous area" where a good feeder system by buses is provided and private vehicle use is limited.

(2) Future Primary Arterial System and Multi Modal Corridor System

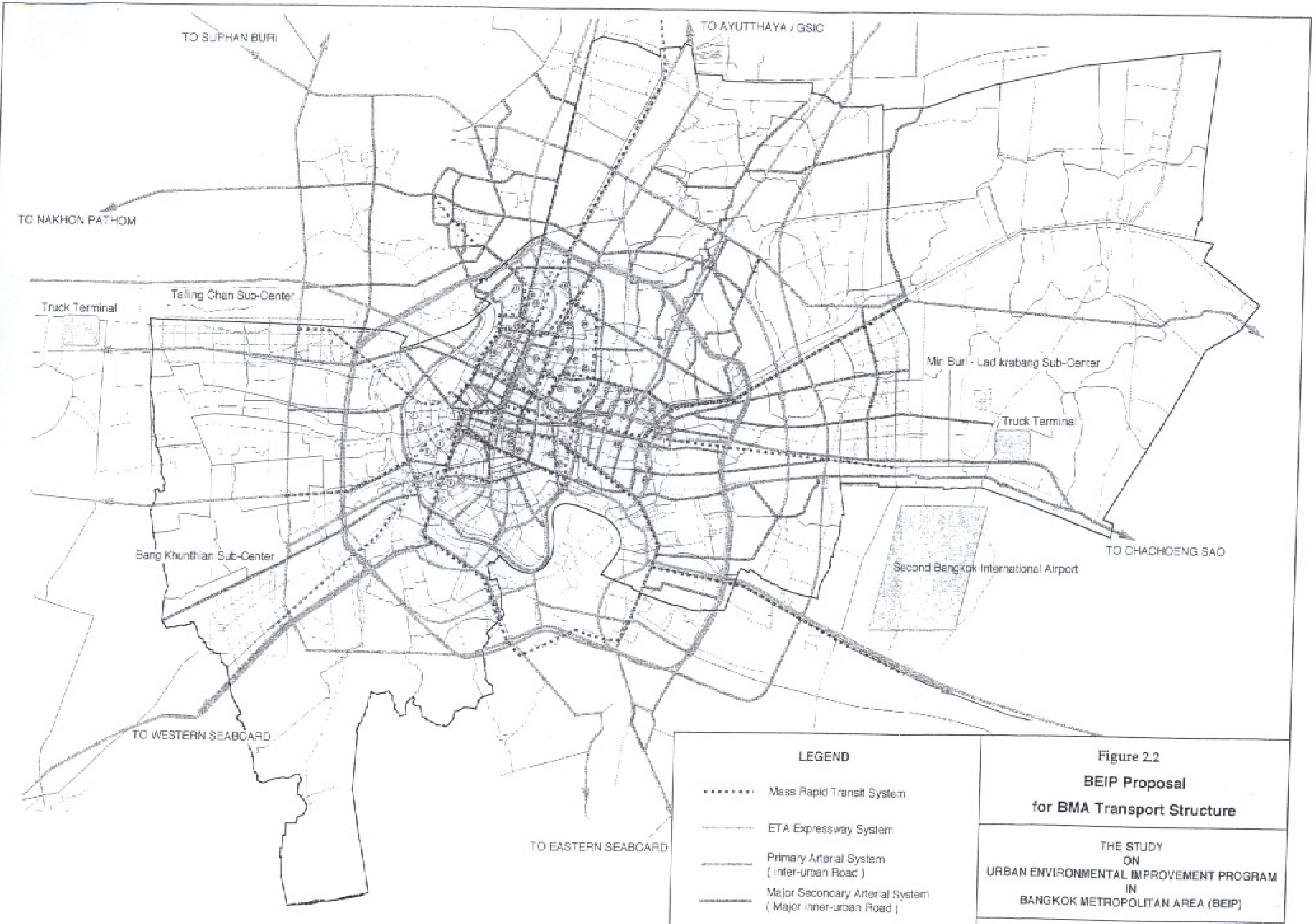
Primary Arterial Road here is defined as a trunk road system for inter-urban and inter-regional transport. Heavy vehicles for freight transport are always allowed to use it. The Outer Ring Road by DOH, a new ring road system being formed by new roads beneath the ETA's expressway system and the fourteen national highways connected to the ring roads are proposed as primary arterial system in the year 2011.

The New Middle Ring Road is recognized as the fringe of extension of urbanization from the center of Bangkok. There is no primary system inside the NMRR, thereby heavy vehicles are restricted to enter the central area.

Eight "Multi Modal Corridors are designated as shown in Figure 2.2. These corridors are connecting the three sub-centers and the central area. Exclusive bus lanes should be introduced on the arterial roads.

In addition to the existing three inter-city bus terminals, two new inter-city bus terminals are proposed at Huay Khwang and nearby Taksin Monument. At these five bus terminals, special interchange terminals should be provided which are "controlled areas" to allow feeder bus passengers to make cross-platform interchange with express buses.

There are some 20 transfer locations between deferent MRT systems. These transfer locations are likely to be developed as attraction centers in the central area. A master plan should be prepared to ensure coordination between deferent systems and private sectors development.



LEGEND

- Mass Rapid Transit System
- ETA Expressway System
- Primary Arterial System (Inter-urban Road)
- Major Secondary Arterial System (Major Inner-urban Road)
- BEIP Proposal for Secondary System
- BEIP Proposal for Sub - Centre

Figure 2.2

BEIP Proposal for BMA Transport Structure

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)

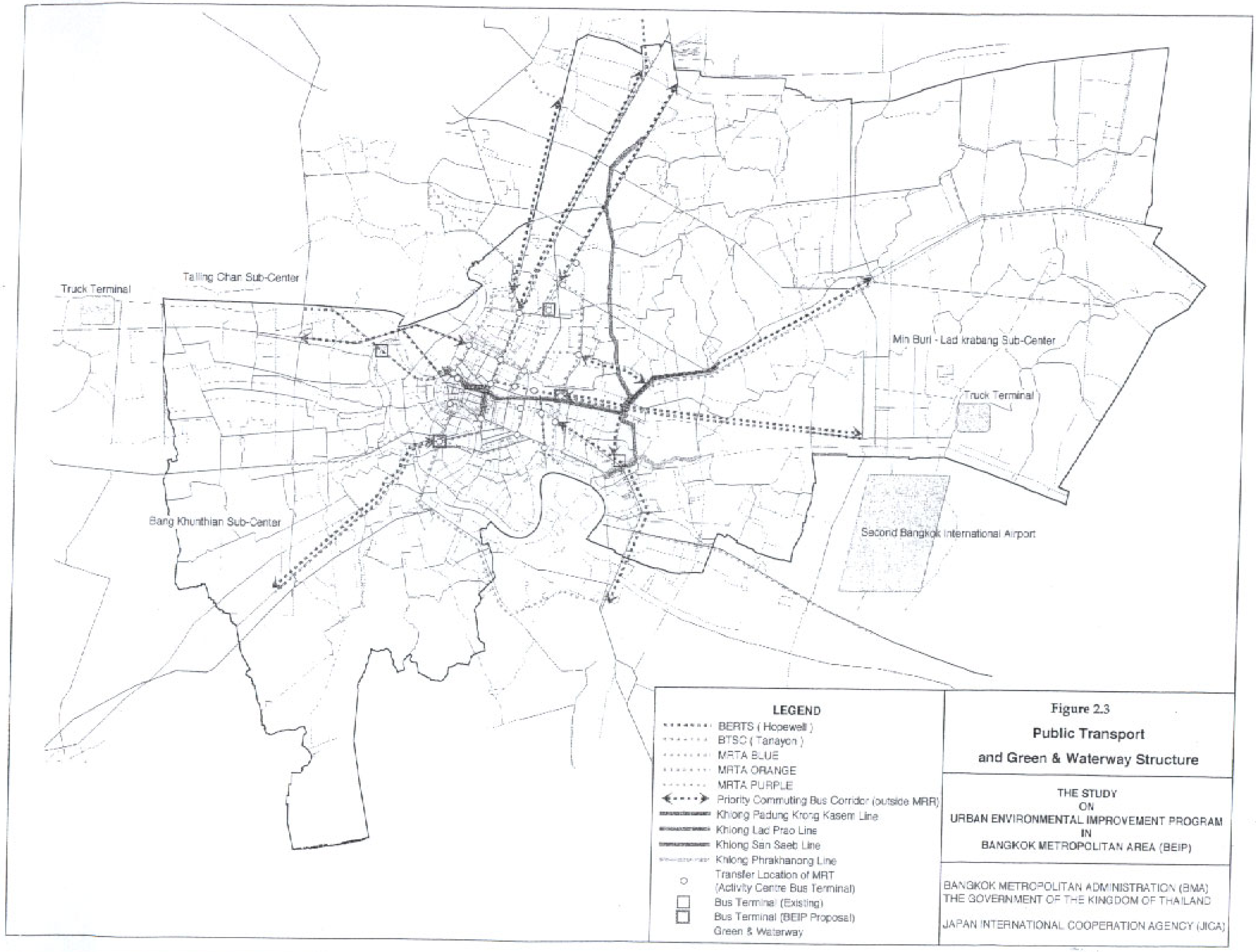


Figure 2.3

Public Transport and Green & Waterway Structure

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)

(3) Future Secondary Arterial System

Table 2.1 shows proposed secondary roads in addition to the BMA's 8th Plan projects. Every road should be developed with the common purpose of promotion of public transport. The proposed projects can be categorized into nine packages as follows;

1) Package 1: BEIP_01 - BEIP_10

These projects are very important for BERTS, MRTA Orange and MRTA Blue lines. By these secondary system, metro passengers can access to job places, education places, among others in Bangkok Noi, Bangkok Yai, Thonburi and Khlong San areas. The secondary roads to be place here will also contribute to creating a new large activity center west-side of the Chao Phraya River.

Package 2: BEIP_11 - BEIP_14

These projects are prepared to increase road capacity of the gate of the North Multi Modal Corridor : Phahon Yothin Rd, Wiphawadi Rangsit Rd. and New roads proposed by BMA (B 3.12) and DOH (DOH74).

Package 3: BEIP_15 - BEIP_19

These projects are necessary for BERTS, MRTA Orange and MRTA Purple systems, providing improved feeder routes in south of Bangsu area.

Package 4: BEIP_20 - BEIP_21

These projects are beneficial to BTSC and BERTS, providing better feeder routes in Phaya Thai area.

Package 5: BEIP_22 - BEIP_30

These projects are beneficial to BTSC, BERTS and MRTA Orange lines, providing better feeder routes in Phaya Thai and Huay Khwang areas.

Package 6: BEIP_31 - BEIP_32

These projects will be proceeded together with re-development of Makkasan area, providing better connection between Ploenchit Rd. and Petchaburi Rd.

Package 7: BEIP_33 - BEIP_35

These projects will be proceeded together with a re-location program of the Chulalongkorn University (assuming relocated to one the BEIP sub-centers). This is a very challenging project package.

Package 8: BEIP_36 - BEIP_37

These projects will be proceeded together with re-development of Thai Tabacco Monopoly.

Package 9: BEIP_38 - BEIP_46

These projects will create a new large activity center such as Silom area outside the Middle Ring Road. Transport system for this are is consist of BERTS, MRTA Orange, MRTA Blue and Bus services.

Table 2.1 BEIP Proposal for Secondary Roads inside the Central Area

CODE	PROJECT NAME	LANE	LENGTH
BEIP_01	ConnectingroadbetweenBMA1.18andBEIP03	4	2.6
BEIP_02	Connecting road between Charan Sanit Rd., Itsaraphao Rd. and Arun Amarin along the Khlong Mon with "Eco-Street".	4	1.7
BEIP_03	Connecting road between Charan Sanit Rd. and Itsaraphao Rd. at the intersection of Wang Doem Rd. and Itsaraphao Rd..	4	1.5
BEIP_04	Connecting road between Charan Sanit Rd. and Itsaraphao Rd. along the Khlong Bangkok with "Eco-Street".	1	4
BEIP_05	ConnectingroadbetweenBEIP03andBEIP04.	4	1.3
BEIP_06	'Connecting road between Rachadaphisek Rd. and Somdet Phra Chao Taksin Rd. along the railway. (between Wongwian Yai st. and Taladpllu st.)	1.6	4
BEIP_07	'Connecting road between BEIP06 Rd. and Somdet Phra Chao Taksin Rd. along the Khlong Samre. (crossing PWD01)	4	1.8
BEIP_08	'Connecting road between Somdet Phra Chao Taksin Rd. and Charoen Nakhon Rd. along the Khlong Samre.	4	1.3
BEIP_09	'Connecting road between Somdet Phra Chao Taksin Rd. and Charoen Nakhon Rd.	4	1.7
BEIP_10	"Connecting road between Lad Ya Rd. and BEIP08 including flyover at Krung Thonburi Rd.	4	2.6
BEIP_11	'Connecting road between Pracha Rat Rd. and BEIP13 along the railway.	4	3.6
BEIP_12	Extension of DOH74 project from Ratchadaphisek to Pracha Rat Sai 2 (Widening).	6	2.8
BEIP_13	Extension of BMA3.12 project from Ratchadaphisek to Techa Wanit Rd. with "Eco-street"	4	3.2
BEIP_14	'ConnectingroadbetweenPhahoyothinRd.andBEIP13.	4	2
BEIP_15	'Connecting road between Pracha Rat Sai 1 Rd. and Kamphaeng Phet Rd. along the Khlong with "Eco-Street".	4	2
BEIP_16	'Connecting road between Pracha Rat Rd. and Pradiphat Rd. along the Khlong with "Eco-Street".	4	1.3
BEIP_17	'Connecting road between Samsen Rd. and Rama V Rd. along the Khlong with "Eco-Street".	4	1.2
BEIP_18	'Connecting road between Tha Han Rd. and Amnuai Song Khram Rd. with "Eco-Street".	4	1.25
BEIP_19	'Connecting road between Tha Han Rd. and Nakhon Chaisri Rd.	4	1.8
BEIP_20	'ConnectingroadbetweenPhahoyothinRd.andRamaVIRd..	4	1.2
BEIP_21	'ConnectingroadbetweenPhahoyothinRd.andRamaVIRd..	4	1.2
BEIP_22	Widening Suthisarn Winit Chai Rd.	6~8	2.8
BEIP_23	Connecting road between Lad Phrao Rd. and Suthisarn Winit Chai Rd.	4	3
BEIP_24	Connecting road between Lad Phrao Rd. and Suthisarn Winit Chai Rd.	4	2.4
BEIP_25	'ConnectingroadbetweenPhahoyothinRd.andRatchadaphisekRd.	4	3
BEIP_26	'Connecting road between Suthisarn Winit Chai Rd. and Asok Din Daeng Rd.	4	3
BEIP_27	'Connecting road between Suthisarn Winit Chai Rd. and Pracha Songkhro Rd.	4	1.6
BEIP_28	'ConnectingroadbetweenBEIP25andBEIP30.	4	1
BEIP_29	Widening Suthisarn Winit Chai Rd.	6	1.4
BEIP_30	Wideningto6laneduetoDinDaeingRe-Development.	6	2
BEIP_31	'Connecting road from Phaho Yothin to Wireless Rd. including underpass.	6	1.5
BEIP_32	'Connecting road from Pracch Song Rd. to Soi Na Na Nua including underpass.	6	1.5
BEIP_33	'Connecting road (including widening) between Henri Dunant Rd. and Rong Muanng	4	1.7

	Rd.4lanewith"Eco-Street".		
BEIP_34	'Connectingroadbetween HenriDunant Rd. and Banthat Thong Rd. with "Eco-Street".	4	1.4
BEIP_35	'Connectingroadbetween Ratchadamri Rd. and Banthat Thong Rd. with "Eco-Street".	4	3.9
BEIP_36	'Connectingroad between Ratchadaphisek Rd. and Wireless Rd. along the Khlong with "Eco-Street".	6	2
BEIP_37	'Connecting road between Sukhumvit Rd. and Rama IV Rd. along the railway.	4	3
BEIP_38	Widening Pracha Uthit Rd.	6~8	5.2
BEIP_39	'Connectingroadbetween Ratchadaphisek Rd. and Soi Sukhumvit 4lanewith "Eco-Street".	4	4
BEIP_40	'ConnectingroadbetweenBEIP38andBEIP39.	4	3.7
BEIP_41	'ConnectingroadbetweenBEIP38andBEIP39.	4	3.7
BEIP_42	'Connectingroad between BEIP38 and Rama IX Rd.	4	1.8
BEIP_43	'ConnectingroadbetweenBEIP46andRatchadaphisekRd.	4	6.5
BEIP_44	'Connectingroad between BEIP46 and Soi Sukhumvit.	4	0.8
BEIP_45	'Connectingroad between BEIP46 and Soi Sukhumvit Rd.	4	0.8
BEIP_46	Extension of BMA3.08 to Sukhumvit Rd.		5.5
BEIP_47	Connection DOH72 and Sukha Piban 1 Rd.	6	26
	TOTAL		137 km

LEGEND

The Central Area (BEIP Definition)
Major Secondary Arterial Road
Minor Secondary Arterial Road
Mass Transit System
BMA Road Project
Proposed Secondary Road
(No) Project Code
Metro Stations
Major Interface on the Middle Ring Road

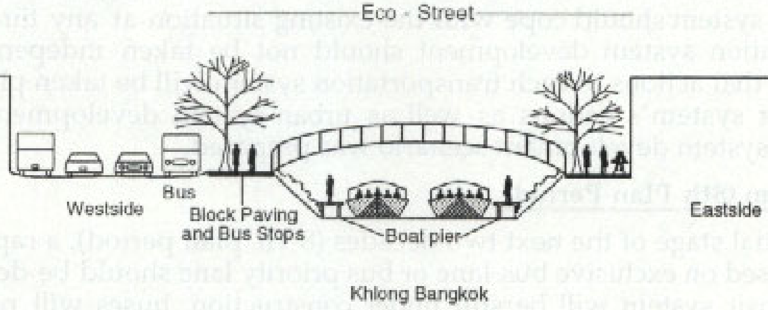
Note : Secondary System : Major Road System in the urbanized area.

Figure 2.4

Future Secondary Arterial System
and
Mass Transit System
in
The Central Area

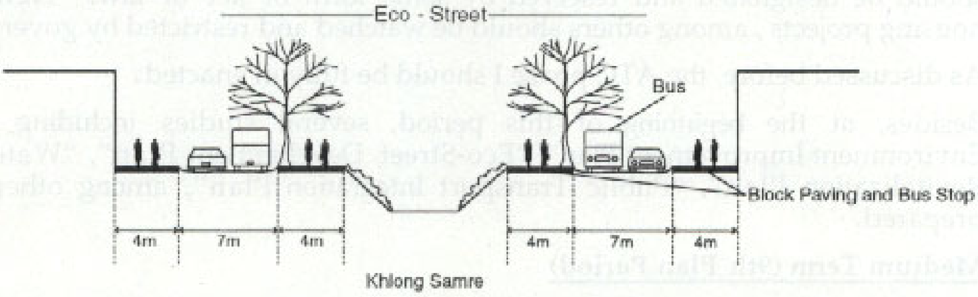
THE STUDY
ON
URBAN ENVIRONMENTAL IMPROVEMENT PROGRAM
IN
BANGKOK METROPOLITAN AREA (BEIP)

Figure 2.5 Images of Cross Section of Secondary Road with Eco-Street



PROJECT BEIP_04:

Connecting road between Charan Sanit Rd. and Itsaraphao Rd. along the Khlong Bangkok with "Eco-Street".



PROJECT BEIP_08:

Connecting road between Somdet Phra Chao Taksin Rd. and Charoen Nakhon Rd. along the Khlong Samre.

(4) Transport System Development Scenario

Transport facility and system development needs to be carried out continuously for the long term towards the "Traffic Calmed" city. Traffic management and modification in use of the system should cope with the existing situation at any time. Actions in each transportation system development should not be taken independently. It is very necessary that actions in each transportation system will be taken place in coordination with other system's actions as well as urban system development. In this sense, a transport system development scenario was prepared.

Short Term (8th Plan Period)

At the initial stage of the next two decades (8 Th. plan period), a rapid and reliable bus system based on exclusive bus-lane or bus priority lane should be developed. As mass rapid transit system will be still under construction, buses will play a vital role in commuting.

To attract more people to the bus system, pedestrian environment should also be improved. Sidewalk around major bus stops in the activity centers should be given priority.

In order to develop a good arterial road system in the central area, future road spaces should be designated and reserved by some form of act or law. New or renewal housing projects , among others should be watched and restricted by government staffs.

As discussed before, the ATC phase I should be fully in enacted.

Besides, at the beginning of this period, several studies including "Pedestrian Environment Improvement Plan", "Eco-Street Development Plan", "Water Transport Revitalization Plan", "Public Transport Integration Plan", among others should be prepared.

Medium Term (9th Plan Period)

At this stage, the "core" MRT system will be in operation. Accordingly, the bus system is required to provide better feeder services to/from the stations of the MRT system. Based on the bus re-routing plan prepared in 8th plan period, bus system should be modified. Some supplemental facilities development such as bus bay and bus stops are also needed.

Some form of restraint of private vehicle use can be introduced as effective alternatives such as the MRT core system and modified buses are available.

Long Term (10th Plan Period)

At this stage, the Priority MRT network will be in full operation. Bus system will again be reformed based on the bus re-routing plan prepared in 9th plan period. Besides, much restrictive way of private vehicle use can be introduced.

At The Year 2011

A complete integrated public transport system and quality environment for pedestrian will be fully realized. A very strict restraint on private vehicle use in the central area should be introduced. Bangkok will shine based on the "Traffic Calmed City".

Figure 2.6 Environment Initiative Transport Development Scenario

SYSTEM \ TERM	SHORT TERM (8 th Plan period)	MEDIUM TERM (9 th Plan period)	LONG TERM (10 th Plan period)	DISTANT FUTURE
	2001	2006	2011	
Mass Rapid Transit System	Core Network Development (Hopewell, BTSC, MRTA Blue : 103 km)	Priority 1 Network Development (BTSC, MRTA Blue, MRTA Orange) Core Network Operation	Priority 2 Network Development (Hopewell, MRTA Orange, MRTA Purple) Priority 1 Network Operation	Full Master Plan Network Operation
		Inter Modal Facility Development	Inter Modal Facility Development	Bangkok is shining based on
Bus System	Bus Transport Improvement : Bus Priority Corridor - Exclusive Bus Lane, Bus Priority Lane - Improvement of Terminal	Bus System Modernization and Supplemental System Development Bus re-routing Phase 1 - Feeder service to/from the Core Network	Bus re-routing Phase 2 - Feeder service to/from the Priority 1 Network	- Integrated Transport System - Multi Modal Corridor - Quality Pedestrian Facilities - Well organized Secondary System - Sophisticated Traffic Management
		Inter Modal Facility Development	Inter Modal Facility Development	
Water Transport System	Water Transport Improvement - Pier Capacity Improvement - Landscape improvement	- Make piers into part of inter-modal facilities - Introduction of electric boats		The People are enjoying
		Inter Modal Facility Development	Inter Modal Facility Development	
Pedestrian	Pedestrian Environment Improvement - Pedestrian Improvement around public transport terminals	Footpath development with "Green and Waterway"		- Safe and Friendly Environment - Beautiful Scene of Walk Street - Improved Mobility and Accessibility - Multiple Choices of Transport Mode
Street System	Reservation of land for new secondary system	Provision of better routes for public transport		Bangkok Urban Economy become more strong based on the efficient transport system for commodity
Primary Arterial System	ORR southern section connecting HWY 34 and HWY 35	Primary arterial system development together with ETA system Introduction of Exclusive Bus Lane on the primary system		Research and Development on More Sophisticated Technology of Freight Transport
Expressway System	Accelerate development of the ring system (northern part first)	Introduction of Exclusive Highway Bus System	Raising tariff of private cars	
Traffic Management	Study on restraint of private vehicle ATC Phase 1 Full Operation	Introduction of several scheme (trial) ATC Phase 2 Development	Full operation of ATC within the MRR	Strict Area Restraint in the Central Area
Urban System		Development of Sub-Centers Housing and Commercial Development at the terminals of the Core MRT system		

Table 2.2 Major Component of Strategic Projects (1: Short Term)

Urgent Actions

	Proposals for Environment-initiative Urban Transport	Implementing Body	Related Agency	Total Cost (mil.Baht)
ET11	PedestrianEnvironmentImprovementPlan - sidewalk around inter-modal facilities (800 m x 100 locations) - sidewalk improvement in commercial area (Silom, World Trade Center) - sidewalk improvement in the heritage area (Ratana Kosin) - pedestrian bridge development on major secondary roads - soi revitalization projects (connecting and block paving selected sois to develop effective footpaths to public transport terminals)	BMA		60
ET12	Eco-StreetDevelopmentPlan Sidewalk and path for non motorized vehicle along the major khlong and connecting streets between major parks)	BMA	MOTC	40
ET13	Water Transport Revitalization Program - improvement of waterways and boat piers in Chao Phraya River and major Khlongs -Landscape and footpath development along major khlongs (Water & Green Network)	MOTC /BMA		40
ET14	PublicTransportIntegrationPlan - bus re-routing plan - fare and ticket integration plan	OCMRT /BMA	BMTA	60
ET15	Master Plan and Feasibility Study on Public Transport Terminals and Inter-Modal Facilities - metro to metro transfer (22 locations) - metro to bus transfer facilities (5 inter-city bus terminals and 22 metro transfer locations) - bus/metro to boat	OCMRT /BMA	MOTC /BMTA	60
ET16	Feasibility study and Engineering Study on Major Primary and Secondary Road - BEIP proposal (Primary road : 47 km , Secondary road : 137 km)	BMA		140
ET17	Area Road Pricing plan - more detail analyses and assessment should be proceeded.	OCMRT	BMA /MOTC	60
ET18	Review of Primary Road System Sub-center development, WSB, ESB, GSIC should be taken into consideration in prioritizing	OCMRT	MOTC /ETA	20
ET19	Implementation of Projects for BMA 5th Five-year Plan	BMA		54,400
ET20	Implementation of Projects for DOH 5th Five-year Plan	DOH		
ET21	Implementation of Projects for PWD 5th Five-year Plan	PWD		
ET22	Implementation of Projects for ETA 5th Five-year Plan	ETA		
ET23	Proceed BERTS, BTSC, MRTA (Blue and Orange)			

Table 2.2 Major Component of Strategic Projects (2 : Medium Term)

Medium-term Projects/programs

	Proposals for Environment-initiative Urban Transport	Implementing Body	Related Agency	Total Cost (mil.Baht)
ET24	Pedestrian Environment Improvement Phase 1 (based on ET11) - sidewalk improvement around BTS, MRTA, BERTS stations (80 locations) - sidewalk improvement in commercial areas (2.5km in Silom area, 20 km along the Skhumvit Rd, Petchaburi Rd. Rama IX Rd.) - sidewalk improvement in Para Nakhon (2km) -pedestrian bridge (100 locations) - soi revitalization projects (20km inside the MRR)	BMA		3,910
ET25	Eco-Street Development Phase 1 (based on ET12) - Khlong Samsen (11km) - Khlong San Sap (6.5km)	BMA	MOTC	680
ET26	Water Transport Revitalization Phase 1 (based on ET13) - Khlong Samsen (11km) - improvement of boat pier (Pattu Nam and other 6 locations close to metro system)	MOTC /BMA		840
ET27	Public Transport Integration Phase 1 (based on ET14) -together with the Green Line implementation schedule, bus re-routing should be implemented. - monthly ticket for BTS, MRTA, BERTS and feeder buses - common ticket for BTS, MRTA, BERTS	BMTA	MOTC	100
ET28	Public Transport Terminals and Inter-Modal Facilities Development (based on ET15) - Mor Chit Terminal (Bus/BTS/MRTA) - Sukhumvit / Soi Asok Terminal (Bus/BTS/MRTA) - Huay Khwang Terminal (together with MRTA Depot development) - Pattu Nam Boat Station with bus terminal - Bus stop and bus bay at MRT stations	MOTC /BMTA /BMA	OCMRT	7,480
ET29	Implementation of Major Secondary Road Projects (based on ET16) BEIP Proposal (50%)	BMA		2,450
ET30	Implementation of Area Road Pricing Project (based on ET17)	BMA	MOTC /OCMRT	300
ET31	Formulation of Transport Master Plan for 9th National Development Plan	OCMRT	NESDB	60
ET32	Proceed Implementation of Extended Mass Transit System Projects (71.4km)	MRTA	MOTC /BMA	42,080

Table 2.2 Major Component of Strategic Projects (3 : Long Term)

Long-term Projects/Programs

	Proposals for Environment-initiative Urban Transport	Implementing Body	Related Agency	Total Cost (mil.Baht)
ET33	Pedestrian Environment Improvement Phase 2 (based on ET11) - sidewalk improvement around MRTA Purple stations (15 locations) - sidewalk improvement in commercial area (10km) - pedestrian bridges on major khlongs - soi revitalization projects	BMA		1,360
ET34	Eco-Street Development Phase 2 (based on ET12) - Khlong Samsen (and Khlong San Sap, 40km)	BMA	MOTC	1,560
ET35	Water Transport Revitalization Phase 2 (based on ET13) - improvement of waterway (40km) - improvement remaining boat piers (38 locations)	MOTC	BMA	1,550
ET36	Public Transport Integration Phase 2 (based on ET14) - bus re-routing - fare and ticket integration (common ticket for all metro system)	OCMRT	BMTA	100
ET37	Public Transport Terminals and Inter-Modal Facilities Development (based on ET15) - 20 metro to metro transfer stations - 44 boat stations with bus terminal - bus stops and bus bay at metro stations	MOTC /BMTA /BMA	OCMRT	640
ET38	Implementation of Major Secondary Road Projects (based on ET16) - BEIP proposal (50% of 184 km)	BMA		32,390
ET39	Formulation of Transport Master Plan for 10th National Development Plan	OCMRT	NESDB	100
ET40	Proceed Implementation of Mass Transit System Projects (63.6km)	MRTA	MOTC /BMA	37,400

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.

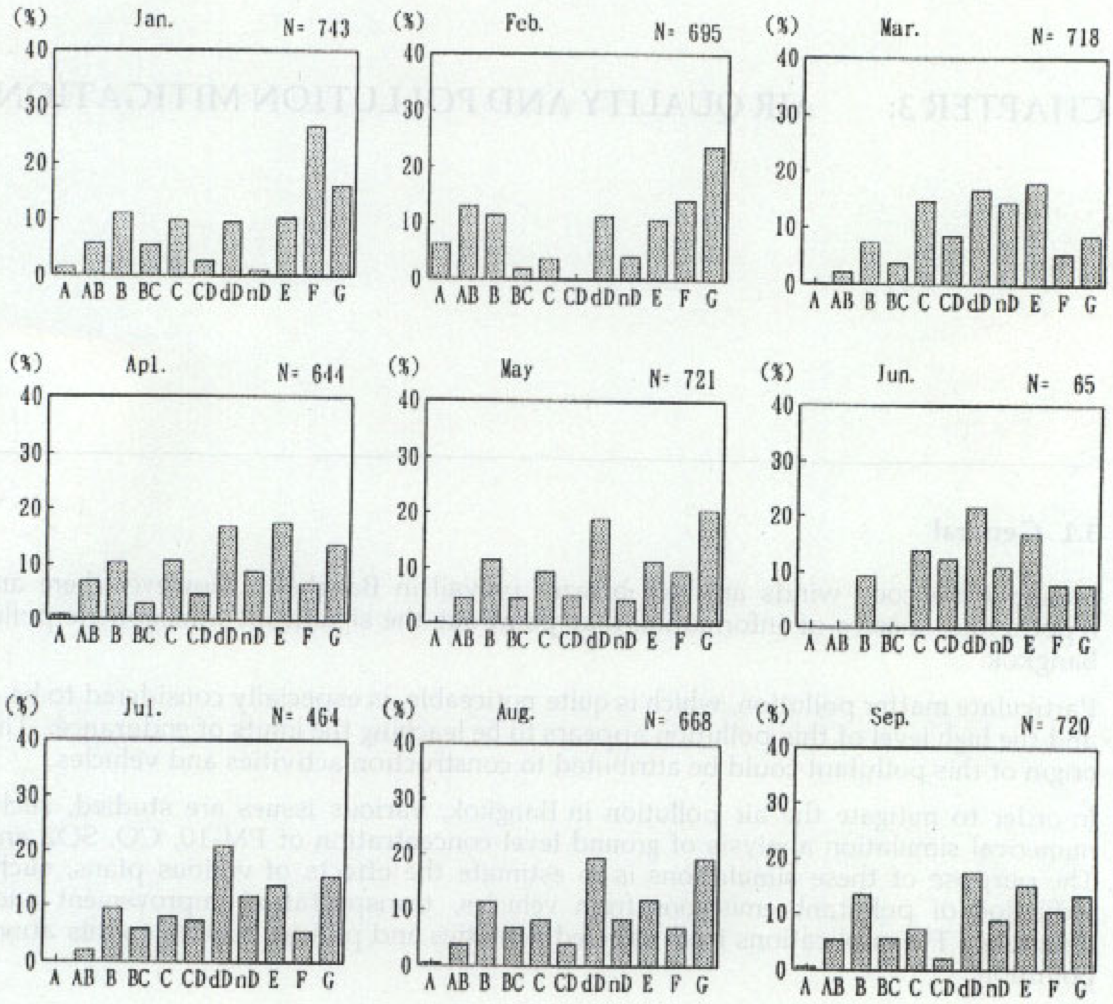
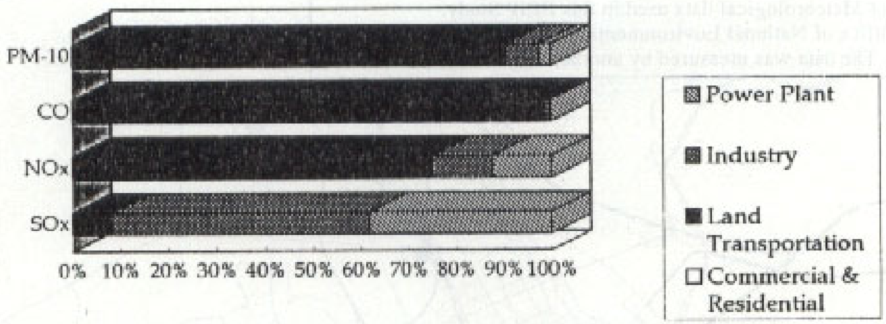


Fig. 3.1 Appearance Frequency of Atmospheric Stability 1988 (2531)

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.

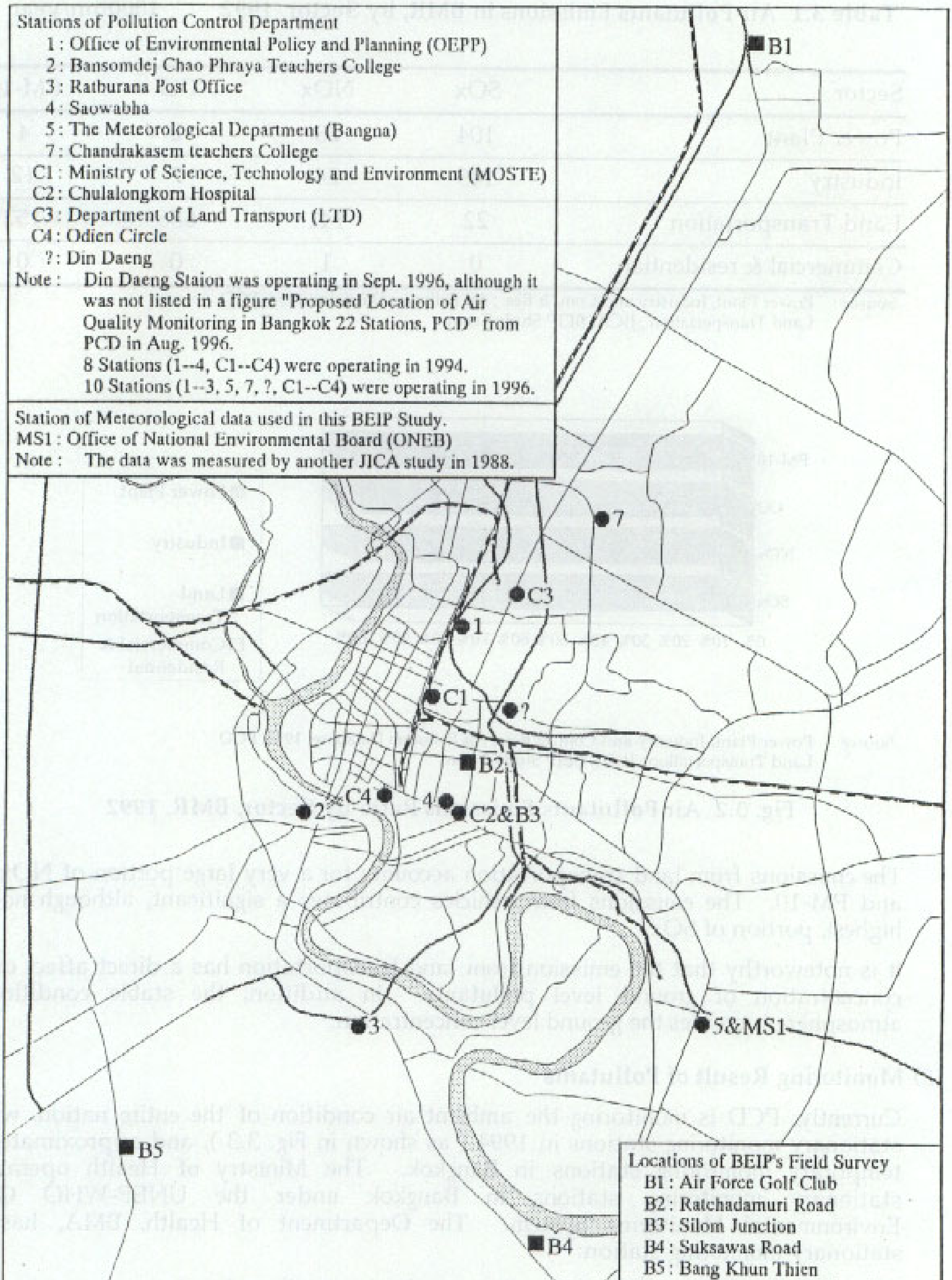


Fig. 3.3 Locations of Monitoring Stations

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 _...10ƒÊm

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.

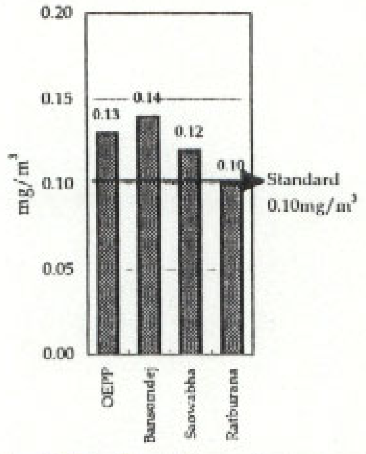


Fig. 3.4 TSP, One Year Average 1994,

General Stations

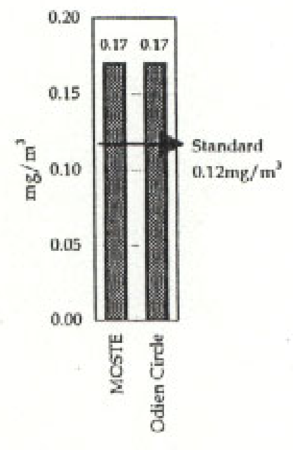


Fig. 3.5 PM-10, Max. of 24Hr Ave. 1994

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.

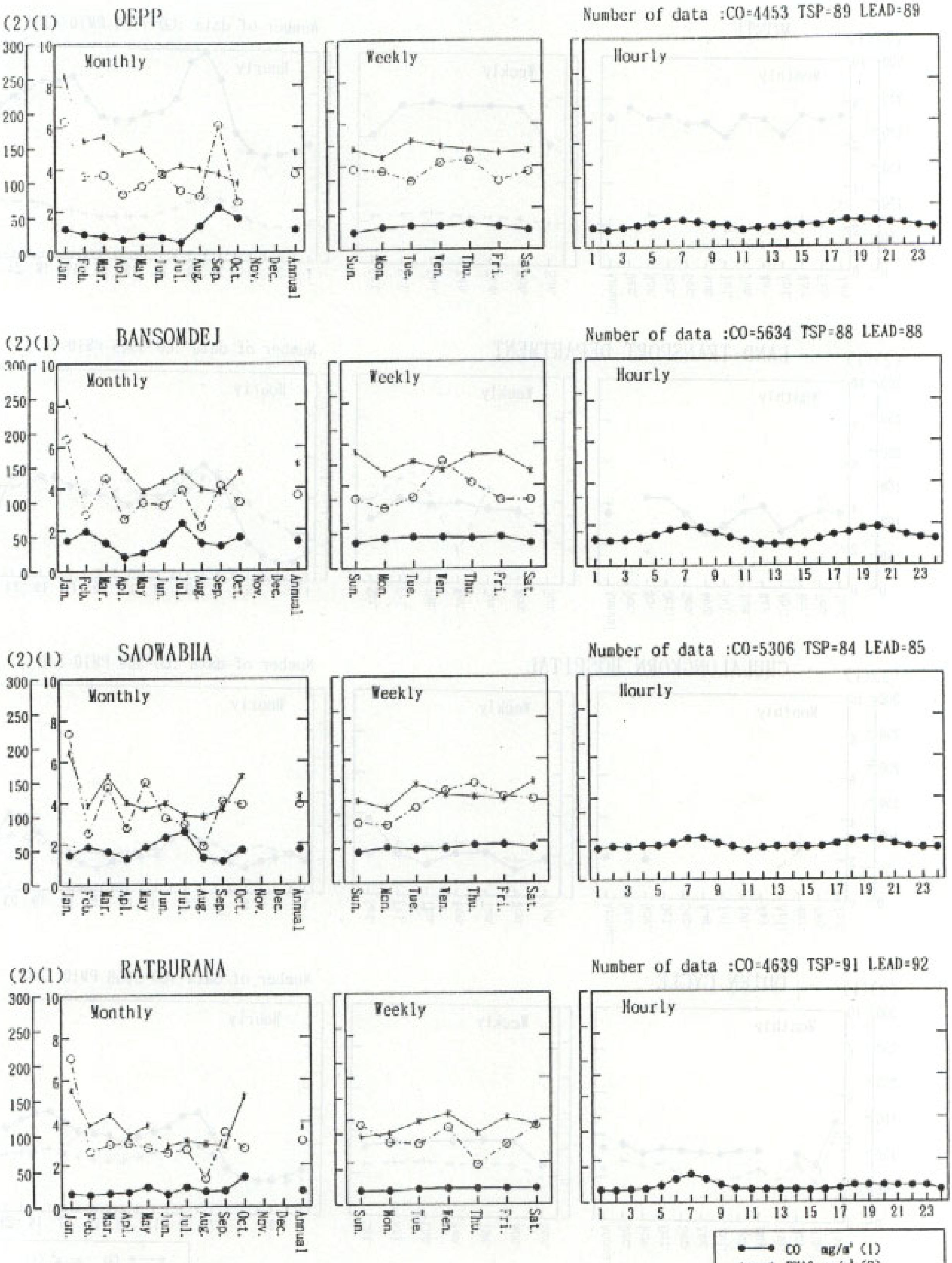
TSP consists of PM-10 and other coarse particles, exceeding 10 microns in diameter. It might be supposed that construction activities on and around roads and vehicles traveling on dusty roads are major sources of the coarse portion of TSP. In addition, peeling off dust from vehicle tires and bodies and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

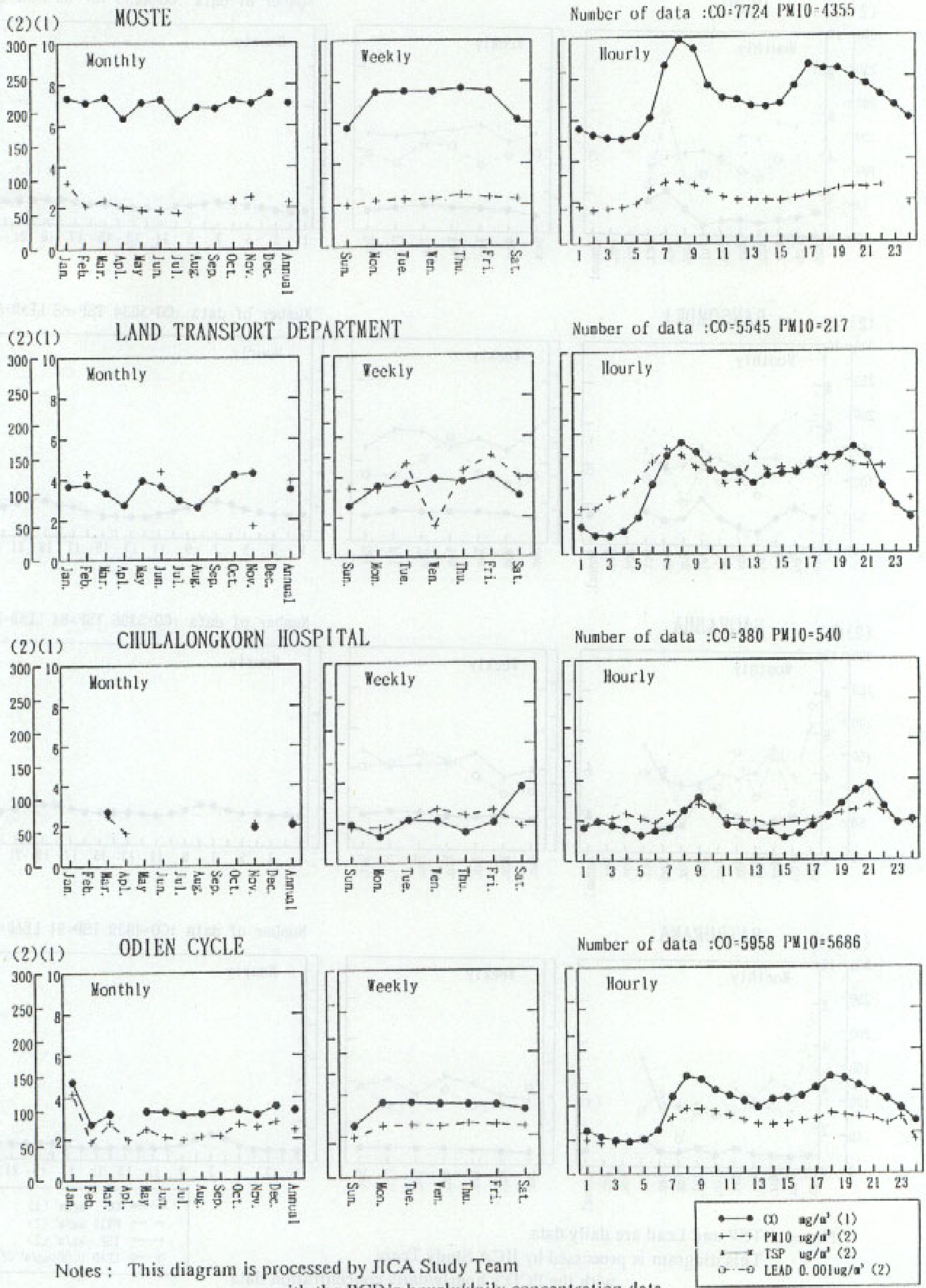
Third, there are many loopholes for reviewing the current atmospheric pollution. The monitoring activity is not sufficient. SO2 and NO2 were not monitored in 1994. PCD has already started monitoring of SO2 and NO2 mainly at residential area stations. This activity should be strengthened to monitor not 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.

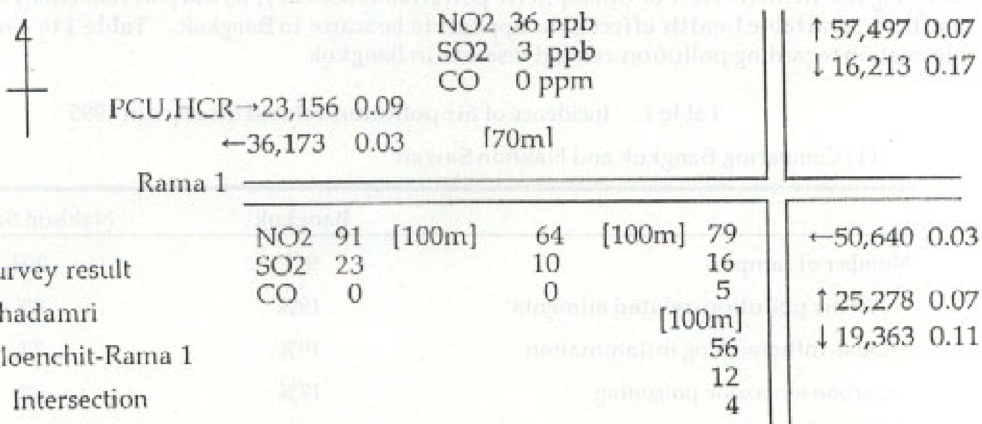


Fig. 1 Survey result Ratchadamri /Ploenchit-Rama 1 Intersection

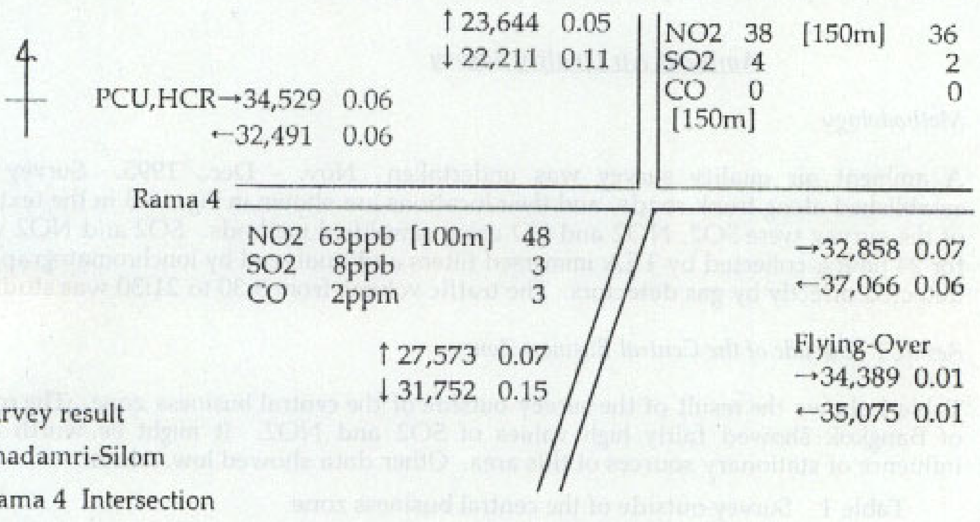


Fig. 2 Survey result
Ratchadamri-Silom
/Rama 4 Intersection

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).

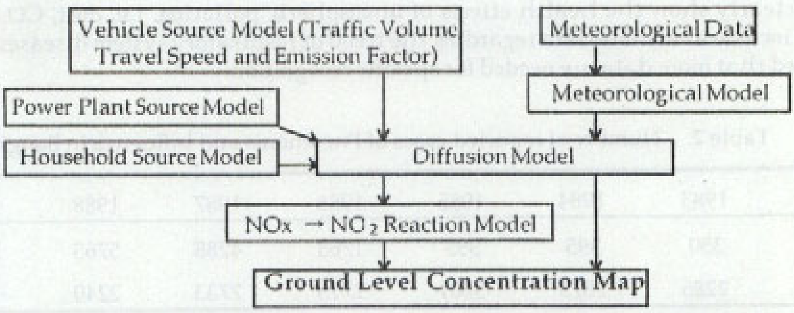


Fig. 3.8 Flow Chart of Simulation

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;

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

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.

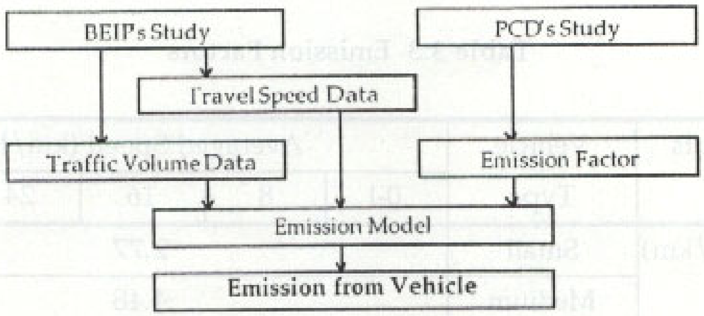


Fig. 3.9 Flow Chart to Estimate Emission from Vehicles

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 x 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.

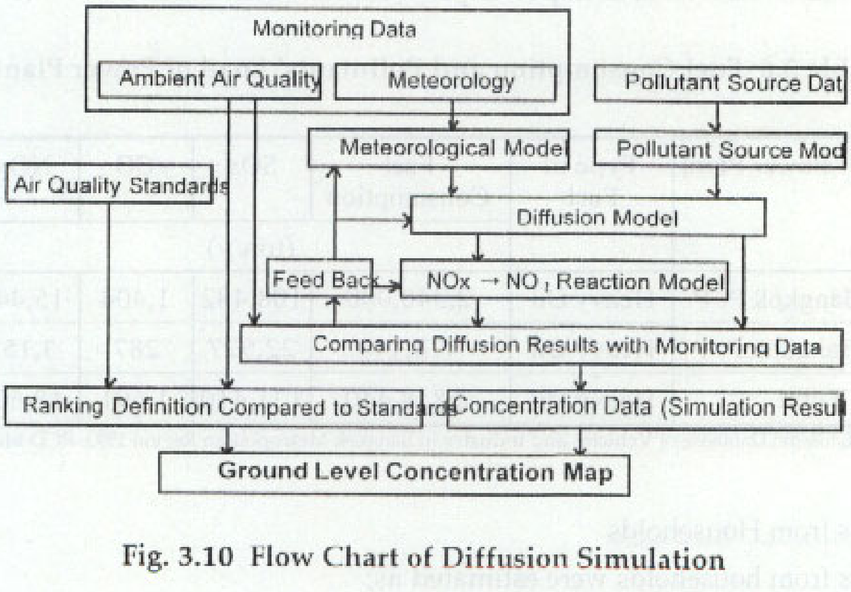


Fig. 3.10 Flow Chart of Diffusion Simulation

Targets of Simulation

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

- Simulated air pollutants are SO_x, 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.

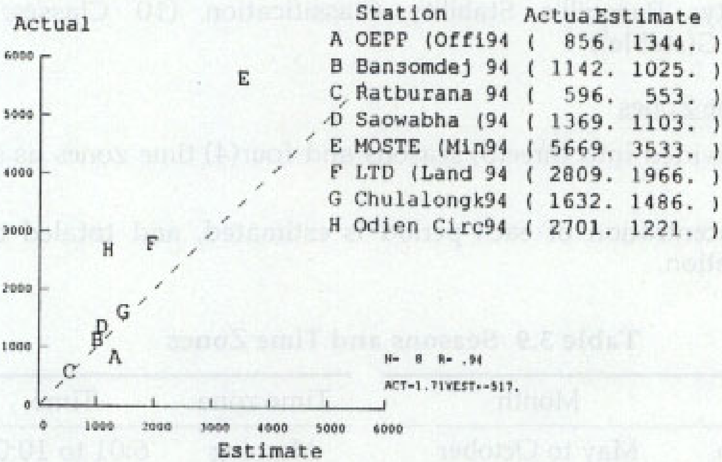


Fig. 3.11 Scatter Diagram Comparing the Simulation Result (Estimate) and the Monitoring Result in 1994 (Actual) (CO, ppb)

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/m^3)	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)

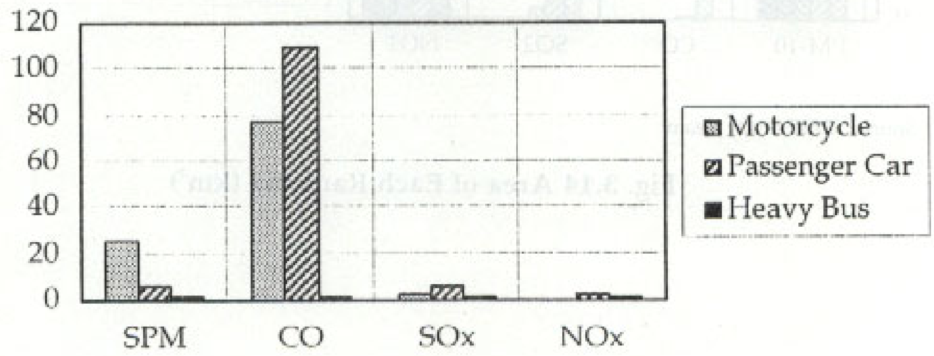
Emission per Distance per Passenger

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.

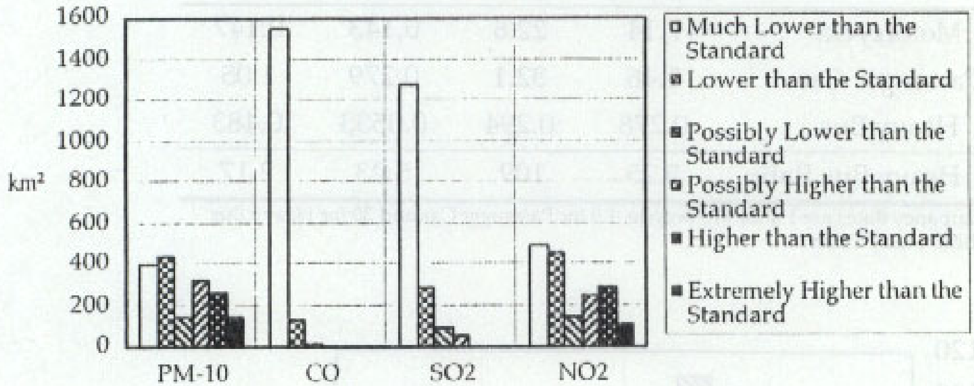
Air Pollutant Distribution

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

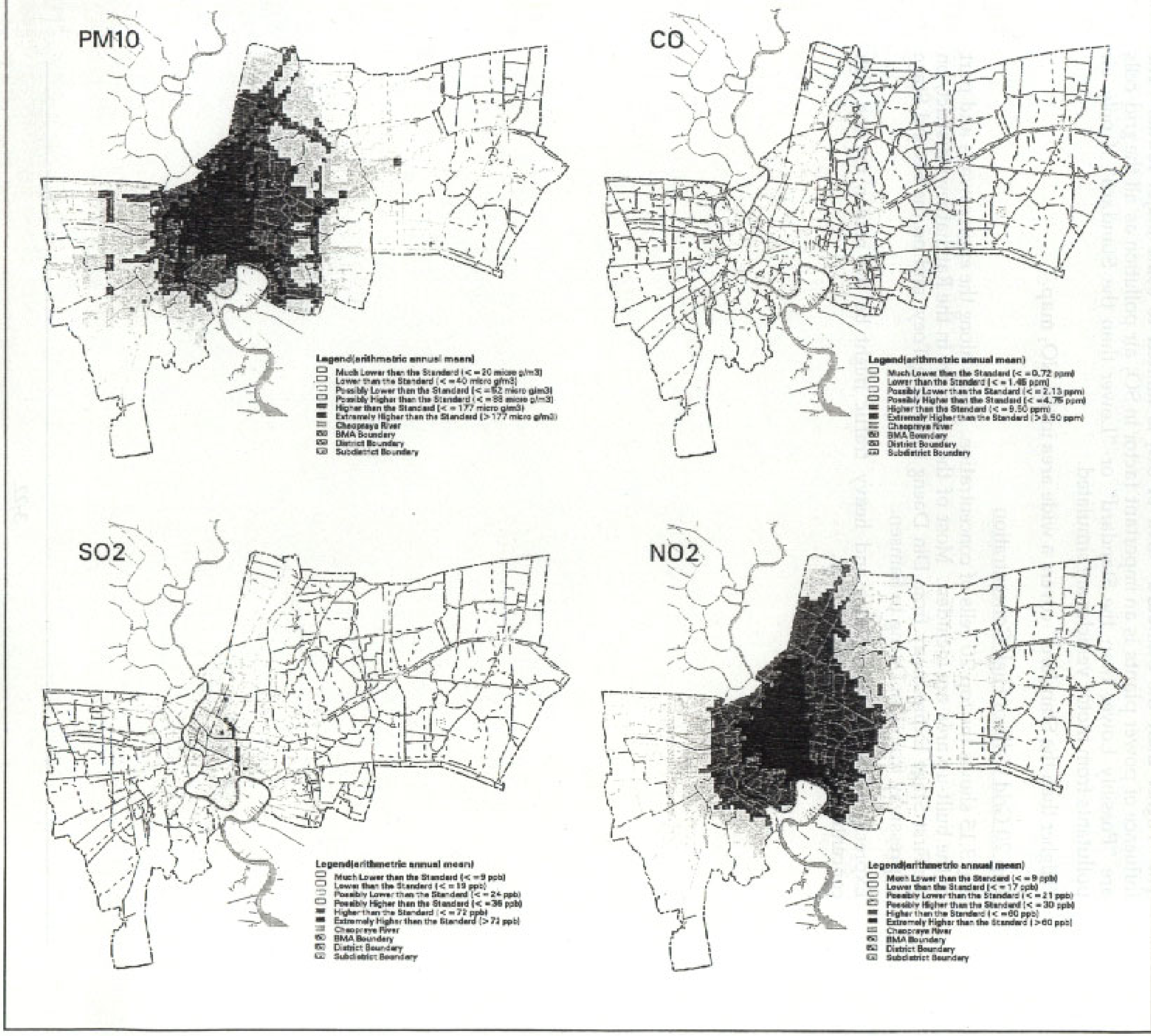
Fig. 3.14 Area of Each Ranking (km^2)

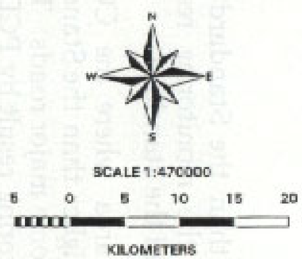
Fig. 3.13

Air Pollution Simulation

Case 1

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





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

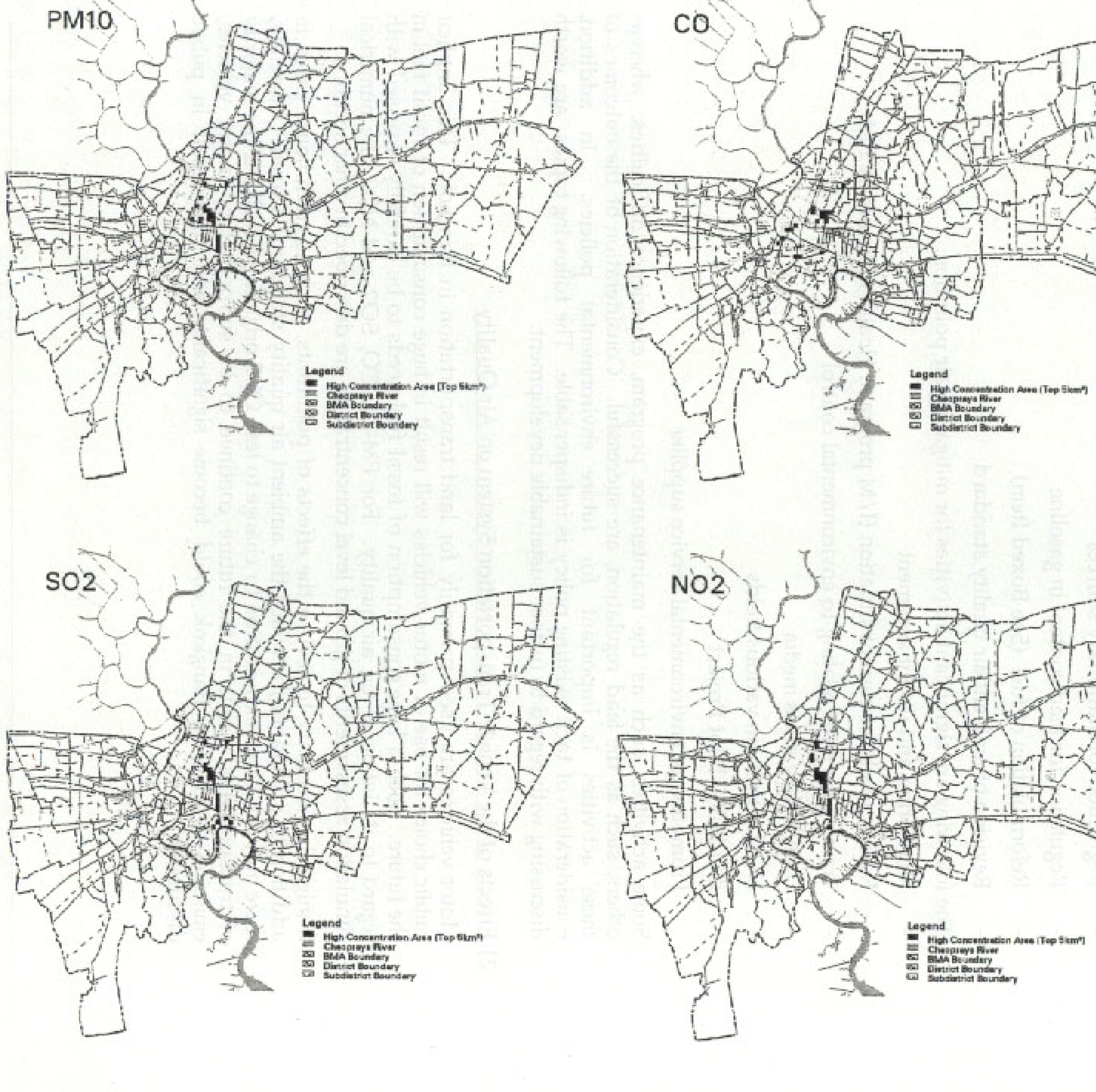
Fig. 3.15 shows the top 20 cells of concentration. Areas along the expressways and part of the built-up area are included. Most of the areas are in the Ratchathewi district, on the First Stage Expressway from Din Daeng to Khlong Toey, and on the Second Stage Expressway from Din Daeng to Samsen.

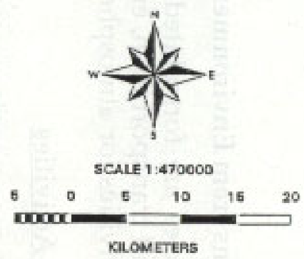
Expressways with many lanes and heavy traffic might be the reason for the high concentration in the urbanized area.

Fig. 3.15

Air Pollution Simulation High Concentration Area (Top 5 km²)

Case 1





THE STUDY
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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

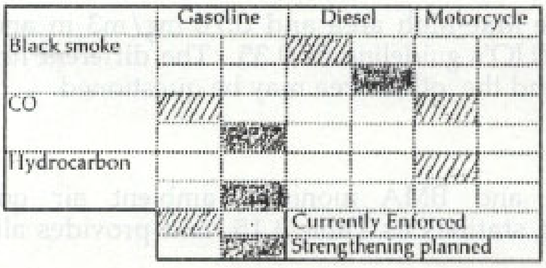
EURO 1, EURO 2 are formulated by EEC.

• 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	I 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.

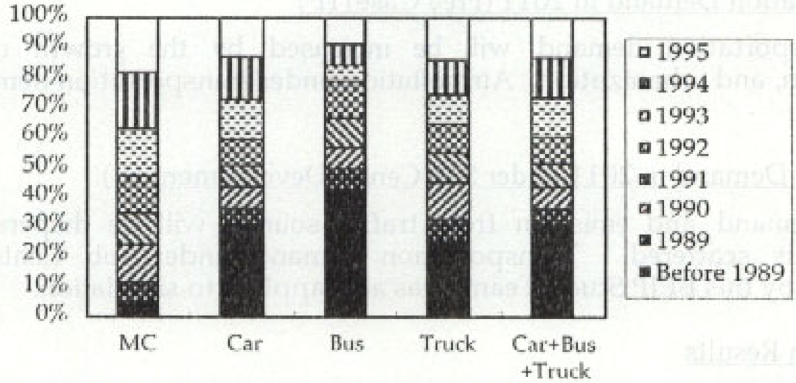
Table 3.17 Simulated Cases

*	Case 1 C)	2 P)	3 P)	4 P)	5 P)	6 P)	7 B)	8 A)	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 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	77,644
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
	(micro 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

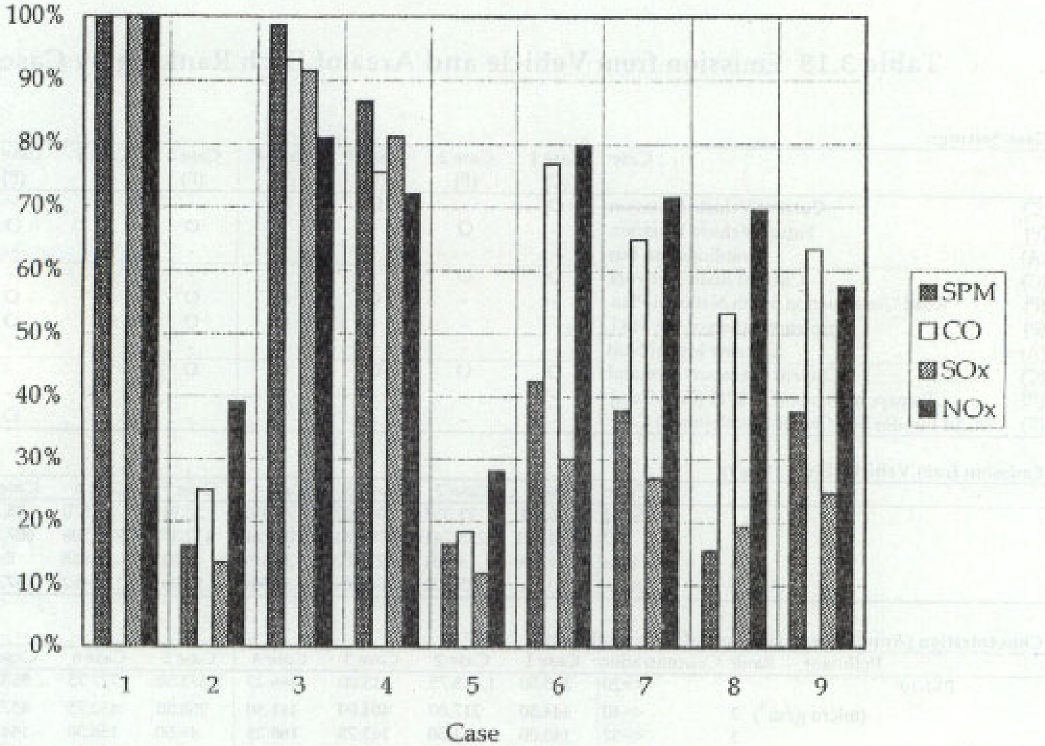


Fig. 3.17 Emission from Vehicle, Compared with Case 1

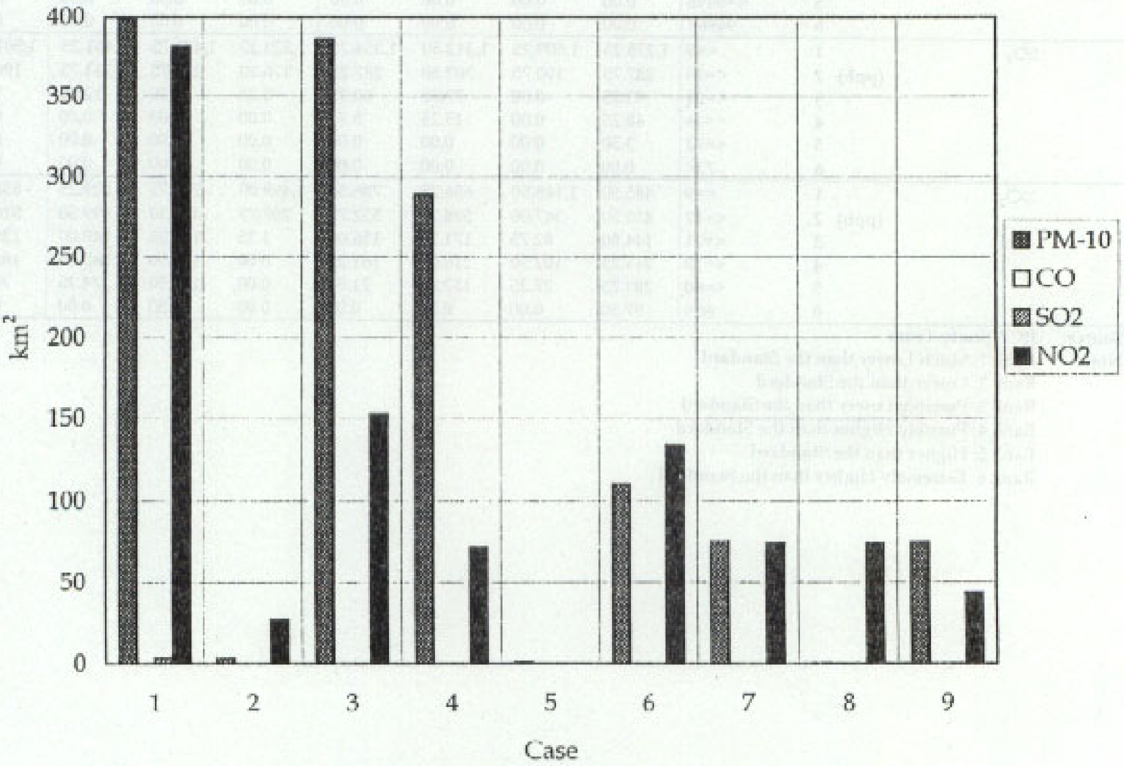


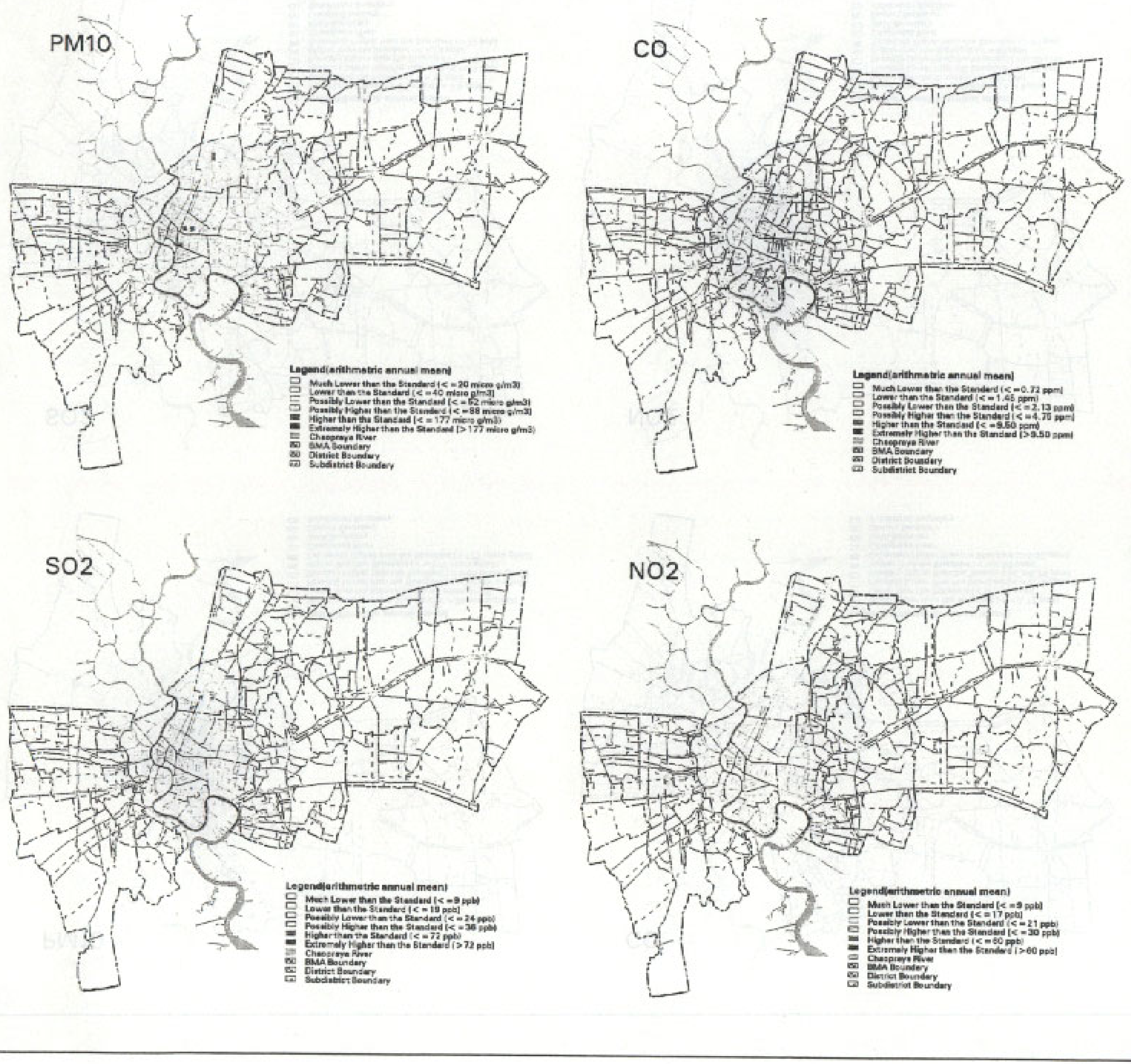
Fig. 3.18 Area of Higher than the Standard (Rank 5 + Rank 6)

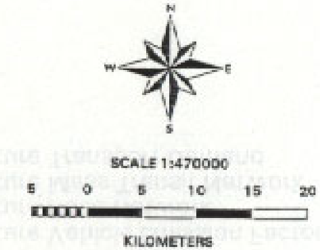
Fig. 3.19

Air Pollution Simulation

Case 5

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





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)

Fig. 3.20

Air Pollution Simulation

Case 6

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

N
W E
S

SCALE 1:470000

5 0 5 10 15 20

KILOMETERS

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

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THE GOVERNMENT OF THE KINGDOM OF THAILAND

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

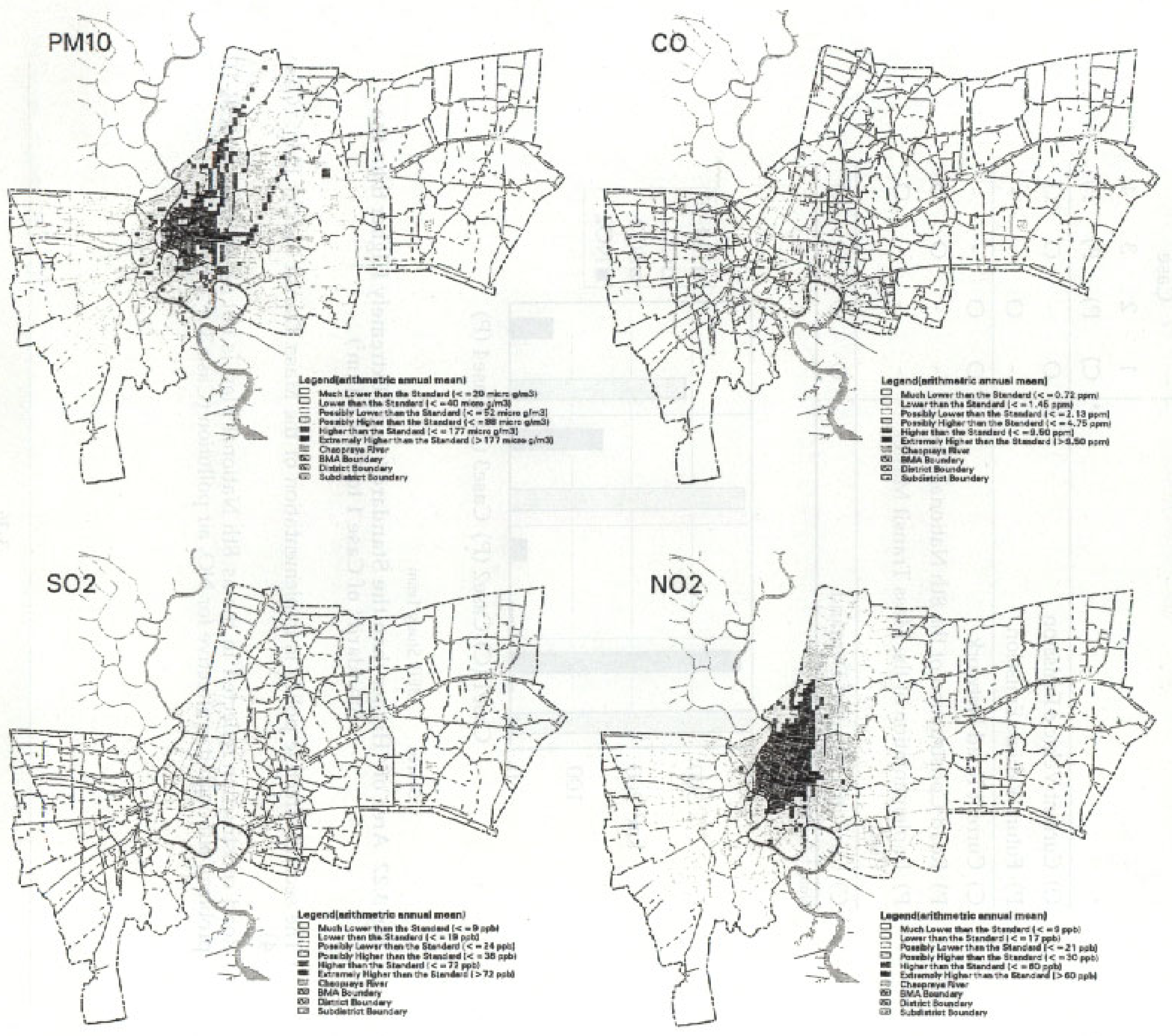

Fig. 3.21

Air Pollution Simulation

Case 7

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

SCALE 1:470000

5 0 5 10 15 20

KILOMETERS

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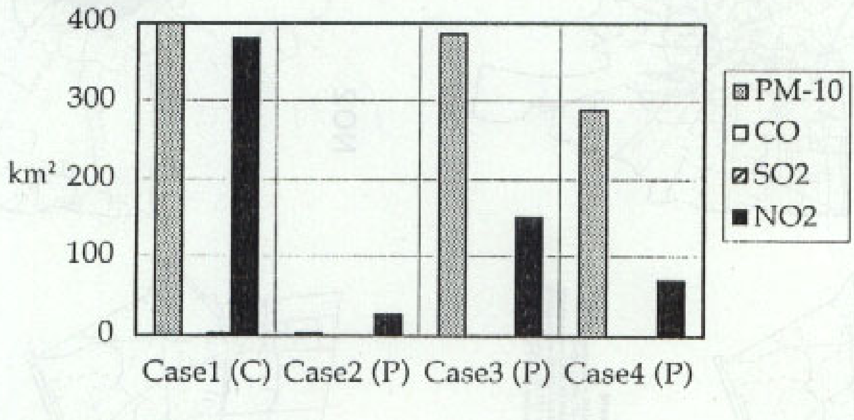
Comparison of Future Probable Policies (P)

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	Case 2	Case 3	Case 4
*	C)	P)	P)	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.

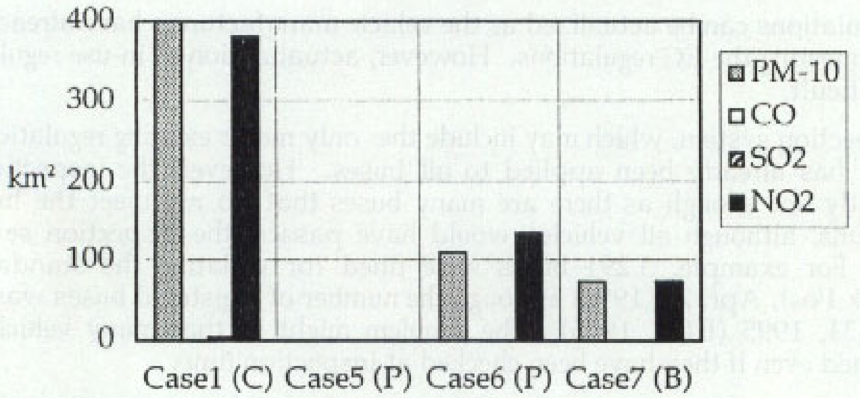
Future Probable Policies (P) vs Future Transport Demand in 2011 (P)

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

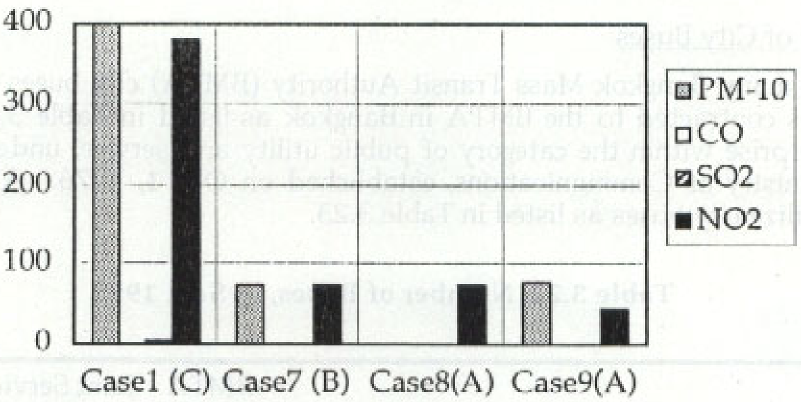
Fig. 3.23 Area of "Higher than the Standard" and "Extremely Higher than the Standard" of Case 1 and Case 5 to Case 7 (km^2)

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

	Every		
	2 weeks	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
	Thailand	34.2	30	10.26	9							Non-Dispersive
CO	WHO	30		10								Infrared Detection
	Japan				20		10					
	Thailand	0.32	0.17									Chemi-
NO_2	WHO	0.4				0.15						luminescence
	Japan						0.04-0.06					
	Thailand	0.78	0.3			0.30	0.12			0.1*	0.04*	UV-Fluorescence
SO_2	WHO	0.35				0.15						
	Japan		0.1				0.04					
	Thailand					0.33				0.10*		Gravimetric-High
TSP	WHO					0.15-0.23				0.04-0.06		Volume
	Thailand					0.12				0.05		Gravimetric-High
PM-10	WHO					0.07						Volume
	Japan	0.20				0.10						
O_3	Thailand	0.20	0.1									Chemi-
	Japan		0.06									luminescence
Lead	Thailand							1.5($\mu g/m^3$)				Atomic Absorption
	WHO									0.5-1($\mu g/m^3$)		Spectrometer

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.

CHAPTER 4: WATER SUPPLY SYSTEM

4.1 General

The rapid economic and population growth in Bangkok Metropolitan and its surrounding suburbs caused a concern from the view point of water management to cope against environmental degradation. In addition, natural uncertainty like recent drought remind the water shortage crisis in the Metropolitan Area as well as in the Kingdom. The expansion of urbanization towards suburbs of BMA brought realization to the MWA for expansion of water distribution system to the newly grown urbanized area.

The projects recommended through the second Master Plan has been implementing but the rapid urban development in Bangkok Metropolitan and its surrounding suburbs are become necessary to include in the plan and update the Master Plan to meet with the present and future forecasting developments. Parallel to the reviewed development plans, there should have some water saving policy which may include extensive water saving campaigns and educate people to make aware of the users about value and necessity of water.

4.2 Assessment on Present Conditions

As a first step for exploring the water supply system in BMA, 5 years data were taken into consideration for study. On the basis of data, findings are as follows.

(1) Present Situation on Water Service in BMA

The Metropolitan Waterworks Authority (MWA), responsible for supplying water to the customers provides in the half of the BMA area through two different systems, namely, central or main system and separate system. The main system supplies water to the center core of Bangkok Metropolitan and parts of Nontaburi and Samut Prakarn provinces and the separate system consists in Minburi, and Bang Bua Thong water supply systems. MWA organizes the whole BMA into 16 service blocks for its water service systems covering about 893 km2 as a whole.

The water production in 1995 was about 1405 million cubic meter of which about 1318 million cubic meter or 94 % was provided from surface water and 87 million cubic meter or 6 % was yielded from groundwater.

Total number of MWA customers are 1,241,000 connections of which 903,000 connections are domestic water users and 338,000 connections are other business water users including commercial, industries, state enterprises, government agencies, etc. Total amount of water sold to the customers was 870 million cubic meter of which 445 million cubic meter or 51 % was domestic water use and 425 million cubic meter or 49 % was consumed by the other business users. The water consumption per connection reach at 41 m3/month and 105 m3/month for domestic use and other business use respectively whereas an average water consumption is 58 m3/month per connection.

(2) Main System and Separate System

The MWA withdraw raw water from the Chao Phraya River for the main waste source. Utilization of ground water is very less compared to surface water. The raw water from Chao Phraya river is pumped at the rate of 3.6 million m3/day at Sam Lae pumping station located 90 km upstream from the estuary of the river and convey for production to the Bang Khen and Sam Sen water treatment plants in the East Bank of Main System and Thon Buri Water Treatment Plant in the West Bank of Main System. Raw water is pump-up to the Khlong Prapa of capacity 3.6 million cubic meter per day which feeds Bang Khaen Treatment Plant first at km 19, then feeds to Bang Sue pumping station at km 30 for feeding Sam Sen and Thonburi Treatment Plant.

Table 4.1 shows capacity of the existing water supply system in MWA's Main Service System. The largest water treatment plant at Bang Khen produce 3.2 million cubic meter per day (mcmd) followed by Sam Sen 0.70 mcmd, Mahasawat 0.4 mcmd and Thonburi Treatment Plant 0.17 mcmd. Total water treatment capacity including the separate system is 4.8 mcmd as of 1995.

There are eleven main distribution pump stations, namely, Bang Khen 0.80 mcmd, Pahon Yothin 0.48 mcmd, Lat Phrao 0.48 mcmd, Lumpini 0.64 mcmd, Samrong 0.64 mcmd and Khlong Toei 0.48 mcmd are used to distribute water to the East Bank. Thapra and Ratburana pumping stations receive treated water from Bang Khen Water Treatment Plant to supply 0.64 and 0.48 mcmd respectively in the West Bank of Metropolitan area. In addition, Mahasawat pumping station distribute water 0.48 mcmd to the West Bank. Total water distribution capacity including other smaller system reach at 6.3 mcmd.

Underground water is the major source of Separate System followed by the smaller surface water systems. This system is totally isolated from the main system, hence named separate system. Water production capacity of the separate system is 0.33 mcmd as of 1995. But in future the separate system will be connected with the main system.

Table 4.1 Existing Water Supply System Capacity

Water Treatment Plant	Plant Capacity (cum/day) Present	Plant Capacity (cum/day) A.D.2005	Plant Capacity (cum/day) A.D.2017	Pumping Station	Pumping Capacity (cum/day) Present
1. Bang Khaen	3,200,000	3,600,000	4,000,000	1.1 Bang Khaen	800,000
				1.2 Phon Yothin	480,000
				1.3 Lat Phrao	480,000
				1.4 Lumpini	640,000
				1.5 Thapra	640,000
				1.6 Samrong	640,000
				1.7 Khlong Toei	480,000
				1.8 Ratburana	480,000
				Subtotal	4,640,000
2. Sam Sen	700,000	700,000	700,000	2. Sam Sen	700,000
3. Thonburi	170,000	170,000		3. Thonburi	170,000
4. Mahasawat	400,000	1,200,000	3,200,000	4. Mahasawat	480,000
5. Nong Chok	1,200	1,200		5. Nong Chok	1,200
6. Bang Bua Thong	4,500	4,500		6. Bang Bua Thong	4,500
7. Mobile Plant				7. Mobile Plant	
7.1 Rama VI	50,000	50,000		7.1 Rama VI	50,000
7.2 Khlong Tawee Watana	10,000	10,000		7.2 Khlong Tawee Watana	10,000
7.3 Maha Sawat	15,000	15,000		7.3 Maha Sawat	15,000
7.4 Bang Bua Thong	5,000	5,000		7.4 Bang Bua Thong	5,000
				Subtotal	80,000
8. Deep Well (80 units)	240,000	(emergency use)		8. Deep Well (80 units)	240,000
Total Production Capacity	4,795,700	5,755,700	7,900,000		6,315,700
East Bank Total	3,951,200	4,351,200	4,700,000	East Bank Total	4,271,200
West Bank Total	604,500	1,404,500	3,200,000	West Bank Total	1,804,500
Deep Well	240,000	(emergency use)		Deep Well	240,000
Total	4,795,700	5,755,700	7,900,000		6,315,700

Table 4.2 gives some idea about the water production in two systems as well as percentage of surface and ground water uses. Total MWA water production is 1405 million cubic meter already mentioned, of which 98.37% is in the Main System and 1.63% is in the Separate System. In the Main System, 95% production comes from surface water and 5% production from underground water. On the other hand, in Separate System, 19% production comes from surface water and 81% production from underground water

Table 4.2 Water Production in Main and Separate Systems in 1995

Fiscal Year	Main System			Separate System			Grand Total
1995	Plant	Deep Well	Total	Plant	Deep Well	Total	
Oct-Dec	314.11	18.01	332.12	1.112	4.78	5.892	338.012
Jan-Mar	317.73	16.63	334.36	1.058	4.48	5.538	339.898
Apr-Jun	333.85	16.26	350.11	1.086	4.56	5.646	355.756
Jul-Sep	348.21	17.52	365.73	1.069	4.76	5.829	371.559
Whole year	1313.9	68.42	1382.32	4.325	18.58	22.905	1405.225
% Within System	95.1%	4.9%	100%	18.9%	81.1%	100%	
% Inter System			98.4%	(1.63%)		1.6%	100%

(3) Water Service Blocks and Location

To provide overall speedy service to the customers MWA divide 16 service zones under 12 branch offices. Ten branch offices in Nontaburi, Bang Khen, Phayathai, Phrakanong, Samut Prakarn, Bangkok Noi, Phasicharoen, Taksin, Toongmahamek, and Mansri to serve the Main System. Other two branch offices, Minburi and Bangbuathong are serving water to the Separate System.

(4) Water Production and Consumption in the Last 5 Years

Water production data in the last 5 years shows that yearly water production is increasing though consumption rate per connection is decreasing as indicated in Table 4.3. This is simply because of rate of increase of connection is higher than the rate of increase of production needed for the increased service. Increased rate of water production over previous year for the last 5 Fiscal Years are calculated in Table 4.3. From the Table, it is found that in the 1994 Fiscal Year over the previous 1993 Fiscal Year water production increase is very less (0.76%) and that in this year over previous year is very high (13.85%). This is because of serious drought in the 1994 Fiscal Year and heavy rainfall with demand in this year. During the period from 1991 to 1993 increase rate varies from 4% to 6% annually. Percentage of water sold to water production is clearly decreasing during the last 5 years which indicates that the system loss is increasing.

Block-wise average water production and sales are shown in Table 4.4. At present, the highest water production in the Main system is in Samut Prakarn branch office of 0.492 mcmd and the lowest in Bangkok Noi branch office of 0.221 million mcmd. The total average production is 3.85 million mcmd and it is 26.64% higher over the Fiscal Year 1991. The increase rate of water production is very high in both blocks of the Separate System compared to Main System Blocks. Among the blocks in the Main System, the increase of production in Phasicharoen, Toongmahamek and Samut Prakarn blocks are higher, varying from 59- 61%. Production in Phayathai and Mansri blocks are decreased by 23% and 0.62%, respectively. In other 5 blocks- Nontaburi, Bang Khen, Phrakanong, Bangkok Noi and Taksin water production are increased by 27-33%.

Table 4.3 Summary of Water Consumption in 1991 - 1995

Fiscal Year	Water Production	Water Sold	Rate of Water Sold	Number of Connection	Water Consumption per Connection
	million m3	million m3	%	pcs.	m3/month
1991	1109.2 (5.7)	781.5 (8.7)	70.5	1,027,623	63.4
1992	1175.5 (6.0)	823.4 (5.4)	70.0	1,090,995	62.9
1993	1224.9 (4.2)	836.1 (1.5)	68.3	1,139,299	61.2
1994	1234.3 (0.8)	816.1 (-2.4)	66.1	1,194,161	57.0
1995	1405.2 (13.9)	870.3 (6.6)	61.9	1,241,380	58.4

Note : Figures in parenthesis indicate increase or decrease over the previous year

Table 4.4 Block-wise Water Production and Consumption (1991 - 1995)

	1991		1992		1993		1994		1995		IncreaseRatio	
	Prod.	Sold	Prod	Sold	Prod	Sold	Prod	Sold	Prod	Sold	Prod	Sold
Nonthaburi	0.273	0.211	0.328	0.229	0.293	0.205	0.306	0.198	0.349	0.216	27.88%	2.19%
BangKon	0.291	0.211	0.330	0.227	0.340	0.234	0.346	0.236	0.385	0.253	32.46%	19.74%
Phayathai	0.387	0.261	0.385	0.266	0.343	0.232	0.326	0.222	0.314	0.229	-18.94%	-12.21%
PhraKanong	0.328	0.224	0.316	0.235	0.341	0.242	0.338	0.234	0.418	0.248	27.54%	10.64%
SamutPrakarn	0.308	0.215	0.338	0.240	0.370	0.257	0.410	0.271	0.492	0.301	59.64%	39.77%
BangBo	0.014	0.010	0.013	0.008	0.006	0.003	—	---	—	—	—	—
Min Buri (Sep.)	0.026	0.021	0.029	0.023	0.029	0.027	0.035	0.028	0.045	0.033	74.14%	56.86%
Bangkoknoi	0.166	0.133	0.180	0.139	0.199	0.142	0.195	0.138	0.221	0.146	33.13%	9.77%
Phasicharoen	0.223	0.157	0.231	0.163	0.269	0.174	0.301	0.171	0.360	0.188	61.63%	19.60%
Taksin	0.328	0.232	0.357	0.245	0.360	0.253	0.369	0.254	0.434	0.271	32.43%	16.63%
Toongmahamek	0.196	0.130	0.190	0.132	0.289	0.184	0.279	0.171	0.312	0.178	59.06%	36.98%
Mansri	0.481	0.323	0.493	0.324	0.486	0.317	0.440	0.286	0.478	0.291	-0.60%	-9.79%
BangBua Thong(Sep.)	0.019	0.014	0.023	0.017	0.030	0.022	0.036	0.028	0.041	0.032	116.89%	125.83%
Total (mcm/year)	3.040	2.142	3.212	2.250	3.356	2.291	3.381	2.236	3.850	2.384	26.64%	11.30%
Total	1109.8	781.8	1172.3	821.1	1224.9	836.1	1234.1	816.2	1405.2	870.2		

Note: Figures in the culumn "increase ratio" indicates a increase or a decrease of water amount between 1991 and 1995.

(5) Water Consumption by Types of Water Users

Water consumption data on the type of water users are not clear but categorized by the available data and shown in Table 4.5. The first category domestic water users and the second category business users including commercial, state enterprises, government agencies, industries, etc. consume almost the same amount of water since 1991.

Though total consumption during the last 5 years is increasing which is quite natural except the Fiscal Year 1995. This exception is due to serious drought flow of the Chao Phraya River in 1994. In 1995, 444.5 million cubic meter per year or 51 % is consumed by domestic purpose and that by business, industry and others are 321.57 million cubic meter per year or 49 %.

Table 4.5 Water Consumption by Type of Water Users(1991 - 1995)

Fiscal Year	Domestic Water Consumption			Business Water Consumption			Total Water Consumption (million m3)
	Water Consumption (million m3)	Increase or Decrease over Previous Year (%)	Rate to Total Water Consumpti on (%)	Water Consumption (million m3)	Increase or Decrease over Previous Year (%)	Rate to Total Water Consumption (%)	
1991	391.70	6.00	50.13	389.60	11.50	49.87	781.30
1992	405.40	3.50	49.23	418.00	7.29	50.77	823.40
1993	413.90	2.10	49.50	422.20	1.00	50.50	836.10
1994	415.80	0.46	50.95	400.30	-5.19	49.05	816.10
1995	444.50	6.90	51.08	425.78	6.37	48.92	870.28

Note : Business water consumption include commercial, state enterprises, government agencies, industries, public water supply & others

4.3 On-going and Future Development Plans

Development projects of water supply facilities of MWA are carried out based upon the Master Plan formulated in October 1990 with the target year 2017 covering about 3,080 sq. km including the entire BMA area and the neighboring Nonthaburi and Samut Prakarn provinces.

Major current and future development projects are described herein and in Table 4.6 for the benefits to study on urban environmental Improvement program for BMA area from the viewpoint of the major urban facilities to maintain satisfactory public health and sanitation. Figure 4.1 shows water service area, water transmission projects and expansion plan of the current Master Plan.

(1) On-going Projects

1) The Fourth Bangkok Water Supply Improvement Project (1991-1996)

This project aimed at the increase of water production capacity of Bang Khen Water Treatment Plant by 400,000 m3/day, accompanied by distribution pipes and a pumping station at Lat Krabang. The project will expand the service area by an additional 180 km2 into Sukhaphiban 3, Sri Nakarin, Bangna -Trad, Rom Klao, Theparak and King Kaew roads.

2) The Fifth Bangkok Water Supply Improvement Project (1992-1996):

This will provide a new Mamasawat Water Treatment Plant located on the West Bank of Metropolitan Bangkok to supply sufficient water to the people in Thonburi area and Nonthaburi province. This project will extend service by 400,000 cubic meters of water per day and that will increase service area and population by 80 km2 and 800,000 person, respectively. After completion of this project MWA total capacity will be 4.5 million cubic meter per day to the service area 930 km2. And hence 85.1% population will be beneficiaries from MWA. The total project cost is 7,663.5 million Baht.

3) The Sixth Bangkok Water Supply Improvement (1994-1999)

This project will provide additional production capacity to the Mamasawat Water Treatment Plant by 400,000 cubic meters per day. The project includes construction of pumping station at Pechakasem Road, construction of transmission line approximate length of 34 km and installation of distribution pipes to extend the service area by about 80 km2. After completion of this project MWA total production capacity will be raised to 4.9 million cubic meter per day to the service area 1,030 km2. As a result 90.5% population will be served from MWA. The total project cost will be about 10,113.0 million Baht.

4) The West Bank Raw Water Canal Project (1995-1999), Phase II

This project aimed at construction of upstream portion of raw water canal from Mae Khlong River upper Vajiralongkorn Dam, Kanchanaburi Province to Tha Chin River approximately 70 km. The total project cost will be about 4,885.5 million Baht.

5) The Network System Improvement Project (1994-1997)

To improvement and develop water pipe system and distribution system for the increase of pumping capacity and distribution efficiency to cope with the rising demand in central business and high rise districts. Total project cost will be about 4,690.1 million Baht.

(2) Future Project (1997-2001)

- Installation of raw water pump at Mamasawat Water Treatment Plant
- Increased production capacity of Mamasawat Water Treatment Plant by 400,000 cubic meter per day. Construction of clear water reservoir of 60,000 cubic meter capacity with other appurtenant facilities.
- Construction of distribution pumping system, surge tower, and transmission line in both East and West Bank of Metropolitan Bangkok. Construction of transmission system in the East Bank.
- Increase facilities in Minburi service area by purchasing land, construct pump station, clear water reservoir and appurtenant facilities.
- Installation of an additional water pump to increase pumping capacity at Pechakasem pump station.
- Installation of various sizes of pipelines approximately 600 km in whole service area.

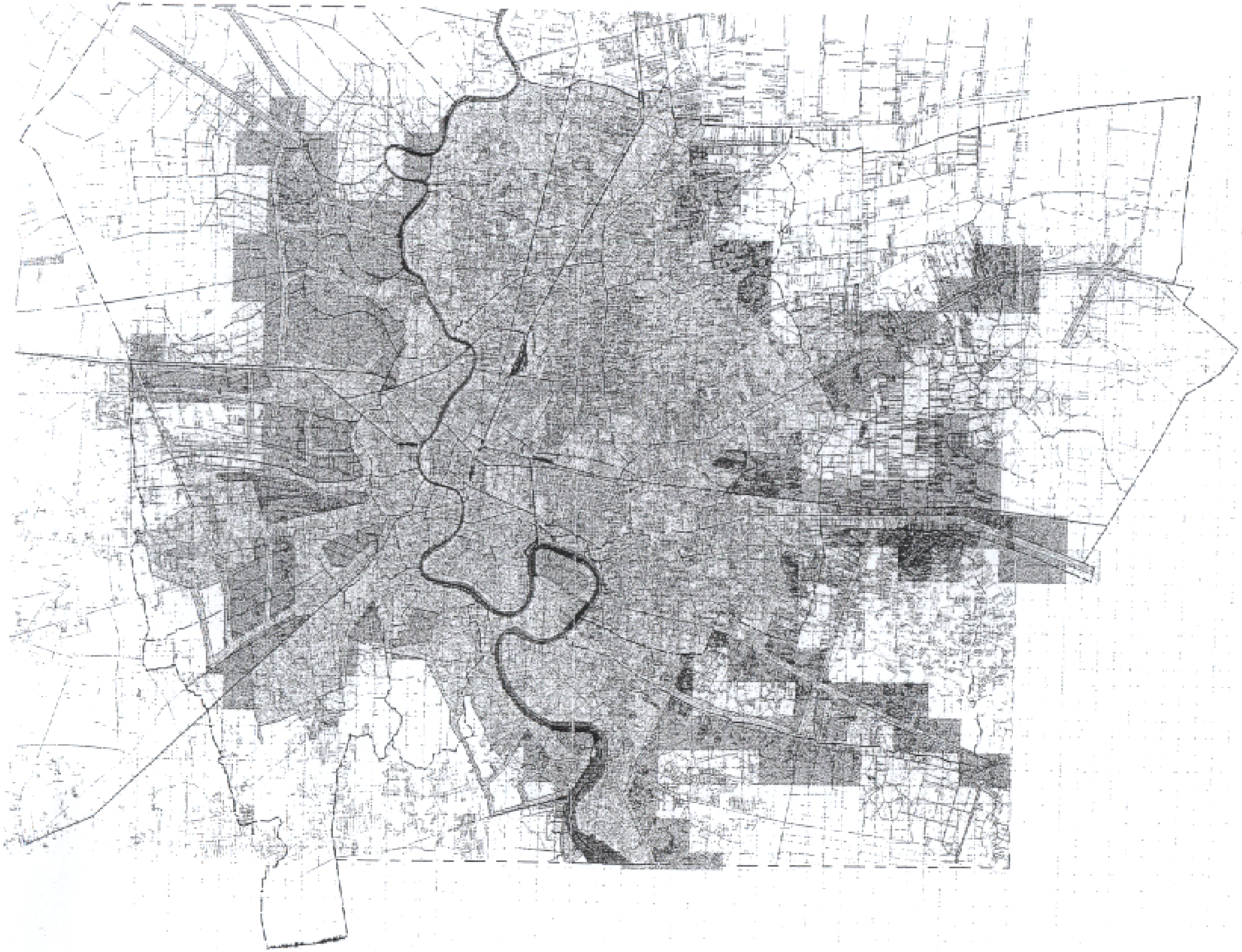
After the completion of the project in the year 2001, total MWA water production capacity will be 5.7 million cubic meter per day to cover the service area 1,090 km2. Total number of customer will be increased to 1.6 million for 8.2 million population. And hence, 93% population will be served by MWA. Total project cost will be about 12,431.0 million Baht.

Table 4.6 List of Water Supply Development Projects

	Projects	Type	Purpose	Location	Cost (million Baht)	Completion Year
On-GoingProjects						
1	TheFourthBWSIP	Pumpingstation& distributionpipeat Krabang	Increasewater productioncapacityof BangKhaenWater Treatmentplantby 400,000cmd	BangKhaenEast suburb	7,798.10	December1996
2	The Fifth BWSIP	Maha SawatWater TreatmentPlant, additionalpipeline	Increasesystem capacityby400,000 cmd	BangKruai, Nontaburi	7,863.50	1996
3	The Sixth BWSIP	PhetKasemPumping station;additionalpipe line	Increasecapacityof MahaSawatTreatment Plantby400,000cmd	PhetKasemRoad,	10,113.00	1998
4	The West Bank Raw Water Project	Rawwatercanal	Rawwatersupply	Mae Khlong River to Tha Chin River	4,885.50	1999
5	The Network System Improvement	Monitoringpipe system & repair	improvepumping capacityanddistribution efficiency	Whole system	4,690.10	1997
FutureProjects						
1	MinburiProject	Pumpingstationwith otherfacilities	Increasecapacity	Minburi,EastBank	-	2002
2	BangPleeProject	Pumpingstationwith otherfacilities	Increasecapacity	BangPlee,East Bank	-	2006
3	Thonburi&ThaPhra Project.	Transmissionpipeline fromMaha Sawatto ThonburiandTha PhraPS	Increasecapacity	westBank	-	2017

Figure 4.1

Water Service Area Expansion Plan



Legend

- Water Service Area in 1995
- Water Service Area before 1997
- Water Service Area before 1997
- Water Service Area before 2007
- Water Service Area before 2017
- Chaopraya River
- River
- Road
- MWA Boundary
- Rail
- BMA Boundary
- District Boundary
- Subdistrict Boundary

N E S W

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JICA JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

4.4 Policy Directions and Planning Issues

Planning of water supply system is not dealt in the scope of work of the study concerned since water supply system does not directly related with the issues as it is discussed the urban environmental improvement program for the city. However, in view of a key role of water supply system composing the urban facilities to maintain sanitary environment in daily life, the study was made in brief to evaluate the water supply system of Metropolitan Waterworks Authority(MWA).

The suggestions described in the following paragraphs will be beneficial to the MWA to strive for solving the planning issues for accomplishment of effective water supply system. Moreover, it is expected that the suggestions are also effective for BMA to create a water-saving or energy-saving society for sustainable development of the city of Bangkok.

(1) Review of Water Supply Master Plan

MWA is carrying out the development projects steadily based on the Water Supply Master Plan set forth the phased development plans up to the final target year in 2017.

Currently, the 4th expansion plan is underway to complete the project by the end of 1997. The 5th and 6th expansion projects are scheduled for the period 1992 - 1997 and 1994 -1999 respectively. Upon completion of the final phase, the MWA water supply system will be made available with the water consumption amount of 5.3 million m3/day or equivalent to the served population 15.5 million in the year 2017 in whole service area and the population in BMA area accounts for 10.6 million or approximately 70 % amongst in MWA service area. For individual water consumers, the amount of water will be secured at the least by about 60 m3/month per connection in average for every consumers or 30-40 m3/month per connection for domestic water user.

It is understood that implementation of the projects proposed in the water supply Master Plan would make it possible to supply sufficient amount of water to the people in the service area. However, the recent phenomena taking place in urbanization such as the direction and speed of urban growth, change of life style, quality of life, etc. shall need review of the water supply development projects to accommodate better service of water to the consumers.

Tendency of urbanization in the recent years has changed the population distribution pattern toward suburban area, besides the decentralization project having been promoted by the government. In relation with the current urban renewal plan of Bangkok and that of the neighboring provinces, review of the Water Supply Master Plan will be necessary for coordinating with the city development plans to perform water supply onward target for continuous service of safe and sufficient water to the people.

Prediction of future water consumption, location of distribution pump stations, restructuring of water transmission pipes, distribution pipe network and water service blocks, and phasing of the development projects are the important issues as the Master Plan is reviewed in connection with the urban renewal plan.

(2) Water Leakage Protection and Pipeline Information System

Unaccounted water amount reached at 38 % or 534 million m3/year in 1995 statistic. Most of the unaccounted water amount is caused of water leakage from the pipeline system composed of water transmission, water distribution and water service to the consumers. Distribution water is produced through the physical and chemical processes with spending a lot of expenses for purification of water meeting with the drinking water standards. Water leakage from the pipeline system is something like a waste of investment or loss of energy in other word.

It is recommended to set a provisional target of water leakage protection at 20 % in consideration of the least water leakage ration at 30 % performed in 1992.

Firstly, inventory survey of the pipelines and networks will be useful to work with as - built drawings and site survey using the advanced underground explore equipment. Then, all the data and information shall be input in the graphic information system for constructing the pipeline information system covering entire water service area. Secondary, field investigation shall be carried out in the water leakage investigation block divided properly into smaller blocks by the data obtained from the pipeline information system. After analysis of the zonal water leakage amount and ratio, detail investigation shall be conducted to search for the water leaking pipelines for design and for immediate measures. The third step work shall be conducted to repair, renew or replace the damaged pipelines based on the design. Final step of this program is to renew the data and information of the pipeline information system to input the repair records. The water service area controlled by each branch office shall be divided into smaller blocks for block-wise operation to implement the leakage protection program one by one.

(3) Improvement of Water Quality

West Bank Raw Water Canal Project is under way to withdraw raw water from the Tachin River to Mahasawat Water Treatment Plant by the end of 1997 and complete the project after extending the raw water intake site further to the Maeklong River Basing in future. Completion of the project will make available to increase the rated capacity of Mahasawat Water Treatment Plant up to 3.2 million m3/day.

The past and on-going projects aimed at securing sufficient quantity of water and MWA is materializing the plan successfully up to now. Now, the people in Bangkok is achieving stability in his livelihood and his consciousness in daily life is changing to obtain rather the quantitative than the qualitative things. Movement of environmental conservation activities in the recent years is an example that people is asking for better quality of life.

To cope with the changes of the society, MWA have to set up the program to improve water quality in purification and water distribution processes.

Fortunately, raw water in the Chao Phraya River is not yet contaminated with hazardous matters but there is a phenomena of water contamination with organic matters especially in drought period. Organic contamination by fumic acid have a potentiality to generate Tri-haro-methane which is known as one of a carcinogenic substances produced as residual fumic acid contact to chlorine in disinfection process. Chemical dosing, sedimentation and filtration processes must be controlled carefully to produce better filtered water quality before chlorination .

Turbid water is observed frequently when tap water is contained in sink or in bath tub. Turbids from the service pipes occurs as sediments or scale in the pipe float caused by shock flow, pipe repair work, insufficient blow-off operation, and so forth. Those cause mentioned above can be improved easily through strengthening operation and maintenance works of distribution pipe network.

Deterioration of raw water quality will be the problem being afraid in near future as long as pollution loading increase continuously in future. Water pollution control projects must be carried out soon by the authority concerned to avoid probable water pollution problem in the area of water resources in future.

Accordingly, it is recommended to start up the program for water quality improvement of MWA water supply system with strengthening water purification process control and operation & maintenance of the distribution pipe network through utilizing the existing function of MWA.

CHAPTER 5: FLOOD PROTECTION AND DRAINAGE SYSTEM

5.1 General

Devastating flood in October - November, 1995 reminded the citizens and the official agencies concerned with flood protection that the flood problem is one of the major disaster in the urbanized comfortable civic life.

There are many arguments came from the implementing agencies concerned are suggesting the method of solutions to improve and enhance the flood protection facilities in BMA and its neighboring areas. Those suggestions include stormwater diversion directly to the seashore, storm water retention to cut peak flow period, dredging of the existing canals to secure enough carrying capacity, construction of the retaining wall of 2.5 m high along both sides of the Chao Phraya River and so forth.

A cause of flooding in BMA in 1995 may be the excessive discharge from the upstream reaches was interrupted by the backflow from the sea which raised water level in the Chao Phraya River to exceed the embankment level and caused of flooding in Tonburi, Nontaburi and the low-lying area along the Chao Phraya River.

However, the flood problem in BMA can not be concluded simply by the cause mentioned above but it is related to some other factors such as the flat terrain, land subsidence, capacities of flood protection and drainage facilities, etc., and increase of stormwater run off coefficients caused by the current urbanization in suburban area.

Planning of flood protection system was not dealt with a major scope of works in the Study aiming at formulating the urban environmental improvement program since the phenomena of flooding is not deemed as an element categorized in environmental deterioration as compared with air pollution, water pollution, etc.

However, the flood protection system is one of the important infrastructures in BMA Area to provide disaster-free comfortable life to the citizen and the planning of the system is influential factors as the city planning and/or land use plan is discussed. Accordingly, the study was conducted aiming at suggesting only the approach to solve the flood problems based on an angle of restructuring the city of Bangkok to cope with improvement of urban environment in the BMA Area.

5.2 Assessment on Present Condition

(1) Current Flood Protection Work

1) Implementing Agency

Department of Drainage and Sewerage (DDS), BMA undertake the services of flood protection in BMA Area. Drainage System Development Division take charge of the services from planning to construction work while. Drainage System Control Division take charge of operation and maintenance of the khlongs, pumping stations and control gates.

Royal Irrigation Department(RID) take charge of the flood protection work in the eastern suburbs, outside of the King's Dike, in cooperation with DDS to control flood water entering to the inner core area of Bangkok.

2) Existing Facilities

Figure 5.1 shows the location of the existing flood control facilities including pumping stations and control gates. The total pumping capacity reach at 863.4 cum/sec and the breakdown of each area is 422.6 cum/sec in east bank, 239.8 cum/sec in west bank and 201 cum/sec in the coastal area in Samut Prakarn.

(2) Floods in October - November ,1995

The Chao Phraya River recorded the highest water level of 2.27 m MSL at the Memorial Bridge in October, 1995, which is higher water level than that was observed in 1983 when most part of the BMA Area suffered a very heavy flooding for several weeks.

Since the severe floods in 1983, the flood protection facilities such as polders, pumping stations and control gates have been in the central area of Bangkok. Major development projects have now shifted to Tonburi side to construct the flood protection and drainage facilities.

However, ironically, heavily inundated area in 1995 flood occurred outside of the flood protection area in the low lying area along the Chao Phraya River caused by overflow from the river. The area damaged by the flood extended to the municipality area of Nonthaburi, Pakkred in Nonthaburi Province, Bang Yai, Bang Bua Thong, Bang Kruay, Khlong San, Bang Phlat, Taling Chan, Bangkok Noi, Bang Khuntien, and Lat Krabang in Bangkok.

Figure 5.2 and 5.3 show inundation area during floods in 1983 and 1995 respectively in BMA Area.

(3) Inundation-prone Roads in Bangkok

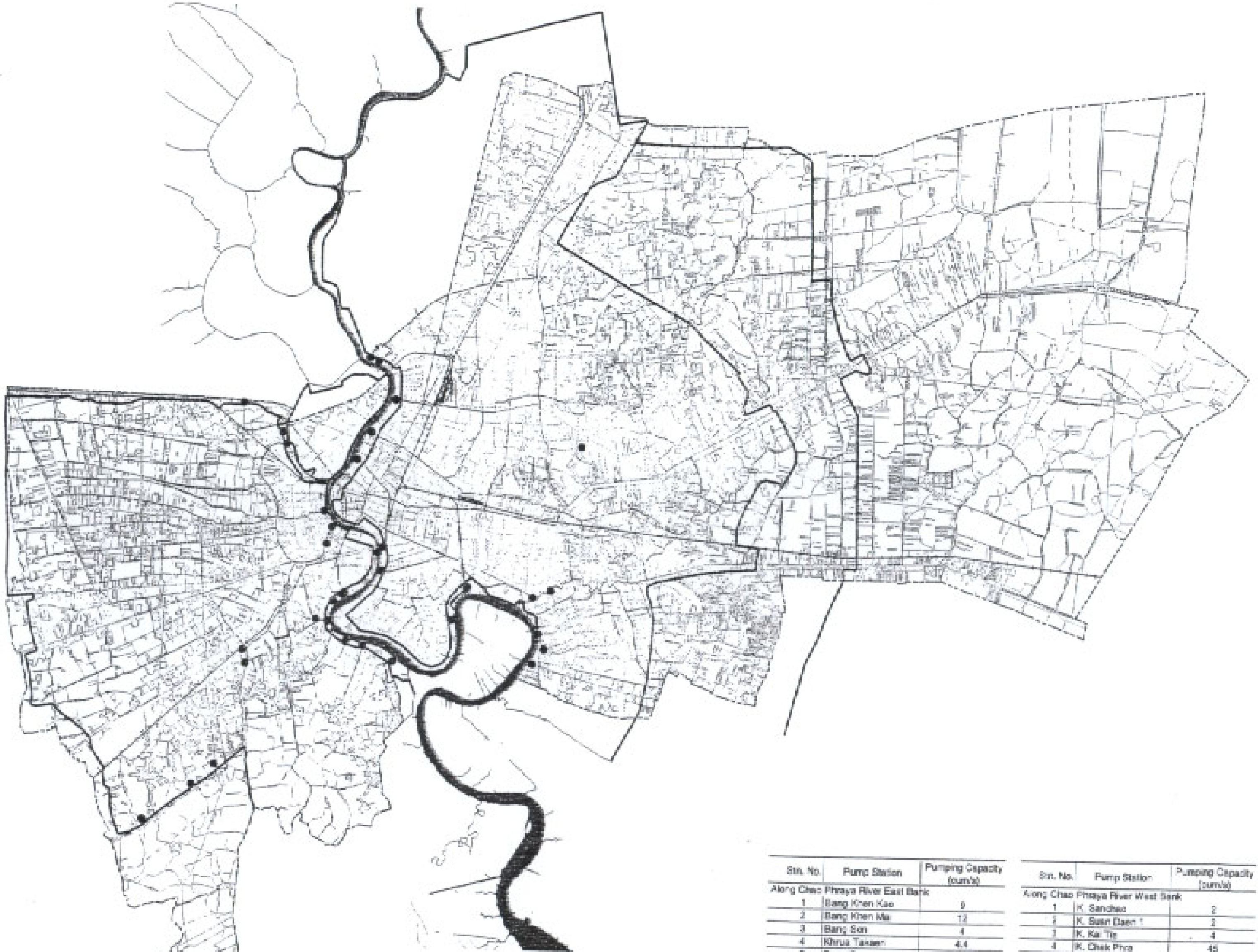
In wet season, inundation damage extended to many roads and sois and cause of traffic congestion chaos in many sections in BMA Area. Figure 5.4 shows inundation records on major roads recorded by DDS during 1993 to 1995. Inundation-prone roads were picked out and listed in Table 5.1 for the inundation records more than 20 times in two years. Those roads include Phahon Yothin, Lat Phrao, Sukhmvit, Charoen Krung, Charoen Nakhon, Charan Sanitwong, etc.

Figure 5.1

Existing Flood Protection Facilities

Legend

- Buildup Area
- Chaopraya River
- River
- Rail
- Road
- Flood Protection Barier
- BMA Boundary
- District Boundary
- Subdistrict Boundary
- Pumping Station
- Watergate



Stn. No.	Pump Station	Pumping Capacity (cum/s)
Along Chao Phraya River East Bank		
1	Bang Khen Kao	9
2	Bang Khen Mai	12
3	Bang Son	4
4	Khrua Taksen	4.4
5	Bang Sue	31
6	Sam Sen	45
7	Thewes	5
8	Krung Kasem	25
9	Sathon	12
10	Khlong Kruai	3
11	Sathu Pradit	2.2
12	Wat Sai	18
13	Chong Nonsi	30
14	Nang Linchi	2
15	Rama IV	24
16	Khlong Toei	30
17	Phra Khanong	105
18	Khlong Chek	6
19	Bang Chak	2
20	Bang Or	13
21	Bang Na	15

Stn. No.	Pump Station	Pumping Capacity (cum/s)
Along Chao Phraya River West Bank		
1	K. Sanchao	2
2	K. Suan Daen 1	2
3	K. Kai Tia	4
4	K. Chak Phra	45
5	K. Mon	24
6	K. Bangkok Yai	64
7	K. Wat Anong-kharam (water Gate)	1.8
8	K. San	4
9	K. Bang Sai-kai	4
10	K. Samrei	4
11	K. Bang Namchon	4
12	K. Dao Khanong	45
13	K. Bang Sakae	4
14	K. Bang Pakok	6
15	K. Ratburana	9
16	K. Chaeng Ron	9
17	K. Sakae-ngam	6
18	K. Lam-pain	6
19	K. Ra-ham	6

N W E S

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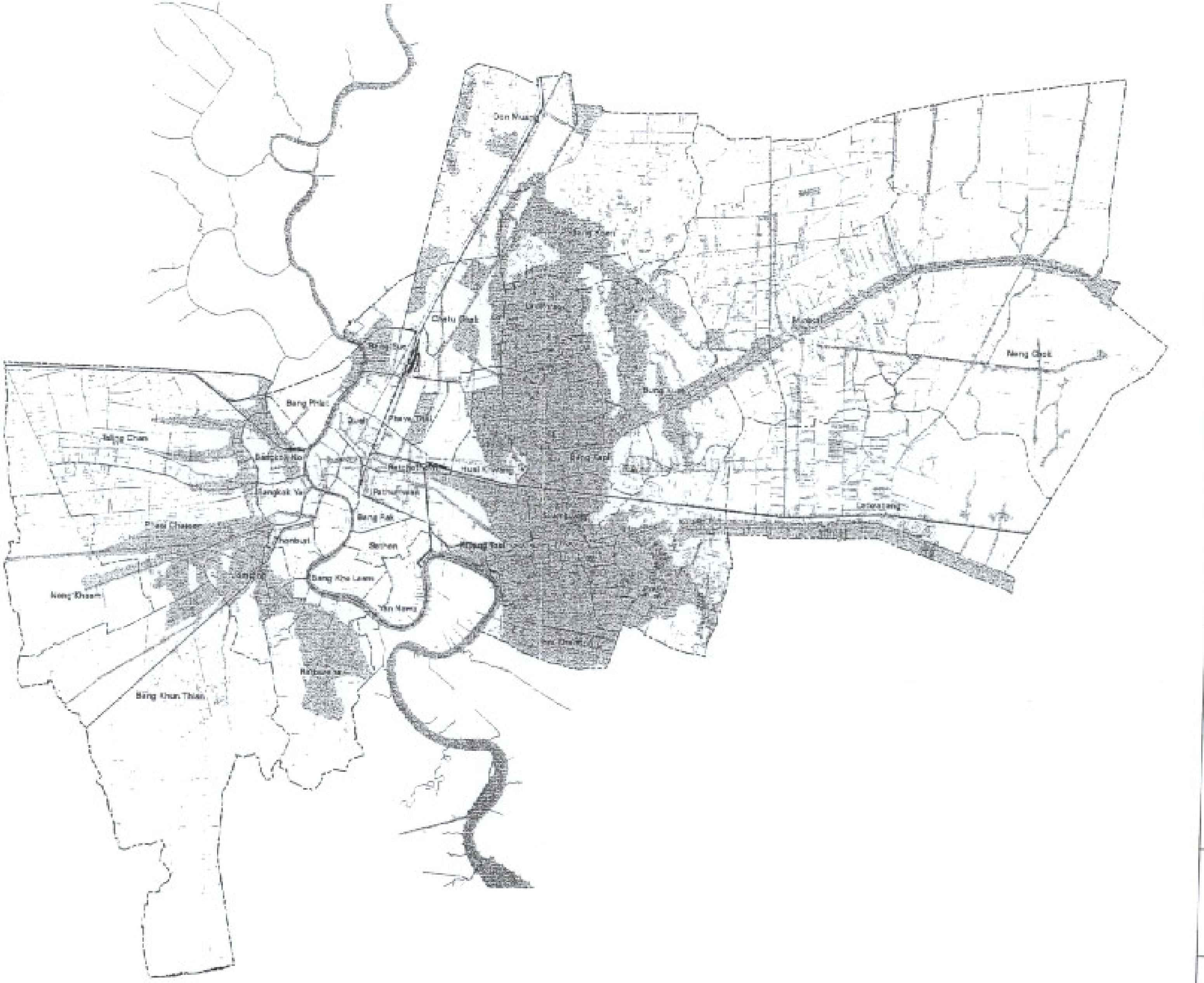
Figure 5.2



Inundated Area in 1983

Legend

- Flooded Area in 1983
- Roads
- Chaopraya River
- Khlongs
- Railways
- BMA Boundary
- District boundary

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Figure 5.3

Inundated Area in 1995

Legend

- Flooded Area
- Temporarily Flooded Area
- Chaopraya River
- BMA Boundary
- District Boundary
- Subdistrict Boundary
- Flood Protection Barier

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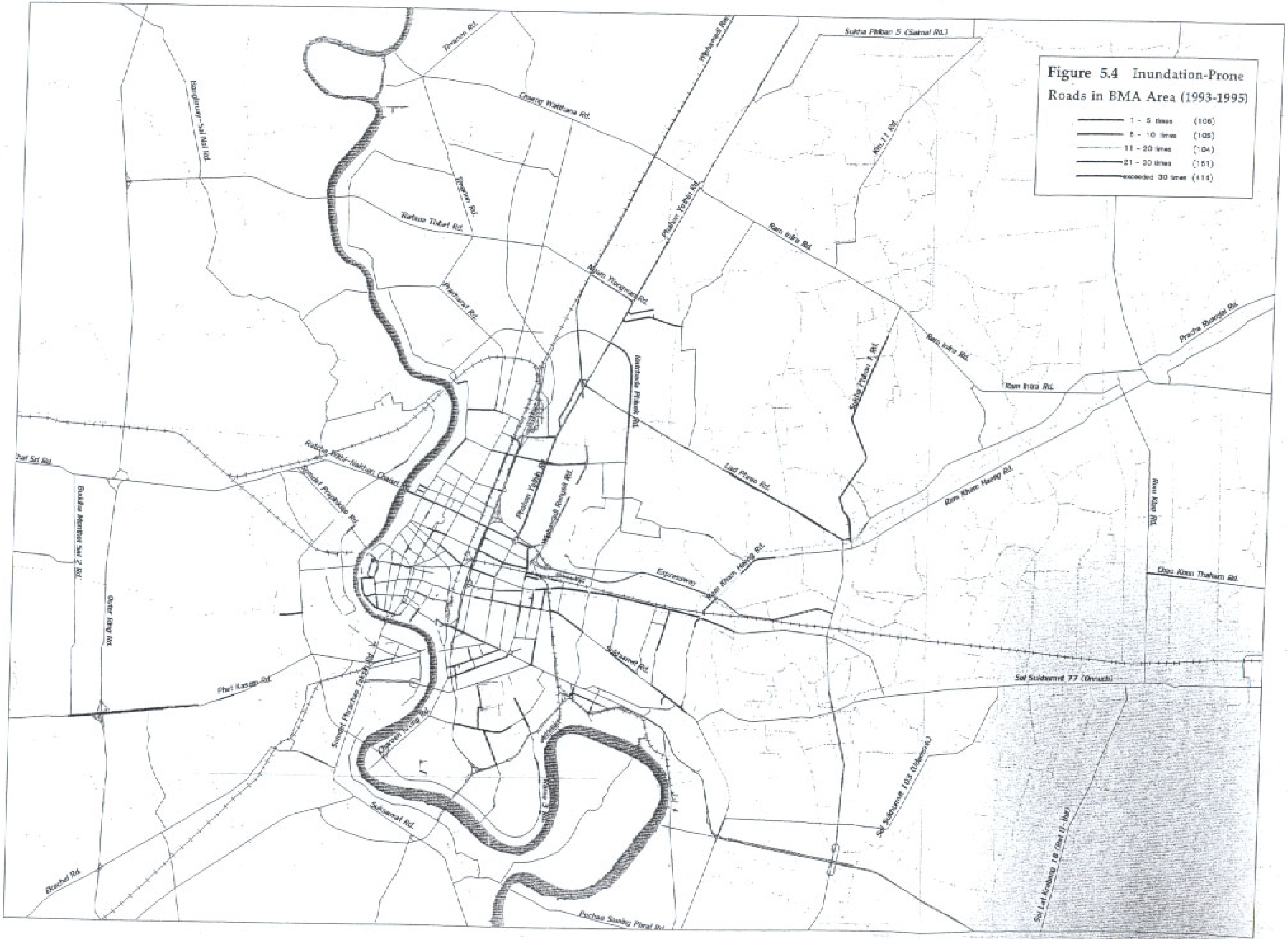


Figure 5.4 Inundation-Prone Roads in BMA Area (1993-1995)

Table 5.1 Frequent Inundation Roads in BMA Area

Inundated More Than 30 times During 1993-1995

No	Name of Road	From	To
1	Phetchakasem	BuddhaMonthon Sai2	Phetchakasem54
2	PhahonYothin	PhahonYothin32	PhahonYothin46(K.BangBua)
3	PhahonYothin32	PhahonYothinRd.	WatLadPlakao
4	PhahobYothin34	PhahonYothinRd.	ThaiCottonIndustrialFactory
5	PhahonYothin	PhumipholHospital	
6	PhahonYothin	PhahonYothin24	Ratchadaphisek
7	Ratchadaphisek	PhahonYothinRd.	K.BangSue
8	LatPhrao	Chokchai4(junction)	
9	LatPhrao	LatPhrao86	BangKapi
10	SukhaPhiban2	BangKapi	
11	PhahonYothin1	AnusawariChaisamoraphum	LatPhrao
12	Ratchawithi	AnusawariChaisamoraphum	DinDaengJunction
13	Ratchawithi	AnusawariChaisamoraphum	Rama VI
14	Rama VI	Ratchawithi	Phetchaburi
15	Phetchaburi	Rama VI	PhayaThai
16	Phetchaburi	Phetchaburi	SoiNanaNua
17	SoiNanaNua	K.SaenSaep	Phetchaburi
18	RamKhamhaeng	RamKhamhaeng27	RamKhamhaeng65
19	Sukhumvit	Sukhumvit39	Sukhumvit55
20	Sukhumvit	Sukhumvit63	Sukhumvit71
21	Sukhumvit	Sukhumvit103	Bang Na-Trad
22	Ratchadaphisek	nearbySoonthornKosa	
23	Chan	K.ChongNonsi	Express Way
24	NangLinchi,SoiSuanPhlu	Chan Rd.	SathonTai
25	CharoenKrung	nearby Tok Rd. (intersection)	
26	Rama III	SoiWatKlongPhum,nearbyintersection	
27	CharoenNakhon	CharoenNakhon40	

Inundated 21-30 times During 1993-1995

No	Name of Road	From	To
1	SukhaPhiban1	BangKapi	SuanSiamRd.
2	SukhaPhiban2	BangKapi	KlongChanFlat
3	RamKhamhaeng	KlongTan	Rama IX (Junction)
4	Sukhumvit	nearbyPhraKhanongintersection	
5	SathuPradit	ChongNonsiRd.	Chan Rd. (infrontofYannawaPostOffice)
6	SathuPradit		PublicHealthCenter7
7	Chidlom	K.SaenSaep	PloenchitRd.
8	Ratchadamri	nearbyRatchaprasongintersection	
9	Ratchaprarop	Pratu-nam(IndhaHotel)	DinDaengJunction
10	SriAyudthaya	Ratchaprarop	Rama VI Rd.(junction)
11	SriAyudthaya	Rama V Rd	PhitsanulokRd.
12	Ratchawithi	nearbyTukChalintersection	
13	Ratchadaphisek	nearbySoonthornKosaintersection	
14	ArunAmmarin	SomdejPhraPinklaoRd.	K.BangkokYai
15	CharanSanitwong	Soi96/2	K.BangkokNoi
16	SomdejChaoPhraya	PrachathipokRd.	LadYaRd.
17	CharoenNakhon	CharoenNakhonSoi1	ChomThongRd.
18	Ratburana	ChomThongRd.	NakhonKhuanKhinRd.(WatRuak)

(4) Flood Protection and Drainage Plans in the Past

A historical map dated 1690 of the Chao Phraya River shows that the original Chao Phraya River meandering system and secondary connecting khlong system. It shows a diversion channel to the west of Bangkok which cut the shortest path from the Chao Phraya River near Nonthaburi to the sea. Secondary diversion khlongs are also shown connecting other meanders to the river. Many of the wide meanders of the Chao Phraya River had been shortcut by 1960's and the main river had been shortened significantly to carry more flow. Currently, the only large meander remain in the section of Yannawa and Phra Phradaeng.

Flood control planning has been conducted for several decades in the Bangkok area. However, the flood damages have become catastrophic state as to the expansion of urban area. In the past ten years multiple plans have been developed and implemented to different degrees. The severe flood in 1983 in Bangkok was a turning point to tackle with flood protection and drainage works in planning and in construction of the facilities.

The following paragraphs provides a summary of the flood control and drainage studies performed for the Bangkok area.

1) Greater Bangkok Plan (1960)

Litchfield, Whiting, Bowne & Ass. Adams Howard and Greely proposed the Greater Bangkok Plan in 1960. This plan consist primarily of two perimeter canals on the East and West banks of the Chao Phraya River. The plan also laid out several zones in the city on both sides of the Chao Phraya River to install flood protection barriers. This concept is a type of polder system functioned together with pumps to drain stormwater to the Chao Phraya River.

Priority was given to the down town areas of Dusit, Phra Nakhon, Pom Prap Suttru Phai and Pathumwan Districts.

2) Camp, Dresser McKee Plan (1968)

The Camp, Dresser McKee Plan proposed the polder systems divided considerably large area of Bangkok into 11 zones ranging the area size from 11 to 100 km2 to cover the East and West banks of the Chao Phraya River. The proposed polder systems intend to protect the city from flood inflow from the surrounding area of Bangkok. Roads, concrete walls and embankments structure the flood protection barriers for each polder, while the khlongs and the Chao Phraya River function as main drains. Stormwater inside of the polders is drained to the Chao Phraya River through drain pipes, pump station, and the khlongs.

The khlongs proposed for the main drain drains in the plan consist of Khlong Bang Sue, Khlong Lat Phrao, Khlong Saen Saep, Khlong Phra Khanong, and Khlong Samrong on the East Bank. In the West Bank, Khlong Maha Sawat, Khlong Bangkok Noi, Khlong Phasicharoen, and Khlong Sanam Chai are proposed for predominantly use for the main drains.

3) City Core Project (1984)

An area of 86 km2 on the East Bank of the Chao Phraya River is covered in this plan. The plan consist of feasibility study and detail design and conducted by NEDECO in joint venture with NECCO and Land Marine/Span. The polder system was endorsed in the plan to protect the central from flooding from outside area. The polders were subdivided into 6 drainage based on the previous studies and protected by a secondary flood barrier installed around the area. The secondary flood barrier, called inner dike, is installed by raising level of the roads for flood wall. Stormwater inside the polders is drained directly to the Chao Phraya River from the drainage pump stations. In addition to 5 existing pump station at the time, 11 drainage pump stations were proposed with the capacity ranging from 10 to 35 m3/s.

4) Master Plan and Feasibility Study on Flood Protection/Drainage Project in Eastern Suburban - Bangkok, JICA (1986)

This master plan consisted of structural and non structural measures to provide adequate flood protection and drainage methods and to study Bangkok's flood management organization and management structure. Based on the recommendation in this study, many projects were carried out for the area of 260 km2 located in the east side of the central area of Bangkok.

The structural elements of the plan consist of endorsing the polder system, strengthening drainage system by pumps and diversion gates, and non-structural measures to mitigate flood flow by the idea of flood plain management by the retention ponds and natural retardation area such as swamps, ponds, borrow pits and other open fields scattered in the east side of the polder. Most of the existing flood protection and drainage facilities in the East Bank are were developed based on this plan.

Also implemented from this plan is the Bangkok Metropolitan Flood Control Center (FCC) now operated by DDS in BMA 2 City Hall. The FCC was designed to establish on-line monitoring of the information such as water level etc. related with flooding condition in the central area of Bangkok. Twenty five monitoring stations are now in function at the major drainage pump stations and water gates in the area covering about 600 km2. Each monitoring station equipped with a) rain gauge, b) water level gauge, c) pump operation gauge, d) water-gate opening detector, and e) water quality meter. Data from the monitoring station is recorded and transmitted automatically to FCC by telemetering system utilizing TOT leased line. FCC receives data telemetricaly from the 25 monitoring stations. The data are processed and displayed on the graphic panel to monitor the flood situation in all over the monitoring area.

5) The RID-Plan (1985)

The Royal Irrigation Department (RID) encompassed a regional flood control in the west side of the Chao Phraya, extending from north of Ayutthaya and continuing south to the Gulf of Thailand and extending west to the Tha Chin River. The system consist of construction of dikes enclosing the area between the Chao Phraya and Tha Chin rivers along the Khlong Phraya Banlu and Khlong Phra Pimon. The plan proposed to construct 2 control gates, 12 pumping stations and dredging of canals in the area between the Chao Phraya River and the Tha Chin River.

6) Study on Tawee Wattana by AIT (1985)

This study encompassed the planning in the western side of the Chao Phraya River expanded to the Tha Chin River in the south of the Khlong Maha Wawat covering 500 km2. The plan intended to strengthen drainage capacity by connecting the Khlong Tawee Wattana with the Khlong Khoon Ratpinidjai and drain to the sea. Result of the study shows that the plan is not feasible because of a lack of hydraulic gradient and a polder system was proposed even in the this area. The polder dikes were proposed in line with the 1985 RID Plan.

7) Alternative Flood Control Schemes Proposed by AIT (1985)

AIT conducted a study of several alternative flood control measures and recommended several measures. The study examined the change in water levels and flood periods in the Chao Phraya River assisted by the proposed alternatives. These alternatives include ;

- Cutoff channel for the Chao Phraya River at Phra Pradaeng to shorten the length of the river to increase carrying capacity and lower water level as well.
- Construction of by-pass floodway with the carrying capacity 500 cum/s along the East Bank of the Chao Phraya River from Ban Mai to the sea in the east of Samut

Prakan, and

- Construction of dikes along the Chao Phraya River from Bangsai to the estuary and dredging the river from Pakkret to the estuary.

The study concluded that a by-pass channel with a 500 cum/s capacity is the best alternative although it was projected to improve the flood peak condition by a small amount because of the strong tidal influence.

8) Chao Phraya 2 (1986)

The Chao Phraya 2 study formally named the Bangkok Flood Protection, Chao Phraya 2 Feasibility study was prepared by the Thai Austrian Consortium in cooperation with the Asian Institute of Technology in July 1986. This study aimed at developing an integrated flood control plan by reviewing all the previous flood protection and drainage plans and developed a comprehensive flood control program. The study covered the area including Bangkok and the vicinity area.

This plan recommended to lower the water levels in the Chao Phraya River by constructing a diversion channel around the western side of the city. Water levels in the city would be controlled with two control structures. The upper control structure would be located at Bangsai and divert peak flows into the diversion channel to carry flood flow nearby the estuary nearby estuary of the Chao Phraya River in the West Bank. The control structure located in the down-stream side consist of a sea-barrier structure. The structure prevent sea water intrusion to the Chao Phraya river and to the khlongs in high tide period.

9) Master plan for Flood Protection and Drainage of Thonburi and Samut Prakan West by NEDECO and SPAN CO, Ltd. (1987)

The NEDECO study cover the study area of 432 km2 on the west side of the Chao Phraya River. This study analyzed multiple alternatives and developed a plan maximizing flood protection inside of the protected area while minimizing impacts on the areas outside of the flood protection dikes. The aim of the recommendations is to control inflow of flood water from outside the polder and to drain excess stormwater inside of the polder.

The master plan was developed to cover 135 sq.km of the study area and recommended alternatives including construction of new or raising existing flood barriers around and throughout the study area, and construction or rehabilitation of regulation water gates in the khlongs.

The study determined the best alignment for the surrounding flood barrier onto the Southern Railway in the north side, the Chao Phraya River in the east side and generally along the Khlong Sanam Chai in the south side. Two locations were investigated for the western boundary. The first location was recommended to set the flood barrier along the Tha Chin River, however, the plan was not adopted because of the urgency to improve the flood situation and construction cost of the barrier along the Tha Chai River. Instead, the interim barrier along Phutthamonthon sai 4 Road and Soi Bang Bon 3 was recommended and constructed. Approximately seven kilometers of the inner flood barriers were recommended located along the Khlong Dan in Bang Khun Thian, along the Khlong Bang Khun Thian, along the Chao Phraya River, and across Amphoe Phra Pradaeng.

Regulators and flood control gates were also recommended on the Khlong Maha Sawat, along the Khlong Chak Phra, on the Khlong Sanam Chai, on the Khlong Bang Khun Thian, along the Khlong Ratburana, and on the Khlong Lat Luang.

5.3 Policy Direction and Planning Issues

To formulate the urban environmental improvement program for BMA Area, the following issues are raised for discussion to attain the role of the flood protection and drainage faciliitiies in the area.

(1) Flood Control Plan in Low Area Along the Chao Phraya River

Low lying area along the Chao Phraya River suffer floods problem as the river water overflow from the low sections of the embankment walls. Arguments is now being raised to raise the flood protection walling, embankment, to the level at 2.5 m MSL along both sides of the banks of the Chao Phraya River in the section from Bang Khaen to Bang Na.

This plan shall be carefully studied together with the comprehensive flood control analysis in the river basin against the probable influence to the upper stream reaches and the countermeasures, periodical dredging plan for the Chao Phra River, etc.

(2) Flood Control Plan in BMA Area

Installation of the drainage facilities in Bangkok side has been completed with the major facilities and shifted to development of the facilities in the subdrainage areas. In Tonburi side, construction projects of the main pumping stations have started development since merely in 10 years ago and the projects shall be continued and be accelerated from now on.

Structural measures have took an effect on flood protection with the capacity as it is. Flood flow increase in the recent years tend to exceed the capacity of the existing facilities. Destruction of the tropical forest and land development projects cause more stormwate flow discharge in nowadays. Flood protection and drainage plan in future shall be associated with the non-structural, soft measures, to control stormwater run off in the river basin planning.

Vacant areas or the occupied areas squatters exist along both sides of the khlongs can be developed for retention ponds. Development of the retention pond in small area may be constructed a deeper pond by diaphragm wall method.

Abandoned sand borrow pits scattered in the north east of Bangkok, Min Buri, Nong Chok districts are also expectable for the retention ponds. The borrow pit of the area 100 rai, or 16 ha, can store water more than 1 million cum since , generally, the pit is dug to the sand stratum which lies at the level approximately 20 to 25 m below the ground level. The stored flood water may be discharged back to the khlongs or utilized for groundwater recharging purpose. Those deep retention pond plan shall be required to design by gravity inflow and pumping out flow systems.

Bangkok Plan presented 14 places of the existing and proposed retention area having the total area of approximately 400 ha or the storage volume of 16 million cubic meter. The plan envisage the retention area using as the public parks in dry season.

Those retention area will be functioned effectively to cut the peak flow discharge in the subdrainage area to minimize an excessive investment as designed by the peak flow. The main drainage system shall be reviewed to maximize the flood water carrying capacity by the network of khlongs and the pumping stations. A comprehensive flood control management system shall be established including the flood plain management covering each subdrainage area.

DDS, BMA is conducting a review study over the whole BMA Area except for the eastern part of the King's Dike by the contract with a associated group of the consultant companies. Points of reviewing the flood control system shall include review of the runoff coefficient, the capacity of existing canals and pumping stations of the main drainage systems and subdrainage systems, coordination with the on-going sewage projects, introduction of flood plain management plan, selection of feasible stormwater retention areas or ponds, review of the flood protection polders in connection with the flood protection plan in outer area, etc.

(3) Flood Control Plans in Eastern Suburbs and Western & Northern City Boundaries

Applying the concept of hierarchy system into the planning, the primary drain and the tirtially drain may be located with the Chao Phraya River and the khlong network in the city area. However, the effective secondary drain can not be located in both of the East and West banks. The Khlong Thanon, Khlong Lat Phrao, Khlong Saen Saep, Khlong Tan and Khlong Prakanong line in the East Bank and the Khlong Tawee Wattana, Khlong Phasicharoen, Khlong Sanam Chai, Khlong Maha Chai or, Khlong Khoon Ratpinidjai line may be functioned as the secondary drain. However, these floodways do not function well due to the scale and the installations against flood control measures.

Installation of the secondary drain or called the floodway holds a key to solve the flood problem in BMA Area drastically. The Gham Ling project in the West Bank and the floodway project targeted for the conservation in the East Bank and New Bangkok International Airport can be developped to have a function for the secondary drain. What is called the Chao Phraya River 2 Plan has been in discussion from time to time for more than 20 years but the plan was not implemented due to difficulty in land acquisition and financial burden. It is about the time to spotlight onto this plan as to attain a sustainable development of the city of Bangkok in the next centuries.

The Royal Irrigation Department (RID) is conducting study and construction of the facilities in cooperation with DDS, BMA, Public Works Department(PWD), Ministry of Interior and other government agencies concerned. These projects mentioned above, initiated by the King, basically consist of securing the floodways connected to the sea and the flood plain management by the retention ponds, are the main subjects to be studied in detail. with the topics including as follows.

Widening and improvement of the existing khlongs will be the practical way to secure the flood ways running to the coastal area at Samut Prakarn in the East Bank and at Samut Sakhon in the West Bank.

In the eastern suburbs, Khlong Nguhao and Khlong Jorake Yai have high potential conditions to achieve the objectives. These khlongs are running across the site of new international airport, Nong Nguho, however these alignment of the khlongs will be replaceable by designing the ditches surrounding the airport to carry stormwater discharge from the eastern suburbs.

(4) Strategic Plan in The 5th BMA Five Year Development Plan

The programs were drafted by the Department of Drainage and Sewerage, BMA to develop, operate and maintain the flood protection and drainage facilities to protect the city from flood damages. The coming Five Year Plan is emphasized on construction of flood protection and drainage facilities in Thonburi side since the major part of the system in Bangkok side has been constructed in the previous and current Five Year Plans. In Bangkok side, flood control is practiced by introducing the flood plain management to retard stormwater runoff to cut peak flow and release in low water level period of the floodway. The major development projects in the Five Year Plan were listed below and summarized in the following paragraphs.

Program 1:	Flood Plain Management
Program 2:	Construction of Drainage System in Phra Nakhon (Bangkok) Side
Program 3:	Construction of Drainage System in Thonburi Side
Program 4:	Construction of Embankment along the Chao Phraya River in Bangkok Section and Khlong Bangkok Noi
Program 5:	Construction of Flood Protection Barrier in Southern Thonburi

Program 6: Construction of Flood Protection and Drainage in Bang Phlat and Bangkok Noi Districts
Program 7: Survey, Study and Preparation of Master Plan for Sub-Polder System in Bangkok and Thonburi
Program 8: Development and Improvement for Cleansing and Beautification of Khlongs in Whole Bangkok Area

Activities of the Strategic Plan

Program 1: Flood Plan Management

1) Procurement of Public and Private Lands for Stormwater Retention
2) Improvement of the Existing Flood Wall, Ponds, etc. to dam up water for Flood Protection
3) To specify the Preservation Areas for Stormwater Retention
4) To install Signboards at the Flood Risk Areas
5) To mark Flood Water Levels in the Past
6) To Prepare Flood Risk Area and Flooded Area Maps

Program 2: Construction of Drainage System in Phra Nakhon(Bangkok) Side

1) To support Main Drainage System in Urgent Period by providing stormwater retention areas at Nong Bon Pond,, Phibulwattana Pond, Krom Prachasamphan Pond and Phong Krathiam Pond to save budget for reducing the scale of Pump Station, Large Drainage Pipes and Gates
2) To improve inner drainage system by dredging and construction of Drainage Tunnel to discharge stormwater efficiently to the River and Sea

Program 3: Construction of Drainage System in Thonburi Side

1) To improve drainage system in Phetkasem Road, Buddha-Monthol Road, Pinklao-Nakhon Chaisri Road, Charoen Nakhon Road, etc. where suffering flood damages every year
2) To improve main drainage khlongs by constructing concrete retaining wall, pump stations, gates and drainage pipes
3) To provide retention area for supporting and increasing efficiency of drainage system

Program 4: Construction of Embankment along the Chao Phraya River in Bangkok Section and Khlong Bangkok Noi

1) Construction of Embankment approximately 37 km including appurtenances such as walkway etc. in East Bank of the Chao Phraya River
2) Construction of Embankment approximately 18.3 km including appurtenances such as walkway etc. in West Bank of the Chao Phraya River
3) Construction of Embankment approximately 5.6 km including appurtenances such as walkway etc. in along the Khlong Bangkok Noi in Thonburi

Program 5: Construction of Flood Protection Barrier in Southern Thonburi

1) Construction of 18 water gates and one pumping station in Bang Khun Thian, Nong Khaem and Ratburana areas
2) Construction of Embankment approximately 4 km in Nong Khaem
3) Construction of 4 water gates in Bang Khun Thian
4) Construction of flood wall approximately 6 km in Bang Khun Thian to prevent waste water flowing into animal farms

Program 6: Construction of Flood Protection and Drainage Facilities in Bang Phlat and Bangkok Noi Districts

1) Construction of embankment approximately 17.3 km along the Chao Phraya River and the Khlong Bangkok Noi
2) Construction of 51 gates and pumping station
3) Improvement of the khlongs approximately 33.9 km
4) Installation of drainage pipes approximately 47.4 km
5) Improvement of drainage pipes approximately 48.8 km

Program 7: Survey, study and preparation of Master Plan for sub-polder system in Bangkok and Thonburi

1) Study and formulation of Master Plan for sub-polders in BMA area except some part of Bang Phlat and Bangkok Noi
2) Feasibility Study of the projects and prioritization
3) Detail design of sub-polders including water gates, pumping stations, improvement of the khlongs, etc.
4) Preparation of tender documents for construction works
5) Preparation of existing and proposed drainage system maps

Program 8: Development and Improvement for cleansing and Beautification of the khlongs in BMA Area

1) Development, cleansing and improvement of the khlongs not less than 933 khlongs in 38 districts
2) Beautification, provision of relaxation spots, water transportation and drainage functioning

5.4 Planning Targets and Framework

(1) Planning Targets

Establishment of the system of "Flood-Free Urbanization" is not achieved simply by installing the flood control facilities but it will be required to take measures for overflow problem from the Chao Phraya River and urban growth control measures to minimize increase of run off coefficient. The planning issues discussed earlier including development of flood protection and drainage facilities, land use control and urban growth management are the key elements to take comprehensive measures against flooding in BMA Area.

Accordingly, the target for planning of the flood protection and drainage system shall be put basically on the point to take measures against the causes of man-made flooding as well as against the natural-cause flooding to create " Flood-free Urbanization " for the next centuries and the drainage facilities may be designed to 5 year probability rainfall intensity for practical means.

(2)Proposed Action Plan to Achieve the Targets

As described earlier, the action plans for flood protection work shall be prepared on the view point to take measures for both natural and artificial causes to create " Flood-free Urbanization " for BMA Area and the surrounding provinces. To this target, the Study Team proposed the action plans presented as follows.

1) For Development of Flood Protection and Drainage Facilities

Action Plan 1 : Flood Control Plan in Low Area along the Chao Phraya River

Present Situation as of 1995

- Due to increase in stormwater run-off and high tide, the flowrate of the Chao Phraya River exceeded the maximum carrying capacity, thereby resulting in water level rise and overflow
- Embankment along the lower Chao Phrarya River section is not always high enough to protect the area from inundation in high water period in the end of wet season

Action Plan during 1997 - 2001

- Implementation of the urgent projects to raise the embankment level along the Cho Phraya River and Khlongs in Bang Phat, Bangkok Noi, and Bangkok Yai districts
- Formulation of Comprehensive Water Management and Flood Control Master Plan in the Lower Chao Phraya River Basin in collaboration with RID/PWD
- Start construction of the floodwall water diversion project based on the recommendations of the Master Plan in collaboration with RID/PWD

Action Plan during 2002 - 2006

- Continuation of the flood water diversion project based on the recommendations of the Master Plan in collaboration with RID/PWD

Action Plan 2 : Flood Control Plan in the Polder System (Draft Plan)

Flood protection and drainage facilities inside of the polder system have been developped for its major facilities and have functioned for drainage in the central part of the city. Construction works is shifting to the development projects in the sub-drainage area and improvement of the existing facilities as well.

Action Plan 2 endorse those strategic plans proposed for the 5th Five Year Plan and at the same time add the non-structural measure projects to be developped together with the future land use planning. The flood plain management planning shall be implemented in collaboration with the authorities concerned with the city planning and land procurement.

Note) Action Plan 2 will be adjusted waiting for the on-going study reviewing the Master Plan in Eastern Suburbs expected to be finalized in two moths

Present Situation as of 1995

- Main part of the BMA Area is protected by the polder systems
- Major drainage facilities in the East Bank have almost completed and the development projects are underway in the East Bank
- Stormwater run-off tend to increase caused by urbanization
- The Flood Control Master Plan for the East Bank is now being reviewed to meet with future urbanization condition and land use patterns

- Settlements and foreign matters sometimes block the drainage system and cause of flooding in local areas

Action Plan during 1997 - 2001

- Complete the projects in sub-drainage areas in the East Bank
- Accelerate the development projects in the West Bank
- Land inventory survey and procurement of sites for flood water retardation purpose
- Implementation of the urgent projects proposed in the master plan for Flood Protection and Drainage Systems in Eastern Suburban
- Review of the flood control Master Plan in the West banks
- Implementation of the flood plain management projects in suburban areas and drainage control linking with the main drain system in the East Bank
- Strengthening of the flood control center for regional level flood monitoring and forecasting
- Strengthening of cleaning and dredging work for drain pipes and khlongs

Action Plan during 2002 - 2006

- Implementation of the flood plain management projects based on the proposed plan in the revised Master Plan for the West Bank linking with the main drain system
- Completion of the flood plain management facilities in the East Bank
- Continuous operation and maintenance of the flood protection and drainage facilities both in the East and West banks

Action Plan during 2007 - 2011

- Completion of the flood plain management facilities in the West Bank
- Operation and maintenance of the total flood control system supported by the facilities developed for the structural and non-structural measures

Action Plan 3 : Flood Control Plans in Green Area and City Boundary Area

Present Situation as of 1995

- Drainage system in the Green Area and out side of the polder system in the surrounding area the BMA city boundary are not adequate and ineffective
- Stormwater flow is interrupted by the dikes and flood control gates and thereby causing severe flooding problems in outside of the polders

Action Plan during 1997 - 2001

- Land inventory survey along the routes of the floodways based on the comprehensive flood control Master Plan
- Design of the floodways in the East Bank
- Planning and design of the flood management facilities
- Review of the Gham Ling Project and strengthening the system if necessary

Action Plan during 2002 - 2006

- Design of the floodways in the West Bank
- Start construction of the floodways in the East Bank
- Start construction of the flood plain management facilities in the East Bank

Action Plan during 2007 - 2011

- Start construction of the floodways in the West Bank
- Completion of the floodways and full system operation & maintenance
- Completion of the flood plain management facilities in the West Bank

- **For Rational Priority of Urbanization Process**

Action Plan 4 : Control of Land Development Projects to Minimize Stormwater Run Off

Present Situation as of 1995

- Stormwater run-off is increasing due to uncontrolled land development without flood protection measures
- The current standards are not enforced effectively to regulate stormwater flow

Action Plan during 1997-2001

- To study the Building Code and the relevant Laws, Royal Decree, regulations, standards to add, alter or modify the articles to cope with increase of run-off coefficient caused of land development projects
- Enforcement of the Building Code for the land development projects to obligate installation of stormwater regulation facilities

Action Plan during 2002 - 2006

- Review of the situation of enforcement of the Building Code and adjustment if necessary
- Continuous administrative control for the land development projects
- **For Control of Environmentally Preserved Land**

Action Plan 5 : Urbanization Control in the Green Area to Conserve Stormwater Retention Area

Present Situation as of 1995

- Urbanization is in progress in the Green Area
- Current Bangkok City Plan or the General Plan, is not always effectively enforceable to control land development projects in the Green Area

Action Plan during 1997-2001

- Authorization of the land use plan in the Bangkok City Plan
- Establishment of a standardized control system for land development projects in respect of flood control
- Restriction of land development projects in the Green Area

Action Plan during 2002- 2006

- Review of the land use plan and adjustment if necessary
- Review of the land development regulations and adjustment if necessary
- Maintenance and conservation of stormwater retention area

CHAPTER 6: WATER QUALITY

6.1 General

Water quality survey was carried out to document a state of current water pollution problems in the Khlongs in BMA Area. In addition, water samples were collected from waste water discharge points and from drainage pipes to make a use of water pollution load analysis. Actual survey works for sampling and water quality tests were sublet to the Thai environmental consultant company to conduct the services under the direction of the JICA Study Team with a support and cooperation provided by Department of Drainage and Sewerage (DDS), BMA.

The first survey, Water Quality Investigation on Major Khlongs in BMA were carried out through water sampling from 28 points out of the khlongs and the Chao Phraya River for wet and dry season, started in November 1995 and finished in February 1996 Meanwhile, the other survey, Investigation on Prediction of Water Pollutants Loads in BMA Area, was carried out during from January to March 1996 with 53 sampling points by which the water samples can represent the source of each type of wastewater.

In addition to the field surveys conducted in connection the study concerned, past datum were collected for water quality in the city khlongs and the Chao Phraya River respectively from DDS, BMA and Pollution Control Department (PCD), Ministry of Science, Technology and Environment.

The results of the survey were analyzed and presented the summary as shown in the following sections.

6.2 Water Quality Survey in the Major Khlongs in BMA Area

(1) Purpose

This water quality test was conducted at the representing points of the major khlongs running in both banks of the Chao Phraya River. The survey is aiming at investigate distribution of the water pollution area in the city and check the seasonal differences between the wet and the dry seasons. In addition, the existing past test records were collected from DDS and analyzed for searching the tendency of the elapsed-time changes of water pollution from the past to the present days.

(2) Conditions of Investigation

Water sampling, test and analysis are conducted based on the following conditions:

1)Sampling Points

Khlongs in Bangkok Side	:	13 points
Khlongs in Tonburi Side	:	10 points
Chao Phraya River	:	5 points
Total	:	28 points

2) Frequency of Sampling

Wet Season 1 time and Dry Season 1 time

Water sampling in dry season was conducted during 7 to 20 November, 1995 in consideration to avoid the abnormal high water level conditions in this year. Meantime, Water sampling for the dry season was carried out during 6 to 16 January ,1996.

3) Water Quality Parameters

pH/ DO/ PO4/ NH4/ NO3-N/ Tr/ COD/ T-Cr,T-CN/ Pb for each water sample

4) Test Device

Water Test Kit, KYORITSU Model M-WAL-M

(3) Water Quality Test Results

Fig. 6.1 (1/2) & (2/2) show the summary results of the surveys conducted by the Study team. The figures show the relative level of water contamination expressed with DO and COD observed in wet and dry seasons.

1) Test results in Wet Season

From the test results, the higher concentration areas are spreading considerably over the central areas in Bangkok and Tonburi sides judging from the indices of Dissolved Oxygen (DO) less than 5 mg/lit and of Chemical Oxygen Demand(COD)more than 30 mg/lit. Out of the total 28 water sampling points, 17 points shows less than 5 mg/lit in DO and 8 points exceed 30 mg/lit in COD. All the 8 higher COD points coincided with the lower DO points.

Sampling points in the north-east of Bangkok , Lat Krabang, Min Buri, etc. and the north city boundary of Tonburi in Taling Chan, do not show remarkable water contamination in wet season.

In the previous years, the khlong water quality in the eastern suburbs of Bangkok had been improved in wet season and this is because of the inflow from the eastern khlongs. But water quality in this year deteriorated because of control of water gates in the eastern suburbs to stop inflow to the minimum extent for protection of the central area of Bangkok from flooding or due to increase of water pollution loading. Whatever may be the causes, it seems that the water pollution area is expanded to the suburbs gradually by keeping the same direction and pace of urbanization.

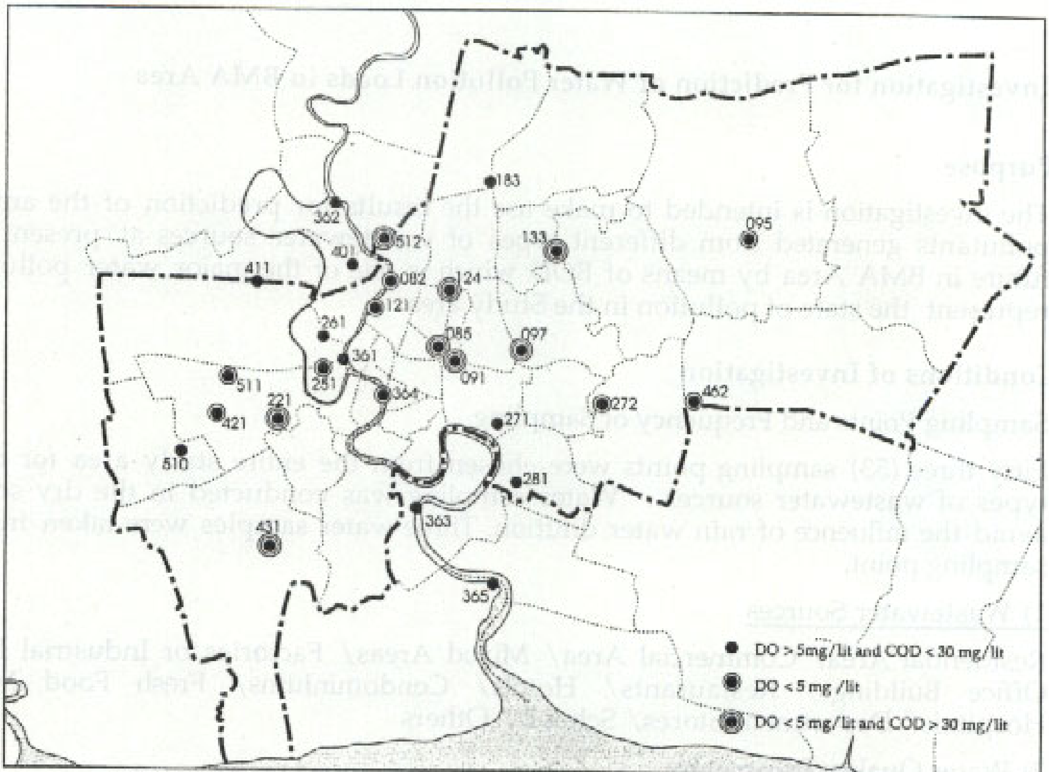
2) Test Results in Dry Season

The water quality survey in dry season was conducted by the Study Team at the same sampling points conducted in wet season. Out of the total 28 water sampling points, 20 points shows less than 5 mg/lit in DO and 10 points exceed 30 mg/lit in COD. All the 10 higher COD points coincided with the lower DO points.

As well as the results in dry season, the sampling points in the north-east of Bangkok, Lat Krabang, Min Buri, etc. and the north city boundary of Tonburi side in Taling Chan, do not show a sign of serious water contamination in dry season.

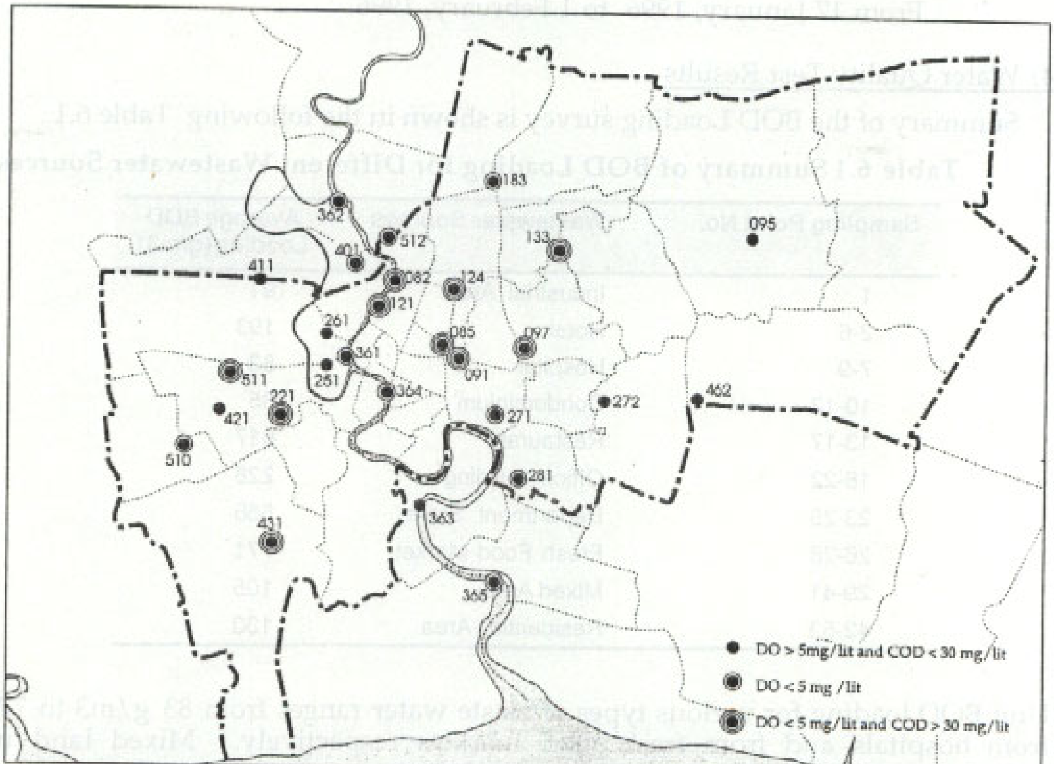
3) Comparison of Water Quality in Wet Season and Dry Season

Water quality test results conducted by the study shows that 10 sampling points are in worse condition in dry season compared with 8 sampling points in wet season. The result do not indicate any significant improvement in wet season through rainfall. But, on the contrary, unlike the normal phenomena observed in BMA, water quality in the far eastern part of the BMA Area is improved in dry season. This phenomena may be due to control of water gates close in wet season and open in dry season and water pollutants are diluted by the flow entering from the eastern khlongs in dry season but the flowrate may be too low to be effective for entire zone.



Water Quality Test Result in Major Klongs & Chao Phraya River (Wet Season Investigation : 7 to 20 November, 1995)

Fig. 6.1 (1/2) Water Quality Test Result in Major Khlongs and the Chao Phraya River(Wet Season)



Water Quality Test Result in Major Klongs & Chao Phraya River (Dry Season Investigation : From 6 to 16 January, 1996)

Fig. 6.1 (2/2) Water Quality Test Result in Major Khlongs and the Chao Phraya River(Dry Season)

6.3 Investigation for Prediction of Water Pollution Loads in BMA Area

(1) Purpose

The investigation is intended to make use the results for prediction of the amount of pollutants generated from different types of watstewater sources at present and in future in BMA Area by means of BOD which is one of the major water pollutants to represent the state of pollution in the Study area.

(2) Conditions of Investigation

Sampling Points and Frequency of Sampling

Fifty three (53) sampling points were chosen from the entire study area for different types of wastewater sources . Water sampling was conducted in the dry season to avoid the influence of rain water dilution. Three water samples were taken from each sampling point.

1) Wastewater Sources

Residential Area/ Commercial Area/ Mixed Areas/ Factories or Industrial Estates/ Office Buildings/ Restaurants/ Hotels/ Condominiums/ Fresh Food Markets/ Hospitals/ Department Stores/ Schools/ Others

2) Water Quality Parameters

pH/ BOD/ COD/ SS/ DO/ T-N/ T-P/ Flowrate

3) Sampling Period

From 17 January, 1996 to 1 February, 1996.

4) Water Quality Test Results

Summary of the BOD Loading survey is shown in the following Table 6.1.

Table 6.1 Summary of BOD Loading for Different Wastewater Sources

Sampling Point No.	Wastewater Sources	Average BOD Loading (g/m3)
1	Industrial Area	91
2-6	Hotel	193
7-9	Hospital	83
10-12	Condominium	85
13-17	Restaurant	617
18-22	Office Building	228
23-25	Department Store	556
26-28	Fresh Food Market	771
29-41	Mixed Area	105
42-53	Residential Area	130

Unit BOD loading for various types of waste water ranges from 83 g/m3 to 771 g/m3 from hospitals and from fresh food markets respectively. Mixed land use area including commercial area, offices, hotels, department stores, etc., shows 105 g/m3 in terms of unit BOD loading in average. Meanwhile, waster water discharged from residential area including housing estates, town houses and single houses indicate 130 g/m3. Table 6.2 tabulate the process of unit BOD loading calculation.

Table 6.2 Calculation of BOD Loading for Different Wastewater Sources

Sampling Point No.	Flowrate (m3/day)	BOD5 (mg/lit.)	BOD Loading (kg/day)	WasteWater Sources	Avg. Unit BOD Loading (g/m3)	Remarks
1	15850	91	1442.350	Industrial Area	91	
2	320	230	73.600	Hotel	193	
3	517.8	360	186.408	Hotel		
4	650	140	91.000	Hotel		
5	703.6	47	33.069	Hotel		
6	511.6	270	138.132	Hotel		
7	150	190	28.500	Hospital	83	
8	6000	80	480.000	Hospital		
9	305.3	96	29.309	Hospital		
10	225	49	11.025	Condominium	85	
11	252.7	44	11.119	Condominium		
12	272.8	154	42.011	Condominium		
13	69.4	650	45.110	Restaurant	617	
14	46.8	617	28.771	Restaurant		
15	48.6	800	38.880	Restaurant		
16	54.4	470	25.568	Restaurant		
17	68.7	572	39.296	Restaurant		
18	96.2	53	5.099	Private Office	228	
19	223.7	68	15.212	Private Office		
20	481.2	58	27.910	Private Office		
21	304.6	720	219.312	Private Office		
22	158.3	130	20.579	Private Office		
23	174.8	480	83.904	Department Store	556	
24	413	530	218.890	Department Store		
25	450	610	274.500	Department Store		
26	128.7	910	117.117	Fresh Foods Market	771	
27	20.5	388	7.954	Fresh Foods Market		
28	20.4	280	5.712	Fresh Foods Market		
29	51.4	140	7.196	Mixed Area I (-)	71	105
30	73.5	100	7.350	Mixed Area I		Avg. of Mixed Area
31	11.6	260	3.016	Mixed Area I		
32	16.7	24	0.401	Mixed Area I		
33	179.5	64	11.488	Mixed Area II (-)	58	
34	222.6	66	14.692	Mixed Area II		
35	123	31	3.813	Mixed Area II		
36	430	126	54.180	Mixed Area II (-)		
37	468	126	58.968	Mixed Area II		
38	34	110	3.740	Mixed Area III	154	
39	47.2	154	7.269	Mixed Area III		
40	51	190	9.690	Mixed Area III		
41	21	140	2.940	Mixed Area III		
42	1300	144	187.200	NHA	130	
43	5000	100	500.000	NHA		
44	2161	190	410.590	NHA		
45	108	112	12.096	School	107	
46	45	119	5.355	School		
47	99	97	9.603	School		
48	0.58	111	0.064	Town House	85	
49	0.47	61	0.029	Town House		
50	0.68	79	0.054	Town House		
51	1.8	120	0.216	Single House	146	130
52	2.07	250	0.518	Single House		Avg. of Residential Area
53	1.9	58	0.110	Single House		NHA,Town House, Single House

(3) Khlong Water Quality Monitoring Data by DDS

Water quality monitoring data of the khlongs in BMA area during the last 6 years from 1990 to 1995 was collected from DDS, BMA for more than 228-550 water samples from 73 monitoring stations located in major khlongs in BMA Area and analyzed for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD5) as indicated in the following paragraphs.

1) Trend of Annual Water Quality Change

Fig. 6.2 indicate annual changes of average DO and BOD values for all the data in each year. In the last 6 years, DO change from 0.66 to 1.88 mg/lit and BOD change from 24.45 to 23.43 mg/lit with the highest value at 29.94 mg/lit in 1992. in the last 6 years. Judging from these values, water pollution level is high but there is a sign of water quality improvement in the city khlongs in BMA Area.

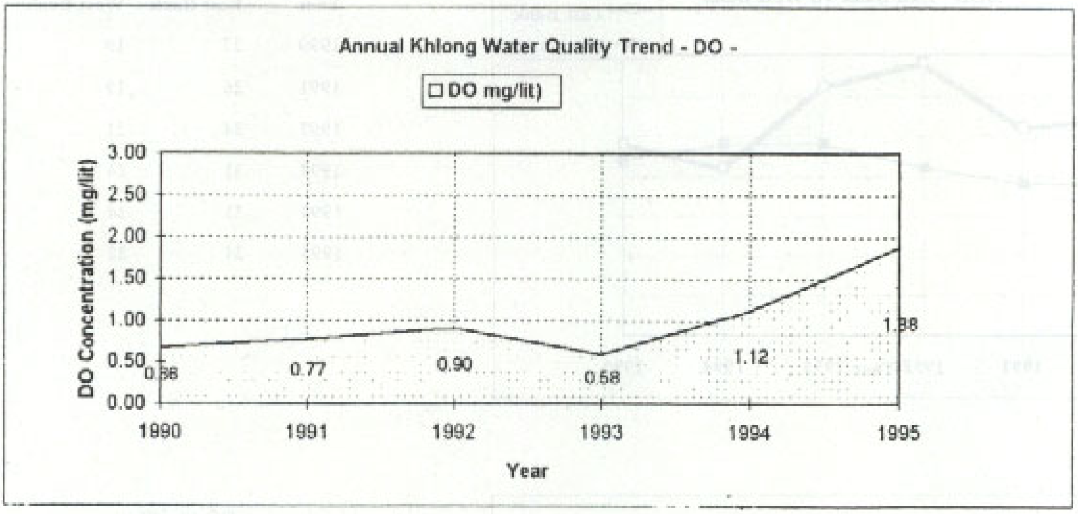
2) Water Quality in the East and West Banks

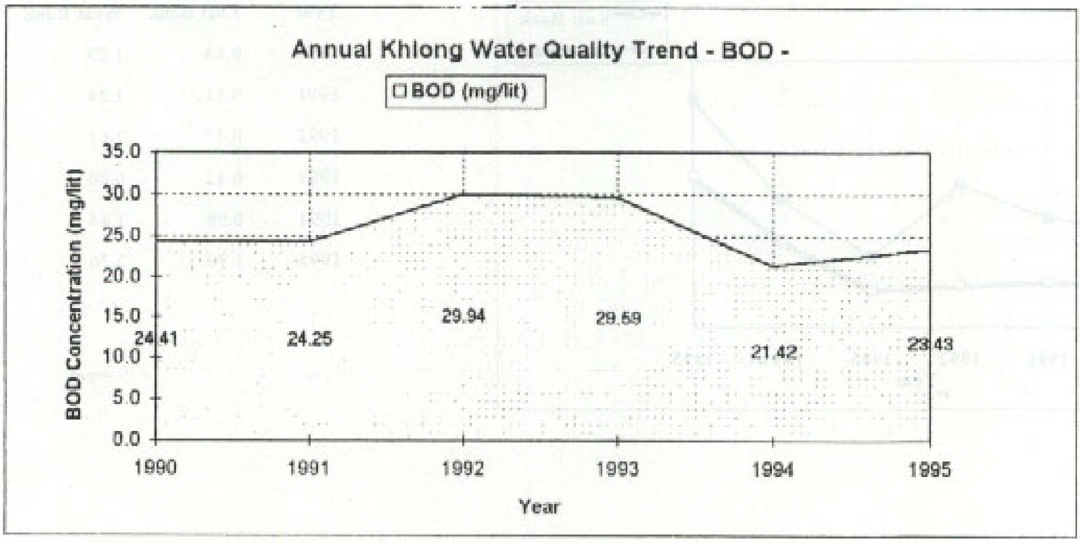
Difference of water quality in the khlongs between the East Bank, Bangkok side and the West Bank is indicated in Fig. 6.3. DO in the East Bank change from 0.43 to 1.70 mg/lit, whereas DO in the West Bank changes from 1.09 to 2.56 mg/lit with the lowest annual average value at 0.80 in 1993. Meanwhile, BOD in the East Bank changes from 27 to 24 mg/lit and it changes from 19 to 22 mg/lit in the West Bank. Representative water quality parameters, DO and BOD, shows that the water quality in the East Bank is slightly worse than that in the West Bank. Water quality shows somewhat improvement in both Bangkok and Tonburi sides but the level of water pollution is still high for the people residing along the khlongs to live a comfortable life.

3) Water Quality in Wet and Dry Seasons

Trend of water quality differences between the wet and dry seasons were analyzed and summarized in Fig. 6.4. As learned it from the graphs, there is no distinctive difference between the seasons. That means, even in the wet season the level of water quality does not improved from high pollution level throughout the BMA Area. However, on the contrary, close observation on the khlongs in Rathanakosin Area show that the water quality in dry season is improved with the effect of introduction of the Cho Phray river water into the khlongs operated by DDS since 1990 for flushing or dilution of water pollutants. In other words, the Khlong Water Quality Improvement Project is effective to keep a possible water quality deterioration in dry season to almost the same water pollution level in wet season.

Fig.6.5 (1/2) & (2/2) show the water quality test data analyzed for the seasonal change for the year 1995. Four teen (14) points out of twenty (20) points show less than 2 mg/lit in DO and higher than 15 mg/lit in BOD in dry season. In wet season, the number of water contamination point increased by one(1) point and become fifteen (15) points. As well as the results mentioned above, seasonal change is not clearly shown in the figure but the water pollution areas are observed over the widely spreaded area in both Bangkok and Tonburi area.



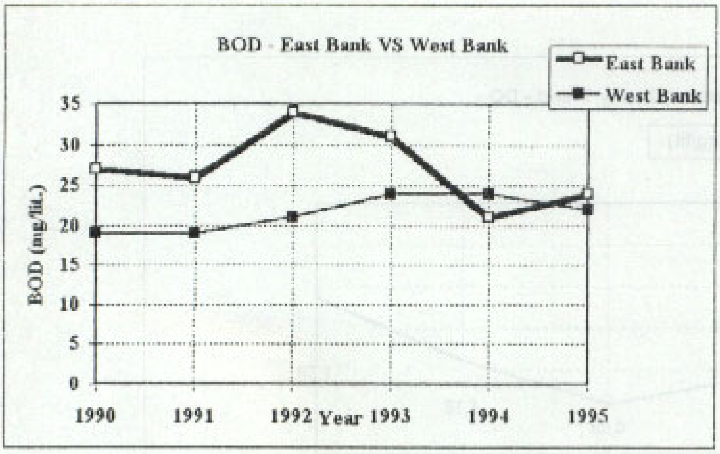


	Water Quality Parameters		Nos. of Sampling Points	Nos. of Samples	
Year	DO (mg/lit)	BOD (mg/lit)		for DO	for BOD
1990	0.66	24.41	73	514	550
1991	0.77	24.25	73	473	476
1992	0.90	29.94	73	288	301
1993	0.58	29.59	73	228	231
1994	1.12	21.42	73	234	240
1995	1.88	23.43	73	342	345

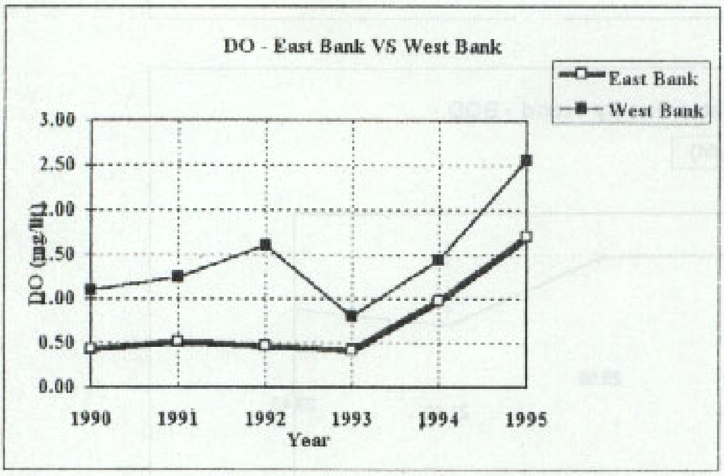
Note : BOD stand for Biochemical Oxygen Demand

DO stand for Oxygen Demand

Fig. 6.2 Trend of Water Quality in the Major Khlong of BMA Areas during 1990-95

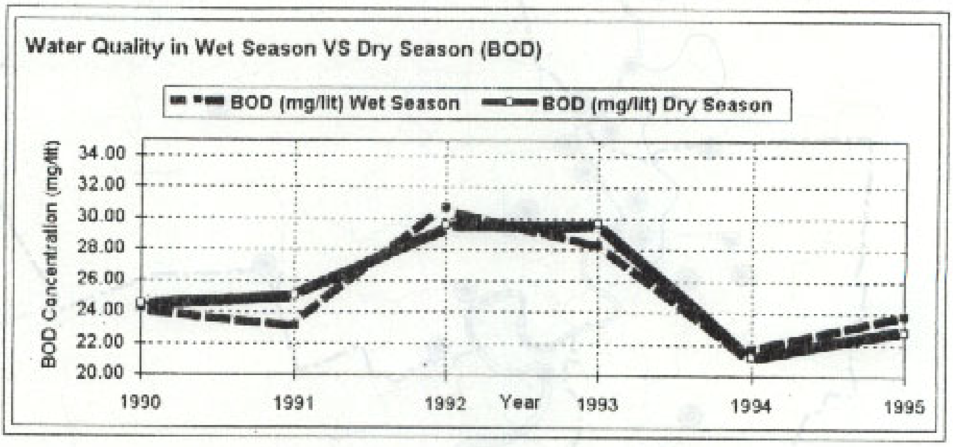


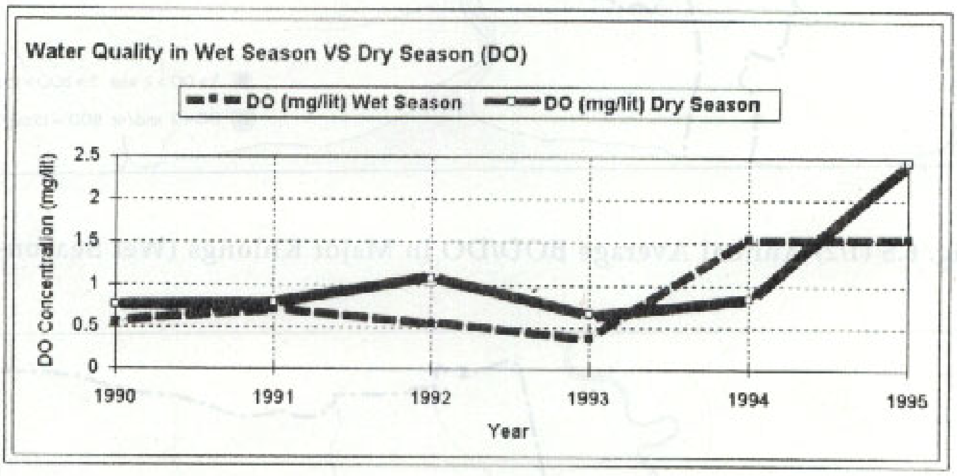
BOD (mg/lit.)		
Year	East Bank	West Bank
1990	27	19
1991	26	19
1992	34	21
1993	31	24
1994	21	24
1995	24	22



DO (mg/lit.)		
Year	East Bank	West Bank
1990	0.43	1.09
1991	0.51	1.24
1992	0.47	1.61
1993	0.42	0.80
1994	0.98	1.44
1995	1.70	2.56

Fig. 6.3 Water Quality Changes in Major Khlongs in East and West Banks





Year	BOD (mg/lit)		DO (mg/lit)		Numbers of Samples BOD		Numbers of Samples DO	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
1990	24.34	24.48	0.56	0.76	302	248	286	228
1991	23.14	25.01	0.71	0.80	193	283	193	280
1992	30.64	29.59	0.55	1.08	99	202	97	191
1993	28.29	29.70	0.37	0.66	59	172	58	170
1994	21.73	21.20	1.54	0.84	98	142	95	139
1995	23.80	22.78	1.56	2.45	219	126	216	126

Note : BOD stand for Biochemical Oxygen Demand
DO stand for Oxygen Demand

Wet Season : May - October
Dry Season : November - April

Fig. 6.4 Trend of Water Quality in Wet Season & Dry Season in the Major Khlong of BMA Areas during 1990-1995

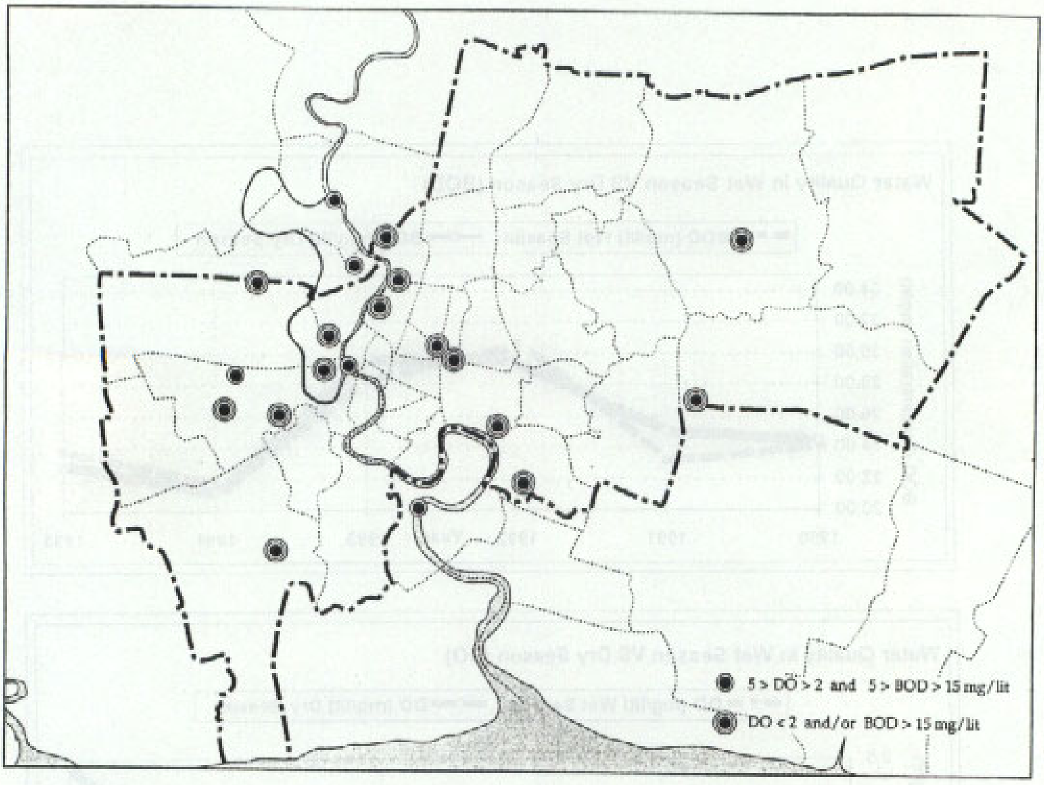


Fig. 6.5 (1/2) Annual Average BOD/DO in Major Khlongs (Wet Season-1995)

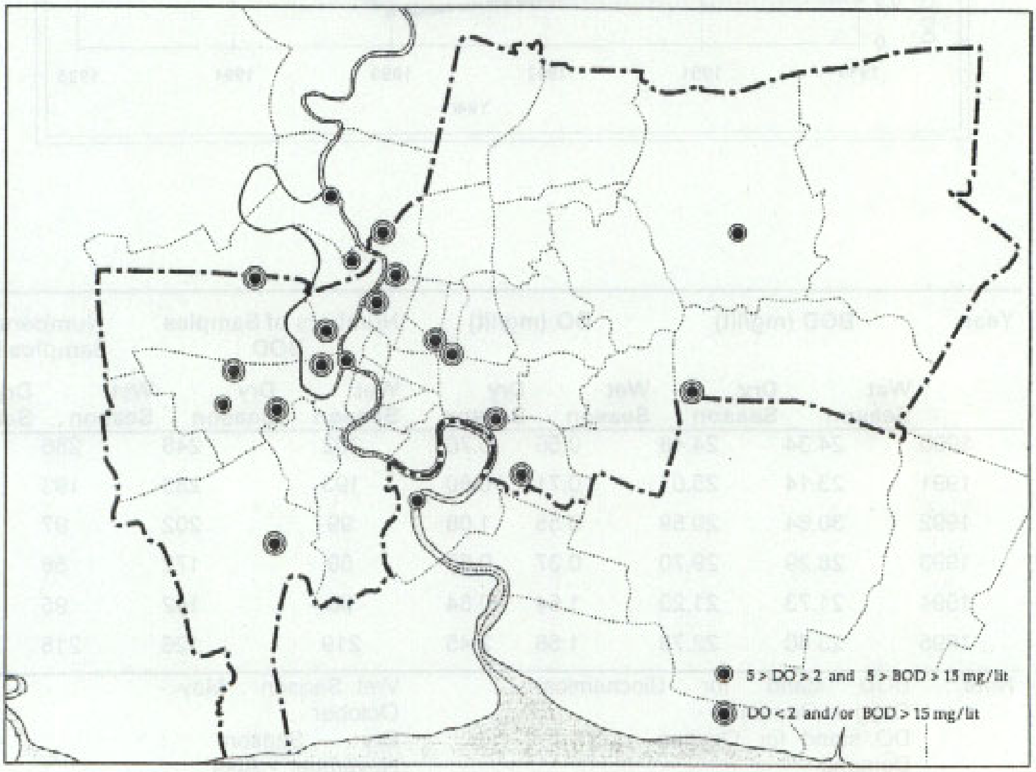


Fig. 6.5 (2/2) Annual Average BOD/DO in Major Khlongs (Dry Season-1995)

(4) The Cho Phraya River Water Quality Monitoring Data by PCD

An analysis of water quality was made on the basis of the data collected from Pollution Control Department, Ministry of Science, Technology and Environment for the last 17 years from 1978 to 1994. Three monitoring points, from the up stream reach, Rama 7 Bridge, Krungthep Bridge, and confluence with the Khlong Prakanong, were picked out to show the water contamination level along the river in Bangkok section and each monitoring point locate 58 km, 41.5 km and 27 km respectively from the estuary of the Chao Phraya River.

Average values of DO and BOD in the last 17 years were calculated to show the water pollution level along the stream and found that the water pollution level is increasing gradually from the up stream to the down stream reaches as tabulated in the following Table 6.3.

Table 6.3 Water Pollution Trend along the Cho Phraya River

Item	Confluence with Khlong Phrakanong (27 km)	Khrungthep Bridge (41.5 km)	Rama 7 Bridge (58 km)
Avg. DO (mg/lit)	0.97	1.33	2.46
Nos. of DO Samples	13	16	16
Avg. BOD (mg/lit)	2.76	2.60	1.90
Nos. of BOD Samples	13	15	15

Data Source : PCD, MOSTE

Annual change of DO and BOD was shown in Fig. 6.6 for the three monitoring points from 1978 to 1994. Change of annual water pollution level is not clear because of the missing datum and fluctuation of the data but the trend line of DO declines from around 2 mg/lit in 1978 to 1 mg/lit in 1994, whereas the trend line of BOD ascending from around 2 mg/lit in 1978 to 3 mg/lit in 1994. BOD level is still lower than that noticed by the environmental standard, 4 mg/lit in the Bangkok section. The state of water pollution level on the basis of DO and BOD can be mentioned that it would not take long time as the water pollution level exceed the environmental standards in the lower reach of the Bangkok section unless water pollution control projects, such as the development of sewage systems are immediately implemented by the authorities concerned.

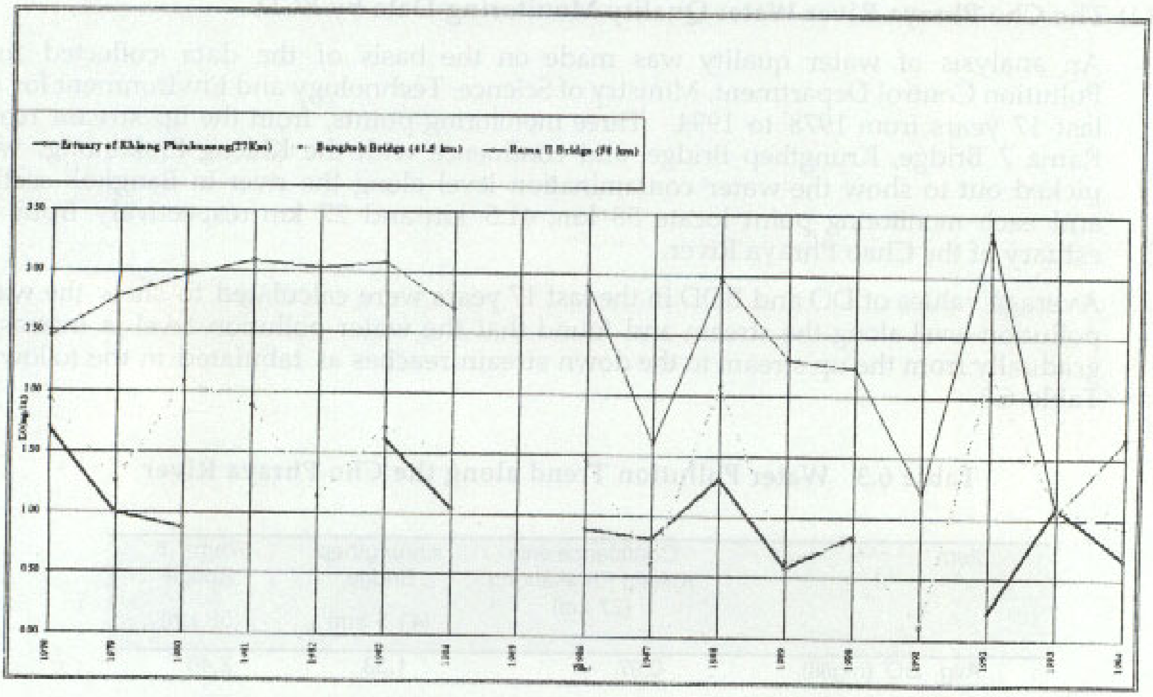


Fig. 6.6 (1/2) Annual Changes of DO in the Chao Phraya River

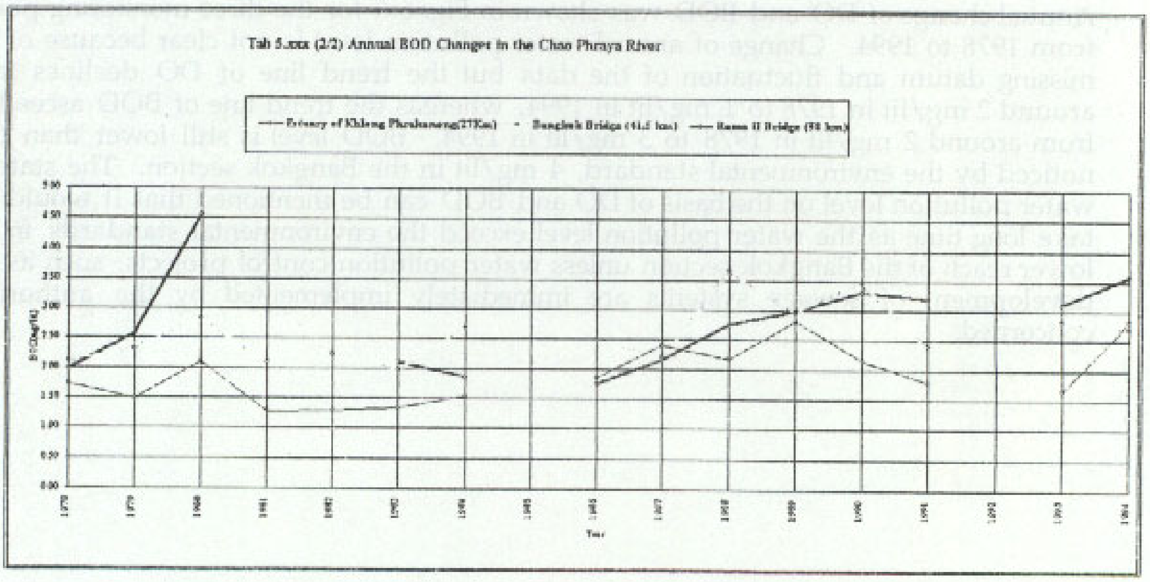


Fig. 6.6 (2/2) Annual Changes of BOD in the Chao Phraya

CHAPTER7: SEWERAGE SYSTEM

7.1 General

Increasing water consumption in domestic, business and industrial activities generated a large amount of water pollutants, especially in the densely populated areas and caused of water pollution in the klongs as well as in the Chao Phraya river.

Water pollution problems in the khlongs has been pointed out in the core area of Bangkok since 1960's. In spite of the recommendations in many studies and the reports in early stages of water pollution problem, implementation of the sewage projects were not materialized until the Sipraya Sewage System started operation in the end of 1994.

The Sewage Master Plan, "Bangkok Metropolitan Region Wastewater Management Master Plan" issued in March, 1993 by the Pollution Control Department(PCD), MOSTE, formulates the sewage systems in BMA Area and the municipalities in the vicinity areas.

Decentralization policies and plans of the Government and the Bangkok Plan, the city planning for BMA Area, prepared by MIT, EC consultant teams and the Department of Policy and Planning, BMA towards the 5th BMA Five Year Development Plan, 1997-2001, and other infrastructure projects by government agencies including mass transit and roads projects, would influence the changes of future land use pattern, population distribution, etc. Accordingly, the sewage master plan shall be proposed in line of the restructuring plans for the city of Bangkok to improve the deteriorated environmental quality and retrieve nature to the Chao Phraya river and the klongs in the area.

7.2 Assessment on Present Condition

(1) Current Sewage System

1) Implementing Agency

At present, Wastewater Quality Control Division of DDS, BMA take charge from planning to operation and maintenance of the sewage systems within the administration boundary of Bangkok.

2) On-going Sewage Projects

As of December, 1995, there are 6 sewage projects including 7 sewered areas have implemented in the central area of Bangkok. Locations of each projects and some more detail information is shown in Figure 7.1 and Table 7.1 respectively. After completion of the projects, the total sewage treatment capacity will reach at 992,000 cum/day in terms of dry weather flow for the sewered population of approximately 2.86 million. Comparing with the water consumption records of the whole water service area of MWA in the fiscal year 1995, which is 870.3 million cum. per year, the coverage of sewered area reaches at about 41 percent.

Table 7.1 On-going Sewage Projects in BMA Area

Project Name	Progress of Works (cum/day)	Plant Capacity
1. Sipraya	plant operation	30,000
2. Rattanakosin	under construction	40,000
3. Bangkok (Stage 1)	under construction	350,000
4. Yannawa (Stage 2)	under construction	200,000
5.1 Nong Khaem & Phasicharoen (Stage 3)	construction started	157,000
5.2 Ratburana (Stage 3)	construction started	65,000
6. Chatuchak (Stage 4)	preparation of TOR	130,000

Note : Reference shall be made to " Environmental Atlas " for location of the project
Source : Department of Drainage ans Sewerage, BMA

(2) Wastewater Management Authority (WMA)

The Royal Decree to establish the new organization "Wastewater Management Authority(WMA)" was enacted on 20 July, 1995 to control wastewater projects within the "Waste Water Management Area (WWM Area)" in Bangkok Metropolis, Nakhon Province, Nonthaburi Province, Pathum Thani Province, Samut Prakarn Province and Samut Sakhorn Province. Since then, a close coordination is required among the sewage works agencies such as PCD, MOSTE, Public Work Department (PWD), and DDS, BMA for budgeting and implementing towards coordination for implementing the future wastewater projects in the WWM Area under the WMA administration.

Objective of the WMA stipulated in the Royal Decree is comprehended that the WMA realize a common/combined/central/regional wastewater treatment system in the WWM Area and provide and conduct the services and activities continuously and economically for establishment of the efficient wastewater treatment system.

Authorized power for management and other important roles were cited from the Royal Decree and attached to APPENDIX :"WATER-RELATED ENVIRONMENT" (separate cover).

7.3 Policy Direction and Planning Issues

Sewage system in Thailand is designed not only for the facilities to reduce water pollution loading to the public water courses but also for the function to support drainage because of the sewer system designed in most of the municipalities by the combined sewer system. However, the primary role of the sewage system shall be designed for the facilities to contribute toward water quality conservation in the public water course.

Tendency of the society and the advanced technology of recent years has come to require the sewage system to consider the worldwide tendency for establishing the energy-saving society into design. Accordingly, reuse of treated sewage, treatment and resource recovery of sludge and low-energy-consumption design of overall sewage system are the important factors to formulate the development plan in respect of energy-saving concept in mind. Considering these factors, the major five issues were selected and described in the following sections.

This section also include the strategic plan drafted by DDS for The 5th BMA Five Year Development Plan and the prediction of sewage amount in 2011 putting together with every issues related with future planning.

(1) Sewage Master Plan and Stage Development

The Sewage Master Plan by PCD determined the sewered area in BMA into 24 zone and formulated the 3 phase implementation plan for the remaining 18 zones including Chatuchak and Lad Phrao districts as shown in the followings. Table 7.2 and Figure 7.1 shows a basic information for stage development of each sewage zone proposed in the Sewage Master Plan by PCD.

Table 7.2 Stage Development in Sewage Master Plan

Phasing	Design	Sewer Construction	STPConstruction
First Phase(5-10 years)			
First Group :	X	X	X
Second Group:	X	X	
Second Phase(10-15 years)			
Second Group:	X		X
Third Group :	X		
Third Phase(15-20 years)			
Third Group :		X	X

Note: First Group include 8 zones — Zone 14, 15, 4, 6, 6, 7, 3 and 2
Second Group include 4 zones — Zone 1, 10, 16 and 8
Third Group include 6 zones — Zone 9, 11, 17, 18, 12 and 13

Source : "Bangkok Metropolitan Region Wastewater Management Master Plan", 1993, PCD, MOSTE.

The Master Plan shall be updated, reviewed and modified considering the current and future conditions related such as the new Bangkok city plan, direction of urban growth in future, coordination with drainage plans, available construction sites, administration issues concerned with MWA, etc.

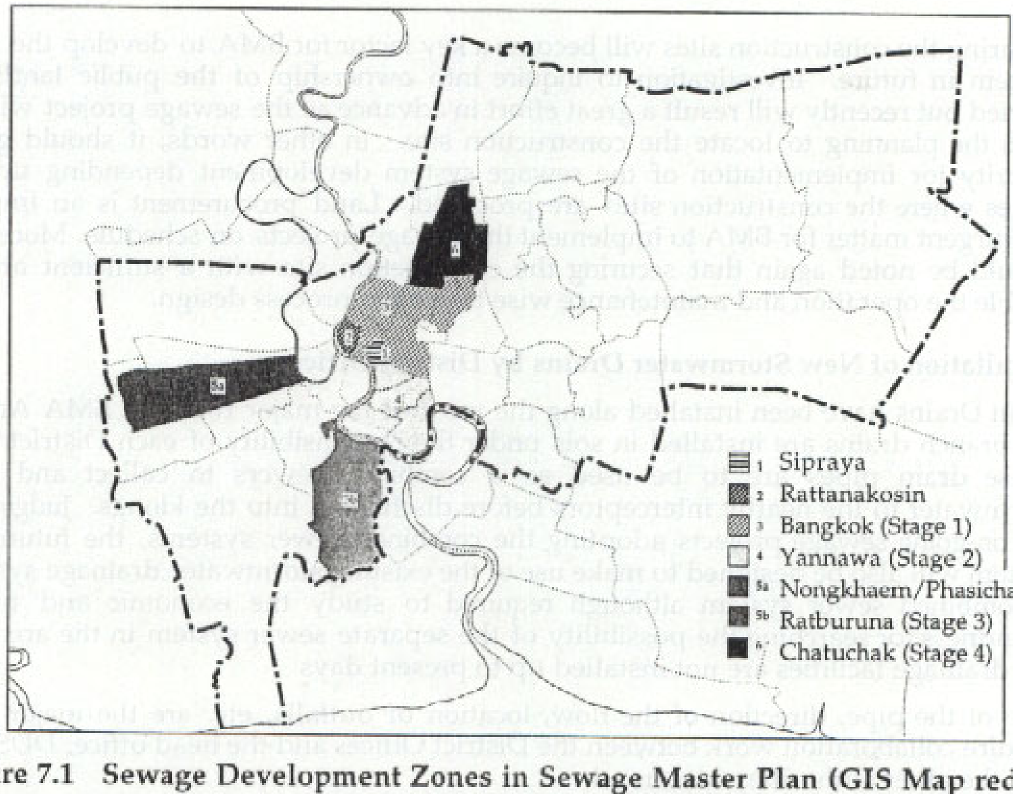


Figure 7.1 Sewage Development Zones in Sewage Master Plan (GIS Map reduce to A3, Sewage Zoning Proposed by PCD)

(2) Procurement of Construction Sites

Every on-going sewage projects procured the public land for construction of the wastewater treatment plants. However, the land area of each site is too small to layout the facilities with standard design for easy operation and maintenance, except for the construction site of Nong Khaem - Phasicharoen Project secured at a corner of Nong Khaem Final Disposal Site. The following data indicates the plant area of the on-going projects to unit sewage treatment capacity.

Table 7.3 Plant Site Area per Treatment Capacity

Treatment Plant	Plant Capacity (m3/day)	Site Area (m2)	Per Unit Area (m2/m3/day)
1. Sipraya	30,000	1,600	0.053
2. Rattanakosin	40,000	6,400	0.160
3. Bangkok (Stage 1)	350,000	27,200	0.078
4. Yannawa (Stage 2)	400,000*	32,000	0.080
5.1 Nong Khaem & Phasicharoen (Stage 3)	157,000	83,200	0.530
5.2 Ratburana (Stage 3)	65,000	14,400	0.222
6. Chatuchak (Stage 4)	130,000	11,200	0.086
7. Tokyo(10 Plants)	6,233,000	2,890,693	0.464

Note : The mark * indicates the plant capacity after completion of Phase 2 construction

Securing the construction sites will become a key factor for BMA to develop the sewage system in future. Investigation to inquire into ownership of the public lands being carried out recently will result a great effort in advance as the sewage project will begin with the planning to locate the construction site. In other words, it should give the priority for implementation of the sewage system development depending upon the zones where the construction sites are procured. Land procurement is an important and urgent matter for BMA to implement the sewage projects on schedule. Moreover, it should be noted again that securing the construction site with a sufficient area will enable the operation and maintenance wise treatment process design.

(3) Installation of New Stormwater Drains by District Offices

Main Drains have been installed along the most of the major roads in BMA Area and the branch drains are installed in sois under the responsibility of each District Office. These drain pipes are to be used as a combined sewers to collect and convey stormwater to the nearby interceptors before discharged into the klongs. Judging from the on-going sewage projects adopting the combined sewer systems, the future sewer system will also be designed to make use of the existing stormwater drainage system as a combined sewer system although required to study the economic and technical soundness for searching the possibility of the separate sewer system in the area where the drainage facilities are not installed up to present days.

Size of the pipe, direction of the flow, location of outfalls, etc. are the major factors require collaboration work between the District Offices and the head office, DDS, BMA and the other authorities concerned.

(4) Saving Water to Reduce Loading to the Nature and Economize Plant Capacity

Wastewater generates as people use water. Reducing water consumption will bring about discharge of pollutants to the public water courses to the minimum extent and possibly reduce the capacity of the wastewater treatment plant and increase economic feasibility of the projects.

Water pollutants for example, detergents and food oil are commonly consumed in home and discharged to the public water course every day. Excessive amounts of Phosphate, ABS, etc., are the major possible cause of eutrophication in ponds and the slow-flow khlongs. Increase of water pollutants has been carried in with improvement of quality of life and the people take it for granted.

"Saving Water" and "Reducing Water Pollutants" are the key phrase for betterment of life in comfortable urban environment. Water quality conservation need participation of individual people and the social change in awareness to the value of the nature. If the sewage flow increase continuously, the infrastructures such as the sewage system always need expansion of the facilities with a large amount of expenditure for investment forever.

Accordingly, the public campaigns to inspire the consciousness of the people that "Saving Water" and "Reducing Water Pollutants" are essentially required for establishing the water-environment friendly city of Bangkok.

(5) Khlong Water Quality Improvement Project (Clean and Green Khlongs Project or CGK Project)

After completion of the on-going sewage projects, wastewater being discharged into the klongs will be collected, conveyed and treated at the wastewater treatment plant in each sewered area. The systems will be able to collect more than 95% of wastewater and it is expected to improve the state of water pollution in the klongs considerably. However, here is a very pessimistic viewpoint about the improvement of water quality in the klongs caused by the water pollutants carried from the up-stream sections, discharge of the water pollutants remained in the treated sewage discharge to the klongs, sediments in the klongs, etc. Consequently, water quality improvement in the klongs could be realized after the most part of the built-up area will be have been covered in the sewage project area, which will be probably wider than 60 to 70% of the built-up area in BMA Area.

The "Khlong Water Quality Improvement Project" implemented by DDS, BMA in the East Bank shall be maintained for the time being until the water quality in the klongs will have been improved to the satisfactory level.

The system consists of the facilities and works to withdraw dilution water from the Chao Phraya river into the khlongs, dredging of sediments in the klongs, construction of retaining wall on both sides of the klongs, and installation of direct aeration system. For better functioning of the system, installation of more numbers of direct aeration stations will be effective since diffusing air into the khlongs will enable decomposition and purification of pollutants at the sites.

Khlong Water Quality Improvement Project is not yet implemented in the West Bank, Tonburi side up to now. With respect to the successful results performed in the East Bank, the similar system shall be introduce in the East Bank to improve water quality in the klongs in main area of Tonburi side.

Installation of automatic water quality monitoring stations will be beneficial to monitor water quality in the khlongs and in the Chao Phraya River. Recent technology in water quality measuring device, data transmission, processing and analysis make it easier to monitor water quality in the office by installing the automatic monitoring system.

Water quality monitoring play a very important role in conservation of water environment to inform us the degradation of water quality in the public water course so that the monitor can take immediate action to investigate the cause and take proper measures against the wastewater sources. Initially, the study shall be conducted with the water quality monitoring parameters and the location of the monitoring stations in consideration of the locations of the water level monitoring stations maintained by

DDS, BMA and the monitoring stations maintained by PCD, MOSTE.

(6) Strategic Plan Proposed in The 5th BMA Five Year Development Plan

Department of Drainage and Sewerage drafted the strategic plan for development of sewage system in the 5th BMA Five Year Development Plan implemented during 1997 to 2001. The strategic plan consists of four programs as indicated below. These plans are duly examined as the action plans of the Study are proposed to improve urban environmental quality in BMA Area.

Program 1 : Construction of 4 Wastewater Projects Invested by BMA and the Government
Program 2 : Improvement Work for NHA Wastewater Treatment Plants
Program 3 : Administration and Management Preparation
Program 4 : Public Relations

1) Activities of the Programs

Program 1 : BMA and Government Investment 4 Projects

- Implementation of the Stage 4 Project
  Wastewater Treatment Site at Bang Sue :site area 7 rais
  Plant Capacity :130,000 cum/day
  Sewered Area :Dusit, Phaya Thai, Huay Khwang,Chatuchak
  Starting in :1996
- Implementation of the Bangkok Yai - Bangkok Noi Project
  Wastewater Treatment Site at :site area 60 rais
  Plant Capacity :173,400 cum/day
  Sewered Area :Bangkok Yai, Bangkok Noi
  Starting in :1997
- Implementation of the Stage 5 Project
  Wastewater Treatment Site : site area 20 rais
  Plant Capacity :320,000 cum/day
  Sewered Area :Phra Khanong, Khlong Toei, Pravet
  Starting in :1998
- Implementation of the Nong Bon Project
  Wastewater Treatment Site : site area 45 raise
  Plant Capacity :125,400 cum/day
  Sewered Area :Pravet, Phra Khanong
  Starting in :1998

Program 2 : Improvement Work for NHA Wastewater Treatment Plants

Six (6) plants including, Huay Khwang, Bang Na, Khlong Chan, Ram Intra, Tung Song Hong 1, Tung Song Hong 2

Program 3 : Administration and Management Preparation Study of a sewage charge system

Program 4 : Public Relations

- Public relations to follow effluent quality standard
- Effluent water quality control for buildings

(7) Prediction of Sewage Amount

1) Method of Prediction

Prediction of future sewage amount was conducted on the basis of prediction of water consumption, the rate of wastewater entering to the collection pipes and the rate of groundwater infiltration into the pipes. Water consumption prediction is generally predicted by water consumption per capita per day in consideration of domestic, commercial, industrial and other water use in business activities.

In respect of a specific feature in this Study made available to use GIS system for urban environmental improvement planning, water consumption was predicted in proportion to the relation between the land use type and the water consumption to unit area. Sewage amount was estimated by 80 % of water consumption entering to the pipes and by another 20 % infiltration of groundwater in flowing down to the plant. Thus, future sewage amount prediction is practicable for the city planner by estimating the area of future built-up and land use area.

Sewage amount in the Study was predicted in accordance with the following sequence.

Step 1 :	Calculation of unit area water consumption to residential area and business area in each water service block for 1995.
Step 2 :	Calculation of population density increase ratio between 1995 and 2011 for built-up area in proposed sewage zones
Step 3 :	Assumption of unit area water consumption to residential and business area for 2011 from the results of Step 1 & 2.
Step 4 :	Obtain the future built-up area and land use from the city planning data
Step 5 :	Prediction of amount of water consumption each sewage zone from the results of Step 3 & 4
Step 6 :	Convert amount of water consumption to the amount of sewage in each sewage zone
Step 7:	Evaluate the unit sewage amount and adjust if necessary.

2) Sewage Amount in 2011

Result of sewage amount prediction was summarized in Table 7.4 for each sewage zone. Total sewage amount reached at 2.7 million m3/day in 2011 in the built-up area of BMA. The current sewage projects construct 6 sewage treatment plants having total capacity of 972,000 m3/day, which is equivalent to 36 % as against for the year 2011. The remaining sewage amount 64 % or about 1.75 million m3/day need construction of the facilities hereafter.

Total plant capacity predicted in the Sewage Master Plan by PCD in together with that of the on-going project indicate approximately 2 million m3/day. Although difference in target year, sewage amount predicted by the Study exceeded by 35 % or 0.7 million m3/day comparing with the plant capacity in the current planning.

In Tokyo, 10 plants treat sewage 5.1 million m3/day in average for the sewered area and population approximately 545 km2 and 8.1 million respectively as of 1993. From these data, the sewage plant capacity to unit area is obtained at 9,400 m3/day/km2. In case of Bangkok, sewage amount at plant sites was estimated at 2.7 million m3/day for the future built up area 715 km2 and the sewage generation rate to unit area was calculated with 3,800 m3/day/km2. Assuming the plant capacity by 1.2 times of the inflow, the sewerage plant capacity to unit built-up area is estimated at 4,600 m3/day/km2 and the ratio to Tokyo become about 50 %.

Meanwhile, water supply in Tokyo and the neighboring area supply 4.8 million m3/day for the served area 1,150 km2 in Tokyo. From these data the water supply ratio per unit area is estimated at 4,200 m3/day/km2 whereas water service area in MWA 890 km2 consume water 2.4 million m3/day and the water consumption ratio per unit area is obtained at 2,700 m3/day/km2.

Difference of sewage generation and water supply ratio per unit area is because of the sewage service area covers densely populated area against the water supply service area cover more wider low-density area. Difference of the figures between Tokyo and Bangkok may be caused of water consumption in business activities.

BOD loading in each sewage zone was predicted based on the sewage flow at the plant site and shown in Table 7.5. Average unit BOD loading obtained from the field survey conducted in connection with the Study show 130 g/m3 and 105 g/m3 for residential and business area respectively. Future unit BOD loadings were assumed to increase by 20 % respectively as the betterment of life. Total BOD loading in 24 sewage zone reached at 382 tons per day in 2011 which is equivalent to29 grams per capita per day.

Table 7.4 Prediction of Wastewater Amount in Sewage Zones (2011)

No.	SewageZoneName	Water Consumption (m3/day)	Generated Sewage Amount (m3/day)	Ground Water Infiltration (m3/day)	Sewage Amount at WWTP (m3/day)	Estimated Sewage Amount at WWTP (m3/day)	Required Construction Site Area per Unit Flow (m2/m3/day)	Required Construction SiteArea (ha)	Phasing Plan
1	SiPhraya	27,743	22,194	4,439	26,633	27,000	0.059	1,600*1	Phase1
2	Rattanakosin	29,713	23,771	4,754	28,525	29,000	0.221	6,400*1	Phase1
3	DinDaeng	253,803	203,042	40,608	243,651	244,000	0.111	27,200*1	Phase1
4	Yanawa	181,961	145,569	29,114	174,682	175,000	0.183	32,000*1	Phase1
5.1	NongKhaem/Phasicharoen	107,012	85,610	17,122	102,731	103,000	0.808	83,200*1	Phase1
5.2	Ratburana	93,354	74,683	14,937	89,620	90,000	0.160	14,400*1	Phase1
6	Chatuchak	164,174	131,339	26,268	157,607	158,000	0.071	11,200*1	Phase2
7	Tonburi	119,317	95,454	19,091	114,545	115,000	0.300	34,000	Phase2
8	KhlongToey	254,236	203,388	40,678	244,066	244,000	0.300	73,000	Phase2
9	SuarLuang	133,721	106,977	21,395	128,372	128,000	0.300	38,000	Phase2
10	BangKhaen/DonMuang	271,755	217,404	43,481	260,885	261,000	0.300	78,000	Phase3
11	BangKhaen/Minburi	37,312	29,850	5,970	35,820	36,000	0.300	10,000	Phase4
12	DonMuang/BangSue	144,871	115,896	23,179	139,076	139,000	0.300	41,000	Phase3
13	HuayKhwang	133,278	106,622	21,324	127,947	128,000	0.300	38,000	Phase3
14	BangKapi/LatPhrao	164,127	131,302	26,260	157,562	158,000	0.300	47,000	Phase3
15	BungKum	165,905	132,724	26,545	159,269	159,000	0.300	47,000	Phase3
16	Pravet	168,415	134,732	26,946	161,678	162,000	0.300	48,000	Phase4
17	Latkrabang	6,209	4,968	994	5,961	6,000	0.500	3,000	Phase4
18	NongChok	3,541	2,833	567	3,400	3,400	0.500	1,700	Phase4
19	TalingChangWest	58,306	46,645	9,329	55,973	56,000	0.300	16,000	Phase4
20	TalingChangEast	43,216	34,573	6,915	41,488	41,000	0.300	12,000	Phase4
21	NongKhaem	40,334	32,267	6,453	38,720	39,000	0.300	11,000	Phase4
22	ChomThong	198,789	159,031	31,806	190,837	191,000	0.300	57,000	Phase3
23	BangKhunTien	33,758	27,006	5,401	32,408	32,000	0.300	9,000	Phase4
	Total	**2,834,85(**	**2,267,88(**	**453,57(**	**2,721,45(**	**2,724,40(**		**739,70(**	
								176,000*2	
	Bangkok VS Thonburi							**563,700*3**	
	Bangkok	2,140,765	1,712,612	342,522	2,055,134	2,057,400			
	Tonburi	694,086	555,268	111,054	666,322	667,000			
	Bangkok(%)	75.5	75.5	75.5	75.5	75.5			
	Tonburi(%)	24.5	24.5	24.5	24.5	24.5			

Sewage Amount in Stage Development

Phase1	668,000	24.5%
Phase2	645,000	23.7%
Phase3	1,036,000	38.0%
Phase4	375,400	13.8%
Total	2,724,400	100.0%

Note:
*1 indicate the sites procured already
*2 indicate total site area procured alreadyre
*3 indicate the total site area required in future

Table 7.5 Prediction of BOD Loading in Sewage Zones (2011)

Sewage Zone No.	Sewage Amount (m3/day) Domestic Use	Businesss Use	Total	BOD Loading (kg/day) BOD Loading by Domestic Use	BOD Loading by Business Use	Total
1	166	26,467	26,633	26	3,335	3,361
2	3,719	24,805	28,525	580	3,125	3,706
3	72,873	171,022	243,896	11,368	21,549	32,917
4	70,609	104,073	174,682	11,015	13,113	24,128
5.1	51,538	51,193	102,731	8,040	6,450	14,490
5.2	45,551	44,069	89,620	7,106	5,553	12,659
6	76,789	80,818	157,607	11,979	10,183	22,162
7	61,185	53,359	114,545	9,545	6,723	16,268
8	116,270	127,796	244,066	18,138	16,102	34,240
9	88,387	39,986	128,372	13,788	5,038	18,827
10	102,018	158,867	260,885	15,915	20,017	35,932
11	22,158	13,662	35,820	3,457	1,721	5,178
12	74,161	64,915	139,076	11,569	8,179	19,748
13	51,788	76,159	127,947	8,079	9,596	17,675
14	60,406	97,156	157,562	9,423	12,242	21,665
15	86,502	72,767	159,269	13,494	9,169	22,663
16	71,945	89,734	161,678	11,223	11,306	22,530
17	3,989	1,972	5,961	622	249	871
18	3,400	0	3,400	530	0	530
19	48,874	7,099	55,973	7,624	895	8,519
20	32,988	8,500	41,488	5,146	1,071	6,217
21	24,816	13,904	38,720	3,871	1,752	5,623
22	112,161	78,676	190,837	17,497	9,913	27,410
23	23,469	8,939	32,408	3,661	1,126	4,787
Total	1,305,763	1,415,938	2,721,701	203,699	178,408	382,107
Bangkok VS Thonburi						
Bangkok	905,180	1,150,199	2,055,379	141,208	144,925	286,133
Tonburi	400,583	265,739	666,322	62,491	33,483	95,974
Bangkok(%)	69.3	81.2	75.5	69.3	81.2	74.9
Tonburi(%)	30.7	18.8	24.5	30.7	18.8	25.1

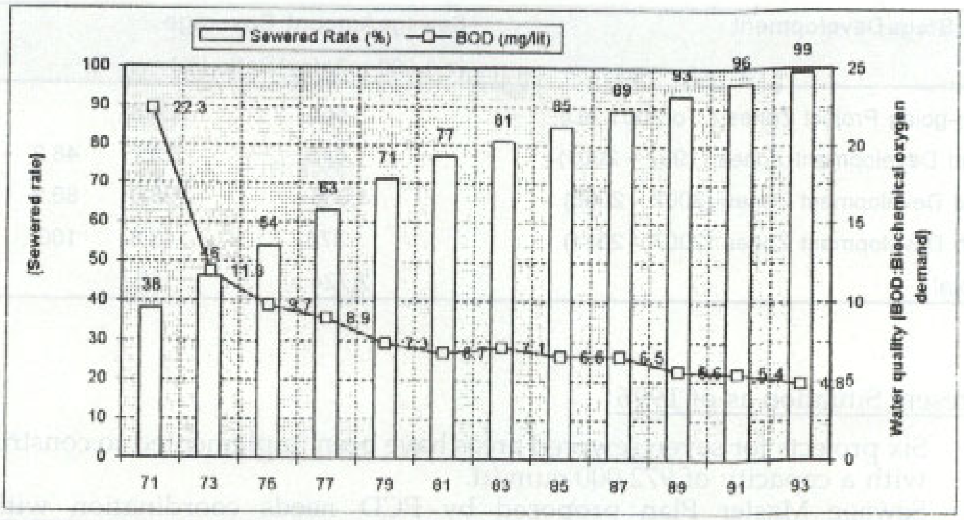
7.4 Planning Targets and Framework

(1) Planning Target

Creation of "Water-Friendly Eco-City" which is the planning issue No. 6 , denotes that environmental improvement on water in rivers, canals and ponds is an essential matter to achieve the objectives. Municipality water use such as domestic use, business use, commercial use etc. are the major wastewater sources and industrial water use is a minor source of water pollutants in BMA Area as described in the Section of " Water Supply ". Accordingly, environmental quality deterioration on water pollution mainly caused of pollutants from urban activities can improved considerably by development of sewage systems.

For an example of the phased development of sewage system in Tokyo, water quality in the rivers running across the downtown was evidently improved as the coverage ratio of sewered area reached at 60 to 70 % range as shown in Figure 7.2. Completion of the on-going sewage projects can cover the treatment capacity of 972,000 cum/day or approximately 40 % of water consumption as of 1995 in MWA service area. Therefore, referring to the experience in Tokyo, the target sewage development capacity for the next phase shall be set in the range of 1 to 1.3 million m3/day by 2011 in total for creation of "Water-Friendly Eco City" in early stage.

In addition, the Study Team set a target to the on-going Khlong Water Quality Improvement Project which shall support the sewage development projects for improvement of water quality in major khlongs. The first step target level is proposed to Level 3, less than 15 mg/lit in BOD, which is aiming at retrieving the nature in central urban area back to 1960's when people could enjoy playing with water in the city khlongs.



Year	71	73	75	77	79	81	83	85	87	89	91	93
Sewered Rate (%)	38	46	54	63	71	77	81	85	89	93	96	99
BOD (mg/lit)	22.3	11.8	9.7	8.9	7.3	6.7	7.1	6.5	6.5	5.6	5.4	4.8

Remarks
1.Sewered rate : sewered area against area of the Sumida River Basin (the wards of Itabashi, Kita and Nerima)
2. BOD : BOD measured through the year at Odaibashi bridge (75% of the standard value, prepare by the Bureau of Sewerage from the data of the Bureau of Environmental Protection)
Source: Bureau of Sewerage, Tokyo Metropolitan Government

Figure 7.2 Water Quality of the Sumida River and Sewage Construction

(2) Proposed Action Plans to Achieve the Targets

Considering the planning issues discussed in the previous section, most of the tasks to be tackled during the first 5 years are covered in the Strategic Plan for the 5th Five Year Plan proposed by DDS but the following five action plans included some key issues of the 5th Five Year Plan as for the major factors to play a important role for improvement of urban environmental quality in BMA Area.

1) Action Plan 1 : Formulation of Sewage Master Plan and Stage Development

Action Plan 1 consist of the works to review, correct, modify, alter and add the existing Sewage Master Plan to meet with the current and future urbanization conditions and construct the system based on the stage development plan to be formulated in the Master Plan. The Sewage Master Plan has to be formulated not only construction of the wastewater treatment plants but also it should include at least the items for sludge treatment, recycling and disposal, reuse of treated sewage, improvement of the existing drain pipes, sewage fee, project financing, sewage system data and information center, etc. which will be required sooner or later to complete development of the high-efficiency and comprehensive sewage system for BMA in future. In addition, the action plan require the measures for strengthening operation and maintenance of the completed sewage systems to meet satisfactorily with the function of the plant and the system as intended in the design.

The Study proposed stage development as shown in Table 7.6 and Figure 7.4. Proposed stage development plan was formulated to perform the target coverage of sewered area with 60 to 70 % in view of forwarding improvement of water pollution in early stage therefore the plan shall be reviewed again carefully from the angle of availability of the financial sources.

Table 7.6 Sewered Area Coverage Ratio UnderProposed Stage Development

Stage Development	SewageAmount (x 1,000 m3/day)	Coverage Ratio (%)	
On-going Project Zones (To 2001 AD)	668	24.5	
2nd Development Zones (1997 - 2001)	645	23.7	48.2
3rd Development Zones (2002 - 2006)	1,036	38.0	86.2
4th Development Zones (2007 - 2011)	375	13.8	100
Total	2,724	100	

Present Situation as of 1996

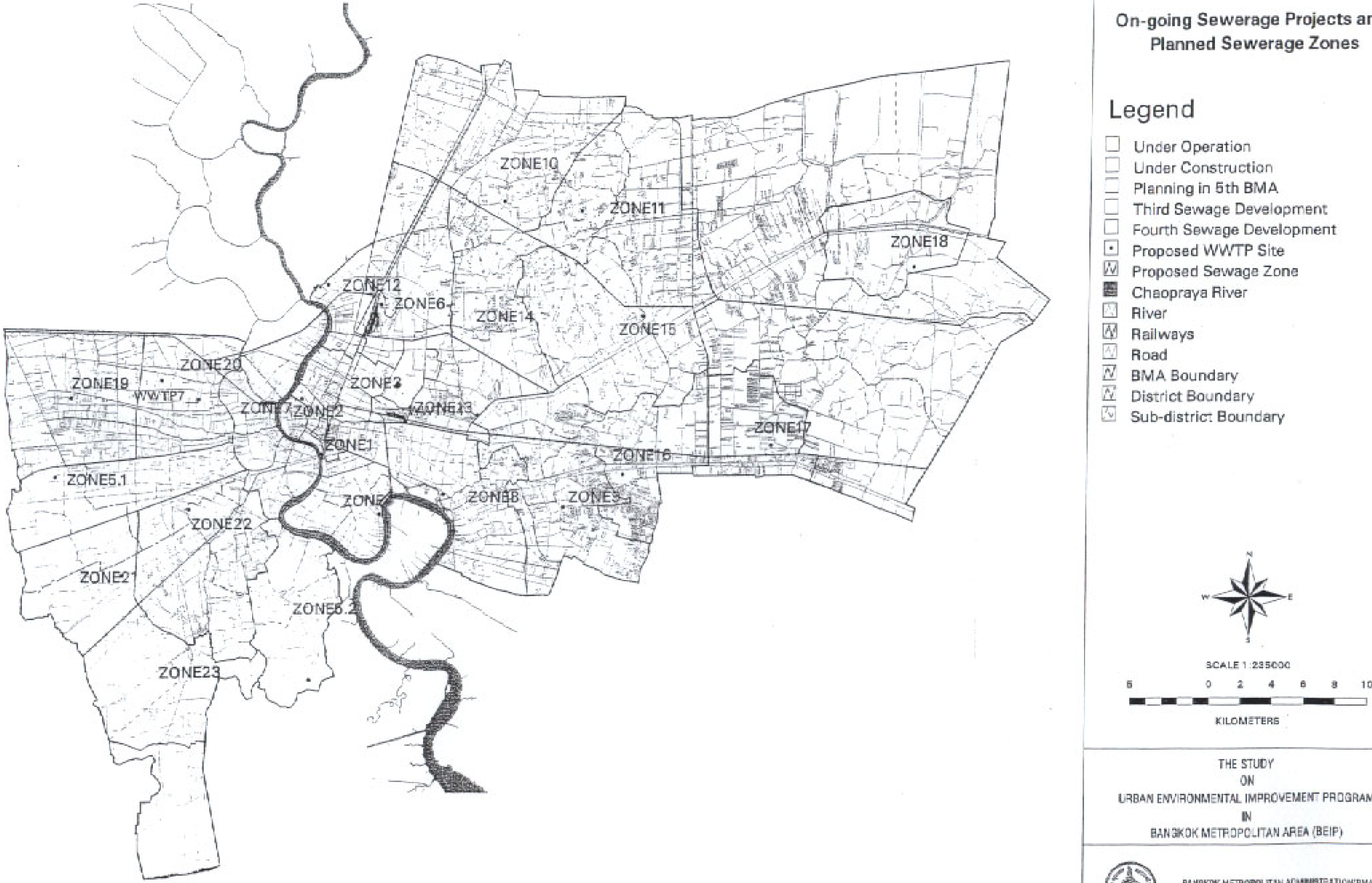
- Six projects for seven sewered areas have been implemented to construct the plants with a capacity of 972,000 cum/d.
- Sewage Master Plan proposed by PCD needs coordination with the urban restructure plan of BMA

Action Plan during 1997 - 2001

- Completion of the on-going sewage projects
- Completion of the on-going sludge treatment and disposal project
- Review of the Swage Development Master Plan in coordination with the BMA City Plan
- Planning, design and bidding for the projects in 2nd Sewage Development Zone
- Securing skillful O&M staff for sewer systems and treatment plants
- Improvement of NHA sewerage system

Figure 7.3

On-going Sewerage Projects and Planned Sewerage Zones



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

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

JICA JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

Action Plan during 2002 - 2006

- Completion of the projects for the 2nd Sewage Development Zone
- Planning, design and bidding for the projects in 2nd Sewage Development Zone
- Implementation of sewage and solid waste corroboration project(s)

Action Plan during 2007 - 2011

- Completion of the projects for the 3rd Sewage Development Zone
- Planning, design and bidding for the projects in 4th Sewage Development Zone

2) Action Plan 2 : Procurement of Construction Sites

Based on the proposed sewage zoning and future sewage amount, the remaining 17 sewage zones require the construction site area about 62 ha. or 390 rai in minimum. Due to a foreseeable difficulties to acquire the plant sites disliked by the neighboring residents, a task team shall be established to accelerate procurement of the land to be proposed in the revised Sewage Master Plan. The site area shall be wide enough to layout buffer zone surrounding the plant to avoid probable influence to the neighboring area. Action Plan 3 was proposed to call the authority's attention to recognize importance of land acquisition as implementing the project on schedule.

Present Situation as of 1996

- On-going projects procured the site owned by the public agencies
- Layout plans of the on-going projects are too narrow for convenient O&M and better environmental installation to the neighboring

Action Plan during 1997 - 2001

- Inventory investigation of vacant lands in BMA Area
- Procurement of construction sites approximately 19 hectares for 3 plants in the 2nd Sewage Development Zone

Action Plan during 2002 - 2006

- Procurement of construction sites approximately 31 hectares for 6 plants in the 3rd Sewage Development Zone
- Provisional utilization of the sites for public services

Action Plan during 2007 - 2011

- Procurement of construction sites approximately 12 hectares for 8 plants in the 4th Sewage Development Zone

3) Action Plan 3 : Installation of New Stormwater Drains by District Offices

Prior to proceed to the Action Plan 3, it is required to formulate the Sewage Master Plan in each sewage zone indicating the sewage amount, plant site, type of sewer system, route of interceptor mains and collection trunk mains, etc. With the information of the Sewage Master Plan, drain system in soi shall be designed to match with the overall sewer system.

Coordination is required not only with the Sewage Master Plan but also required for road pavement work to avoid duplication construction work in narrow sois. Technical guidance and assistance also should be made available from the authorities concerned.

Present Situation as of 1996

- District offices are responsible for installation of drain pipes in sois
- Existing drain pipes are not always designed properly in sizing, slope and flow direction

Action Plan during 1997 - 2001

- Establishment of a technical coordination system among the agencies concerned
- Installation of drain pipes linking with main drains and sewer systems
- Implementation of regular cleaning of drain pipes

Action Plan during 2002 - 2006

- Continuous collaboration work among the agencies concerned

4) Action Plan 4 : Saving Water to Reduce Pollution Loading to the Nature and Economize Plant Capacity

Water pollution problem arise from where people use water. Saving water in daily life in home, office, and business activities will be useful to reduce generation of water pollutants discharged to the public water course as well as saving energy.

Excessive use of synthetic detergent for washing and cleaner for washing dishes are the a habit of urban dwellers and the have been spread to all over the country nowadays. Solution of water pollution problem can be found not only by the administrative officials but realized by the consumer

Intention of Action Plan 4 is to set up project team and prepare public campaign program to forward the movement of environmental conservation from the water environmental view point. The campaign shall be implemented with two main subject which are "Saving Water" and "Reducing Water Pollutants".

Public campaigns through mass media, school curriculums, circulation notice in workplace, visiting sewage plant open for the public, etc., will be helpful to arouse awareness of the people to participate in the campaign. National level saving water campaign in collaboration with MWA, PWA, PCD and other government agencies will be more effective way.

Present Situation as of 1996

- Average water consumption reaches at 480 liter per capita per day in MWA service area in 1995
- Betterment of life discharging more water pollutants into the public waters

Action Plan during 1997 - 2001

- Set up Project Team and preparation of public campaign program
- Start public campaigns "Saving Water" and "Reducing Water Pollutants" by reforming the current energy-consuming life style
- Public campaigns to reduce generation of water pollutants in daily life

Action Plan during 2002 - 2006

- Continuous public campaigns for saving water and for reducing water pollutants in daily life

5) Action Plan 5 : Khlong Water Quality Improvement Project (Clean and Green Khlongs Project or CGK Project)

The main activities in Action Plan 5 consist of a) operation and maintenance of the CGK Project in the East Bank, b) set up CGK Project in the West Bank, and c) preparation of automatic water quality monitoring system. Stage-wise activities of Action Plan 5 is proposed in the followings.

Present Situation as of 1996

- Khlong water quality improvement project is being implemented for 390 km2 in the East Bank

Action Plan during 1997 - 2001

- O&M for CGK System in the East Bank
- Planning for formulation of CGK Project in the West Bank
- Investigation for establishment of automatic water quality monitoring system

Action Plan during 2002 - 2006

- Implementation of the CGK Project in the West Bank
- Construction of on-line automatic water quality monitoring stations and a monitoring center and start monitoring operation

Action Plan during 2007 - 2011

- O & M for CGK systems in the East and West banks

CHAPTER 8: SOLID WASTE MANAGEMENT SYSTEM

8.1 General

Public services on solid waste management in BMA Area have become an important problem caused by the increasing amount of solid wastes, insufficient capacities of collection vehicles, treatment facilities, final disposal sites, etc. In other words, rapid growth of the city brought about the increase of solid wastes amount at the level exceeding the capacity of the facilities provided by the city authority.

The amount of solid wastes collected in 1995 from 38 districts of BMA reaches at 6,540 tons/day in average. Comparing with the solid waste collected in 1985, which was 3,260 tons/day in average, the solid waste amount required for treatment and disposal become double in the past 10 years and the rate of annual increase reach at 7-8 % which is almost the same rate of economic growth in the same period in Thailand.

Economic growth is bringing prosperity in exchange for many problems including traffic, floods, air pollution, water pollution, etc. and a heap of garbage produced every day. A very simple method of numerical prediction shows that the daily average solid waste amount to be collected in 2011 reaches at the range from 14,000 to 18,000 in BMA Area.

Despite pressing problem to improve the solid waste management situation in the city of Bangkok, BMA could not provide effective facilities and manpower for years. However, recently, the projects for construction of solid waste incineration plants, etc. have started to cope with the chronic problems.

In 1995, there were many topics reported frequently on news papers over the solid waste projects implemented such as the cases in Chiang Mai Incineration Plant Project, Lad Krabang Final Disposal Project, Hazardous Wastes Treatment Center in Rayong, etc. opposed by the neighboring residents of the construction sites for fear of environmental degradation after the plant operation started. Any kind of the development projects probably containing the elements to influence environmental degradation to the people and to nature require the primary consensus from the people reside in the project site and the surrounding areas.

Department of Public Cleansing(DPC), BMA is now practicing the separation of wastes into dry waste and wet waste in several districts, which may be intended for the compost plant in operation in On Nut Landfill Site and the forthcoming incineration plant construction project. This is one way of participation of the people to the public services to make one aware that the individual resident shall be responsible for the solid waste management through the garbage generated from his house, collection, treatment and disposal for the purpose of keeping a sanitary living environment in the society.

The study review the contents of the on-going projects and policy of public cleansing services in respect of future urban development policies and the points of urban environmental improvement in BMA Area.

8.2 Assessment on Present Condition

(1) Current Solid Waste Management

1) Implementing Agency

Department of Public Cleansing(DPC) undertake services of solid waste management from planning to operation and maintenance. Collection work is carried out under the management of each district office.

2) Existing Facilities

Existing facilities in operation under DPC is listed as follows. Figure 22.1 shows the location of each plant site.

Nong Khaem Landfill Site

- Landfill Site 375 rai
- Transfer Station 1,500 ton/day

On Nut Landfill Site

- Landfill Site 590.86 rai
- Transfer Station 1,200 ton/day
- Compost Plant 1,200 ton/day

Ram Intra Landfill Site (Tha Raeng)

- Landfill Site 59 rai
- Transfer Station 1,500 ton/day

Collection Vehicles

- Compactor, 10 cum 929 units
- Compactor, 2 tons 73 units
- Sided Loader , 12 cum 171 units
- Container Truck, 8 cum 139 units

(2) On-going Solid Waste Projects

DPC has implemented the projects for construction of the intermediate treatment facilities summarized in the followings.

1) Nong Khaem Compost Plant

Compost plant of 1,000 tons/day is now under construction at Nong Khaem Landfill site and expected to start operation in 1999.

2) On Nut Incineration Plant by Turn Key

Construction project of an incineration plant at On Nut Landfill Site with the capacity of 1,350 tons/day (450 x 3 furnaces) is in the process of bidding to start construction in 1997. The plant is expected to start operation in 2000.

3) Nong Khaem Incineration Plant by Turn Key

Turn key project will be implemented at Nong Khaem Landfill site to construct incineration plant of the capacity likely 1,350 tons/day (450 x 3 furnaces). However, the details have not decided yet.

4) Incineration Plant by BOT

Construction project for incineration plant by BOT is expected to start soon. The plant capacity is likely more than 1,000 tons/day ,however, the details have not decided yet.

5) Central Sludge Treatment Plant

The project is implemented at Rama Intra Landfill site by turn key base contract. Sludges from the wastewater treatment plants of BMA, fat and greases collected from greases traps from the wastewater treatment plants in restaurants, hotels, etc. shall be treated by the following facilities.

- Liquid Waste Max. 300 m3/day
- Sludge, Grease & Fat Max. 480 m3/day

The project is expected to start in 1996 and complete in 1999.

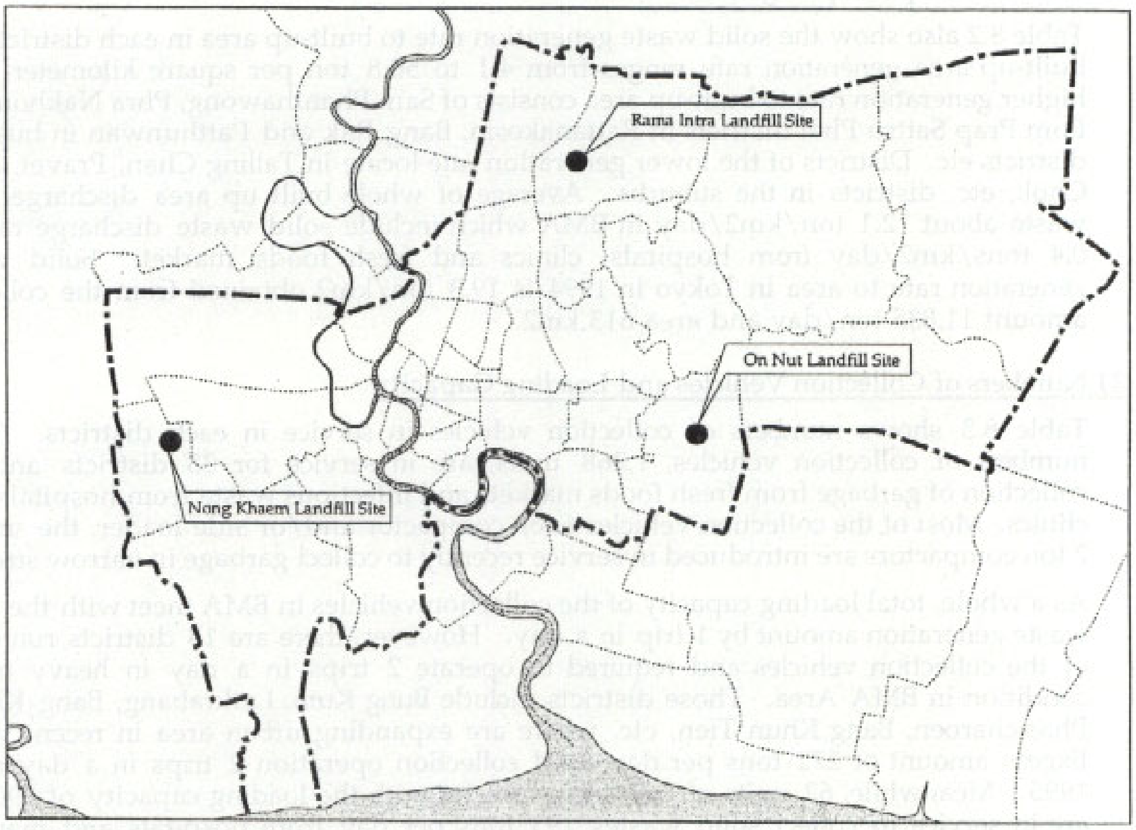


Figure 8.1 Location of Solid Waste Treatment and Disposal Facilities

(3) Solid Waste Amount in BMA Area

1) Solid Waste Amount in 1990 - 1995

Solid waste amount generated in BMA Area increase from 4,513 tons/day in 1990 to 6,539 tons/day in 1995 as shown in Table 8.1. Annual increase rate reached at 7.7 % in the last 6 years. Increase rate is more or less the same rate with the economic growth in Thailand. Meanwhile, population in the same period increase from 6.9 million to 8.1 million in BMA with the increase rate at 3.4 % per annum, which mean that the increase rate of solid waste is higher than the population increase rate and the solid waste generation rate per capita in the same period increase from 657 grams/day in 1990 to 805 gram/day in 1995 which is increasing about 4.1 % annually. Meanwhile, solid waste generation amount in Tokyo recorded the peak in 1989 and tend to decrease since 1990. Total collected solid waste amount ranges approximately 13,400 ton/day in 1989 to 11,800 ton/day in 1994. Per capita generation rate also shows decrease from 1,625 to 1,493 g/c/day in the same period.

2) Unit Solid Waste Generation Rate in District in 1995

Table 8.2 indicate solid waste generation rate in each district converted to the unit generation rate per resident population and per built-up area. Per capita solid generation rate ranges from 296 to 1,947 grams/day. Average of whole BMA indicate 805 grams per capita per day. Districts of the higher per capita generation rate are Phra Nakhon, Huai Khwang, Khlong Toei, Chatuchak, Sathon, etc. and the lower per capita generation rate districts locate in Nong Chok, Bang Sue, Talling Chan, Bang Phlad, Pom Phrap Sattru Phai, etc. Districts of the higher population density shows rather lower per capita generation rate.

Table 8.2 also show the solid waste generation rate to built-up area in each district. Per built-up area generation rate ranges from 4.1 to 50.8 ton per square kilometer. The higher generation rate to built-up area consists of Sam Phanthawong, Phra Nakhon, and Pom Prap Sattru Phai districts in Rattanakosin, Bang Rak and Patthunwan in business districts etc. Districts of the lower generation rate locate in Talling Chan, Pravet, Nong Chok, etc. districts in the suburbs. Average of whole built up area discharge solid waste about 12.1 ton/km2/day in BMA which include solid waste discharge rate of 0.4 tons/km2/day from hospitals, clinics and fresh foods market. Solid waste generation rate to area in Tokyo in 1994 is 19.3 ton/km2 obtained from the collected amount 11,835 ton/day and area 613 km2.

3) Numbers of Collection Vehicles and Loading Capacity

Table 8.3 shows numbers of collection vehicles in service in each districts. Total numbers of collection vehicles, 1,268 units, are in service for 38 districts and for collection of garbage from fresh foods markets and infectious waste from hospitals and clinics. Most of the collection vehicles 6 ton compactor and/or side loader, the smaller 2 ton compactors are introduced in service recently to collect garbage in narrow streets.

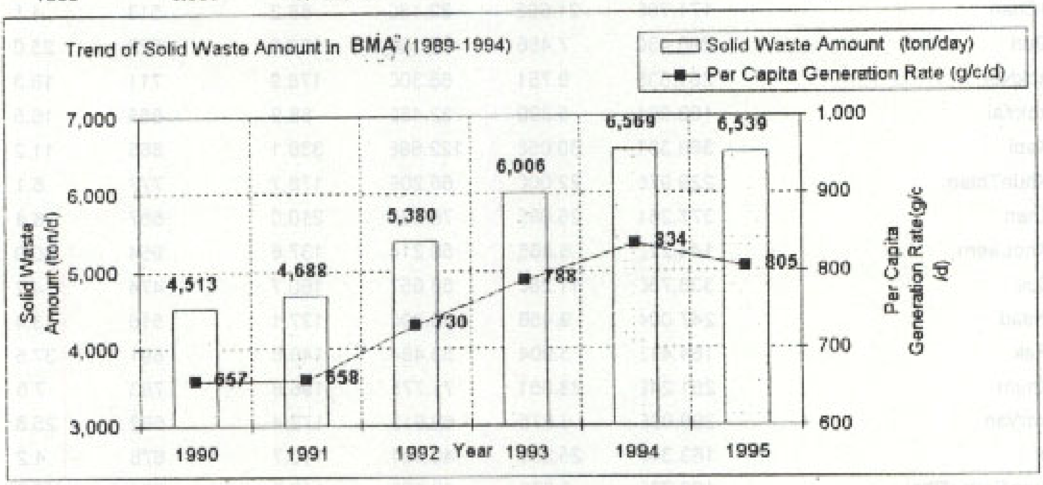
As a whole, total loading capacity of the collection vehicles in BMA meet with the solid waste generation amount by 1 trip in a day. However, there are 18 districts run short of the collection vehicles and required to operate 2 trips in a day in heavy traffic condition in BMA Area. Those districts include Bung Kum, Latkrabang, Bang Khaen, Phasicharoen, Bang Khun Tien, etc. where are expanding urban area in recent years. Excess amount of 272 tons per day need collection operation 2 trips in a day as of 1995. Meanwhile, 62 units of collection vehicles with the loading capacity of 290 ton are in service to collect solid wastes 193 tons per day from hospitals and markets. Figure 8.2 was prepared using the data in Table 8.3 to show visually the loading ratio between the amount of solid waste and the total loading capacity of the collection vehicles in each district.

DPC has started the Khlong Beautification Program since 1991 to collect floating garbage from the khlongs in Tonburin and Bangkok by the budget of 6 million Baht for 35 units of boats. Later 17 units of boats were added by spending budget about 3.7 million. The Program collect garbage about 25 to 30 tons/day from 38 khlongs in total. Table 8.4 shows the list of collection boats in service as of 1995.

Table 8.1 Trend of Solid Waste Generation Amount in BMA 1990-1995

Trend of Solid Waste Generation Amount in BMA 1990 - 1995

Year	Solid Waste Amount (ton/day)	Population	Per Capita Generation Rate (g/c/d)	Solid Waste Increase Ratio (%)	Population Increase Ratio (%)	Per Capita Generation Rate Increase Ratio (%)
1990	4,513	6,873,300	657	100	100	100
1991	4,688	7,123,864	658	104	104	100
1992	5,380	7,374,429	730	119	107	111
1993	6,006	7,624,995	788	133	111	120
1994	6,569	7,875,560	834	146	115	127
1995	6,539	8,126,125	805	145	118	123



Trend Solid Waste Generation Amount in Tokyo Metropolitan Area (1989 -1994)

Year	Solid Waste Amount (ton/day)	Population	Per Capita Generation Rate (g/c/d)	Solid Waste Increase Ratio (%)	Population Increase Ratio (%)	Per Capita Generation Rate Increase Ratio (%)
1989	13,429	8,111,731	1,625	281	118	247
1990	13,178	8,129,377	1,587	275	118	242
1991	12,898	8,154,404	1,519	264	119	231
1992	12,390	8,059,267	1,496	257	117	228
1993	12,057	8,111,731	1,486	257	118	226
1994	11,835	7,927,084	1,493	252	115	227

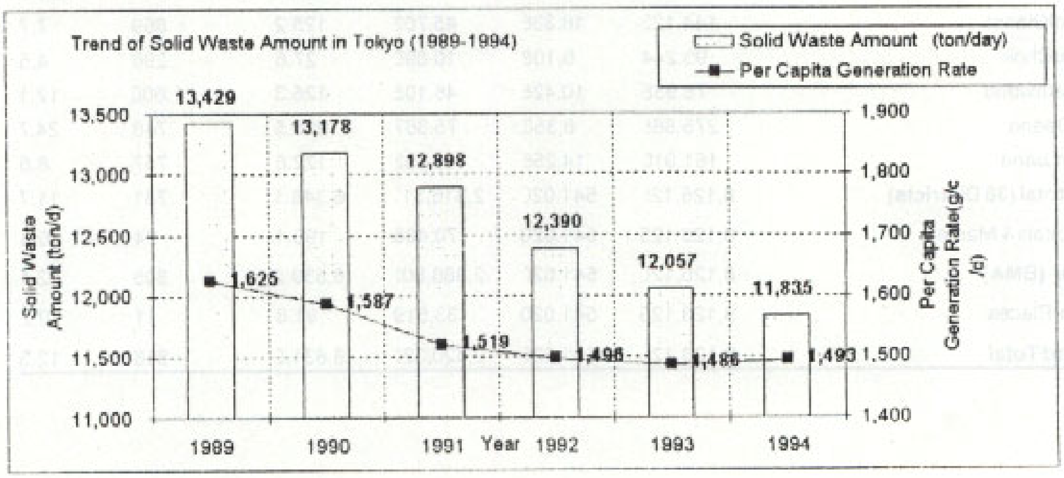


Table 8.2 Solid Waste Amount and Unit Generation Rate in 1995

District	Population	Built-up Area	Solid Waste Amount		Unit Generation Rate	
		km2	ton/year	ton/day	per capita per day	perkm2 perday
1 PhraNakhon	106,334	4.139	75,551	207.0	1,947	50.0
2 KhlongToei	306.564	26.141	138.918	380.6	1.241	14.6
3 KhlongSan	144.402	5.420	47.630	130.5	904	24.1
4 Chatuchak	227.700	29.064	100.157	274.4	1.205	9.4
5 ChomThong	199.282	12.954	59.337	162.6	816	12.5
6 DonMuang	298.654	38.286	92.876	254.5	852	6.6
7 Dusit	283.042	8.832	75.149	205.9	727	23.3
8 TalingChan	171.706	21.693	32.180	88.2	513	4.1
9 ThonBuri	296.430	7.456	68.103	186.6	629	25.0
10 BangkokNoi	251.535	9.751	65.300	178.9	711	18.3
11 BangkokYai	103.961	5.399	32.452	88.9	855	16.5
12 BangKapi	388.381	30.058	122.686	336.1	865	11.2
13 BangKhunThian	229.975	22.000	65.209	178.7	777	8.1
14 BangKhen	377.261	25.085	76.638	210.0	557	8.4
15 BangKhoLaem	144.223	6.865	50.214	137.6	954	20.0
16 BangSue	338.730	11.280	58.657	160.7	474	14.2
17 BangPhlad	247.004	9.456	46.390	127.1	515	13.4
18 BangRak	164.413	3.904	53.494	146.6	891	37.5
19 BungKhum	251.249	28.051	71.775	196.6	783	7.0
20 PathumWan	290.939	6.675	62.912	172.4	592	25.8
21 Prawet	163.345	26.283	40.401	110.7	678	4.2
22 PomPrapSattruPhai	198.739	2.370	40.163	110.0	554	46.4
23 PhayaThai	254.027	8.868	58.103	159.2	627	18.0
24 PhraKhanong	258.079	29.280	80.239	219.8	852	7.5
25 PhasiCharoen	314.860	23.161	89.469	245.1	779	10.6
26 Minburi	185.830	13.373	44.387	121.6	654	9.1
27 YanNawa	152.804	10.281	54.200	148.5	972	14.4
28 Ratchatavee	259.641	6.859	61.363	168.1	648	24.5
29 RatBurana	264.724	15.279	68.936	188.9	713	12.4
30 LatKrabang	123.696	11.614	40.050	109.7	887	9.4
31 LatPhrao	164.073	17.429	46.685	127.9	780	7.3
32 SanPhanthawong	73.479	1.237	22.933	62.8	855	50.8
33 Sathon	136.963	7.004	51.742	141.8	1.035	20.2
34 NongKhaem	144.123	16.336	45.703	125.2	869	7.7
35 NongChok	93.244	6.108	10.090	27.6	296	4.5
36 HuaiKhwang	78.938	10.425	46.105	126.3	1.600	12.1
37 DinDaeng	275.865	8.350	75.367	206.5	748	24.7
38 SuanLuang	161.910	14.255	44.753	122.6	757	8.6
Subtotal (38 Districts)	8,126,125	541.020	2,316,317	6,346.1	781	11.7
Hospitals & Markets	8,126,125	541.020	70,486	193.1	24	0.4
Total (BMA)	8,126,125	541.020	2,386,803	6,539.2	805	12.1
OtherPlaces	8,126,125	541.020	33,519	91.8	11	0.2
Grand Total	8,126,125	541.020	2,420,322	6,631.0	816	12.3

Table 8.3 Operation Condition of Solid Waste Collection Vehicles (1995)

District	Solid Waste Amount		1-4 Year Vehicles			5-6 Year Vehicles		More than 7 Year Vehicles		Total Number of Vehicles	Total Loading Capacity	Loading Capacity Ratio *1	Loading Balance *2	Urgency Ranking *3
	ton/year	ton/day	2ton	3.5ton	6ton	3.5ton	6ton	3.5ton	6ton	units	ton	ton/ton	ton	
Bang Kapi	122,686	336.1	2	5	35	1	1	1	4	49	252	1.332	-84	5
Bang Khen	76,638	210.0	2	2	19	0	5	0	1	29	151	1.395	-59	5
Bang Kho Laem	50,214	137.6	2	2	16	2	0	0	4	26	124	1.107	-13	3
Bang Khun Thian	65,209	178.7	1	5	18	0	0	0	2	26	134	1.338	-45	5
Bang Phlad	46,390	127.1	2	2	21	1	0	0	2	28	146	0.873	19	1
Bang Rak	53,494	146.6	2	1	21	0	2	0	7	33	164	0.896	17	1
Bang Sue	58,657	160.7	2	2	25	1	0	0	4	34	176	0.915	15	1
Bangkok Noi	65,300	178.9	2	2	23	1	3	0	0	31	165	1.083	-14	2
Bangkok Yai	32,452	88.9	2	2	14	0	0	2	1	21	102	0.876	13	1
Bung Khum	71,775	196.6	1	3	15	0	0	1	3	23	113	1.736	-83	6
Chatuchak	100,157	274.4	2	5	30	2	0	0	6	45	225	1.221	-50	4
Din Daeng	75,367	206.5	2	4	25	0	0	0	10	41	198	1.043	-8	2
Don Muang	92,876	254.5	1	5	25	1	0	1	7	40	195	1.306	-60	5
Dusit	75,149	205.9	2	2	29	0	4	0	3	40	212	0.971	6	1
Huai Khwang	46,105	126.3	2	3	23	2	3	0	0	33	171	0.738	45	1
Jomthong	59,337	162.6	1	2	23	1	0	0	3	30	159	1.025	-4	2
Khlong San	47,630	130.5	2	1	20	1	0	0	4	28	142	0.918	12	1
Khlong Toei	138,918	380.6	2	2	57	2	1	1	0	65	365	1.044	-16	2
Lat Phrao	46,685	127.9	2	3	21	1	0	0	0	27	143	0.894	15	1
Latkrabang	40,050	109.7	1	5	7	1	1	0	2	17	75	1.470	-35	6
Minburi	44,387	121.6	2	3	14	1	0	1	5	26	118	1.032	-4	2
Nong Chok	10,090	27.6	1	3	4	1	0	0	10	19	69	0.400	41	1
Nong Khaem	45,703	125.2	1	4	12	1	1	0	0	19	95	1.316	-30	5
Pathum Wan	62,912	172.4	1	4	25	2	1	0	4	37	188	0.918	15	1
Phasi Charoen	89,469	245.1	2	3	23	2	2	1	3	36	178	1.381	-68	5
Phaya Thai	58,103	159.2	2	3	28	2	0	0	5	40	203	0.785	44	1
Phra Khanong	80,239	219.8	2	6	22	1	0	0	6	37	178	1.238	-42	4
Phra Nakhon	75,551	207.0	2	5	31	3	0	0	4	45	227	0.910	20	1
Pom Prap Sattru Phai	40,163	110.0	2	1	19	0	1	0	2	25	132	0.834	22	1
Prawet	40,401	110.7	2	2	17	1	0	0	1	23	119	0.933	8	1
Rat Burana	68,936	188.9	1	3	21	1	1	2	4	33	161	1.172	-28	3
Ratchatavee	61,363	168.1	2	2	21	2	0	0	9	36	169	0.993	1	1
Sam Phanthawong	22,933	62.8	2	0	12	0	2	0	0	16	85	0.739	22	1
Sathon	51,742	141.8	2	2	24	2	0	0	3	33	169	0.838	27	1
Suan Luang	44,753	122.6	2	2	17	1	0	0	3	25	125	0.984	2	1
Taling Chan	32,180	88.2	2	1	12	1	1	0	0	17	87	1.018	-2	2
Thon Buri	68,103	186.6	2	1	30	1	2	1	2	39	207	0.902	20	1
Yan Nawa	54,200	148.5	1	3	17	3	3	0	7	34	157	0.947	8	1
Sub-total	**2,316,317**	**6,346**	**66**	**106**	**816**	**42**	**34**	**11**	**131**	**1,206**	**6,075**	**1.045**	**-272**	**2**
Hospitals & Markets	70,486	193.1	4	13	33	3	4	2	3	62	290	0.666	97	1
Total (BMA)	**2,386,803**	**6,539**	**70**	**119**	**849**	**45**	**38**	**13**	**134**	**1,268**	**6,364**	**1.027**	**-175**	

Note*

*1 indicate that the figures larger than 1.000 run short of loading capacity of the collection vehicles

*2 obtained the balance by subtracting the solid waste generation amount from the loading capacity in each district

*3 shows the ranking based on the following standard;

Rank 1 : smaller than 1.00 Rank 2 : 1.00 to 1.10 Rank 3 : 1.11 to 1.20 Rank 4 : 1.21 to 1.30 Rank 5 : 1.31 to 1.40

Figure 8.2

Disparities between Solid Wast Collection and Generation

Legend

- Smaller than 1.00
- 1.00 to 1.10
- 1.11 to 1.20
- 1.21 to 1.30
- 1.31 to 1.40
- Larger than 1.41
- Build-up Area
- Chaopraya River
- Main Roads
- Railways

N W E S

SCALE 1:235000

6 0 2 4 6 8 10

KILOMETERS

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)

Table 8.4 List of Collection Boats

District Office	Nos. of Boat	Name of Khlong in Service
Existing Boat		
TalingChan	2	K.Chakphra,K.BangRamard
	4	K.BangPhrom
BangkokNoi	3	K.BangkokNoi
BangKhunThian	2	K.HuaKrabue,K.SanamChai
ChomThong	2	K.SanamChai,K.Dan,K.BangMod
Thonburi	1	K.BangLuang,K.BangkokYai
PhasiCharoen	4	PhasiCharoen,PhrayaRatchamontri, BangWeak,BangChuaknung,BangLuang, K.Dan,SanamChai
BangkokYai	1	K.BangkokYai
BangKapi	1	K.SaenSaep
Pravet,SuanLuangBranch	1	K.PhraKhanong
LatKrabang	2	Pravetburirom,Hua Takei,Nong Brue
Ratburana	2	K.ChaengRon,K.SaphanKhwai
Pravet	1	K.Pravetburirom
DonMuang	3	K.Premprachakhorn
HuaiKhwang	3	K.LatPhrao,K.BangSue
BangKhen	3	K.ThomK.Song
Sub-total	**35**	
New Boat		
ChomThong	2	K.BangKhunThian,K.DaoKhanong, K.Shednah,K.BangMod,K.BangRanaeNoi
BangKapi	1	K.SaenSaep,K.LatPhrao
Ratburana	2	K.BangPakaew,K.BangMod
Pravet	1	
DonMuang	2	K.Premprachakhorn
BangKhen	2	K.SongtoK.Hokwa
Chatuchak	1	K.Premprachakhorn
Minburi	2	K.SaenSaep,K.Samwa
BungKhum	2	K.SaenSaep
PomPrab	2	K.Mahanak
Sub-total	**17**	
Total	**52**	

8.3 Policy Direction and Planning Issues

Changes of the society in recent years burden the administrative officials with the varieties of the problem arising out of the public services on the solid waste management likely as listed in the followings.

- Increase of solid waste amount
- Increase of undegradable waste and scattering of waste
- Difficulty to secure suitable landfill sites due to expansion of urban area
- Request for sanitary and comfortable living environment
- Difficulty to implement projects due to awareness of the people to participate in assessment of the projects in aspect of environmental conservation
- Request for resource recovery and recycling of waste in energy-saving society
- Increase of investment, operation and maintenance cost

Pollutes Pay Principle (PPP) is a topic in argument recently among the people concerned with the environmental conservation activities. PPP is not a slogan to put every responsibility on to the consumer side but to share the responsibility to the central government, local government bodies, enterprises and the consumers.

In solid waste management, the role of the central government is to provide financial sources for development of the facilities and technology in addition to prepare legislative measures. The role of the local government bodies is to install adequate facilities and public services in time whenever needed in addition to carry out an administrative guidance. The enterprises should have the role to take measures for reduction, reuse and recovery of waste and production of harmless consumable easily decomposed in the treatment and disposal processes. The consumers, or the beneficiaries should cooperate with the public cleansing services to attain the role to minimize generation of garbage, recycling, and bear for the due garbage fee.

Considering the planning direction in view of the role of local government bodies in solid waste management, BMA have to accelerate installation of necessary facilities and the measures to reduce solid waste amount supported by the enterprises and the beneficiaries who are also responsible to play their role in environmental conservation.

Three issues were picked out in consideration of the current installation of the solid waste management facilities with reference to the subjects mentioned above. Followings are the planning issues to be discussed for implementing the plan and program to the satisfactory manner to search the way for contributing to provide a healthy and sanitary urban environment through establishment of a adequate public cleansing services.

(1) Reduction of Rate of Solid Waste Generation and Recovery of Resources

Primary purpose of this subject is to economize the future development project in the long run by means of the benefits of reduction of raw waste amount from the sources of generation, the residuals generated from the treatment system for treatment and the final disposal site area.

In fact, control of discharge, recovery of valuables and separation of garbage at home will be the most effective way for treatment of garbage by types at the plants. Through participation of the people to the public services, a mind of saving-resources shall be inspired to the individuals so that the people shall take a glance at the garbage to think it over whether it is really an unusable, valueless, or still keeping a state of reusable in home.

In addition, recovery of resources from the treatment process is beneficial on both sides of the post treatment processes and the recovery of valuables. Resource recovery process or recycling process shall be installed at transfer stations, incineration plants or compost plants.

The more reduction of solid waste through the processes of garbage discharge sources, collection, treatment and disposal processes will lesser the plant scale of the implementation projects. In other words, BMA have to provide all her land for construction of landfill sites unless taking measures to establish recycling society through cooperation from the people and application of suitable technology.

(2) Construction of Intermediate Treatment Facilities

Only one compost plant is in operation at On Nut Landfill Site to treat 1000 to 1200 tons of municipal solid waste every day. Construction of the second compost plant of the rated capacity of 1,000 tons/day is in progress to start operation in 1999. Details of operation condition was not available, however, the final products of the plant is 30 % with the rejects from the process become 70 %. This is to say that large amount the rejects from the compost plant must be disposed at the landfill site. Municipal solid waste contain varieties of garbage and garbage should be segregated in the composting processes or controlled collection of compostable garbage from the sources of discharge. Without practicing proper separation, composting is not an effective treatment process of municipal solid waste.

The major objectives of intermediate treatment facilities of solid waste are intended 1) to reduce volume, 2) to stabilize and 3) to make harmless before disposed at the landfill site. Incineration of urban solid waste is one of the best method to meet with the objectives of solid waste treatment in technical and economic point of view.

The recent incineration technology has developed in combustion process, energy recovery, environmental protection, etc. including the conventional stoker type incinerator, fluidized bed incinerator, pyrolysis furnace, etc. The most feasible type shall be selected in combination with the total process of the treatment facilities suitable for Bangkok taking account of the characteristic of garbage, energy recovery and environmental conservation aspects.

(3) Procurement of Final Disposal Sites

At present, the existing three disposal sites are filled with raw refuse piled up on the garbage hills, raw refuse is transferred to the sanitary landfill sites provided outside of the city boundaries of Bangkok by the hauling & disposal contractors. One solid waste disposal contractors have provided newspaper articles several times before due to the claim from the neighboring residents suffering environmental deterioration caused by hauling garbage and landfill operation in Ladkrabang District. The other contractor haul garbage generated in Bangkok to the landfill site procured in Kanchanaburi Province. There will remain potential news sources in landfill operation without strict control and moral of the contractors.

With the concept of garbage treatment and disposal in the source of generation as a basic rule, BMA should procure the suitable landfill sites within own administration boundaries. Due to a hike of land price in recent years, it would be a hard jobs for officials concerned to find the suitable final disposal sites. Without a final disposal site, intermediate facilities nor public cleansing services itself will not work properly.

(4) Strategic Plan Proposed in The 5th BMA Five Year Development Plan

Department of Public Cleansing (DPC) drafted the proposals for The 5th BMA Five Year Development Plan to tackle with the solid waste problems. The programs are composed of the plans to improve and construct solid waste facilities and equipment for collection, treatment and disposal in participation of public sectors and public campaigns to cope with current and future solid waste management. Proposed programs of DPC for the next 5 year plan are presented as follows.

Program 1 : Promotion for Reduction of Solid Waste Generation Amount

Program 2 : Improvement of Collection Efficiency

Program 3 : Improvement of Disposal Efficiency

Program 4 : Improvement of Night Soil Management Efficiency

Program 5 : Supporting Services for Solid Waste, Night Soil and Hazardous Waste Management

Activities of the Programs

Program 1 : Promotion for Reduction of Solid Waste Generation Amount

- Public campaign for reduction of solid waster generation rates
- Educational campaign for knowledge about hazardous waste
- Public campaign for solid waste recycling and recovery

Program 2 : Improvement of Collection Efficiency

- Collection services for construction wastes
- Collection services for floating matters in waterways
- Provision of extra equipment and vehicles for supporting collection services
- Improvement of efficiency of collection vehicles
- Development of cleaning systems by mechanization in substitution of manpower
- Improvement of collection systems for infectious wastes
- Collection of hazardous wastes for communities
- Upgrading of public cleansing services by staff training and workshop

Program 3 : Improvement of Treatment and Disposal Efficiency

- Privatization of solid waste transfer and disposal services for On Nuch with a capacity not less than 2,000-2,500 t/day
- Privatization for O&M of the compost plant in On Nuch for a capacity not less than 1,000 t/day
- Construction of an incineration plant in On Nuch for a capacity not less than 1,000 t/day at On Nuch
- Privatization of solid waste transfer and disposal services for Nong Khaem with the capacity not less than 1,500-2,000 t/day
- Construction of a compost plant in Nong Khaem for a capacity not less than 1,000 t/day
- Construction of an incineration plant in Nong Khaem for a capacity not less than 1000 t/day
- Privatization of solid waster transfer and disposal services for Tha Raeng with a capacity not less than 2,000 t/day
- Construction of a compost plant in Bang Khaen for a capacity not less than 1000 t/day
- Provision of 5 waste transfer stations for nearby districts

Program 4 : Improvement of Night Soil Management Efficiency

- Privatization for treatment and disposal services for sludge from wastewater treatment plants of BMA, night soil, oil and grease residues at Tha Raeng

- Privatization for operation of the night soil treatment plant at Nong Khaem
- Collection services for oil and grease residues from restaurant and waste oil from gas stations and garages
- Provision of vacuum boats for night soil collection services for the area along waterways
- Provision of night soil vacuum trucks
- Investigation for exemption of night soil collection service fee to support the central wastewater treatment system for Phase I

Program 5 : Supporting Services for Solid Waste, Night Soil and Hazardous Waste Management

- Study for tendency of administration and management of generation, collection, recycle and disposal of solid waste, night soil and hazardous waste
- Feasibility study for utilization of swamp areas for sanitary landfill sites
- Feasibility study for privatization for management of construction and demolish wastes
- Feasibility study on large amount solid waste transportation and disposal at deforest areas

(5) Prediction of Solid Waste Amount

1) Method of Prediction

Generally, prediction of solid waste amount is carried out based on the per capita generation rate for domestic waste and the ratio of solid waste from business activities etc. However, in respect of the aspect to improve urban environment form the city planning to point of view, future solid waste amount was predicted based on the generation rate to built-up area analyzed from the relation between the existing built-up area and the collected solid waste amount in each District. By this method, it will be made available for the city planner to predict future solid waste amount through prediction of future development area. The applied procedures for prediction is indicated in the following steps

Step 1	:	Calculation of unit area generation rate to built-up area for 1995
Step 2	:	Calculation of the increase rate of population density from the data 1990 - 1995
Step 3	:	Calculation of annual increase rate of per capita generation rate from the data 1990 - 1995
Step 4	:	Pre-assumption of per capita generation rate in 2011 from the results of Step 3 and 1995 data
Step 5	:	Adjust the higher per capita generation rate of the Districts to limit the average of whole BMA ,1,501 g/c/d
Step 6	:	Calculation of increase rate of per capita generation rate from the results of Step 5 and 1995 data
Step 7	:	Obtain the future built-up area from the city planning data
Step 8	:	Calculation of unit area generation rate to built-up in 2011 from the results of Step 1, 2 and 6
Step 9	:	Prediction of solid waste amount in each district from the results of Step 7 and 8
Step 10	:	Evaluate the unit generation rate and the predicted amount and adjust if necessary.

2) Solid Waste Amount in 2011

Result of prediction was summarized in Table 8.5. Total solid waste amount generated in BMA Area will reach at approximately 14,700 ton/day in 2011 of which about 97 % is generated from residential and business area and the remaining 3 % is collected from hospitals, clinics and fresh foods markets. Increment compared with 1995 will be 8,100 ton/day in 2011. Department Public Cleansing, BMA predict future solid waste amount in the range of 18,800 and 14,400 ton/day hence the Study predicted the lower side.

An annual rate of increase become 3.4 % and the increase rate compared with 1995 become 2.2 times in 16 years. Intensity or generation rate to built up area was estimated at 23.0 ton/km2/day which is higher than the rate of 1994 data in Tokyo by about 20 %.

Due to increase of solid waste amount, public services in solid waste management will be a burden to the administration officials unless the projects shall implement in accordance with the schedule.

Table 8.5 Prediction of Solid Waste Amount (2011)

District	Solid Waste Amount in 1995 (ton/day)	Solid Waste Generation Rate1995 (ton/km2/day)	Solid Waste Amount in 2011 (ton/day)	Solid Waste GenerationRate 2011 (ton/km2/day)	Solid Waste Amount Increment (2011-1995) (ton/day)	IncreaseRate (2011/1995)(%)
Bang Kapi	336	11.2	812	18.5	476	242
Bang Khen	210	8.4	630	21.8	420	300
Bang Kho Laem	138	20.0	254	35.4	116	185
Bang Khun Thian	179	8.1	732	17.3	553	410
Bang Phlad	127	13.4	207	19.1	80	163
Bang Rak	147	37.5	171	43.8	25	117
Bang Sue	161	14.2	605	48.3	444	376
Bangkok Noi	179	18.4	464	40.1	285	259
BangkokYai	89	16.5	169	27.6	80	190
Bung Khum	197	7.0	769	15.9	572	391
Chatuchak	274	9.4	405	13.6	131	148
Din Daeng	206	24.7	439	52.5	232	213
Don Muang	254	6.6	694	12.7	439	273
Dusit	208	23.3	209	23.7	3	102
Huai Khwang	126	12.1	236	14.3	110	187
Jomtong	163	12.5	440	20.5	277	270
Khlong San	130	24.1	152	27.9	21	116
Khlong Toei	381	14.6	553	20.7	173	145
Lat Phrao	128	7.3	361	13.4	234	283
Latkrabang	110	9.4	240	18.1	131	219
Minburi	122	9.1	407	19.3	285	335
Nong Chok	28	4.5	140	22.9	112	506
Nong Khaem	125	7.7	256	15.3	131	204
Pathumwan	172	25.8	218	32.2	45	126
PhasiCharoen	245	10.6	667	19.1	422	272
PhayaThai	158	18.0	169	19.0	10	106
Phra Khanong	220	7.5	489	15.3	269	223
Phra Nakhon	207	50.0	160	38.6	-47	77
Pom Prap Sattru Phai	110	46.4	121	50.6	11	110
Prawet	111	4.2	518	12.6	407	468
Ratburana	189	12.4	487	23.5	299	258
Ratchathewi	168	24.5	198	28.9	30	118
Samphanthawong	63	50.8	68	54.8	5	108
Sathon	142	20.2	238	33.6	96	168
Suan Luang	123	8.6	342	16.9	219	279
Taling Chan	88	4.1	425	14.4	337	482
Thonburi	187	25.0	486	63.4	299	260
YanNawa	148	14.4	272	25.2	124	183
Subtotal	6,346	11.7	14,204	22.3	7,858	224
Hospitals & Markets	193	0.4	437	0.6	244	227
Total	6,539	12.1	14,641	23.0	8,102	224

Remarks : For reference, prediction by DPC, BMA for the year 2011 is presented as follows.

UpperValue:18,760t/day Average Value : 16,600 LowerValue:14,400t/day

8.4 Planning Targets and Framework

In this section, the target for implementing the plans and programs of individual key issue is proposed to solve the problem. Continuously, the framework and contents of the proposed action plans are presented in the manner of phased development planning. Cost of the projects will be estimated in the final section just for reference to know the scale of the project.

(1)Planning Targets

Daily activities of the human being generate a huge amount of wastes exceeding the permissible level left to the natural decomposition process especially in urban area. Difficulties in implementation of the solid waste projects such as impact on the neighboring area, procurement of land and budget, etc. likely cause of insufficient installation of the solid waste facilities in BMA Area. However, the heaps of garbage of the existing disposal sites can not wait any more delay of the solid waste projects now. Littering of garbage in living environment make the citizens feel uncomfortable, and its insanitary condition eventually caused degradation of quality of life.

The planning targets are set out as follows to achieve by the year 2011.

- Reduction of solid waste amount by 10 %
- Providing intermediate treatment facilities to process two-thirds or 60 - 70 % of solid waste prior to final disposal.
- Procurement of landfill site in BMA Area to serve for 20 -30 years

For contribution to achieve "Up-grading of Quality of Living", the action plans based on the planning targets are formulated in the following sections. Time does not wait now to declare "The Bangkok Garbage War".

(2) Proposed Action Plan to Achieve the Targets

Proposed programs of solid waste management in the 5th Five Year Development Plan has been reviewed on the stand point that the programs are properly selected to solve the current problem and prepared for the foreseeable future problem as well. In conclusion, the proposed programs are covered widely to take measures for the problems arising from solid waste management for BMA. Formulation of the action plans to be proposed in BEIP study will have duplication necessarily with those proposed in the 5th Five Year Plan. Accordingly, the proposed action plans are highlighted to the necessary minimum points effective to improve the situation toward up-grading of "Quality of Life" in consideration of the planning issues described earlier and divided into three phases plan.

Action Plan 1 : Reduction of Solid Waste Generation Rate and Recovery of Resources

Action Plan 1 is intended to materialize reduction of solid waste generation amount for treatment and disposal through participation of the communities, enterprises, District Offices and BMA to achieve reduction amount of 10 % by 2011.

Present Situation as of 1995

- Rate of municipal solid waster generation reached at 805 grams per capita per day in BMA
- Valuable wastes are recovered by collection staff and picked up by squatters at the disposal sites.
- Separation of garbage is practiced with dry and wet in several Districts

  Action Plan during 1997 - 2001

- Investigation of solid waste component, generation amount, etc.
- Investigation of amount of recyclable in garbage such as paper, bottles, steel and aluminum cans, plastics, etc. and market research.
- Study on legislative measures to clarify responsibility and role of the government, local government bodies, enterprises, and consumers.
- Study on conversion waste, compost, heat, electricity, solid fuels, etc.
- Study on searching for organizing recycling activities in communities, schools, temples, election districts, NGO, etc. for domestic solid waste
- Study on possible collaboration activities with enterprises for reducing waste, reuse, resource recovery, and produce degradable consumable
- Formulation of resource recovery and recycling plan in total flow of solid waste management system and relevant facilities
- Public campaigns to control discharge of waste by changing the prevailing energy-consuming life style

Action Plan during 2002 - 2006

- Selection and training of recycling leaders in Districts and recycling groups
- Establishment of Recycling Campaign Center in BMA and in District Offices
- Promotion of recycling activities in pilot area
- Construction of recycling plant(s) and Establishment of Recycling Market
- Public campaign to participate in recycling activities

Action Plan during 2007 - 2011

- Establishment of recycling activities and continuous operation
- Enforcement of regulations or new Decree for recycling and recovery of solid wastes
- Review of the recycling activities during 2002-2006 and necessary improvement

Action Plan 2 : Construction of Intermediate Solid Waste Treatment Facilities

Action Plan 2 is formulated to develop intermediate facilities to meet with the target to realize ratio of solid waste treatment with 60 to 70 % by 2011. To achieve the target, the following facilities must be developed by the year 2011.

Flow of Solid Waste Treatment and Disposal in 2011

Solid Waste Generation Amount	:	14,700 t/day
Compost Plant (1 plant)	:	1,000 t/day
Incineration Plant (5 plants)	:	7,050 t/day
Recycling	:	1,500 t/day
Landfill (Raw Refuse)	:	5,150 t/day
Landfill (Ashes and Rejects)	:	1,550 t/day

Figure 8.3 shows overall solid waste management system proposed for treatment and disposal in 2011 based on the amount shown above.

Intermediate facilities shall be designed to improve efficiency of post-coming final disposal, recover usable materials and to recover conversion products and energy. Because of large energy consumption by the intermediate facilities itself, the design have to consider about efficiency of each component and the total system and it is strongly emphasized that the plants must be equipped with the devices to minimize the secondary pollution.

Action Plan 2 is composed of installation of the facilities listed as follows.

- 2,000 t/day incineration plant in the East Bank (No. 3 Bangkok Incineration Plant)
- 1,000 t/day incineration plant in the East Bank(No. 4 Bangkok Incineration Plant)
- 1,000 t/day recycling/verge transfer plant in the East Bank river side area (Bangkok Recycling Center)
- 500 t/day recycling/verge transfer plant in the West Bank river side area (Tonburi Recycling Center)

Present Situation as of 1995

- Only one 1,000 t/day plant is in operation at On Nut Landfill Site
- Second compost plant of 1,000 t/day is under construction at Nong Khaem Landfill Site
- Turnkey incineration plant of the capacity expected at 1,350 t/day is to be prepared for bidding soon.
- BOT incineration plant of the capacity expected to be larger than 1,000 t/day will be prepare for bidding soon.

Action Plan during 1997 - 2001

- Completion of on-going four projects, 3 incinerators and 1 compost plant, expected to have the total capacity of 5,050 t/day
- Review and formulation of solid waste Master Plan and Feasibility Study for the next 5 Year Plan
- Planning and design of 2,000 t/day incineration plant in the East Bank
- Planning and design of the recycling/transfer plant in the East and the West banks having the capacity of 1,000 t/day and 500 t/day respectively.
- Study for collection of selected waste to increase efficiency of compost plant

Action Plan during 2002 - 2006

- Review of the incineration plants and compost plants constructed in the previous 5 Year Plan and Formulation of the nest 5 Year Plan
- Construction of 2,000 t/day No. 3 Bangkok Incineration Plant
- Planning and design of 1,000 t/day No. 2 Tonburi Incineration Plant
- Construction of recycling/verge transfer plants of 1,000 t/day and 500 t/day in the East and the West banks
- Experimental carry in the selected compostable waste and test operation

Action Plan during 2007 - 2011

- Construction of No. 2 Tonburi Incineration Plant
- Actual operation of the compost plant with selected compostable waste
- Abandon 1,000 t/day On Nut Compost Plant
- Review of the Master Plan and implementation for the next projects

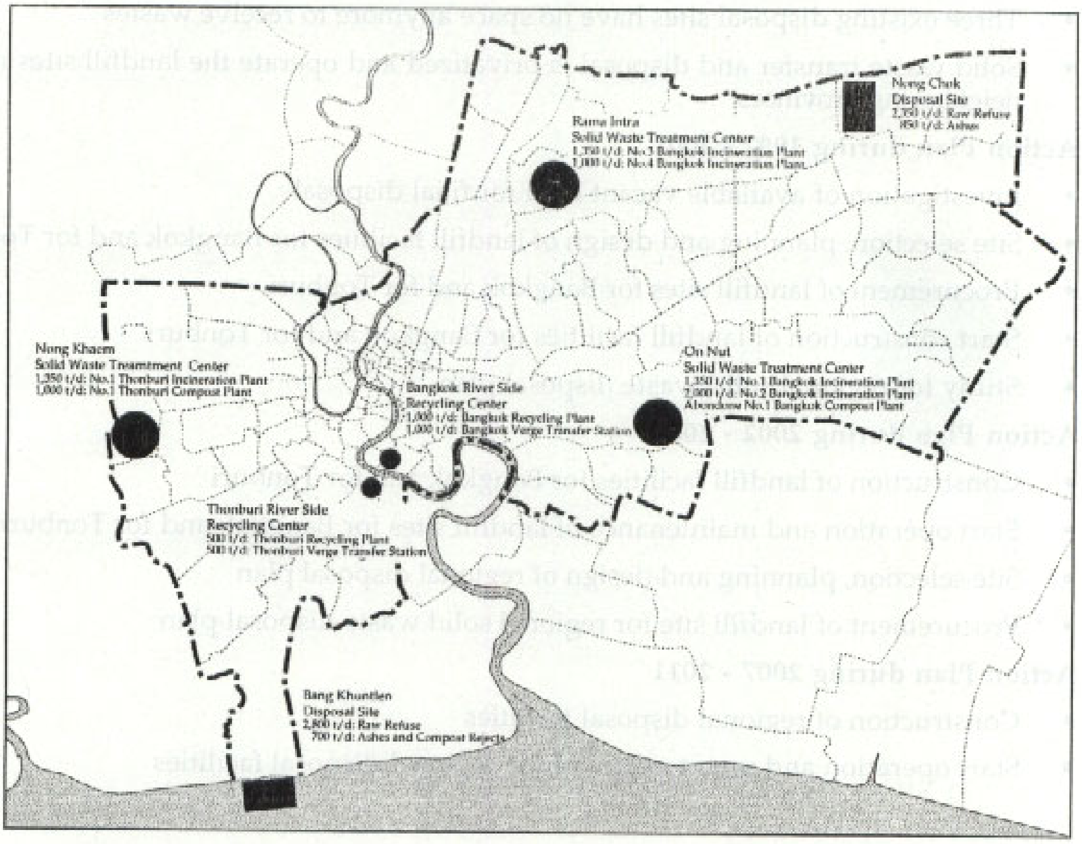


Figure 8.3 Proposed Solid Waste Treatment and Disposal System in 2001

Action Plan 3 : Procurement of Final Disposal Site

In view of no landfill site in BMA Area, Action Plan 3 is proposed to secure the landfill sites within the city boundary in Bangkok and Tonburi sides respectively for operation in the next 20 -30 years. Disposal of solid waste in flat terrain area is generally practiced by sanitary landfill in wet area such as swamp, marsh area, ponds, etc. Investigating the entire BMA Area, the candidate landfill sites are proposed at inland of Nong Chok District in Bangkok side and tidal area in Bang Khuntien District in Tonburi side.

Landfill in wet area or water area as well is associated with the water pollution problem caused by leachate from the filled material therefore suitable protective measures have to be studied prior to start implementation of the project.

For the proposed landfill site in Bang Khuntien, transportation of solid waste shall be made by both ways by land and by sea through the verge transfer station to be located in the river side area in Bangkok and Tonburi side respectively. The verge transfer station shall be designed to have the facilities for unloading and loading of compactor containers and resource recovery process to function also as the recycling center.

Procurement of landfill site in the eastern provinces supported by the railway transportation will be useful as consider the long term plan or as the final alternative sites replacing the landfill sites in Nong Chok and/or Bang Khuntien. In this case, solid waste disposal plan have to be formulated with regional level scheme to collaborate with the provincial governments, municipalities, The State Railways of Thailand, Department of Forestry, Department of Public Works, etc.

Considering the issues mentioned above, Action Plan 3 is proposed as follows. As for reference, conceptual design for landfill site in Bang Khuntien was shown in Figure 8.4.

Present Situation as of 1995

- Three existing disposal sites have no space anymore to receive wastes
- Solid waste transfer and disposal is privatized and operate the landfill sites in the neighboring provinces

Action Plan during 1997 - 2001

- Investigation of available vacant land for final disposal
- Site selection, planning and design of landfill facilities for Bangkok and for Tonburi
- Procurement of landfill sites for Bangkok and for Tonburi
- Start construction of landfill facilities for Bangkok and for Tonburi
- Study for regional solid waste disposal plan

Action Plan during 2002 - 2006

- Construction of landfill facilities for Bangkok and for Tonburi
- Start operation and maintenance of landfill sites for Bangkok and for Tonburi
- Site selection, planning and design of regional disposal plan
- Procurement of landfill site for regional solid waste disposal plan

Action Plan during 2007 - 2011

- Construction of regional disposal facilities
- Start operation and maintenance of the regional disposal facilities

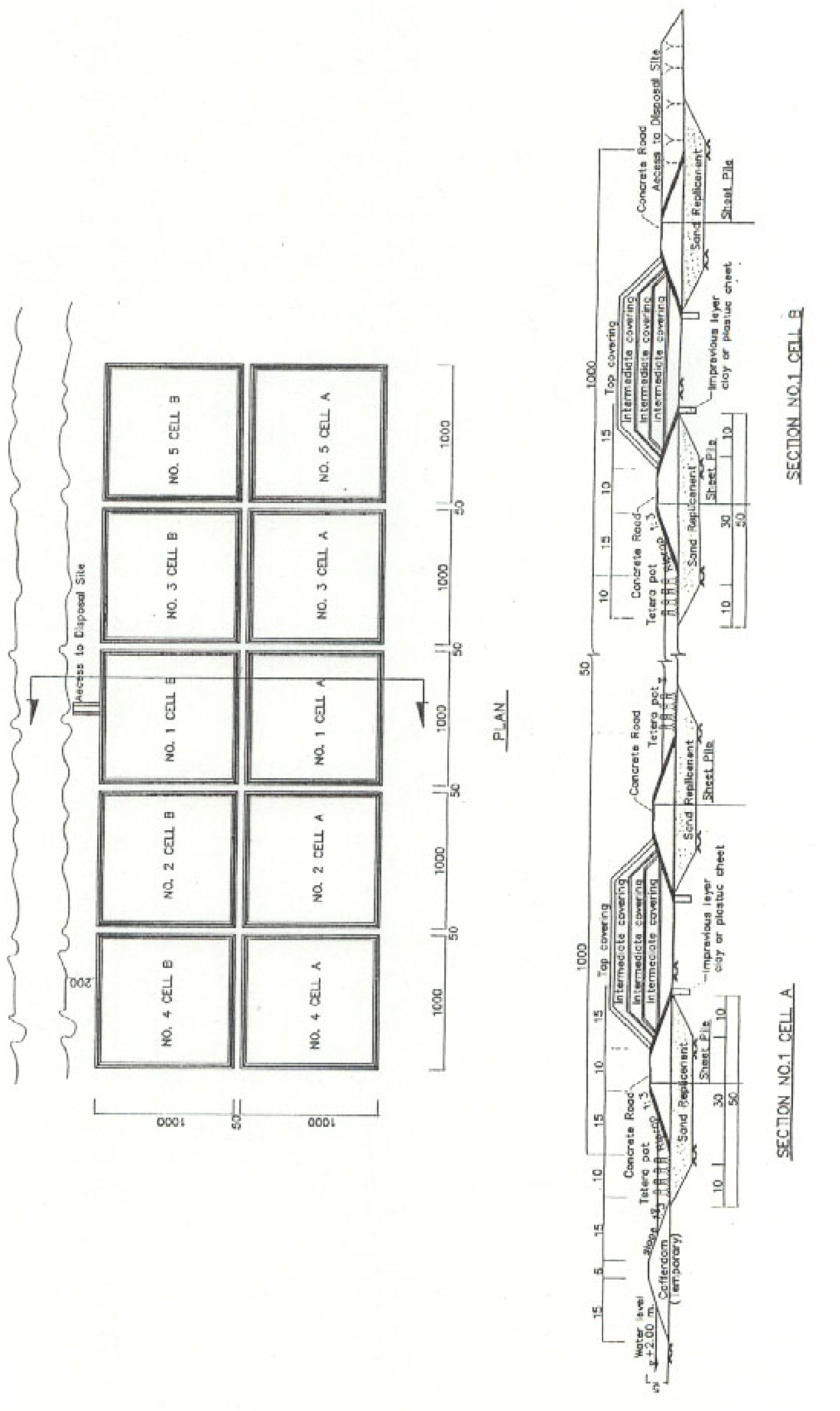


Figure 8.4 Conceptual Design of Bang Khun Thian Off-shore Disposal Site

CHAPTER 9: HOUSING AND HUMAN SETTLEMENT

9.1 General

Bangkok has approximately 5.6 million population with some 1.3 million households in 1993, according to the BMA registration date. However, the actual population is estimated at approximately 8 million in 1995. The number of households has increased at a 4.4% p.a. during the period from 1980 to 1990. The average household size is 3.8 persons/household with a decreasing trend, thus nuclear families seem to be recently increasing.

Bangkok families live in several types of houses such as detached houses, townhouses, apartments and flats, condominiums, row houses, so on. As seen in Table 9.1, 44% of all the families reside in detached houses, and 33%, in either row houses or brick row houses.

Recently, the housing market has been very active, providing with neat townhouses targeting at the middle income families in suburban areas. On the other hand, shanty houses still remain in several areas along Khlongs and the old city.

Table 9.1 Number of Houses by Type in Bangkok

Person	Detached House	Townhouse	Apartment, Frat	Condo-minium	Row House	Brick Row House	Others	Total
1	28,849	9,402	20,137	1,223	14,948	17,161	5,021	96,741
2	69,710	20,718	32,344	1,295	41,566	30,687	11,655	207,975
3	104,006	26,540	29,164	965	42,306	39,073	9,545	251,599
4	129,027	28,199	24,316	492	36,894	47,618	5,916	272,462
5	100,295	18,974	12,799	254	22,906	43,408	3,306	201,942
6	64,277	10,383	6,268	89	12,030	31,882	1,251	126,180
7	38,372	5,206	2,839	37	6,359	19,146	577	72,536
8	23,332	2,348	1,074	8	3,766	12,024	317	42,869
9	13,523	1,479	732	14	2,136	7,108	136	25,128
10 & Over	20,928	1,413	629	13	2,769	9,028	340	35,120
Total	592,319	124,662	130,302	4,390	185,680	257,135	38,064	1,332,552
Average	4.51	3.88	3.17	2.52	3.67	4.59	3.04	4.17

Source: Population and Housing Census, NSO, 1990

9.2 Salient features of Housing in Bangkok

(1) Size of Houses

Although any sufficient date analyzing size of house is not available, the number of bed rooms may represent present features. According to the Population and Housing Census 1990, as shown in Table 9.2, the average size of house per Bangkok family was 2 bed rooms plus 0.3 rooms for the other use. The average family member per unit was 4.51 persons/house for detached house and townhouse accommodate and 3.88 person/house, while 3.17 person/house and 2.52 person/house for apartment/flat and condominium respectively. Thus, apartment, flat and condominium are utilized by small households and the detached house and townhouse, by bigger households.

Table 9.2 Size of Houses in Bangkok 1990

Bed Room/ Other Room	Detached House	Townhouse	Apartment, Flat	Condo-minium	Row House	Brick Row House	Others	Total
No. of Bed Room								
None	14,202	1,125	8,580	8	14,698	3,564	4,988	47,165
1	139,519	12,402	91,922	3,089	113,933	53,101	28,654	442,620
2	182,792	67,042	26,027	907	41,289	95,979	2,759	416,795
3	157,453	33,364	3,137	283	11,108	67,648	918	273,911
4 and Over	97,594	11,029	517	103	4,509	36,342	718	150,812
Unkhown	744	57	116		140	494	24	1,575
Total	592,304	125,019	130,299	4,390	185,677	257,128	38,061	1,332,878
Average	2.31	2.33	1.19	1.40	1.33	2.31	1.05	2.03
No. of Other Room Used for Sleeping								
None	442,184	99,978	89,681	2,930	140,096	204,444	30,047	1,009,360
1	122,846	20,374	38,298	1,271	41,569	43,874	7,460	275,692
2	18,834	3,063	1,692	146	3,062	6,383	474	33,654
3	4,937	686	451		490	1,376	39	7,979
4 &Over	3,155	499	85	46	328	777	38	4,928
Unknown	359	63	90		127	277	12	928
Total	592,315	124,663	130,297	4,393	185,672	257,131	38,070	1,332,541
Average	0.32	0.25	0.33	0.40	0.27	0.25	0.23	0.29

Source: Population and Housing Census, NSO, 1990

(2) Tenure of Houses

46% of households in Bangkok were house owners in 1990, as shown in Table 9.3. The ownership is approximately 30% lower than the national average. Bangkok is characterized by a higher population of renters.

Most of detached houses and townhouses are owned by dwellers, however, most of dwellers at apartment and flat, condominium, and row house are renters. It is interesting that as per condominiums, half are owner and half, renters.

(3) Location of House Supplied

Looking at the locational characteristics of recent housing development from "NHA Annual report, 1994", a considerable number of housing development was located in the area with a 20 km radius from the center of Bangkok. The housing development momentum has a clear development direction towards the North and the East, namely, Don Muang and Bang Khen Districts in the northern part of Bangkok and Min Buri and Lat Krabang Districts in the eastern part of Bangkok.

(4) Slums

As seen in Table 9.4, a total of 1,223 locations of slums were identified in Bangkok in 1993. Out of them, some 325 slums are located in the CBD zone, while 318 and 580 slums in the urbanized and suburban zones respectively. The CBD zone decreases the number of slums, on the contrary, the urbanized and suburban zones slums are increasing in the numbers.

Approximately 1.3 million people are still dwelling in slums, which shares 22.5% of the population of Bangkok. The number of slum dwellers increased by more than 30% only for 3 years during the period from 1990 and 1993. Thus, the slums are still expanding and moving their locations from the central area to the outer area of Bangkok.

Table 9. 3 Tenure of Living Quarters in Bangkok in 1990

	Detached House	Townhouse	Apartment, Frat	Condo-minium	Row House	Brick Row House	Others	Total
Owner	372,148	93,957	8,324	2,196	21,950	117,589	1,255	617,419
Hire Purchaser	12,487	11,640	3,343	0	2,433	13,951	95	43,949
Rent	155,266	14,003	73,022	2,001	109,135	101,559	13,363	468,349
Payment in Kind	8,439	1,246	28,693	60	22,800	8,171	14,422	83,831
Rent Free	15,760	1,617	12,366	77	19,506	6,500	6,704	62,530
No Payment	17,711	452	2,807	58	8,133	4,573	1,461	35,195
Others	2,283	178	541	0	648	680	557	4,887
Unknown	6,165	1,268	902	0	1,481	3,204	110	13,130
Total	590,259	124,361	129,998	4,392	186,086	256,227	37,967	1,329,290
Share								
Owner	63.05%	75.55%	6.40%	50.00%	11.80%	45.89%	3.31%	46.45%
Hire Purchaser	2.12%	9.36%	2.57%	0.00%	1.31%	5.44%	0.25%	3.31%
Rent	26.30%	11.26%	56.17%	45.56%	58.65%	39.64%	35.20%	35.23%
Payment in Kind	1.43%	1.00%	22.07%	1.37%	12.25%	3.19%	37.99%	6.31%
Rent Free	2.67%	1.30%	9.51%	1.75%	10.48%	2.54%	17.66%	4.70%
No Payment	3.00%	0.36%	2.16%	1.32%	4.37%	1.78%	3.85%	2.65%
Others	0.39%	0.14%	0.42%	0.00%	0.35%	0.27%	1.47%	0.37%
Unknown	1.04%	1.02%	0.69%	0.00%	0.80%	1.25%	0.29%	0.99%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: Population and Housing Census, NSO, 1990

Table 9.4 Slums in Bangkok in 1990 and 1993

	No. of Slum			No. of popultion in Slum		
	1990	1993	93/90	1990	1993	93/90
CBD Zone*	338	325	0.96	374,500	355,333	0.95
Urbanised Zone*	295	318	1.08	351,819	406,744	1.16
Suburban Zone*	315	580	1.84	220,520	494,193	2.24
Total	948	1,223	1.29	946,839	1,256,270	1.33
Population				5,546,937	5,572,712	1.00
Share of Slum in Popuation of Bangkok				17.07%	22.54%	

Note: * The division of the districts into the zone is same as Table 2.9.

Source: Statistical Profile of BMA

(5) Parks and Urban Amenities

Table 9.5 shows that community facilities regarding urban amenity such as library, park and youth center. As per parks, Bangkok has a relatively small area in terms of the per capita are, which accounts for only 0.55 m^2/person, including open spaces. This figure is much lower than those of other large cities in the world. In terms of the zonal distribution, the CBD zone has relatively larger area of parks and open space, while the urbanized zone has the smallest. This implies that recent urbanization is not concomitant with sufficient provision on urban amenity facilities.

Table 9.5 Parks and Urban Amenities in Bangkok in 1993

	Libraries	Parks (sq.m)				Youth	Park per Person
		Public Park	Open Space	Play Ground	Total	Center	(sq.m/person)
1 Pra Nakhon	1	36,800	158,382	240	195,422	2	2.13
2 Khlong Toei					0		0.00
3 Klong San	1		892		892		0.01
4 Chatuchak		304,000	94,916		398,916		2.17
5 Chom Thong	1				0		0.00
6 Don Muang					0		0.00
7 Dusit			49,860	80	49,940		0.28
8 Taling Chan	1			420	420	1	0.00
9 Thon Buri			77,720	280	78,000	1	0.34
10 Bangkok Noi			51,300	160	51,460	2	0.29
11 Bangkok Yai	1		100	40	140	1	0.00
12 Bang Kapi		560,000			560,000		2.41
13 Bang Khun Thian					0	1	0.00
14 Bang Khen	1			320	320	1	0.00
15 Bang Kho Laem					0		0.00
16 Bang Sue			1,200		1,200	1	0.01
17 Bang Phlat					0		0.00
18 Bang Rak			1,056	40	1,096	1	0.01
19 Bung Kum					0		0.00
20 Pathum Wan	2	576,000	3,100	3,600	582,700	3	4.72
21 Prawet	1				0	1	0.00
22 Pom Prap			4,100	120	4,220	1	0.05
23 Phaya Thai	1		680		680		0.00
24 Phra Khanong		800,000	1,300	940	802,240	3	3.99
25 Phasi Charoen	1				0		0.00
26 Min Buri					0	1	0.00
27 Yan Nawa			3,612	300	3,912	1	0.04
28 Ratchthewi			25,571		25,571		0.23
29 Rat Buruna		101,280			101,280	1	0.61
30 Lat Krabang		80,000			80,000	1	1.04
31 Lat Phrao	1				0		0.00
32 Sam Phanthawong			1,950		1,950		0.04
33 Sathon					0		0.00
34 Nong Khaem					0	1	0.00
35 Nong Chok		56,800			56,800		0.89
36 Huai Khwang			34,597	560	35,157	1	0.14
37 Din Daeng					0		
38 Suan Luang					0		
Bangkok Total	12	2,514,880	510,335	7,100	3,032,315	26	0.55
By Zone							
CBD Zone*	6	612,800	370,610	4,440	987,850	11	0.52
Urbanised Zone*	2	405,280	138,425	980	544,685	5	0.33
Suburban Zone*	4	1,496,800	1,300	1,680	1,499,780	10	0.74
Total	12	2,514,880	510,335	7,100	3,032,315	26	0.55

Note: * Division of districts into thezone is same as Table 2.9.

Source: Statistical Profile of BMA, 1993

9.3 Current Housing Supply Market in Bangkok

In order to identify the current state of the housing market in Bangkok, the BEIP Team surveyed the real estate/housing information magazines available in the city as of November 1995. The results yielded several implications on suburbanization as well as the land market economy in Bangkok.

(1) Marketable Prices of Housing Units

As seen in Table 9.6, the average price of detached houses was 2.9 million Bath/unit in Bangkok and 1.9 million Bath/unit in vicinity provinces. For townhouses, the average price was 1.5 million Bath/unit in Bangkok and 0.7 million Bath/unit in the vicinities. Housing units located in the CBD zone were the most expensive. The prices tend to decrease in accordance with the distance from the center of Bangkok.

Since the average monthly household income in Bangkok as of 1995 are deemed to be about 21,000 Baht (the BEIP Survey), if it is assumed that the affordable level of house purchase of the average family is more or less 5 times of its annual income, the marketable prices per unit for the average family is computed at 1.26 million. However, the housing supply market does not offer townhouses at such a price in the urbanized area in Bangkok. Inevitably, the average family, if it wants to buy a housing unit, should look for its house in suburban areas or outside Bangkok. This is one of the reasons from the housing market viewpoint why suburbanization is rapidly proceeding without sufficient environmental considerations.

(2) Price Ranges of Current Housing Market

The following findings are identified though this analysis:

- Detached houses are most expensive, followed by townhouses, condominiums;
- 2-3 million Baht is the most popular pricing range for detached houses in Bangkok;
- 1-2 million Bath is the most popular pricing range for the townhouses in Bangkok,
- Less than 500 thousand Bath is the most popular pricing range for the condominiums in Bangkok.

9.4 Policy Directions and Planning Issues

Based on the analyses made in the preceding sections, the following planning issues and policies are identified:

(1) Provision of Adequate Public Utilities and Amenities in Residential Areas

A urban sprawl type of residential development is observed in the suburban area of Bangkok. This eventually causes a large burden on the public sector to provide with adequate urban infrastructures, utilities and amenities. To prevent from the urban sprawl, a development guideline to meet the land use plan should be formulated.

(2) Enhancement of Low and Middle Income Housing Provision

NHA is the responsible agency to provide the low income houses. More efforts are necessary to provide affordable housing units for them. To this end, the subcenter or new town development may be a key to launch a large scale of project. In order to facilitate the land acquisition process, a more diversified system needs to be explored, instead of the current land purchase system, such as application of Land Readjustment System, Joint Development with the private sector and/or Land Trust System.

Tabel 9.6 Housing Prices at Current Housing Suupply Market in Bangkok

	Bangkok				BMR						Other Areas	Total
	CBD	Urbanized	Suburban	Sub-Total	Patun Thani	Nakon Patom	Nontaburi	Samut Prakan	Samut Sakhon	Sub-total		
House for sale												
Less than 500 Thousand Baht	0	0	0	0	0	0	0	0	0	0	3	3
500 Thousand -1 Million Baht	2	4	10	16	1	2	0	3	0	6	7	29
1 -2 Million Baht	1	28	50	79	6	10	2	16	1	35	9	123
2 -3 Million Baht	3	46	44	93	3	16	1	7	0	27	5	125
3 -5 Million Baht	8	51	29	88	1	15	1	7	0	24	2	114
More than 5 Million Baht	11	47	36	94	1	7	0	1	0	9	1	104
Total	25	176	169	370	12	50	4	34	1	101	27	498
Average Price	3,721	2,913	2,737	2,887	2,063	2,181	1,376	1,508	1,500	1,902	1,463	2,610
Townhouse for sale												
Less than 500 Thousand Baht	0	0	1	1	2	1	1	0	0	4	11	16
500 Thousand -1 Million Baht	0	29	89	118	30	46	4	13	13	106	14	238
1 -2 Million Baht	8	137	140	285	10	64	3	22	22	121	4	410
2 -3 Million Baht	8	53	33	94	2	14	0	3	3	22	1	117
3 -5 Million Baht	7	27	12	46	1	1	0	1	1	4	1	51
More than 5 Million Baht	1	8	1	10	0	0	0	0	0	0	0	10
Total	24	254	276	554	45	126	8	39	39	257	31	842
Average Price	1,647	1,653	1,330	1,492	956	1,316	969	1,289	1,289	1,234	702	1,384
Condominium for sale												
Less than 500 Thousand Baht	3	67	60	130	6	26	0	23	3	58	10	198
500 Thousand -1 Million Baht	14	61	21	96	1	17	0	6	0	24	8	128
1 -2 Million Baht	7	16	4	27	1	2	0	1	0	4	1	32
2 -3 Million Baht	2	6	0	8	0	2	0	1	0	3	1	12
3 -5 Million Baht	1	4	3	8	0	0	0	0	0	0	0	8
More than 5 Million Baht	0	1	1	2	0	0	0	0	0	0	0	2
Total	27	155	89	271	8	47	0	31	3	89	20	380
Average Price	991	703	497	664	469	580	-	460	250	517	625	628
Flat for sale												
Less than 500 Thousand Baht	1	8	4	13	0	0	0	2	0	2	0	15
500 Thousand -1 Million Baht	1	2	0	3	0	0	0	0	0	0	0	3
1 -2 Million Baht	0	0	0	0	0	0	0	0	0	0	0	0
2 -3 Million Baht	0	0	0	0	0	0	0	0	0	0	0	0
3 -5 Million Baht	0	0	0	0	0	0	0	0	0	0	0	0
More than 5 Million Baht	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	10	4	16	0		0	2	0	2	0	18
Average Price	500	350	250	344	-	-	-	250	-	250	-	333
Apartment for sale												
Less than 500 Thousand Baht	0	0	0	0	0	0	0	0	0	0	0	0
500 Thousand -1 Million Baht	0	0	1	1	0	0	0	0	0	0	0	1
1 -2 Million Baht	0	0	0	0	0	0	0	0	0	0	0	0
2 -3 Million Baht	0	1	0	1	0	0	0	0	0	0	0	1
3 -5 Million Baht	0	0	0	0	0	0	0	0	0	0	0	0
More than 5 Million Baht	1	5	0	6	0	0	0	3	0	3	0	9
Total	1	6	1	8	0	0	0	3	0	3	0	11
Average Price	7,500	6,667	750	6,031	-	-	-	7,500	-	7,500	-	6,432

Source: The Study Team compiles based on "Akan-Tidin (Building-Land) "(in Thai), 24-30 Nov. 1995, Public-Vattachak

(3) One-More-Step Solution of Slum Problems

The resolution of housing issues, especially slum-problems, will be more vital for the upgrading of people's quality of living as well as the implementation of urban environment. A key for solution of the slum-problems is thought to be the implementation of an integrated policy mix, including, employment, social welfare, housing and urban planning policies.

CHAPTER 10: NOISE AND VIBRATION

There exists areas where the noise level sometimes exceeds 80 dB (LAeq) in Bangkok. Such a high noise level may imply that noise problems should be treated as a matter of the health problem, as well as a matter of urban amenities.

10.1 General

(1) Noise

Noise has two facets in the nature. One is an emotional side, such as unpleasant, uncomfortable feeling, disturbance against sleeping, and so on. Another is the irreversible effect on human hearing ability.

The former is closely related to the amenity of the city. From this point of view, the guideline level is much lower than the level of the latter facet, and may change in accordance with situations such as day time or night time, residential area or shopping area and so on.

The latter is related to human health, i.e. the hearing ability. In this point, for example, Environmental Protection Agency of U.S.A has set 70 dB (LAeq) for protection from worsening inhabitant's hearing ability. International Labor Organization (ILO) has adopted a guideline that 85 dB (LAeq, 8h) is the limit level, i.e., the exceeding of this level at working places is apt to cause some hearing disability in the long run for the factory worker.

It was identified from the survey conducted by the Study Team that the daytime noise level at Patthanakan junction exceeds 80 dB (LAeq) and reaches the level of 85 dB (LAeq). This situation is likely caused by the heavy traffic and the covering effects of flying-over road. It can generally be said that this noise level can be construed as an issue on public health.

People's great concern about air pollution has been focused on TSP so far, but the noise problem is considered to be another significant issue of urban environment soon or later. It is the case that awareness of pollution problem by inhabitants sometimes delays after its actual occurrence.

(2) Vibration

Main characteristic of vibration problems is emotional and local, similar to noise problems. On the contrary, according to the survey result by the Study Team in December 1995, vibration problems do not seem so severe as noise problems.

10.2 Assessment on Present Conditions

(1) Roadside Noise Level in the Central Area of Bangkok

Regarding noise levels in Bangkok, published data is very little. Available information is only graph, so it is difficult to find out clear figures of noise data. According to "Pollution Situation in Thailand 1994", it is reported that roadside 24 hours noise level ($L_{Aeq,24}$) are between 70 to 85 dB(A). It can be observed that the similar situation is prevailing at major roadsides in Bangkok.

(2) Noise Survey Results of the JICA Study Team

The noise level survey was carried out in December 1995 at 5 survey points for road traffic noise, 5 survey points for industrial noise and 2 survey points for railway noise, as shown in Fig. 10.1. The results are summarized in Tables 10.1. to 10.3.

Table 10.1 Roadside Noise Level (LAeq, dB)

Location	Road	Morning	Noon	Evening	Night
Din Daeng	Viphawadi Rangsit Road	80	79	80	79
Lumphini Park	Rama 4 Road	83	81	80	81
Benjasiri Park	Sukhumvit Road	73	65	76	76
Ramkhamhaeng-Patthanakan Crossing	Patthanakan Road	78	84	83	82
Near Kasem Phihaya School	Sukhumvit Soi 71	79	79	82	80

Note: Morning:05:00-09:00,Noon:10:00-14:00,Evening:15:00-20:00,

Night:20:00-9:00

Source: JICA Study Team

Table 10.2 Factory Related Noise Level (LAeq, dB)

Location	District	Morning	Noon	Evening	Night
Ceramic	Phra Khanong	65	64	63	64
Metal (1)	Phra Pradaeng	61	66	65	65
Metal (2)	Phra Pradaeng	70	75	76	76
Utility	Muang	77	77	79	79
Fuel	Phra Khanong	61	71	63	61

Note: Morning:05:00-09:00,Noon:10:00-14:00,Evening:15:00-20:00,

Night:20:00-24:00

Source: JICA Study Team

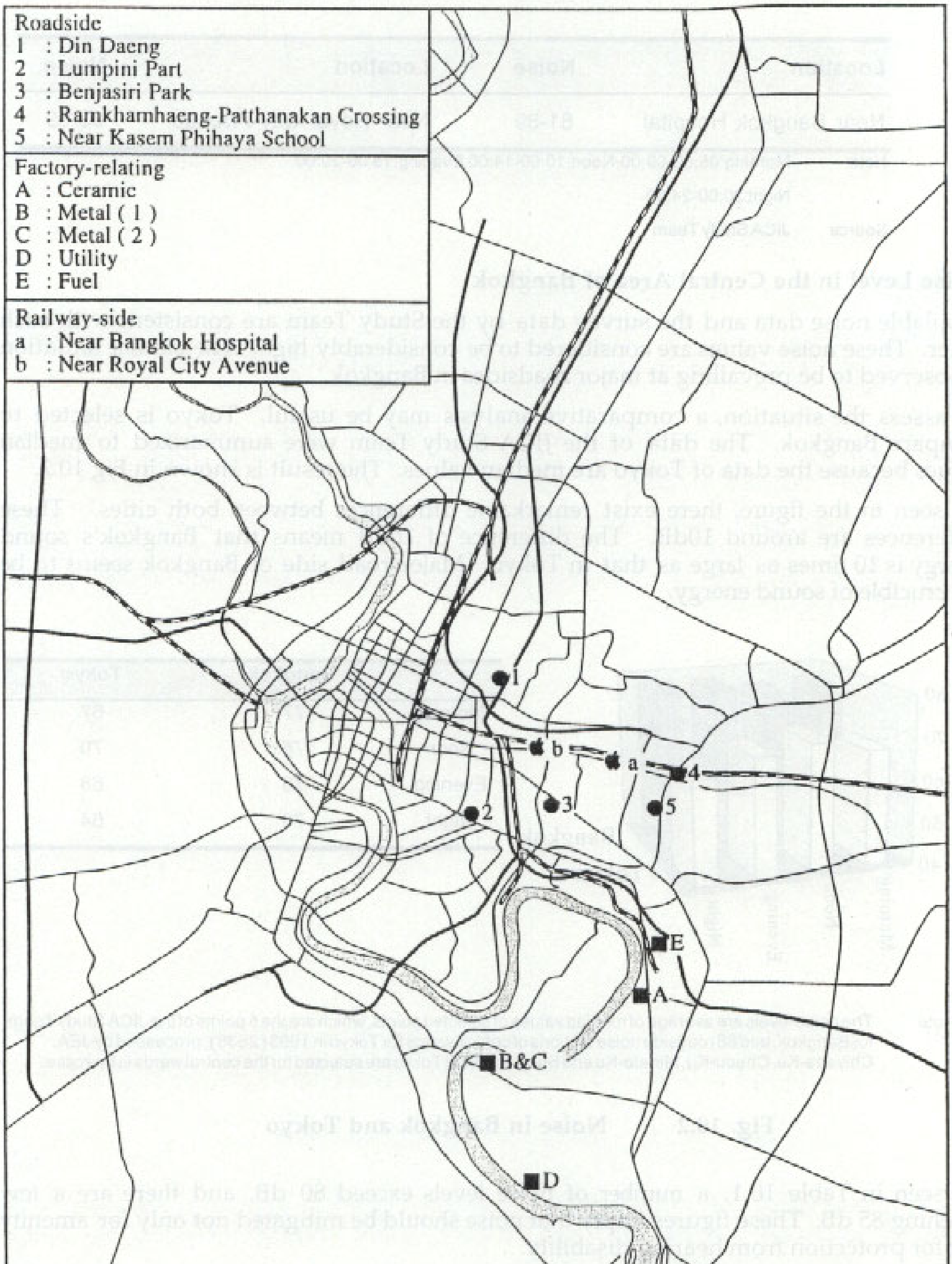


Fig. 10.1 Locations of Monitoring Points

Table 10.3 Railway Side Noise Level (L_{Aeq} dB)

Location	Noise	Location	Noise
Near Bangkok Hospital	81-89	Near Royal City Avenue	83-89

Note: Morning:05:00-09:00,Noon:10:00-14:00,Evening:15:00-20:00, Night:20:00-24:00

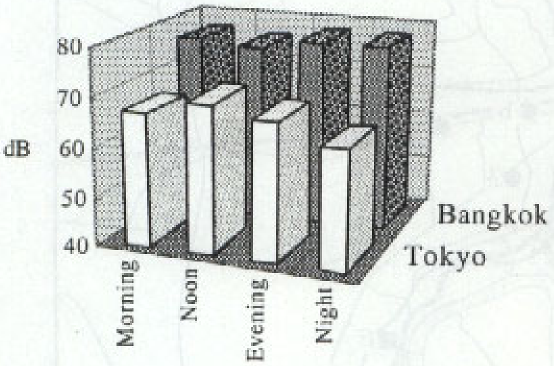
Source: JICA Study Team

(3) Noise Level in the Central Area of Bangkok

Available noise data and the survey data by the Study Team are consistent with each other. These noise values are considered to be considerably high. The similar situation is observed to be prevailing at major roadsides in Bangkok.

To assess the situation, a comparative analysis may be useful. Tokyo is selected to compare Bangkok. The data of the JICA Study Team were summarized to median values because the data of Tokyo are median values. The result is shown in Fig 10.2.

As seen in the figure, there exist remarkable differences between both cities. These differences are around 10dB. The difference of 10dB means that Bangkok's sound energy is 10 times as large as that in Tokyo. Major road side of Bangkok seems to be the crucible of sound energy.



	Bangkok	Tokyo
Morning	77	67
Noon	76	70
Evening	78	68
Night	78	64

Note: The noise levels are average of median values of selected points, which are the 5 points of the JICA Study Team for Bangkok, and 68 roadside noise stations of central wards for Tokyo in 1993 (2536), processed by JEA. Chiyoda-Ku, Chuou-Ku, Minato-Ku and Shinjuku-Ku of Tokyo are selected for the central wards in this case.

Fig. 10.2 Noise in Bangkok and Tokyo

As seen in Table 10.1, a number of noise levels exceed 80 dB, and there are a few reaching 85 dB. These figures imply that noise should be mitigated not only for amenity but for protection from hearing disability.

Noise levels related to factories and railways are shown in Tables 10.2 and 10.3. Taking into account the characteristics of noise, it cannot be necessarily generalized to assess these conditions and the causes. Because the feature of boundary noise problems has the nature of site specific local problem, and depends on various conditions such as operation hour, relation to traffic, inhabitants awareness, and so on.

Recently noise level map of Bangkok metropolice which was one km in central zone and two km in other area grid map was made by ERTC. It reports that noise level of many grids exceed Leq 70 dB(A) in day time, and considerable grids exceed in night time.

(4) Standard and Regulation

To mitigate noise problems, ambient noise standards and noise regulations for vehicle, factory and construction are an important basis for policy making and administrative actions. Formalizing of the standard and regulations which are appropriately applicable to its country is an essential matter. Proper standards and regulations also play an important role of education and enlightenment of people towards mitigating the noise problem. Regarding standards and regulations applicable to the Thai environment, the following items should be further discussed:

Table 10.4 Considerations on Standards and Regulations

	Items
Standards	(1) For reviewing the roadside noise, the guideline set by US. Environmental Protection Agency, i.e. Leq 70 dB, is thought to be applied. This figure is not for amenity but for protection from hearing disability.
	(2) Regional characteristics such as industrial, commercial and residential activities might not be covered.
	(3) Noise in night might not be treated separately.
Regulations	Regulations against vehicle and commuter boat are already implemented.
	(1) But introduction of sound level limit at boundary of factory site is not yet.
	(2) Introduction of construction noise limit according to time is not yet.

(5) Vibration Survey Results of the JICA Study Team

The vibration level survey was carried out by the Study Team in December 1995, and its results are shown in Tables 10.5. and 10.6.

The threshold value of human sensitivity for vibration is 55 dB. The significant effect by vibration to human health is thought to start at 90 dB or higher level. Taking these items into consideration, the information by Tables 10.5 and 10.6 are thought to be imply us that vibration problem is not severe as noise.

Table 10.5 Roadside vibration Level (90 percentile, dB)

Location	Road	Morning	Noon	Evening	Night
Din Daeng	Viphawadi Rangsit Road	56	56	52	56
Lumphini Park	Rama 4 Road	53	53	52	55
Benjasiri Park	Sukhumvit Road	46	47	47	45
Ramkhamhaeng-Patthanakan Crossing	Patthanakan Road	56	58	55	51
Near Kasem Phihaya School	Sukhumvit Soi 71	55	54	55	45

Note: Morning:05:00-09:00,Noon:10:00-14:00,Evening:15:00-20:00, Night:20:00-24:00

Source: JICA Study Team

Table 10.6 Factory Boundary vibration Level (90 percentile, dB)

Industry	District, Road	Morning	Noon	Evening	Night
Ceramic	Phra Khanong	44	46	49	41
Metal	Phra Pradaeng	44	53	52	52
Metal	Phra Pradaeng	54	60	54	56
Utility	Muang	52	52	52	52
Fuel	Phra Khanong	36	40	44	40

Note: Morning:05:00-09:00,Noon:10:00-14:00,Evening:15:00-20:00, Night:20:00-24:00

Source: JICA Study Team

10.3 Policy Directions and Planning Issues

It should be noted that traffic noise issues in the central area and sub-urban areas of Bangkok have different characteristics. For the center of Bangkok, the current noise situation should be mitigated, while in sub-urban areas a main issue of noise is that the noise situation should not be worsened than the present status.

Further study aspects in the center of Bangkok are as follows:

- Improvement of motor vehicle, especially motorcycle, samlor, heavy bus and light to heavy truck ;
- Improvements of road structure, such as elongation of eco-corridor, planting of noise shielding trees, and flatness of pavement ;
- Adequate management of construction work ;
- Consideration for avoiding construction of flying-over in the city canyon ;
- Effluence of traffic ; and
- Public relation of noise situation.

Relating to sub-urban areas the study issues are mainly the built-in of noise mitigating concepts into city planning matters as below:

- By-path road construction ;
- Preparing wide sidewalk which has noise absorbing trees ; and
- Zoning of region.

10.4 Planning Targets and Proposed Measures

Based on above discussion, the main issue is focused on mitigation of motor vehicle noise.

Table 10.7 PlanningTargets and Proposed Measures

Target	Measures
1. Mitigation of motor vehicle noise	(1) Implementation of regulation and inspection procedure against motor vehicle noise
	(2) Improvement of road structures
	(3) Attainment of the Leq 70 dB level at all road side area
2. Future integrated policy	(1) Policies for up-grading of "Quality of Living"
	(2) Depending on the characteristics of the area, such as residential, commercial and industrial

CHAPTER 11: MICRO STUDY

11.1 Objective and Scope of the Micro Study

(1) Objectives

As discussed in the preceding chapters, Bangkok environmental issues are not homogenous but heterogeneous in the nature. Therefore, measures to be undertaken should employ a wide variety of tools including institutional, administrative as well as implementation of infrastructure projects. Since environmental problems always appear at local level, the solutions need to address local reality with concrete images.

The objective of this micro study is to seek one of the appropriate ways to solve the local problems by urban planning approach, based on the implications derived from the macro studies.

(2) Selected Model Areas

Six areas are selected as the model areas with typical environmental problems for which urban planning tools should be employed. The six areas have respective attributes as follows, and the locations are shown in Fig. 11.1.

1) **Lat Krabang Subcenter Zone**: As a model of guided urbanization of subcenter zone development in the eastern Bangkok area where vast potentials are still available to accommodate increasing population and job places.

2) **Taling Chan Subcenter Zone**: As a model of MRT-driven urbanization in the western Bangkok with great potential for rapid urbanization, where disorderly sprawl would take place without infrastructure-led development.

3) **Part of Khlong Toey**: As a model of improvement of road network in the highly built-up area, in relation to the forthcoming MRT systems and restructuring of the inner city areas.

4) **Din Daeng Renewal**: As a model of the public housing renewal project (NHA) in the inner city in association with public projects of New Bangkok City Hall, MRT stations and other new urban projects in the vicinities. Public transportation-based urban re-structuring is the main theme.

5) **Chao Phraya River-front Renewal**: As a mode of Chao Phraya River-front redevelopment by relocation of existing less-functioning warehouses and factories, and new land use for a purpose of environmental facilities development.

6) **Rathanakosin Historical Conservation**: As a model of institutional building for historical conservation based on a review of the on-going Master Plan Study by the

national committee for Rathanakosin Conservation. The conservation of historical assets must be one of important environmental policies.

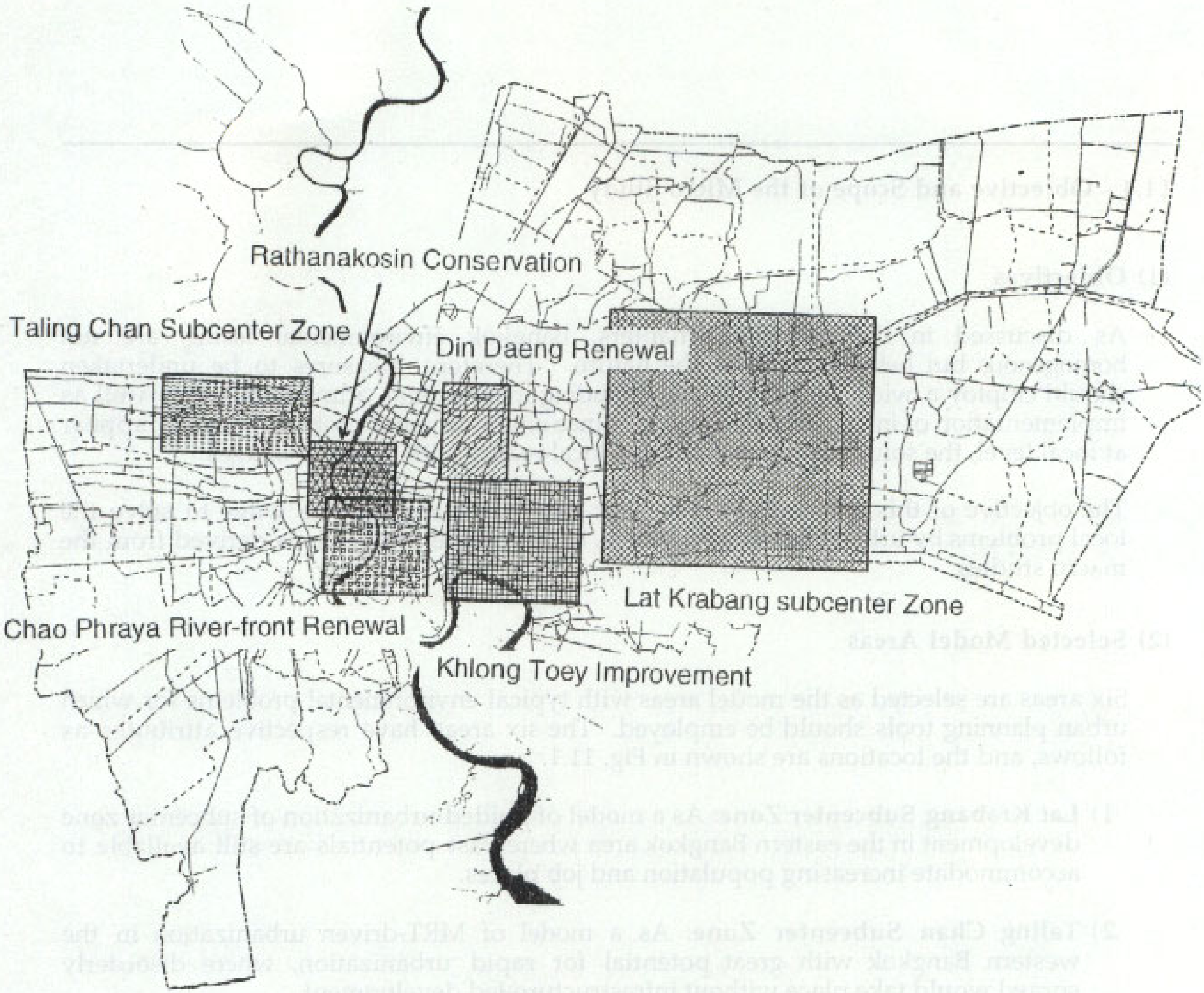


Fig. 11.1 Locations of Micro Study Model Areas

11.2 A Physical Model of Subcenter Zone Development

The basic strategies and planning concepts of "Subcenter Zone Development" are discussed in Section 9.4, Chapter 9: A Vision of Spatial Framework. This section presents physical planning ideas, taking up a model of Minburi/Lat Krabang Subcenter Zone

(1) A Conceptual Model of Minburi/Lat Krabang Subcenter Zone

A model of Subcenter Zone Development with an about half million population imagining, was conceptually depicted to study the needs of land development, infrastructures and road network systems, as shown in Fig. 11.2.

This urban model seeks a physical feature of Environment-friendly Urban Development, considering the following planning concepts:

Rational Land Use Pattern

Three concepts are employed for rationalization of the land use:

- Moderate population density,
- Concise activity center area; and
- Sufficient open space for the environment and public uses.

Given a population density of 140 persons/ha in the average, a total land area of 3,500 ha (about 6 Km x 6 Km) needs to be prepared to accommodate half million population, and with the employment density of 200 jobs/ha, the land area of 750 ha is used for work places for the self-sustained job-housing balance.

The areas to accommodate some special urban functions such as higher educational and government facilities as well as light industries and warehouses, some of which are to be relocated out of the Bangkok central areas, are prepared. Given quality environment, this subcenter zone will be suitable for location of R & D and information-related business.

The area for parks and open space should be prepared for location of public utility facilities such incineration plants, energy facilities and/or resource recycling centers.

Mass Transit-based Urban Development

Stations of MRTs or SRT railway function as activity centers of the new town, providing with station plazas and frontage areas where business, commercial and other urban service facilities are accumulated. Such large traffic generators should be located adjacent to the stations so that workers and business persons may approach them on foot to/from the stations.

Water Channel-cum-Road System

Major streets connecting with MRT stations (Lat Krabang and Minburi) are planned as "**Eco-boulevard**" as an axis of the subcenter zone, as illustrated on Fig. 11.3. The eco-boulevard is structured with secondary roads and drainage channels in association with greens. These channels form "Green-Water Network" over the subcenter zone.

Feeder Public Transport Systems

Bus service routes are connected directly with MRT stations as the feeder transport service network. The feeder bus routes are served so that all residents can reach any bus stop within 500 meter walk.

Hierarchical Road Network System

The subcenter zone is served by regional arterial highway(s), or express way and arterial roads. The secondary roads need to be networked with at least 2 km interval, and the tertiary roads are served with 500-1,000 meter interval.

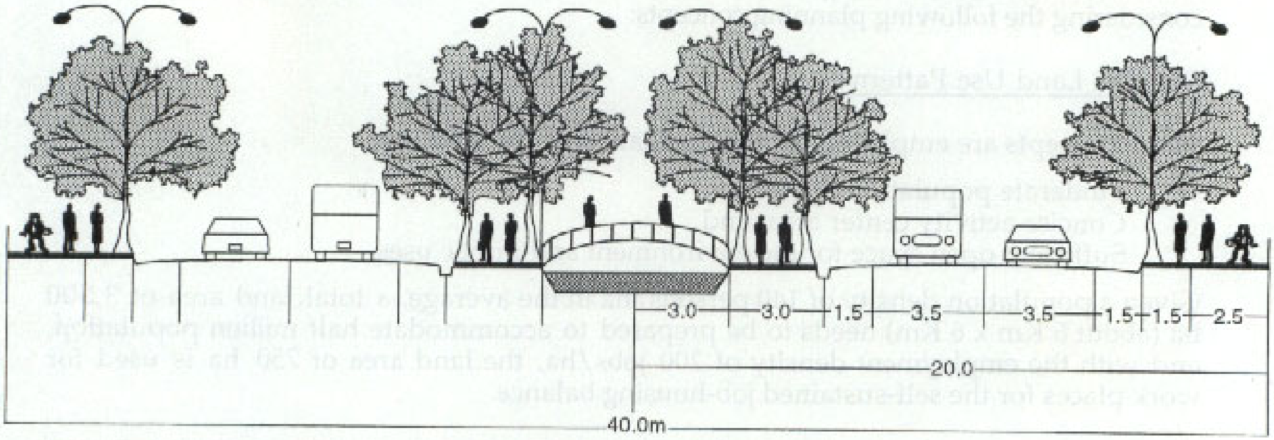


Fig. 11.3 A Proposal for Design of "Eco-boulevard" as an Axis of Subcenter Zone

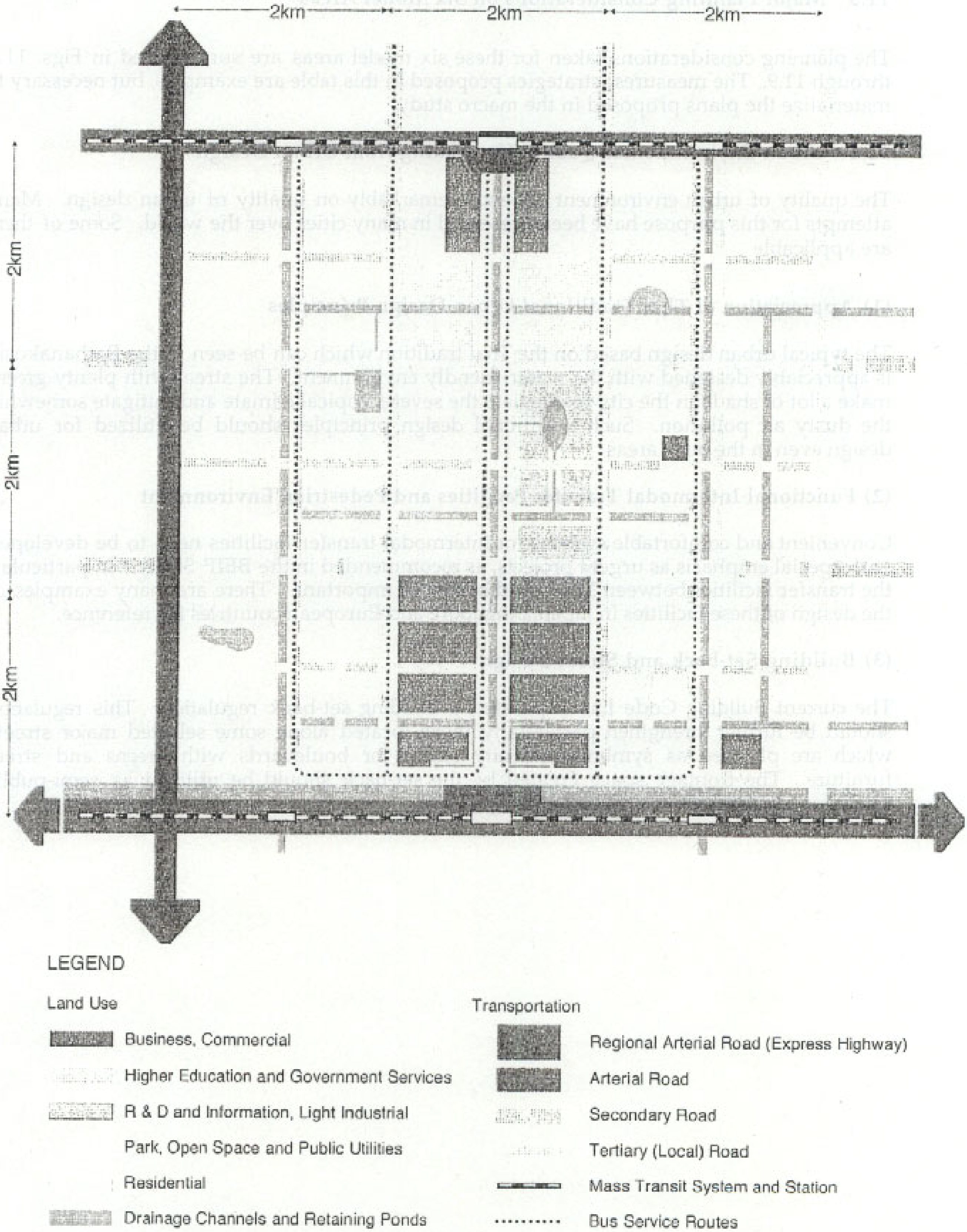


Fig. 11.2 A Conceptual Urban Model of Subcenter Zone Development with 500 Thousand Population

11.3 Major Planning Considerations on Six Model Areas

The planning considerations taken for these six model areas are summarized in Figs. 11.4 through 11.9. The measures/strategies proposed in this table are examples, but necessary to materialize the plans proposed in the macro study.

11.4 Urban Environmental Quality Up-grading from Urban Design

The quality of urban environment depends remarkably on quality of urban design. Many attempts for this purpose have been presented in many cities over the world. Some of them are applicable

(1) Appreciation of Thai Traditional Urban Design Principles

The typical urban design based on the Thai tradition which can be seen in the Rathanakosin is appreciably designed with the water-friendly environment. The street with plenty greens make a lot of shade in the city to alleviate the severe tropical climate and mitigate somewhat the dusty air pollution. Such traditional design principles should be utilized for urban design even in the busy areas.

(2) Functional Intermodal Transfer Facilities and Pedestrian Environment

Convenient and comfortable systems for intermodal transfer facilities need to be developed with special emphasis as urgent projects, as recommended in the BEIP Study. In particular, the transfer facilities between MRTs and buses are important. There are many examples of the design of these facilities in Japan, Singapore and European countries for reference.

(3) Building Set-back and Street Design

The current Building Code has stipulated a building set-back regulation. This regulation should be further strengthen particularly those located along some selected major streets which are planned as symbolic amenity streets or boulevards with greens and street furniture. The frontage space created by the set-back should be utilized as semi-public space for pedestrians as well as landscape belts.

Fig. 11.4

NAME OF THE PROJECT	LAT KRABANG SUBCENTER ZONE DEVELOPMENT

TARGETS OF ENVIRONMENTAL IMPROVEMENT

To facilitate the guided-subcenter zone development initiated by the public sector in the eastern bank of Bangkok, aiming at Mass Transit-driven urban development.

CHARACTERISTICS OF THE LOCATION

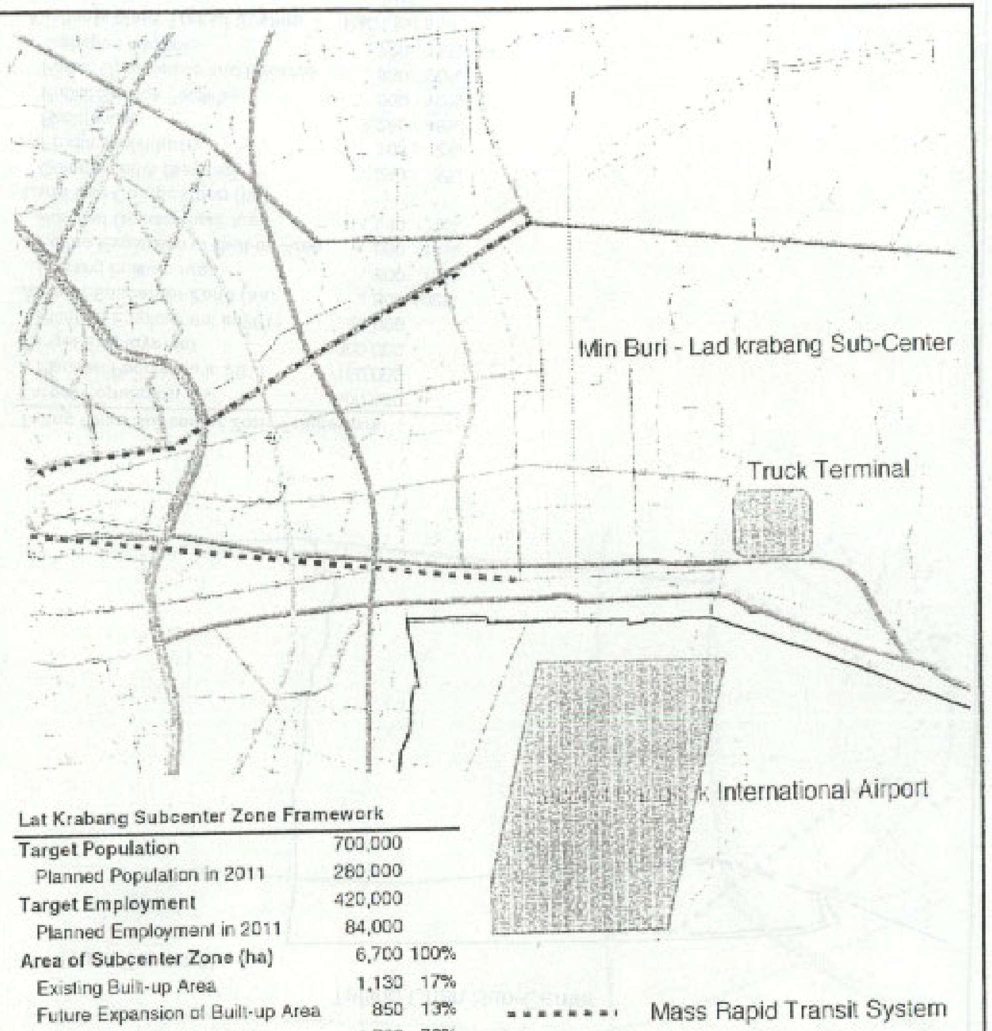
- ☐ The Project area is located in the highly urbanization potential areas in the future, given the completion of the on-going major projects such as the Second Bangkok International Airport, Bangkok-Chonburi Highway and Outer Ring Road.
- ☐ The SRT Eastern Line presently provides commuter trains. The extension of MRT (Red Line) is planned.

PLANNING CONCEPTS

- ☐ Development of the subcenter zone with 700 thousand population, integrating the existing built-up areas and the newly developed areas;
- ☐ Development of infrastructure-led urban area with a housing-and-job balance, inducing business, light industrial, higher educational, R&D and Information, government services, cargo-distribution, commercial and residential facilities;
- ☐ Improvement of environmental and transport infrastructures in the existing built-up areas as part of the subcenter zone development;
- ☐ Development of an environment-friendly urban system, managing and designing water and greens;
- ☐ Development of an intensive bus transport service network linked with MRT stations so that any resident can reach a bus stop by 500 m walk.

FOR THE IMPLEMENTATION

- ☐ To formulate Master Plan and Feasibility Study, reviewing the previous study of "Metropolitan Subcenter Planning" by MIT Consultant Team;
- ☐ To designate the subcenter zone in the legal framework of Urban Planning Act;
- ☐ To explore the implementation system in consideration of application of "Land Readjustment System", and/or "Land Trust System" to deliberately involve the landlords;
- ☐ To organize the implementation body jointly with the public and private sector, including the MRT operators;



Lat Krabang Subcenter Zone Framework

Target Population	700,000	
Planned Population in 2011	280,000	
Target Employment	420,000	
Planned Employment in 2011	84,000	
Area of Subcenter Zone (ha)	6,700	100%
Existing Built-up Area	1,130	17%
Future Expansion of Built-up Area	850	13%
Planned Development Area	4,720	70%
Land Use Composition (ha)		
Commercial & Business	350	5%
Production/industry	350	5%
Residential	2,950	44%
Public Service Facilities	700	10%
Parks, Open space and Reserve	1,350	20%
Transport Facilities	1,000	15%
Existing Core Local Center	Minburi	
Available Mass Transit System	Red & Orange Lines, SRT	

Fig. 11.5

NAME OF THE PROJECT	TALING CHAN SUBCENTER ZONE DEVELOPMENT

TARGETS OF ENVIRONMENTAL IMPROVEMENT

To facilitate the guided-subcenter zone development initiated by the public sector in the western bank of Bangkok (Tonburi Side), aiming at Mass Transit-driven urban development.

CHARACTERISTICS OF THE LOCATION

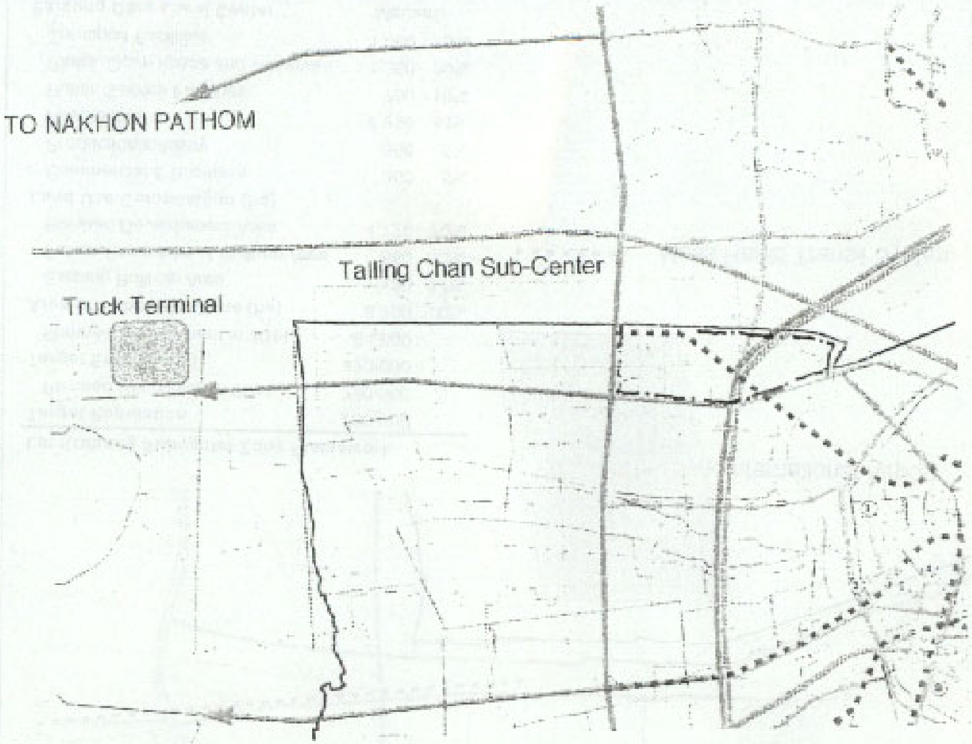
- ☐ The Project area is located in the urbanization potential areas where a number of subdivision projects are recently emerging without adequate infrastructures;
- ☐ The SRT Southern Line presently provides commuter trains from the Taling Chan Station. The extended MRT (Red Line) is planned to serve this corridor.
- ☐ Major arterial roads such as Outer Ring Road and Middle Ring Road 'Expressway) area scheduled to serve the Project area.

PLANNING CONCEPTS

- ☐ Development of the subcenter zone with 500 thousand population, integrating the existing built-up areas and the newly developed areas;
- ☐ Development of infrastructure-led urban area with a housing-and-job balance, inducing business, higher educational, government services, commercial and residential facilities;
- ☐ Improvement of environmental and transport infrastructures in the existing built-up areas as part of the subcenter zone development;
- ☐ Development of an environment-friendly urban system, managing and designing water and greens;
- ☐ Development of an intensive bus transport service network linked with MRT stations so that any resident can reach a bus stop by 500 m walk.

FOR THE IMPLEMENTATION

- ☐ To formulate Master Plan and Feasibility Study, reviewing the previous study of "Metropolitan Subcenter Planning" by MIT Consultant Team;
- ☐ To designate the subcenter zone in the legal framework of Urban Planning Act;
- ☐ To explore the implementation system in consideration of application of "Land Readjustment System", and/or "Land Trust System" to deliberately involve the landlords;
- ☐ To organize the implementation body jointly with the public and private sector, including the MRT operators;

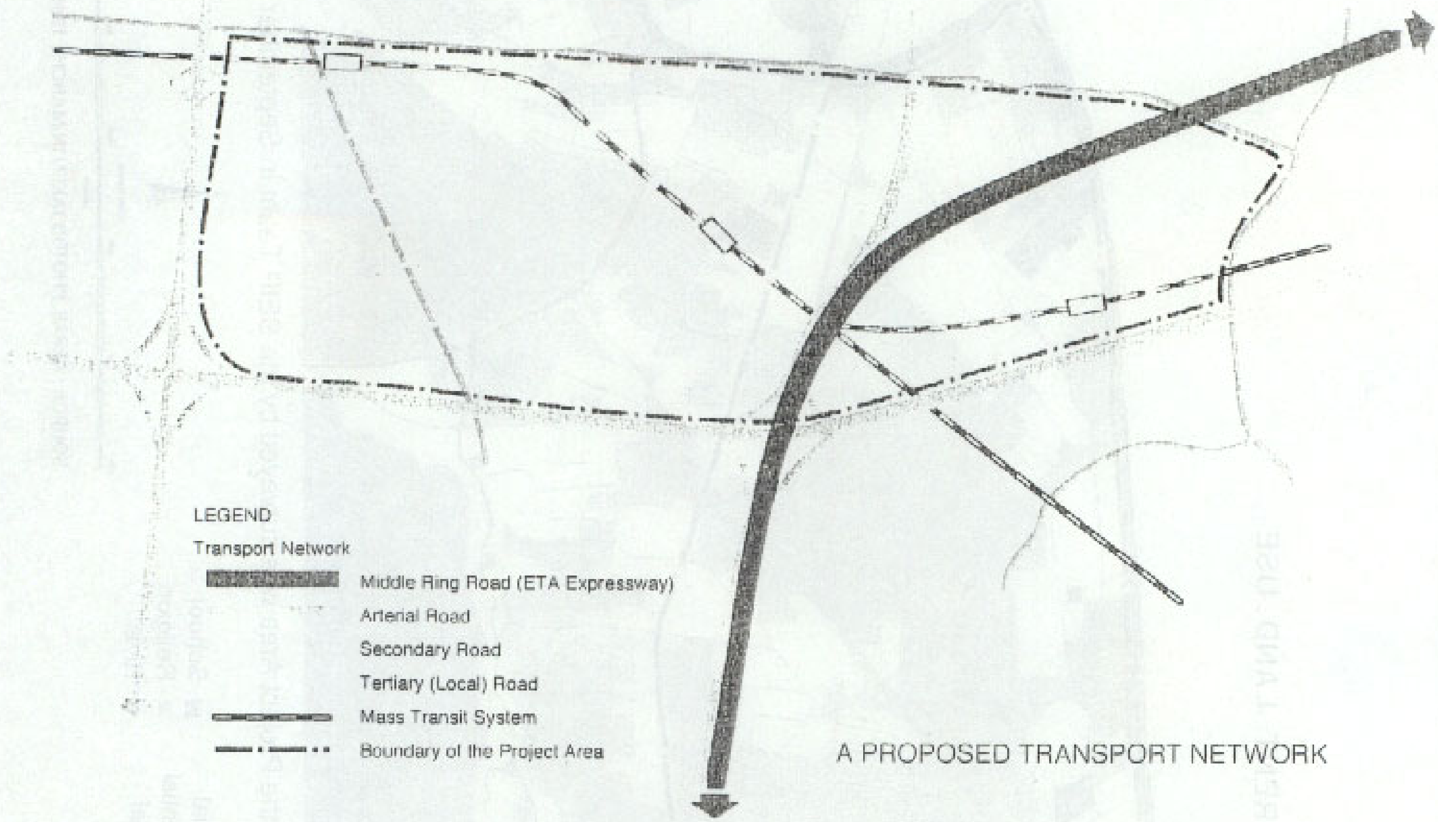


Taling Chan Subcenter Zone Framework

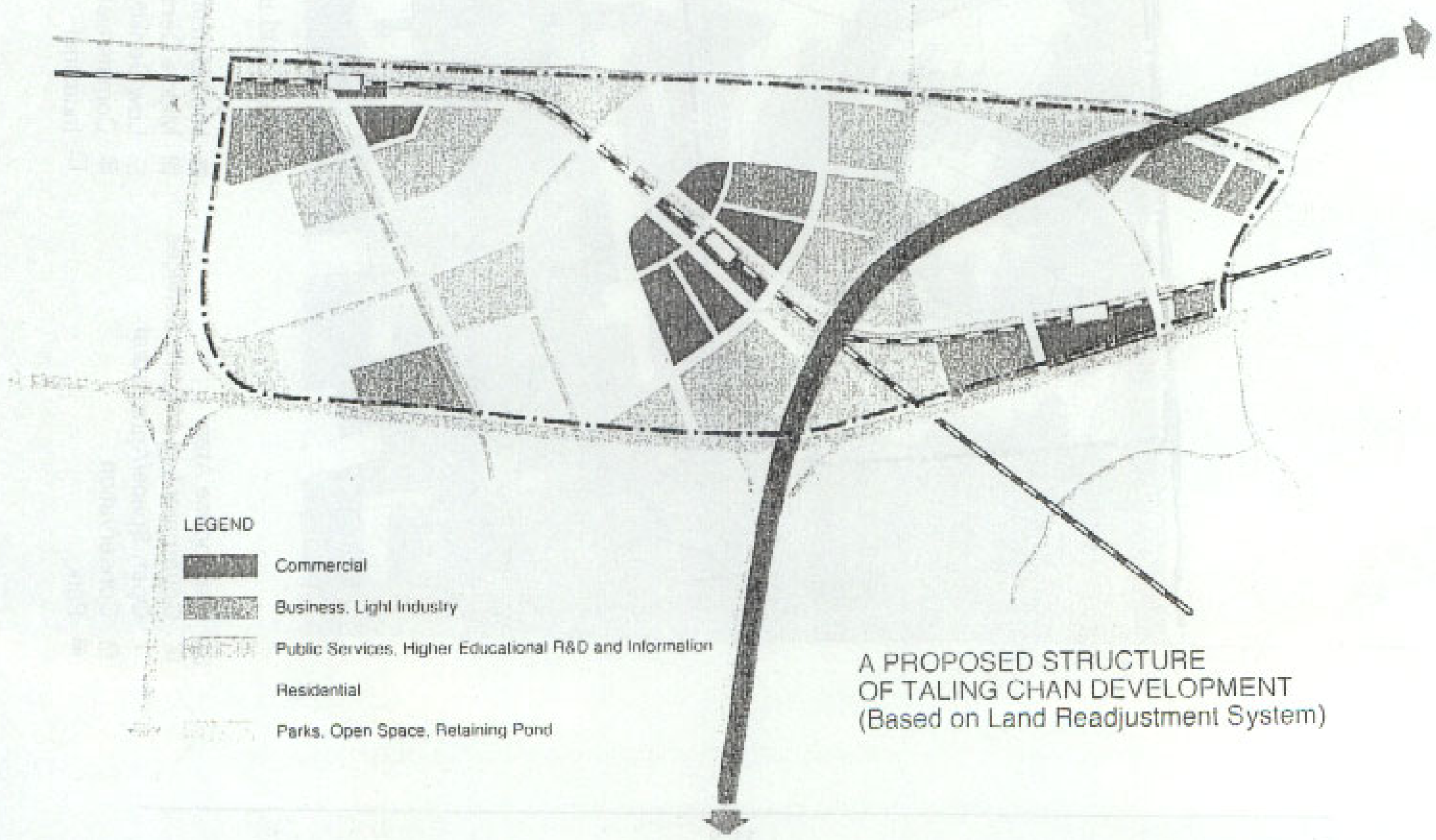
Target Population	500,000	
Planned Population in 2011	150,000	
Target Employment	300,000	
Planned Employment in 2011	45,000	
Area of Subcenter Zone (ha)	4,800	100%
Existing Built-up Area	700	15%
Future Expansion of Built-up Area	660	14%
Planned Development Area	1,040	22%
Land Use Composition (ha)		
Commercial & Business	240	5%
Production/industry	100	2%
Residential	2,280	48%
Public Service Facilities	500	10%
Parks, Open space and Reserve	960	20%
Transport Facilities	720	15%
Available Mass Transit System	Red Line and SRT	


CURRENT LAND USE
The Land use within the Project Area was surveyed by the BEIP Team in September 1996.
Warehouse Area
Government and Public Services
Open Space/Agricultural
Conservation
Park
High Density Residential
Middle Density Residential
Low Density Residential
Commercial
Industrial
School
Religion
River
SOURCE : AERAIL PHOTOS TAKEN IN MARCH , 1995.

A PROPOSAL OF PART OF TALING CHAN SUBCENTER ZONE DEVELOPMENT
(Applied by the "Land Readjustment System")



A PROPOSED TRANSPORT NETWORK



A PROPOSED STRUCTURE
OF TALING CHAN DEVELOPMENT
(Based on Land Readjustment System)

Fig. 11.6

NAME OF THE PROJECT	KHLONG TOEY BUILT-UP AREA IMPROVEMENT

TARGETS OF ENVIRONMENTAL IMPROVEMENT

To improve the environmental conditions in the built-up area of part of Khlong Toey District, focusing on the improvement of transport system with MRT, bus and soi .

CHARACTERISTICS OF THE LOCATION

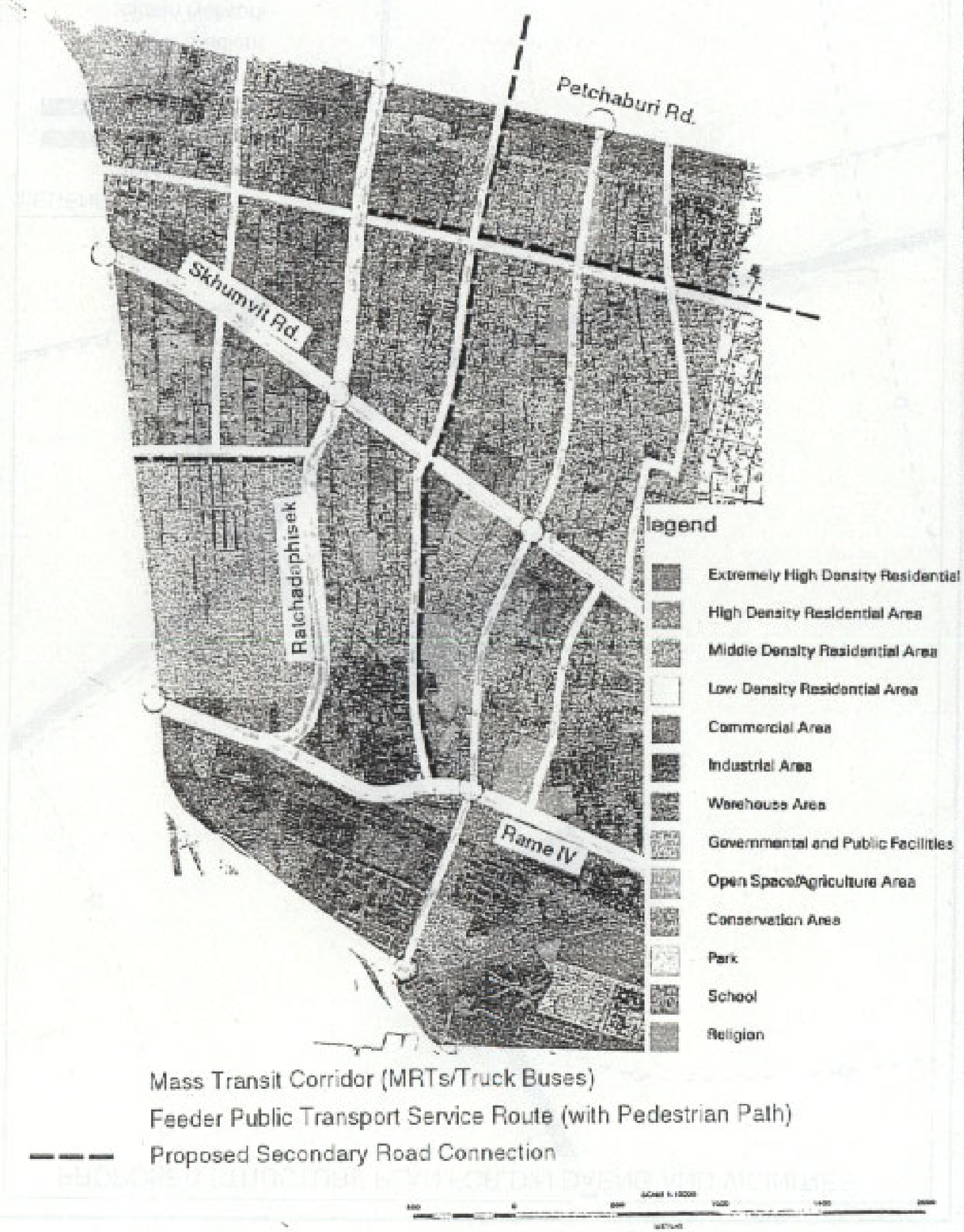
- ☐ The Project area is located in the highly urbanized area where a wide variety of urban economic and housing functions have already been accumulated, thereby making the development of an adequate road network more difficult.
- ☐ The current construction booming encourages the scrap-and-built process in the area, and 10-15% of the land has been changed in its land use for last 7 years.

PLANNING CONCEPTS

- ☐ Restructuring the existing soi-system to a functionally networked access road system in association with the forthcoming MRT (Green Line) on Skhumvit Road;
- ☐ Development of "Public Transport Corridor" on Skhumvit Road with adequate pedestrian environment;
- ☐ Creation of semi-public space for environmental infrastructures and amenity facilities, by enhancing an institutional tool of the "Building Set-back" regulation.
- ☐ Application of "Land Readjustment Scheme" for selected areas without adequate road network.

FOR THE IMPLEMENTATION

- ☐ To review the previous Master Plan Study for Khlong Toey District, and build the Action Plan in the short- and medium-term;
- ☐ To coordinate the legislative inter-relation between the current Urban Planing Act and Building Code in terms of land use, building set-back and the new concept of Semi-public Urban Space;
- ☐ To explore some applicable implementation systems in consideration of Land Readjustment System.



The land use within the project area is based on the BEIP Survey in September 1996

Fig. 11.7

NAME OF THE PROJECT	DIN DAENG RENEWAL PROJECT

TARGETS OF ENVIRONMENTAL IMPROVEMENT

To make the NHA housing renewal project more functional and attractive, integrating related projects being planned in the surrounding improvement such as MRTs (Orange, Red and Blue Lines), New BMA City Hall and Makkasan Redevelopment.

CHARACTERISTICS OF THE LOCATION

- ☐ The Project area is located in the inner city where more intensified land use is required for public services. The public sector owns most of the land, thereby easing land acquisition for the implementation.
- ☐ The NHA housing area is 23.36 ha with 22,690 population at present (931 prs/ha) and the FAR is 169%.

PLANNING CONCEPTS

- ☐ Creation of a "New Bangkok Social Center" in association with improvement of adjacent public service facilities such as New Bangkok City Hall, government offices, the Youth Stadium, hospital and schools;
- ☐ Intensification of the housing land use to accommodate 37,000-38,000 population with a new FAR of 500-550 %, providing high-rise housing buildings;
- ☐ Environmental improvement by preparing affluent open space, pedestrian facilities, community services for elderly people;
- ☐ Formation of a Mass Transit-based transport structure with functional linkages of access roads and pedestrian paths and MRT stations as well as the feeder bus service network.

FOR THE IMPLEMENTATION

- ☐ To formulate an overall development master plan in coordination with relevant agencies/organizations and the communities;
- ☐ To re-consider and/or coordinate the suitable locations of the stations of Orange Line in relation with the Project;
- ☐ To organize a planning committee for the Project with representatives of relevant organizations;
- ☐ To organize the resident community for well-management of environmental activities at community level.

PROPOSED STRUCTURE PLAN FOR DIN DAENG AND VICINITIES

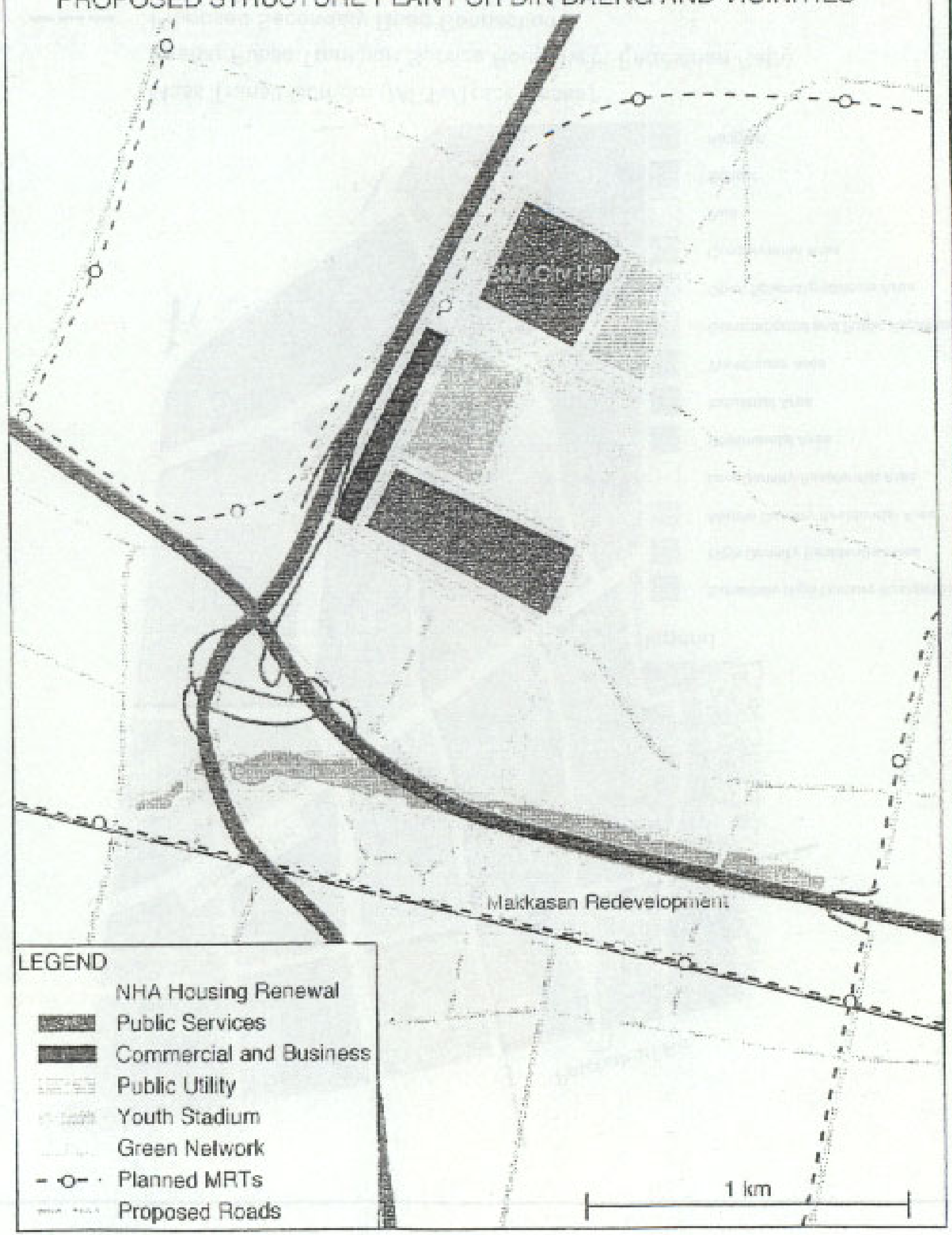


Fig. 11.8

NAME OF THE PROJECT	CHAO PHRAYA RIVER-FRONT REDEVELOPMENT

TARGETS OF ENVIRONMENTAL IMPROVEMENT

To vitalize the land use of the Chao Phraya river-front area (parts of Bang Kho Laem, Yan Nawa and Ratburana), by facilitating relocations of warehouses and factories of which the locations are no longer functional.

CHARACTERISTICS OF THE LOCATION

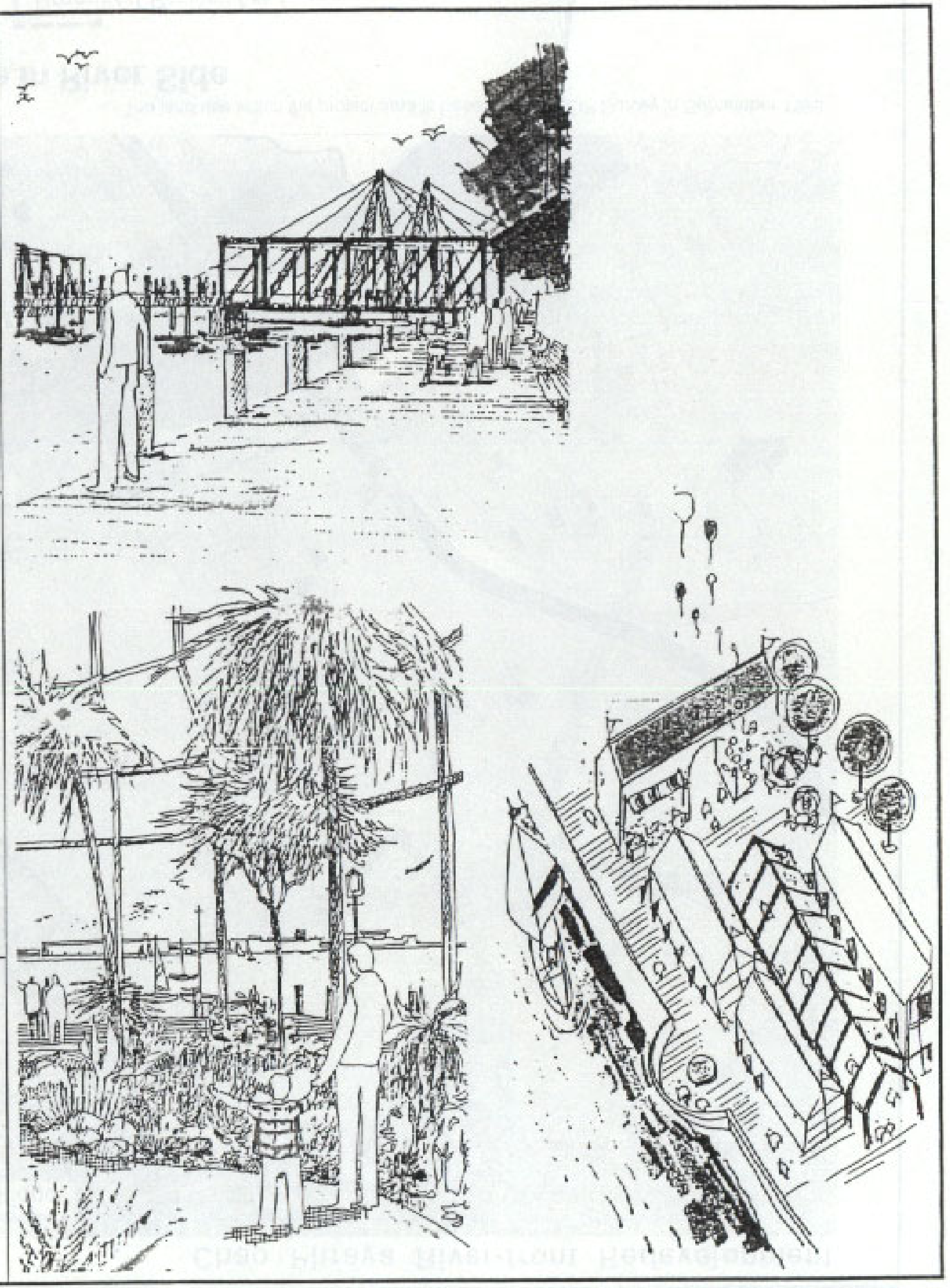
- ☐ The Project area is a strip of Chao Phraya river-front from the Rama IX bridge to the Taksin Bridge where warehouses for rice,beverage and timbers and small-scale factories are located.
- ☐ The land uses are now changing to more land-efficient type of use such as condominium, hotels, supermarkets, so on. Nevertheless, open space still remains in some parts, awaiting new development.

PLANNING CONCEPTS

- ☐ Facilitation of relocation of the less functioning warehouses and factories, providing institutional incentives, substitutive land or compensation schemes;
- ☐ Formation of a linkage program with the relocation program and the Subcenter zone development (preparation of the land for the would-be-relocated facilities);
- ☐ Development of "Chao Phraya River-side Park" with unique landscape and water-friendly facilities for Bangkok people and tourists and develop Waterway Boat Terminal.
- ☐ Facilitation of development of Chao Phraya water management facilities;
- ☐ Preservation of the open space for the environmental purpose, through facilitation of the land purchase by the public sector.

FOR THE IMPLEMENTATION

- ☐ To designate the Project area as the policy zoning area and conduct the survey of land tenures and facilities to seek the possibility of relocation;
- ☐ To formulate the Master Plan and Action Plans for the Project;
- ☐ To explore an institutional framework (tax incentives and compensation) to acquire the land for the public purpose;
- ☐ To organize the Chao Phraya River-side Park Development Corporation" jointly with the public and private sectors.



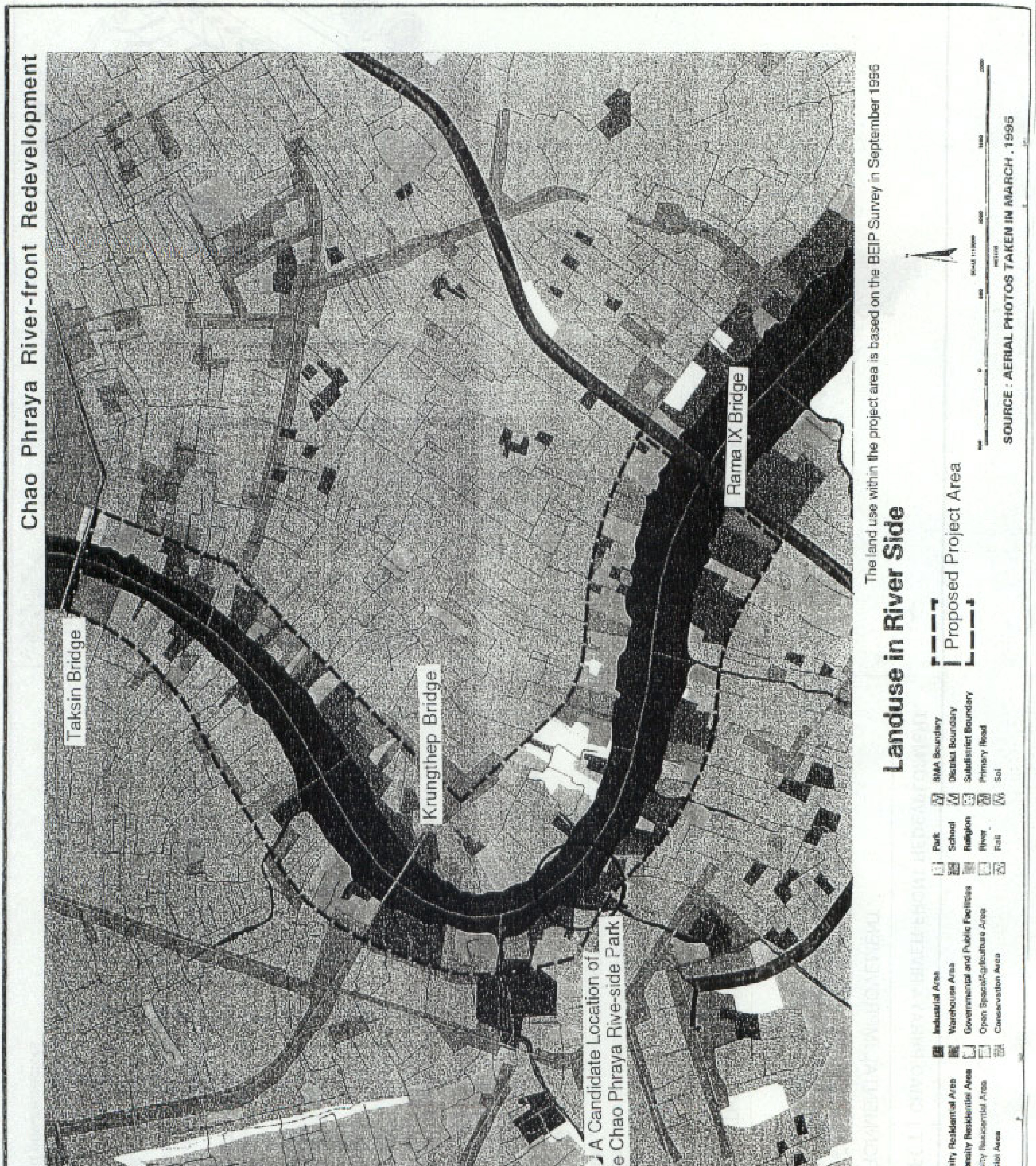

Chao Phraya River-front Redevelopment
Taksin Bridge
Krungthep Bridge
Rama IX Bridge
A Candidate Location of the Chao Phraya Rive-side Park
The land use within the project area is based on the BEIP Survey in September 1996
Landuse in River Side
Proposed Project Area
Legend
River
High Density Residential Area
Middle Density Residential Area
Low Density Residential Area
Commercial Area
Industrial Area
Warehouse Area
Governmental and Public Facilities
Open Space/Agriculture Area
Conservation Area
Park
School
Religion
River
Rail
BMA Boundary
District Boundary
Subdistrict Boundary
Primary Road
Soi
SOURCE : AERIAL PHOTOS TAKEN IN MARCH , 1995

Fig. 11.9

NAME OF THE PROJECT	RATHANAKOSIN CONSERVATION

TARGETS OF ENVIRONMENTAL IMPROVEMENT

To form an institutional framework and propose physical improvement to conserve the historically invaluable assets and districts, while promoting the Thai unique environment.

CHARACTERISTICS OF THE LOCATION

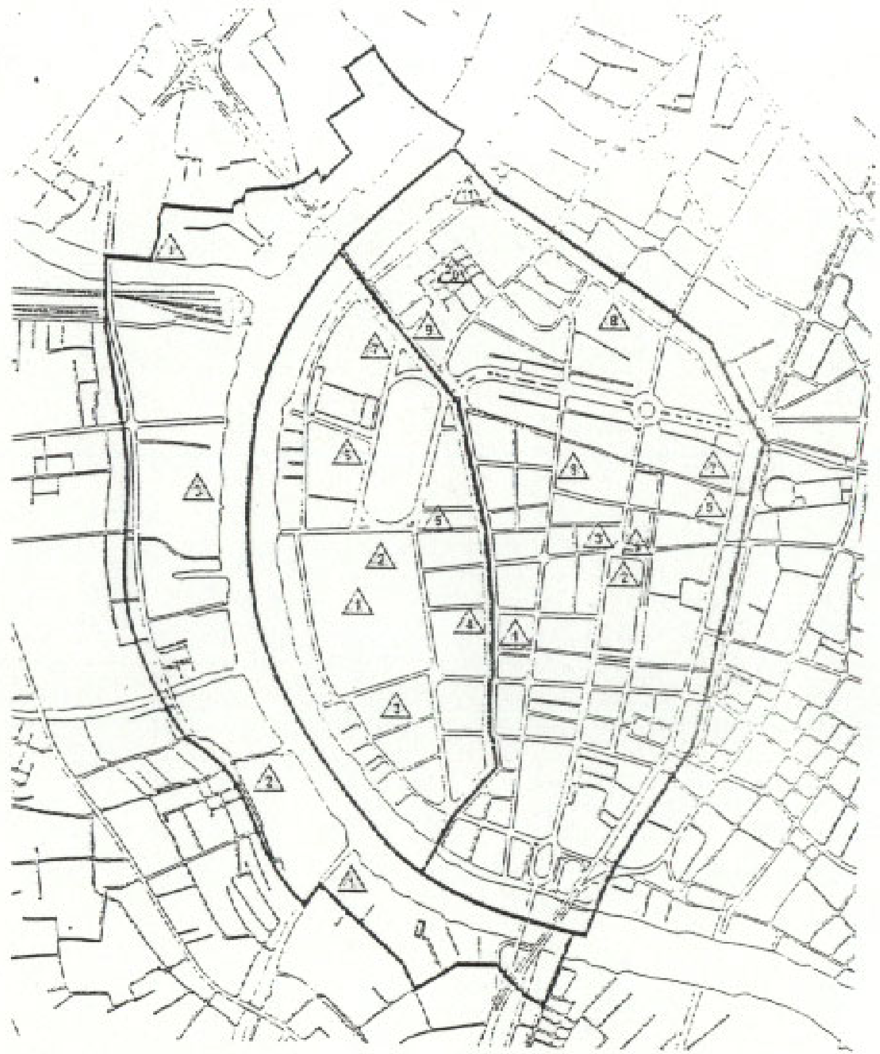
- ☐ The Project area is located in the historical center of Bangkok where is the Thai people's spiritual core.
- ☐ The area is separated in two parts alongside Chao Phraya River, and mixed with a variety of functions such as shops, business offices and houses as well as the historical facilities such as the Palace, museums, temples and government offices.

PLANNING CONCEPTS

- ☐ Strengthening of the current institutional framework to control the private sector's activities for construction and renovation of invaluable buildings and land development;
- ☐ Expansion of the designated area based on the recommendation of the Bangkok Plan proposed by the MIT/EC group;
- ☐ Development/improvement of public parks, selected symbolic streets, landscape facilities and public markets;
- ☐ Facilitation of works for "Urban Design" with a Thai unique concept for street greening, trash boxes, public telephone booths, street benches, pocket parks and so on in the specially designated areas.

FOR THE IMPLEMENTATION

- ☐ To formulate Action Plans to materialize the conservation policies emphasized by the National Committee and by 5th BMA Development Plan;
- ☐ To organize the Joint Rathanakosin Design Committee with representatives from the communities to promote people's participation in the implementation of planned projects;
- ☐ To arrange the Special Rathanakosin Fund for the planned conservation works.



DESIGNATED RATHANAKOSIN HISTORICAL CONSERVATION AREA

CHAPTER 12: APPLICATION OF GIS TECHNIQUE FOR PLANNING

12.1 Introduction to GIS

It is needless to say that huge amount of geographic data will be collected, analyzed, and evaluated at the planning works of any regional/urban development or environmental management projects. Recently, GIS (Geographic Information System) technique which had initially developed and put into market place in early 1980's in USA has been widely applied to the spatial data digitization, analysis, and mapping for various spatial development/management projects in the world. At the initial stage of software development and diffusion of the GIS, cost performance of this system was still in low efficiency, however, because of the recent innovative progress of computer technology, efficiency of data processing is largely improved and packaged system of GIS has been easily installed and used by many users.

In this study, ARC/INFO as the most updated and world standard software of GIS and related computer system (EWS) has installed in the project office to support the planning works. Based on this system, geographic database for the BEIP study has been constructed. As a result of the data manipulation and processing, various type of maps and tables were displayed in the previous chapter of this report. These maps and tables are showing not only the existing environmental conditions of the study area but also the planning indicators of the BMA.

Since the GIS was developed in early 1980s, the spatial analysis in urban or regional development planning has been one of the most effective and cost efficient applications in GIS technology. For a long time, regional planning works have been conducted by manual systems, with records on paper and mylar. Planning works, by its nature as an information-rich discipline, has much to gain from the facilities which the new technology provides. Information organized with GIS therefore provides a framework to support the process of decision making which together constitute planning practice.

Environment is also a great concern in the field of GIS application. One main reason for this is the need to compare a great number of area-related data describing the natural resources involved and their sensitivity to the effects of various impacts. Because GIS can be used to couple area-related data with their attributes, and can be used to overlay these, they represent highly efficient instruments for such planning tasks.

Nowadays, GIS becomes a common tool for all who need to analyze spatial data according to their specified purpose. The growth in GIS technology has been spreading wide and rapidly to not only planning works but wide range of application of physical resource management , environmental assessment and so on.

This technical note describes the contents of BEIP-GIS and points out the several problems as well as necessary measures to be taken for the introduction and application of GIS for the coming information oriented society of the Thailand.

12.2 Concept of the Urban Environmental Information System

The GIS applied in the BEIP study is called as Environmental Information System (EIS), that is specially designed to support the urban land use planning and environmental management for the area of Bangkok Metropolitan Administration(BMA). As illustrated in Fig. 12.1, EIS is a system that incorporates and integrates the functional sub-system of urban planning, transport planning and environmental planning. The functionality and activities associated with each sub-system are needed to define in terms of GIS performance.

(1) Urban Planning Sub-system

This sub-system aims at creating the alternative land use plan by projecting various environmental factors onto the real world, and contributing to the actual urban planning works. Many kind of map data which represent existing urban condition of the BMA and socio-economic statistical data are digitized and stored into the computer as a geographic database. Based on this database, spatial distribution of physical constraints, land use suitability, and future urban development potentiality are analyzed and mapped.

(2) Transport Planning Sub-system

This sub-system aims at creating the alternative transport plan by simulating the traffic volume and congestion based on the existing and planned road networks. For the transport planning, TRANPLAN software was used to analyze existing and future traffic condition. BEIP-GIS supply the basic information on road network, traffic analysis zone(TAZ), and related data. After the necessary data analysis by TRANPLAN, final results were transferred to GIS again and mapped.

(3) Environmental Planning Sub-system

This sub-system aims at creating the alternative environmental management plan by simulating the air, water quality and noise conditions using each environmental mathematical model.

The functionality of the total system can be divided into the following six main elements from which A, D, E and F are directly related to the use of GIS.

(A) Data entry, storage, retrieval and management;
(B) Computation of traffic volume by simulation model;
(C) Computation of Air pollution by emission model;
(D) Spatial (land use) and environmental analysis;
(E) Comparison and evaluation of alternatives;
(F) Presentation and mapping; and
(G) User interface and scenario generator.

The system was designed based on the clear-cut identification of objectives and needs for the analysis. The following attention was paid on the process of database development.

- Examination of data availability in terms of its accuracy, source, method and date of data generation;
- Collection of existing data files in the form of M/T or F/D or M/O to avoid the duplication of data input;
- Examination of model development in GIS in close collaboration with relevant agencies;
- Preparation of output images linked with input from the database
- Examination of the most appropriate system for EIS based on the data volume, input format, output map production, CPU performance, disk capacity and type of package software of GIS; and
- Examination of system compatibility, availability of local system support and maintenance services.

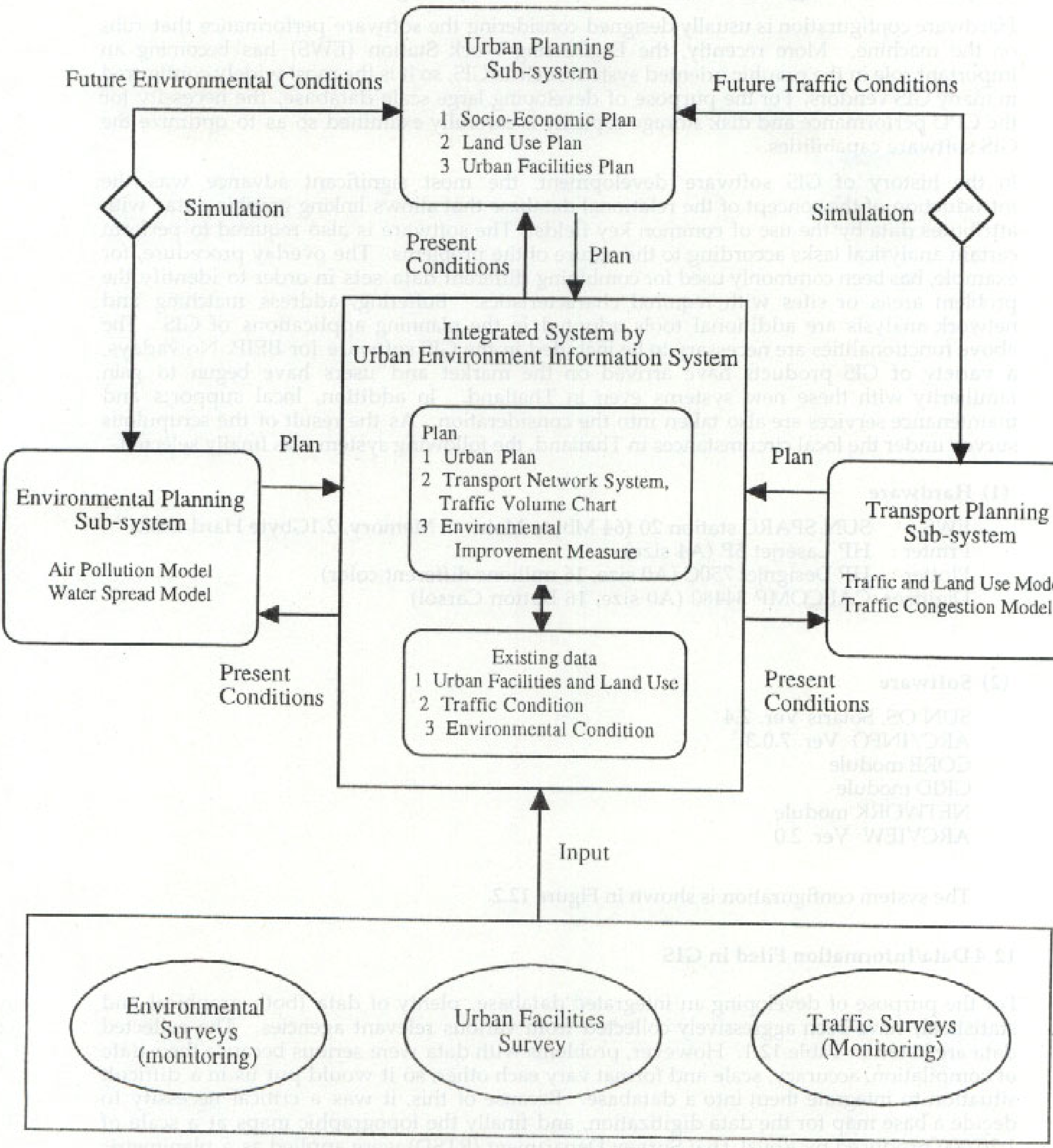


Fig. 12.1 Concept of Urban Environmental Information System

12.3 System Configuration

The typical hardware configuration for GIS comprises a central computer surrounded by memory and storage disks and a number of peripheral devices. Time sharing system is also important because it enables terminal units with lines attached to the central computer to be used at the same time. Like every other computerized information system, GIS are comprised of the integration of hardware and software packages.

Hardware configuration is usually designed considering the software performance that runs on the machine. More recently, the Engineering Work Station (EWS) has becoming an important role in the graphic oriented system such as GIS, so it is the most widely configured in many GIS vendors. For the purpose of developing large scale database, the necessity for the CPU performance and disk storage capacity is carefully examined so as to optimize the GIS software capabilities.

In the history of GIS software development, the most significant advance was the introduction of the concept of the relational database that allows linking graphic data with attributes data by the use of common key fields. The software is also required to perform certain analytical tasks according to the nature of the problems. The overlay procedure, for example, has been commonly used for combining different data sets in order to identify the problem areas or sites with required characteristics. Buffering, address matching and network analysis are additional tools adopted in the planning applications of GIS. The above functionalities are necessary to be included in the GIS software for BEIP. Nowadays, a variety of GIS products have arrived on the market and users have begun to gain familiarity with these new systems even in Thailand. In addition, local supports and maintenance services are also taken into the consideration. As the result of the scrupulous survey under the local circumstances in Thailand, the following system was finally selected.

(1) Hardware

EWS : SUN SPARC station 20 (64 Mbyte Main Memory, 2.1Gbyte Hard Disk)
Printer : HP Laserjet 5P (A4 size)
Plotter : HP Designjet 750C (A0 size, 16 millions different color)
Digitizer :CALCOMP 34480 (A0 size, 16 Button Carsol)

(2) Software

SUN OS, Solaris Ver. 2.4
ARC/INFO Ver. 7.0.3
CORE module
GRID module
NETWORK module
ARCVIEW Ver. 2.0

The system configuration is shown in Figure 12.2.

12.4 Data/Information Filed in GIS

For the purpose of developing an integrated database, plenty of data (both graphical and statistical) have been aggressively collected from various relevant agencies. The collected data are listed in Table 12.1. However, problems with data were serious because their date of compilation, accuracy, scale and format vary each other, so it would put us in a difficult situation to integrate them into a database. Because of this, it was a critical necessity to decide a base map for the data digitization, and finally the topographic maps at a scale of 1:20,000 produced by Royal Thai Survey Department (RTSD) were applied as a planimetric base map for the BEIP.

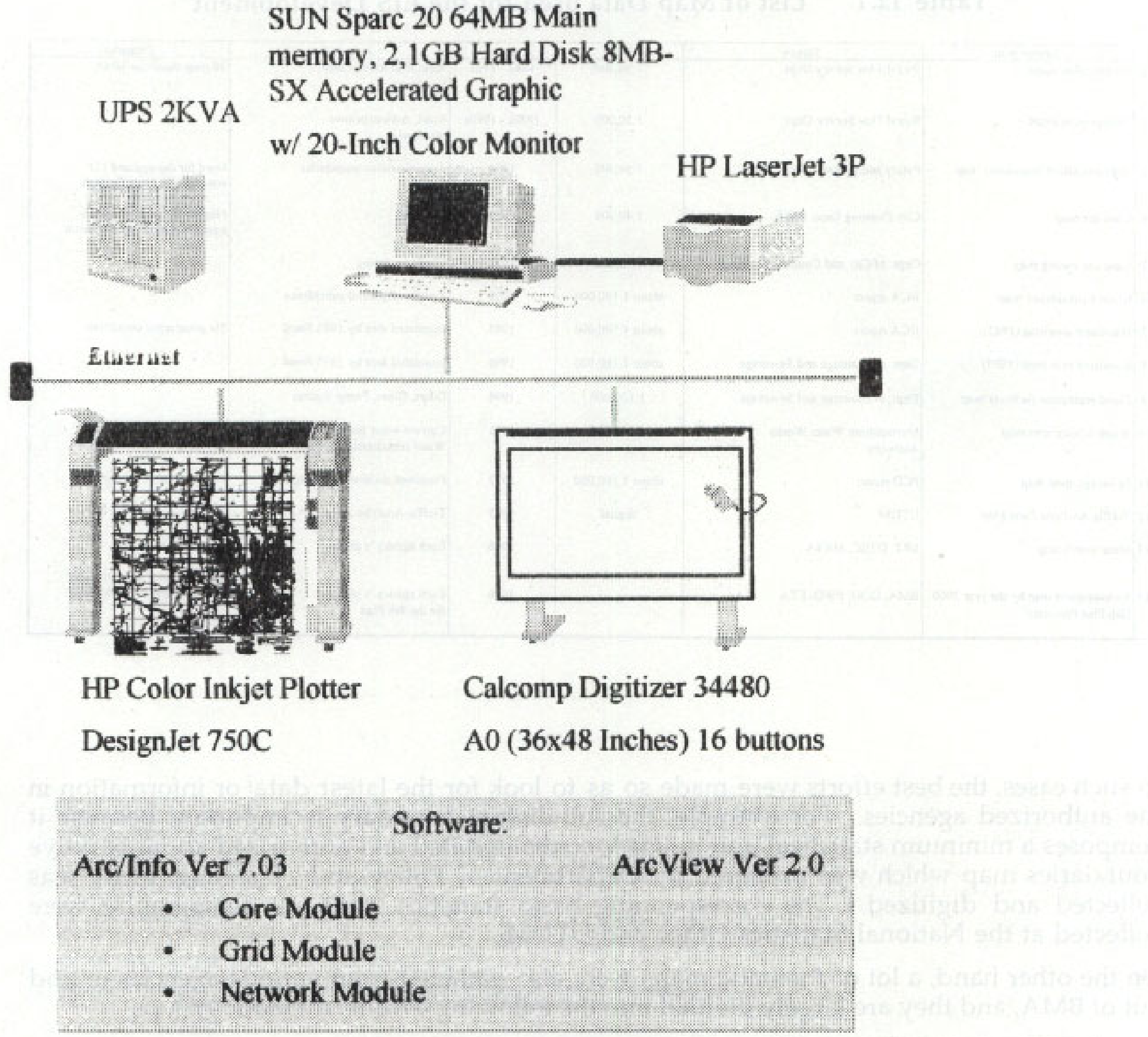


Fig. 12.2 System Configuration

The study area, Bangkok Metropolitan Administration(BMA) is about 1,600 square km and almost covered by 20 (twenty) sheets of the above topographic maps, but some eastern and southern tips of BMA (Nong Chok and Bang Kun Thian districts) are missing on this map series. Topographic maps at a scale 1:50,000 (by RTSD) were supplementary used to fill up such areas as well as covering whole Bangkok Metropolitan Region (BMR). These topographical maps were finally merged each other and compiled into one map sheet scaled at 1:75,000 as a base map for BEIP study.

The status of existing roads, railways, rivers and canals, landmarks, and administrative boundaries were principally derived from the above topographic maps, however, some were lack in details or needed to be updated.

Table 12.1 List of Map Data used for the EIS Development

	Source map	Source	Scale	Date	Information	Remarks
1	Topographic maps	Royal Thai Survey Dept.	1:20,000	1982 - 1992	Road,Rail,River,Canal, Landmark	20 map sheets for BMA
2	Topographic maps	Royal Thai Survey Dept.	1:50,000	1970s - 1980s	Road, Administrative boundaries	
3	Administrative boundaries map	Policy and Planning Dept, BMA	1:50,000	1994	Administrative boundaries	Used for the updated 151 sub-districts identification
4	Land use map	City Planning Dept, BMA	1:40,000	1993	Land use	Not published draft map based on photo interpretation
5	Land use zoning map	Dept. of City and Country Planning	1:75,000	1992	Land use zoning	
6	Ground subsidence map	JICA report	about 1:500,000	1995	Simulated ground subsidence	
7	Inundated area map (1983)	JICA report	about 1:500,000	1985	Inundated area by 1983 flood	No geographic coordinate
8	Inundated area map (1995)	Dept. of Drainage and Sewerage	about 1:100,000	1996	Inundated area by 1995 flood	
9	Flood protection facilities map	Dept. of Drainage and Sewerage	1:100,000	1996	Dikes, Gates, Pomp Station	
10	Water service area map	Metropolitan Water Works Autholity	1:100,000	1995	Current water service area Water transmission system	
11	Sewerage zone map	PCD report	about 1:500,000	1993	Proposed division of sewage area	No geographic coordinate
12	Traffic Analysis Zone Map	UTDM	digital	1995	Traffic Analysis Zone (TAZ)	Derived from MAPINFO
13	Mass transit map	SRT, DTSC, MRTA	–	1996	Each agency 's plans	Not based on maps
14	Road projects map by the year 2000 (8th Plan Projects)	BMA, DOH, PWD, ETA	–	1996	Each agency 's plan for the 8th Plan	Some projects are still under consideration by OCMRT

In such cases, the best efforts were made so as to look for the latest data or information in the authorized agencies. For example, the sub-district boundary is important because it composes a minimum statistical unit in BMA, so the updated and authorized administrative boundaries map which was prepared by Department of Policy and Planning, BMA was collected and digitized. The corresponding basic statistics such as demography were collected at the National Statistics Office and UTDM.

On the other hand, a lot of thematic maps were also gathered from various agencies in and out of BMA, and they are largely divided into the following 4 (four) thematic groups.

- Land resources and conditions, land use, land status,
- Physical constraint, flood area, land subsidence
- Environmental issues, water quality, air pollution, traffic volume
- Social infrastructures, transportation, water service, sewage

The problem at this stage is that these maps are different in date of compilation, scale, accuracy and format and so on because they have not been produced based on the same national base map. It is of primary importance to keep the coordinate accuracy of each map if it will be stored in a sophisticate database. Otherwise, GIS cannot perform any spatial analysis such as overlaying in the next stage.

For this purpose, all thematic maps collected at different agencies are needed to be transferred onto the base map for the preparation of digitization.

Geographical Information System (GIS) is well known for its capability to store both graphical and statistical data at the same time and place. Database Management System (DBMS), one of the most significant advances in GIS software, introduced the concept of the relational database. It serves the very important function of storing very large quantities of information, easily inquiring them, and performing various geographic data manipulation and analysis. In this project, INFO that is the relational DBMS of ARC/INFO is applied to handle basic storage, management and analysis operations for geographic data.

Prior to the data digitization, as described before, all thematic map boundaries were transferred onto a base map (scale 1:75,000) so as to uniform the coordinate control points (TICs), then set on a digitizer. ARC/INFO Ver.7.0.3 was used for all the process of data input, edit, encode and check plots. Statistical information were also stored in conjunction with each statistical unit of maps, especially administrative boundaries map comprised of 151 (one hundred fifty one) sub-districts are frequently used and connected with a lot of attributes data. The contents of the geographic database for BEIP are listed in the followings.

(1) Administrative Boundaries (BMA)

1) Map Data Dource

Topographic maps (1:20,000, partially 1:50,000)

2) Attributes (sub-district base)

Province name in Thai and English
District name in Thai and English
Sub-district name in Thai and English
Sub-district code
Area (square km)
Build-up area (square km)
Build-up ratio (%)
Open space ratio (%)
Population in 1995
Household in 1995
Gross population density in 1995
Net population density in 1995
Population in 1990
Household in 1990
Population increase rate (%) between 1990 and 1995
Gross road density (m/ha)
Net road density (m/h)
Soi rate (%)

(2) Administrative Boundaries (BMR)

1) Map Data Source

Topographic map (1:50,000)

2) Attributes

Province name in Thai and English
District name in Thai and English
Sub-district name in Thai and English

(3) Existing Land Use

1) Map Data Source

land use map (1:40,000) based on the interpretation of aerial photos (1993)

2) Attributes

0 Water bodies
1 High density residential area
2 Middle density residential area
3 Low density residential area
4 Commercial area
5 Industrial area
6 Warehouse

7 Governmental facilities area
8 Agriculture / Open space area
9 Conservation area
10 Park
11 School
12 Religion

(4) Road, Hydrology, Rail (SRT)

1) Map Data Source

Topographic map (1:20,000)

2) Attributes

Road
Road length (m)
Road class (derived from the legend of the topographic map)
1 Primary road
2 Secondary road
3 Through road
4 Soi
5 Express road with Thai name
Hydrology
No attribute
Rail
Station name

(5) Landmarks

1) MapDdata Source

Topographic map (1:20,000)

2) Attributes

Landmark type
31 School
32 Church
33 Temple
34 Mosque
35 Ministry
36 District office
37 Police station
38 Embassy
39 Consulate
40 Hospital
41 Bank
42 Factory
43 Hotel
44 Governmental agencies name in Thai

(6) Inundated Area by 1983 flood

1) Map Data Source

Derived from existing report by JICA

2) Attributes

Inundated area (square km)
Inundated type
1 Inundated
2 Not inundated

(7) Inundated Area by 1995 flood

1) Map Data Source

Derived from existing report by DDS

2) Attributes

Inundated type
1 Inundated
2 Not inundated

(8) Simulated Land subsidence

1) Map Data Source

Derived from existing report by JICA (1995)

2) Attributes

Simulated subsidence class
1 Less than -50 cm
2 -51 to -75 cm
3 -76 to -100 cm
4 -101 to -125 cm
5 -126 to -150 cm
6 More than -151 cm

(9) Traffic Analysis Zone (TAZ)

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Zone number
Zone area (square km)
Land use type
2 CBD
3 China town
4 Urban
5 Sub-urban
6 Rural

(10) Land Use Zoning System

1) Map Data Source

Land use zoning system map

2) Attributes

Land use zoning type
0 Water bodies
1 Low density residential area
2 Middle density residential area
3 Low density residential area
4 Commercial area
5 Industrial area / Warehouse
6 Warehouse
7 Special industrial area
8 Agriculture
9 Recreational / Open space
10 Educational institute

11 Rural agriculture Conservation
12 Conservation for Thai culture
13 Religion
14 Governmental office / Public facilities

(11) Sewage Zone

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Sewage zone number
Sewage zone area (square km)
Operation stage
1 Under operation
2 Under planning
3 Expansion plan

(12) MWA Water Service Area (BMA and BMR)

1) Map Data Source

MWA water service area map

2) Attributes

Zone name
1 Bang Bua Thong
2 Bangkhaen 1
3 Bangkhaen 2
4 Bangkok Noi
5 Mansri
6 Minburi
7 Nonthaburi 1
8 Nonthaburi 2
9 Phasicharoen
10 Phaya Thai
11 Phrakanong - Bnagna
12 Samut Prakarn
13 Sukhumvit - Pattankarn
14 Taksin 1
15 Taksin 2
16 Thung Mahamek
Service stage
1 Service area
2 No service area
Water service area expansion plan
1 Water service area in 1995
2 Water service area before 1997/1
3 Water service area before 1997/2
4 Water service area before 2007
5 Water service area before 2017

(13) BOD Loading Investigation / Water Quality Sampling points

1) Map Data Source

Originally produced in BEIP study based on topographic map (1:20,000)

2) Attributes

Origin type
1 Latkrabang industrial estate
2 Hotel
3 Hospital
4 Condominium
5 Restaurant
6 Private office
7 Department store
8 Fresh food market
101 Mixed area I : Democratic Monument
102 Mixed area II : Phatpong
103 Mixed area III : Wong Wain Yai
11 Residential area (NHA)
12 Residential area (town house)
13 Residential area (single house)
14 School
Sampling point number

(14) Khlong Water Quality Sampling Point and BOD

1) Map Data Dource

Originally produced in BEIP study based on topographic map (1:20,000)

2) Attributes

Sampling type
1 Existing
2 Existing new
3 New
Water quality
1 More than 40
2 30 to 39
3 20 to 29
4 Less than 20
Sampling point number

(15) Flood Prevention and Drainage Facilities

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Protection stage
0 No protected
1 Protected drainage pump station point
Water gate point

(16) Mass Transit Plan (including SRT Rail Project)

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Project type
1 BTSC - green
2 MRTA - blue
3 MRTA - orange

4 MRTA - purple
5 MRTA - red
11 BTSC - green (ext)
12 MRTA - blue (ext)
13 MRTA - orange (ext)
15 MRTA - red (ext)

Project stage
1 On going
2 Proposed

Station plan

(17) Road Project

1) MapData Source

Major BMA road projects in 8th plan, DOH project, PWD project

2) Attributes

Plan type (BMA)

Year 1995	0 improved existing road
Plan 2000	1 new road
Road ID	

Plan type (DOH)

Year 1995	0 improved existing road
Plan 2000	1 new road
Road ID	

Plan type (PWD)

Year 1995	0 improved existing road
Year 2000	1 new road

(18) Boat/Ferry Service

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Ferry pier point

Service type
1 Khlong express boat service
2 Chao Phraya river express boat service
3 Chao Phraya river crossing boat service

Pier name (service type 2 only)

Service line (service type 3 only)

(19) Road Network from TRANPLAN Data

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000 and 1:50,000)

2) Attributes

Road traffic volume (daily base)
Road traffic volume (peak hours base)
Travel speed distribution (peak hours base)
Level of service (peak hours base)
Number of traffic lanes
Number of Bus lanes

(20) Person Trip OD

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Daily base
Peak hours base

(21) The Bangkok Plan (draft), DCP, BMA

1) Map Data Source

The Bangkok Plan report

2) Attributes

Land use type
1 Residential area
2 Commercial area
3 Industrial area
4 Agriculture
5 Park
6 Mixed use
Maximum allowable FARs (FAR type)
1 10:1
2 6:1
3 4:1
4 2:1
5 1:1
6 Rural

(22) Khlong Water Quality Improvement (East Bank), DDS, BMA

1) Map Data Source

Originally produced by BEIP based on the topographic maps (1:20,000)

2) Attributes

Boundary of water dilution system
Dilution water intake station
Dilution water discharge station
Dilution water intake and discharge station
Direct aeration site
Khlongs for direct aeration site 5
Khlongs for dredging work
Khlongs for construction of retaining wall

CHAPTER 13: GIS DATA PROCESSING

13.1 Hierarchical Structure of GIS Data Processing

The geographic database development has completed and data analysis phase based on this database can be started. A GIS application uses the database and system functions in applying the manipulation techniques as follows;

- Performing polygon overlay
- Creating buffer zones
- Using boundary operations
- Manipulating tabular data
- Performing model based simulations

Those are spatial data manipulation in a particular manner required to support the information requirements of the planning expert in BEIP study team. Applications applied in this study involve simple spatial overlay, combinations of data using GRID base, so far as to complex mathematical computation, in both graphic and tabular formats. The GIS analytical process can be schematically illustrated on Fig. 13.1, then divided into three hierarchical stages (primary, secondary and tertiary) according to the degree of spatial data manipulation and the BEIP planning progress.

13.2 Primary Data Analysis

This stage of spatial analysis comprises the initial overlay manipulation of basic map data layers in order to identify new spatial relationships between the various geographic units and features. It includes the cross tabulations of the area, length, density, average and frequency calculation for some specific geographic features per some specific geographic units. Existing land use, for example, was overlaid with administrative boundaries so as to calculate the area of each land use type per each district or sub-district unit (see Table 13.1). On the other hand, the existing socio-economic data stored in the attributes files were manipulated so that new information can be processed from the geographical point of view(see Table 13.2 and 3). In the same way, the following data manipulations were performed, and various cross tabulations were produced as a result of primary data analysis. These table data are showing the existing urban condition of the BMA and having a meanings of planning indicator.

- Existing land use + Administrative boundaries
- Existing land use + Sewage zone
- Existing land use + Water service area
- Existing land use + Inundated area by 1983 flood
- Existing land use + Flood protection zone
- Existing land use + Land subsidence zone
- Land use zoning system + Existing land use
- Land use zoning system + Administrative boundaries
- Road network + Administrative boundaries
- Statistical mapping using attributes (ex. demography)

The results of the above geographic analysis can be communicated with maps, reports, or both. A map is best used to display geographic relationships whereas a report is most appropriate for summarizing the tabular data and documenting any calculated values. The selection of criteria for the model analysis will be formulated based on the interpretation and evaluation of the results of those primary data analysis.

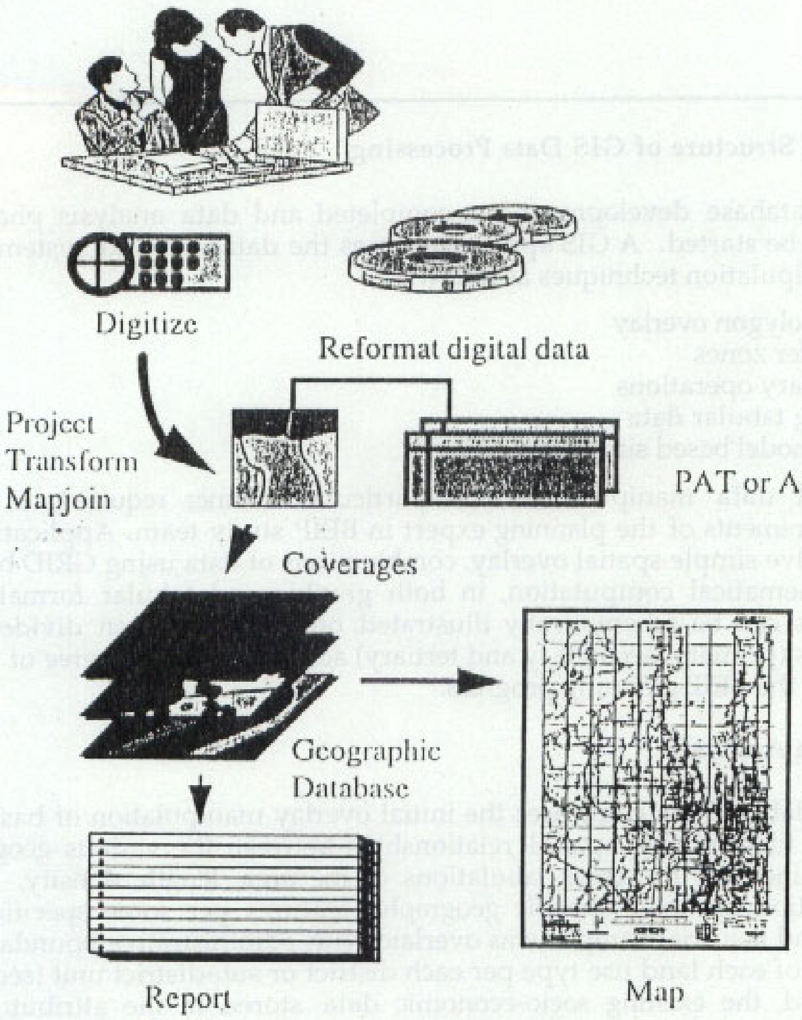


Fig. 13.1 GIS Analysis Procedure

Table 13.1 Land use Statistics by District

DISTRICT NAME	HIGH DENSITY	MID DENSITY	LOW DENSITY	COMM-ERCIAL	INDUS-TRIAL	WARE-HOUSE	GOVERN MENTAL	AGRI-CULTUR	CONSER-VATION	PARK	SCHOOL	RE-LIGION	WATER BODY	TOTAL
Bang Kapi	1.354	14.175	10.415	2.905	0.398	0	0.610	13.434	0	1.584	0.199	0	0	45.074
Bang Khen	0	7.300	8.077	0.836	0	0	8.399	53.256	0	0	0.037	0.438	0	78.343
Bang Kho Laem	0	5.434	0.151	0.552	0.090	0.388	0.115	0.312	0	0.130	0.033	0.100	1.153	8.458
Bang Khun Thian	0	9.663	10.963	0.187	0.910	0.040	0.018	134.339	0	0.011	0.116	0.103	0.203	156.553
Dang Phlat	0	4.089	4.222	0.959	0.038	0	0.016	1.454	0	0	0.085	0.048	0.947	11.858
Dang Rak	0	0.036	0	3.372	0	0	0.274	0	0	0.014	0.205	0.017	0.126	4.044
Dang Sue	7.435	1.289	0.851	0.746	0.693	0	0.161	1.211	0	0	0.091	0.012	0.596	13.085
Bangkok Noi	0.615	3.315	3.379	1.179	0	0	0.882	1.983	0	0	0.168	0.210	0.566	12.297
Bangkok Yai	0.085	3.680	0.157	0.864	0.128	0	0.137	0.653	0	0	0.173	0.175	0.189	6.241
Bung Kum	0.985	18.177	7.535	0.389	0.849	0	0.051	33.332	0	1.736	0.065	0	0	63.119
Chatu Chak	3.519	16.606	2.219	1.368	0.212	0	4.720	0.732	0	2.678	0.419	0	0.005	32.478
Din Daeng	0	6.493	0	1.025	0	0	0.483	0	0	0.128	0.349	0	0	8.478
Don Muang	0.035	15.245	6.451	0.525	0	0	15.586	20.284	0	0	0.447	0	0	58.573
Dusit	0.138	2.674	0.018	0.272	0.144	0	5.185	0	0.897	0.824	0.280	0.119	0.749	11.300
Huai Khwang	0	5.693	3.397	1.227	0	0	0.060	5.925	0	0	0.048	0	0	16.350
Jomtong	0.011	7.869	3.347	0.906	0.393	0	0.050	10.359	0	0	0.097	0.283	0.439	23.754
Khlong San	0	3.900	0	0.984	0.171	0.047	0.138	0.016	0	0	0.124	0.056	0.579	6.015
Khlong Toei	2.309	16.533	0.285	3.147	0.058	0.872	2.590	0.544	0	0.319	0.348	0	0.949	27.954
Lat Phrao	0.521	10.175	5.936	0.620	0.066	0	0.050	11.114	0	0	0.062	0	0	28.544
Latkrabang	0.153	2.314	7.012	0	2.088	0	0	116.979	0	0	0.027	0.020	0	128.593
Minburi	0.052	3.323	7.202	0.529	1.907	0	0.107	163.895	0	0	0.254	0	0	177.269
Nong Chok	0	0.452	5.656	0	0	0	0	234.948	0	0	0.000	0	0	241.056
Nong Khaem	0	5.071	9.530	0.143	0.746	0.012	0.490	30.622	0	0	0.138	0.203	0	46.955
Pathumwan	0.120	0.375	0.024	3.093	0	0	1.709	0.073	0	1.265	1.355	0	0.066	8.080
Phasi Charoen	0.006	16.748	3.523	1.467	0.436	0.196	0.101	33.286	0	0	0.430	0.254	0.175	56.622
Phaya Thai	0	7.989	0	0.289	0	0	0.529	0	0	0.112	0.061	0	0.093	9.073
Phra Khanong	1.424	23.853	0.767	0.789	0.239	1.356	0.332	3.738	0	0	0.520	0	0.924	33.942
Phra Nakhon	0.196	0.244	0.066	2.065	0.017	0	0.778	0	0.294	0.360	0.333	0.442	0.601	5.396
Pom Prap Sattrupha	0.181	0.054	0	1.569	0	0	0.240	0.017	0	0	0.154	0.171	0.058	2.444
Prawet	0	13.125	11.399	0.921	0.814	0	0	38.497	0	0.579	0.024	0	0.117	65.476
Ratburana	0.387	10.048	2.129	0.993	0.546	0.464	0.279	30.235	0	0.083	0.248	0.187	1.126	46.725
Ratchathewi	0.495	1.375	0.466	1.467	0	0	2.605	0.167	0	0.140	0.453	0	0.057	7.225
Samphanthawong	0	0	0	1.033	0	0	0.055	0	0	0	0.026	0.123	0.172	1.409
Sathon	0.003	5.020	0	0.814	0.140	0.098	0.594	0.096	0	0.018	0.298	0.039	0.131	7.251
Suan Luang	0	9.272	4.201	0.492	0.025	0	0.017	6.090	0	0.121	0.247	0	0.276	20.741
Taling Chan	0	5.435	15.712	0	0	0	0.026	65.153	0	0	0.221	0.300	0.755	87.602
Thonburi	0.143	5.202	0.107	1.348	0.072	0.114	0.140	0.200	0	0	0.136	0.194	0.477	8.133
Yan Nawa	1.166	6.957	0.229	0.595	0.087	0.879	0.214	0.526	0	0.025	0.099	0.054	1.574	12.405
Total	21.333	269.203	135.426	39.670	11.267	4.466	47.741	1013.470	1.191	10.127	8.370	3.548	13.103	1578.915

Unit : km

Table 13.2 Sub-district Statistics Produced by GIS Data Manipulation (1)

District	Sub-District	Code	Area (km2)	Build Area (km2)	P_Density Gross (per Km2)	P_Density Net (per Km2)	Increase Rate (%)	Open Space (%)	Build-up Rate(%)	R_Density Gross (m/Ha)	R_Density Net (m/Ha)	Soi Density (m/ha)
Bang Kapi	Hua Mak	101203	15.70	8.27	7,575	14,376	5.92	37.22	52.70	95	181	88.87
	Khlong Chan	101201	12.41	8.52	10,061	14,645	4.94	31.30	68.70	116	168	93.23
	Wang Thong Lang	101202	16.97	13.26	8,523	10,905	6.00	21.85	78.15	118	151	89.23
Bang Khen	Anusawari	101401	15.68	13.99	6,300	7,065	9.55	10.83	89.17	101	113	87.25
	Khlong Thanon	101402	16.90	3.32	10,541	53,698	15.84	80.37	19.63	72	367	84.30
	O-ngoen	101405	13.62	0.82	480	7,953	9.97	93.97	6.03	24	401	68.59
	Sai Mai	101404	14.00	1.84	3,718	28,233	12.90	86.83	13.17	56	422	83.86
	Tha Raeng	101403	18.14	5.12	2,299	8,150	13.82	71.79	28.21	41	145	87.79
Bang Kho Laem	Bang Khlo	101503	4.71	4.02	14,941	17,506	2.15	2.89	85.35	66	77	68.67
	Bang Kho laem	101502	2.14	1.48	13,776	19,882	2.26	6.99	69.29	59	86	71.64
	Wat Praya Kri	101501	1.61	1.36	27,590	32,589	1.75	1.60	84.66	66	79	73.53
Bang Khun Thian	Bang Bon	101303	35.36	8.25	2,687	11,511	10.21	76.62	23.35	25	108	79.98
	Samae Dam	101301	45.93	11.39	2,357	9,502	10.56	74.99	24.81	35	141	80.93
	Tha Kham	101302	75.27	2.35	384	12,283	6.32	96.73	3.13	19	617	88.41
Bang Phlat	Bang O	101704	3.08	1.92	25,310	40,591	17.05	25.16	62.35	58	93	87.30
	Bang Pamru	101702	2.40	2.27	10,149	10,748	-1.45	5.57	94.43	91	96	86.51
	Bang Phlat	101701	3.33	2.59	13,175	16,902	-6.39	16.39	77.95	99	127	80.95
	Bang Yikhan	101703	3.04	2.67	33,111	37,736	19.22	0.00	87.74	73	84	76.65
Bang Rak	Bang Rak	101802	0.48	0.35	27,838	37,758	15.83	0.00	73.73	56	75	55.11
	Maha Phutthararn	101803	0.65	0.64	78,122	78,981	15.16	0.00	98.91	120	121	58.65
	Si Lom	101804	1.56	1.55	17,345	17,411	9.69	0.00	99.62	88	89	19.72
	Si Phraya	101801	0.76	0.76	80,568	80,568	21.45	0.00	100.00	96	96	53.21
	Surawong	101805	0.60	0.60	20,293	20,293	8.76	0.00	100.00	133	133	59.46
Bang Sue	Bang Sue	101601	13.09	11.28	25,883	30,030	2.35	9.26	86.19	100	117	81.17
Bangkok Noi	Arun Amarin	101005	2.94	2.73	24,073	25,926	0.00	1.43	92.85	63	68	83.36
	Ban chang Lo	101004	2.32	2.22	25,973	27,095	-2.21	2.89	95.86	84	87	60.98
	Bang Khun Non	101002	1.65	1.33	6,138	7,630	-12.62	14.11	80.45	53	66	77.88
	Bang Khun Si	101003	4.00	2.31	15,769	27,390	5.31	40.91	57.57	57	100	92.00
	Sirirat	101001	1.38	1.16	34,134	40,567	10.77	0.00	84.14	63	75	57.75
Bangkok Yai	Wat Arun	101102	0.86	0.76	31,834	35,869	4.86	0.00	88.75	79	89	68.98
	Wat Tha Phra	101101	5.39	4.64	14,248	16,539	0.52	0.00	86.15	75	87	81.04
Bung Kum	Khanna Yao	101902	21.31	6.93	2,266	6,971	5.53	59.35	32.51	53	163	88.66
	Khlong Kum	101901	24.85	14.00	6,089	10,810	6.91	43.67	56.33	95	169	93.94
	Saphan Sung	101903	16.96	7.13	3,046	7,249	7.37	57.98	42.02	65	154	87.79
Chatu Chak	Lat Yao	100401	32.48	29.06	7,011	7,835	2.04	2.25	89.49	113	126	86.07
Din Daeng	Din Daeng	103701	8.48	8.35	32,538	33,036	22.79	0.00	98.49	158	161	87.22
Don Muang	Si Kan	100603	20.69	11.20	4,757	8,791	8.22	45.88	54.12	79	145	89.01
	Talat Bang Khen	100602	21.24	16.18	4,133	5,426	7.30	23.82	76.18	60	79	74.54
	Thong Song Hong	100601	16.64	10.91	6,757	10,305	9.36	34.44	65.56	97	148	95.14
Dusit	Dusit	100701	2.36	1.96	20,156	24,196	3.59	0.00	83.30	74	89	40.71
	Si Yak Mahanak	100705	0.37	0.36	49,354	50,912	1.70	0.00	96.94	84	87	37.50
	Suan Chitlada	100704	1.88	0.55	14,530	49,553	-0.97	0.02	29.32	60	206	17.41
	Thanon Nakhon Chaisi	100702	5.57	5.12	32,298	35,162	2.13	0.00	91.85	86	93	60.54
	Wachira Phayabarn	100703	1.13	0.84	26,608	35,697	1.98	0.00	74.54	64	86	54.68
Huai Khwang	Bang Kapi	103603	6.13	3.15	1,101	2,139	-22.34	48.55	51.45	56	108	73.91
	Huai Khawang	103601	4.88	2.73	9,011	16,131	-13.75	44.14	55.86	82	146	83.49
	Samsen Nok	103604	5.34	4.55	5,281	6,207	-6.93	14.92	85.08	129	152	86.35
Jomtong	Bang Kho	100501	3.41	1.57	15,126	32,824	1.83	26.80	46.08	55	119	88.28
	Bang Khun Thian	100503	6.09	3.94	7,539	11,653	2.84	34.64	64.69	39	60	81.16
	Bang Mot	100504	8.85	4.69	5,074	9,579	6.66	44.93	52.97	28	53	60.15
	Chom Thong	100502	5.40	2.75	10,903	21,374	4.58	45.66	51.01	35	70	67.40
Khlong San	Bang Lam Phu Lang	100303	2.25	2.01	22,876	25,648	4.55	0.00	89.19	78	88	81.07
	Klong San	100301	1.08	0.94	29,996	34,236	4.80	0.00	87.62	63	72	52.40
	Klong Ton Sai	100302	1.74	1.61	19,992	21,705	0.90	0.00	92.11	84	91	51.19
	Somdet Chaophraya	100304	0.94	0.86	27,275	29,833	1.08	1.64	91.43	112	123	57.64
Khlong Toei	Klong Tan	100202	11.34	10.86	7,616	7,959	-2.55	4.03	95.69	129	135	83.93
	Klong Toei	100201	9.02	8.13	14,692	16,309	6.10	0.01	90.08	98	109	64.68
	Phra Khanong	100203	7.59	7.16	11,547	12,238	1.68	1.14	94.35	117	124	81.04
Lat Phrao	Chorakhe Bua	103102	14.47	7.14	4,629	9,372	5.72	50.61	49.39	106	215	87.65
	Lat Phrao	103101	14.08	10.28	6,899	9,443	6.24	26.94	73.06	118	162	90.45
Latkrabang	Khlong Sam Prawet	103004	17.44	0.84	457	9,474	12.03	95.18	4.82	36	741	82.04
	Khlong Song Tonnun	103003	16.17	1.63	2,210	21,977	16.91	89.95	10.05	42	417	92.09
	Khum Thong	103002	26.62	1.38	284	5,466	7.38	94.81	5.19	4	69	0.00
	Lam Prathiu	103006	33.28	2.69	558	6,901	9.71	91.91	8.09	31	383	72.09
	Lat Krabang	103001	10.73	3.74	3,593	10,292	3.68	65.09	34.91	70	200	84.30
	Thap Yao	103005	24.36	1.33	630	11,543	8.37	94.54	5.46	18	324	76.42
Minburi	Bang Chan	102604	22.60	3.53	1,677	10,735	14.76	84.38	15.62	47	302	74.37
	Minburi	102601	20.26	5.99	4,364	14,772	13.48	70.46	29.54	56	189	82.57
	Sai Kongdin	102602	13.19	0.35	453	17,122	11.48	97.35	2.65	25	929	75.33
	Sai Kongdin Tai	102603	16.17	0.87	610	11,324	8.67	94.61	5.39	42	777	82.56
	Samwa Tawanok	102606	40.08	0.57	274	19,240	8.31	98.57	1.43	21	1,474	85.15
	Samwa Tawantok	102605	28.72	0.77	233	8,631	8.14	97.30	2.70	20	758	80.79
	Sansaep	102607	36.24	1.29	717	20,130	10.87	96.44	3.56	31	864	77.10

Table 13.3 Sub-district Statistics Produced by GIS Data Manipulation (2)

District	Sub-District	Code	Area (km2)	Build Area (km2)	P_Density Gross (per Km2)	P_Density Net (per Km2)	Increase Rate (%)	Open Space (%)	Build-up Rate(%)	R_Density Gross (m/Ha)	R_Density Net (m/Ha)	Soi Rate (%)
Nong Chok	Khlong Sip	103502	30.70	0.29	274	29,322	9.13	99.06	0.94	10	1,069	51.56
	Khlong Sip Song	103503	41.31	1.08	193	7,379	9.39	97.39	2.61	7	279	0.00
	Khok Faet	103505	21.54	0.93	760	17,588	13.79	95.68	4.32	10	224	38.36
	Khu Fang Nua	103504	18.00	0.14	443	55,495	10.08	99.20	0.80	22	2,802	72.57
	Krathum Rai	103501	40.39	0.77	557	29,248	11.01	98.09	1.91	7	368	0.00
	Lam Phak Chi	103507	33.30	1.02	286	9,315	10.33	96.93	3.07	8	245	24.02
	Lam Toi Ting	103506	24.99	0.52	299	14,458	8.40	97.93	2.07	5	247	0.00
	Nong Chok	103508	30.82	1.36	422	9,572	9.54	95.59	4.41	9	198	0.00
Nong Khaem	Lak Song	103403	17.83	5.84	3,109	9,497	8.43	67.27	32.73	37	112	93.99
	Nong Khaem	103402	14.68	5.21	2,293	6,467	11.27	64.54	35.46	39	110	100.00
	Nong Khang Phlu	103401	14.44	5.29	3,809	10,396	14.74	63.36	36.64	57	155	89.59
Pathumwan	Pathumwan	102002	2.11	1.59	32,184	42,700	13.88	3.47	75.37	39	51	39.45
	Rong Muang	102003	1.25	1.21	68,873	71,072	12.23	0.00	96.91	104	108	37.22
	Suan Lumphini	102004	3.40	2.77	25,175	30,878	17.59	0.00	81.53	77	94	51.67
	Wang Mai	102001	1.33	1.11	38,952	46,647	12.63	0.00	83.50	128	153	60.11
Phasi Charoen	Bang Chak	102504	1.40	0.39	5,730	20,563	4.17	72.13	27.87	21	76	99.45
	Bang Duan	102507	4.25	1.19	8,964	31,974	2.51	71.97	28.03	40	143	82.67
	Bang Khae	102505	8.00	4.04	6,150	12,183	4.96	49.52	50.48	35	69	67.19
	Bang Khae Nua	102506	13.52	5.45	5,259	13,053	6.33	59.71	40.29	44	109	82.92
	Bang Phai	102508	15.96	5.14	2,125	6,606	5.91	67.81	32.17	44	136	69.75
	Bang Wa	102501	5.53	2.79	8,405	16,646	3.82	49.50	50.50	34	67	51.39
	Bang Waek	102509	2.90	1.20	7,859	18,983	4.48	56.03	41.40	50	121	72.69
	Khlong Kwang	102502	2.63	0.87	3,486	10,484	4.74	65.74	33.25	24	73	60.30
	Khuhasawan	102503	0.71	0.47	12,981	19,694	1.25	30.61	65.91	54	82	94.33
	Pak Khlong Pasicharoen	102510	1.72	1.62	15,585	16,550	-0.16	3.35	94.17	80	85	78.19
Phaya Thai	Samsen Nai	102301	9.07	8.87	27,997	28,644	2.94	0.00	97.74	107	109	74.80
Phra Khanong	Bang Chak	102401	15.19	14.54	8,751	9,139	6.28	1.45	95.76	132	138	80.92
	Bang Na	102402	18.75	14.74	6,680	8,501	5.04	18.75	78.58	112	143	78.08
Phra Nakhon	Ban Phan Thom	100106	0.41	0.39	32,382	33,535	-0.49	0.00	96.56	144	149	75.35
	Bang Khun Phrom	100105	0.45	0.44	20,438	20,837	0.59	0.00	98.09	74	76	57.13
	Bowon Niwet	100104	0.49	0.46	23,051	24,594	1.53	0.00	93.73	139	149	51.77
	Chana Songkhram	100102	0.35	0.28	14,025	17,529	-0.99	0.00	80.01	114	142	46.10
	Phra Borom Maha Ratchawang	100107	1.53	0.81	6,051	11,460	0.98	0.00	52.80	66	125	15.86
	Sam Ran Rat	100111	0.22	0.16	30,880	43,285	-0.90	0.00	71.34	81	114	38.72
	San Chao Phor Sua	100110	0.15	0.14	41,594	44,118	0.56	0.00	94.28	111	117	65.09
	Sao Chingcha	100112	0.16	0.13	33,898	41,710	0.32	0.00	81.27	130	160	59.16
	Talad Yot	100103	0.19	0.17	34,011	37,635	-0.12	0.00	90.37	122	135	79.19
	Wang Burapha Philom	100108	0.70	0.57	29,946	37,008	1.51	0.00	80.92	135	166	24.20
	Wat Ratchabophit	100109	0.22	0.21	28,757	31,000	1.36	0.00	92.76	162	175	52.39
	Wat Sam Phraya	100101	0.52	0.38	11,756	16,028	-1.00	0.00	73.35	71	97	52.24
Pom Prap Sattrupha	Ban Bahr	102204	0.40	0.38	79,786	84,544	19.87	0.00	94.37	111	118	13.61
	Klong Mahanark	102202	0.58	0.54	84,842	91,297	22.31	2.87	92.93	97	104	66.12
	Pomprab Satrupthe	102205	0.59	0.59	94,052	94,065	15.57	0.00	99.99	165	165	55.35
	Wat Debsirin	102203	0.43	0.43	77,014	77,146	21.41	0.00	99.83	168	168	61.67
	Wat Soammanut	102201	0.45	0.44	65,443	67,109	19.27	0.00	97.52	146	150	38.89
Prawet	Dok Mai	102102	14.95	4.67	1,400	4,483	12.41	68.78	31.22	65	207	85.17
	Nong Bon	102103	12.89	8.10	3,579	5,690	5.64	36.61	62.90	89	141	86.60
	Prawet	102101	37.64	13.51	2,558	7,128	7.01	62.43	35.89	66	184	92.25
Ratburana	Bang Mot	102904	11.41	3.30	4,778	16,511	10.65	70.17	28.94	26	91	61.74
	Bang Pakok	102903	8.04	4.59	11,771	20,613	5.81	36.20	57.11	37	64	66.18
	Ratburana	102901	5.61	4.02	15,583	21,780	-29.29	84.41	71.55	54	75	66.15
	Thung Khru	102902	21.66	3.37	2,219	14,267	10.30	84.44	15.55	8	52	67.38
Ratchathewi	Makkasan	102804	2.47	2.39	22,893	23,717	13.35	0.00	96.53	92	95	70.03
	Thanon Phaya Thai	102801	1.25	1.25	27,152	27,251	19.55	0.00	99.64	116	116	60.61
	Thanon Phetcha Buri	102802	0.99	0.85	49,346	57,013	13.26	9.91	86.55	79	91	61.58
	Thung Phaya Thai	102803	2.51	2.37	47,900	50,737	31.68	2.43	94.41	72	76	65.16
Samphanthawong	Chakkrawat	103202	0.51	0.44	42,914	50,164	11.29	0.00	85.55	124	145	54.20
	Sam Phanthawong	103203	0.49	0.44	39,792	43,808	11.94	0.00	90.83	130	143	44.30
	Talat Noi	103201	0.41	0.35	78,660	90,409	15.14	0.00	87.00	72	82	32.23
Sathon	Thung Mahamek	103302	2.91	2.91	10,582	10,582	1.56	0.00	100.00	107	107	74.63
	Thung Watdon	103303	2.52	2.42	25,501	26,511	1.55	3.81	96.19	75	78	55.74
	Yannawa	103301	1.83	1.68	23,015	25,055	-0.12	0.00	91.86	88	95	66.53
Suan Luang	Suan Luang	103801	20.74	14.25	7,806	11,358	7.45	29.36	68.72	88	128	87.66
Taling Chan	Bang Chuak Nang	100805	6.95	0.71	1,455	14,167	8.20	87.66	10.27	15	149	49.85
	Bang Phrom	100806	5.13	0.66	3,267	25,206	7.09	84.67	12.96	22	168	63.97
	Bang Ramat	100807	15.36	3.21	1,444	6,916	8.37	78.58	20.88	26	126	73.35
	Chim Phli	100802	15.49	6.00	2,631	6,795	10.77	60.60	38.72	46	119	63.35
	Khlong Chak Phra	100801	2.54	1.42	5,455	9,751	9.14	39.40	55.95	39	70	53.81
	Sala Thammasop	100808	19.53	3.94	1,146	5,681	14.91	79.83	20.18	30	149	67.58
	Taling Chan	100803	6.01	3.83	5,429	8,519	6.63	33.20	63.72	37	58	66.33
	Thawi Watthana	100804	16.60	1.92	787	6,801	9.12	88.42	11.58	25	216	67.94
Thonburi	Bang Yirua	100901	1.19	1.17	47,978	48,846	0.07	0.00	98.22	76	77	66.54
	Bukkhalo	100903	4.30	3.90	34,548	38,054	2.38	1.61	90.79	77	85	70.94
	Hirunruchi	100905	0.66	0.65	40,244	41,079	1.52	0.00	97.97	90	92	82.27
	Talat Phlu	100902	1.24	1.09	32,607	37,129	0.46	0.00	87.82	65	73	51.80
	Wat Kanlaya	100904	0.75	0.65	32,042	36,783	4.34	0.00	87.11	56	64	37.65
Yan Nawa	Bang Phong Pang	102702	4.96	3.74	12,220	16,229	6.73	7.59	75.30	57	76	62.07
	Chong Nonsi	102701	7.44	6.54	12,384	14,083	9.49	2.01	87.93	71	81	59.30
Grand Total	BMA		1,578.91	541.02								

13.3 Secondary Data Analysis

Geographic analysis allows users to study real-world processes by developing and applying models. Such models illustrate underlying trends in the geographic data and thus make new information available. A GIS enhances this process by providing tools which can be combined in meaningful sequences to develop new models. There are two kinds of analytical models, qualitative and quantitative, coupled with the GIS database. In stage of the secondary data analysis, the basis for the model calculation is a polygon overlay with a qualitative model for the urban development suitability and potentiality evaluation. The process of model consists of the following elements.

1) Select criteria;
2) Give different weights to the criteria selected (optional); and
3) Combine different criteria.

First, criteria were selected in terms of physical constraint, urban environment service, transportation service and living facilities service as shown on Table 13.4, and then the weight score was given to each item of thematic map manipulated by GIS.

Next step is to perform the spatial overlay of the plural maps according to the assigned score of each item, and sum up the total score value for four different evaluation maps. The results are shown in the relevant part of this report. The importance from the viewpoint of GIS is to assess the spatial distribution of problems and establish an objective before stating any analysis. To review the problem, the potential area for the urban development in future is being identified within an environmental regime. On this process, the score itself is merely estimated relative value for discriminating a specific site to meet with the planning requirements.

Table 13.4 Criteria and Weighted Score for Urban Development Potential Evaluation

Evaluation Condition		Score	-3	-2	-1	0
Physical Constraint	N1	Ground Subsidence	>1.5m	1.0 - 1.5m	0 - 1.0m	0m
	N2	Inundation by 1983 Flood	Yes			No
	N3	Inundation by 1995 Flood	Yes			No
	N4	Flood Protection Zone *1)	A zone	B zone	C zone	Others

Evaluation Condition		Score	1	0
Urban Environment Services	U1	Water Services	Yes	No
	U2	Sewerage Services	Yes	No

Evaluation Condition		Score	5	4	3	2	1
Transportation Services	T1	Accessibility to Trunk Roads	0.5km of R1/R2	1km of R1/R2	0.5km of R3	1km of R3	None
	T2	Accessibility to Railways	0.5km from STN	1km from STN	1.5km from STN	2km from STN	None
	T3	Accessibility to Bus Services	500m zone		1000m zone		None

Evaluation Condition		Score	5	4	3	2	1
Living Facilities Services	F1	Accessibility to Hospitals	<1km	1 - 2km zone	2 - 3km zone	3 - 5km zone	>5km
	F2	Accessibility to Commercial	<2km	2 - 5km zone	5-10km zone	10-15km zone	>15km

*1) A : Eastern King's Dike
B : Inner Dike - King's Dike
C : Tonburi Lowlands

*2) R1 : Primary Road
R2 : Secondary Road
R3 : Trough Road

13.4 Tertiary Data Analysis

In this stage, simulation modeling analysis for the future urban potentiality in BMA is conducted. The objective of GIS is to provide the means to carry out the analysis which relate specially to the geographic component of the data. The analysis may be more complex and sophisticated. At the advanced level, GIS can allow statistical calculations of the relationship between data sets to be computed or distances between entities may be used to determine the route that must be followed to move as quickly as possible from one location to another. The most sophisticated analysis occurs when modeling is introduced. It is possible, for example, to use atmospheric modeling techniques to discover which area might be affected by pollution resulting from an explosion at a particular hazardous installation, given certain criteria. The traffic conditions were also restored by the simulation method according to the several alternative scenarios of transportation planning.

Finally, various indicators for the future urbanization were combined and analyzed through the mathematical model. Data manipulation capability of the BEIP-GIS is fully applied for the calculation and output mapping of the simulation modeling. The above digital procedures and simulation results are described in each section for land use plan, transportation plan and air pollution mitigation plan.

CHAPTER 14: RECOMMENDATIONS OF INFORMATION SYSTEM DEVELOPMENT

14.1 Development of Mapping System

Experts of BEIP study team have been working for more than one year and have conducted large volume of data collection through the counterpart staff of DPW of BMA. In the course of these efforts, study team have confronted many unseen difficulties such as availability of existing data, accuracy, date of data generation, accessibility to the new and original data, and institutional constraints for informatization etc.,. Those problems are mentioned in the following paragraphs.

(1) Necessity of Large Scale Topographical Map as a Base of Urban Planning

In BEIP study area, those base maps are available for urban planning works such as 1:4,000, 1:10,000, 1:20,000, 1:50,000. In these maps, 1:4,000 and 1:10,000 maps were prepared by JICA as a technical cooperation program in 1987. Royal Thai Survey Department (RTSD) is basically a responsible agency for national survey and mapping. This agency has been made an effort to the preparation and compilation for the national topographical mapping. 1:20,000 and 1:50,000 scale topographical maps are prepared by RTSD as a national base map in 1970's , 1980's, and early 1990's. As we recognize clearly that the urbanization and development activities are so fast in Bangkok that the basic data preparation for land use control or urban planning is totally late. The contents of those maps are now out of date already and updating works of these maps are relatively limited.

For the urban development and management planning of Bangkok as a modern and huge city, fast preparation of large scale topographical map is an essential investment. According to the result of BEIP study, built-up area of Bangkok in 1993 is calculated at 54,000 ha (540 square km), and land use changes are mainly taken place both in business district in the city and fringe area of Bangkok. Eastern agricultural area and south-western marsh land area of BMA are still less developed.

For the economy of mapping cost and time, the new topographical map should be prepared in two scale. In those area where the urbanization is highly expected, 1:2,000 or 1:2,500 scale map should be prepared and rest of area where the development and urbanization is not so high, 1:4,000 to 1:10,000 scale would be acceptable. Administrative boundaries such as district, sub-district or related statistic unit etc., should be drawn clearly in these maps. In case of Japan as a reference, base map scale for urban planning area is regulated at 1:2,500, 1:5,000, and 1:1,0000. All of municipalities are prepared 1:500 or 1:1,000 scale topographical map for taxation and management of urban facilities or utilities in Japan.

(2) Urban Land Use Mapping

In addition to new topographical mapping, it is necessary to grasp the dynamics of urban land use correctly. For this purpose, existing urban land use mapping should be conducted based on the new base map. Preparation of the most updated data for urbanization is a basic responsibility of the urban planning agency, therefore, necessary budget and human resources should be invested in this sector. In this study, existing land use map which is compiled in 1995 by Mapping Division of City Planning Department, BMA is provided to the Study Team, however, the basic scale of this map is 1: 40000 and aerial photographs used for land use interpretation was taken in 1993. Therefore we are able to have only a macro level understanding on the land use pattern in BMA at 1993 from this map. Many buildings and sub-division development have been taking place in these three years, so the necessary updating of this map should be also conducted. New classification system and definition for urban land use mapping based on the large scale topographical map should be discussed so that the final land use map well shows the reality of existing urban conditions.

(3) Preparation of Aerial photograph in BMA

Preparation of the aerial photograph is also very significant to monitor the change of land use in BMA. In order to check the land use change efficiently in urbanized area, basic scale of aerial photograph should be set at 1:5,000 to 1:1,0000 and preferably, aerial photograph should be taken once a year or once every two years.

(4) Involvement of Private Sector for Mapping Service

It is not easy to mention something about the institutional system on mapping and surveying in this country, however, flexibility of various scale of map supply seems to be limited. Existing mapping service capability should be improved in short or middle term point of view. Because of the fast growing of the Thai economy, many kinds of infrastructures have been developed and started to operate. For the efficient operation and maintenance of urban facilities, quick supply of large scale map is an essential thing. Traditionally, survey and mapping functions are managed by military agency in general due to the requirement of national security. Aerial photograph can be taken under the permission of relevant military agency still in many countries, however, even in ASEAN countries like Philippines, Indonesia, or Malaysia,

14.2 Utilization of GIS for Administrative Purposes

(1) Problems for Introduction of GIS Technology

In BMA, many computer systems are installed and used for various data processing. GIS is not an exception. Many EWS or PC based mapping systems including GIS are using mainly in planning agencies. The largest and most critical constraints for the promotion of geographic database development is the supply of basic map data. In case of BLIS, due to the lack of most up-dated map data, old map which was compiled in 1985 had to be input into the most updated computer systems. Clear purpose and long term perspectives are the most necessary things for the development of the geographic database. The meaning of geographic information is to have the newest coordinate data (or geographic boundary data) and related attribute data at the same time. For the urban planning purposes, such data as existing urban land use, location of buildings, type of building use, land use zoning and so on, should be input beside the topographical data. In case of the development of tax assessment system, many factors for tax evaluation must be input together with land ownership data and also the systems for evaluation must be developed as a subsystem. It is very easy to purchase the most updated and sophisticated computer systems, but it is not easy to best use of the system efficiently without the plenty supply of the necessary data. Basic and accurate data preparation should be accelerated for the future informatization in BMA.

(2) Establishment of the System Information Center for BMA

In BMA, GIS has introduced and operated in several departments independently and package software on those systems are either ARC/INFO or MapInfo. Each system seems to be operated and maintained by a few engineers. Although GIS has installed in planning related agencies, application system development is still limited and the system is not fully utilized for planning works. Specific know-how such as urban/regional planning, transportation planning, urban facility management or tax assessment etc., should be well combined with the application of GIS technique. Without those know-how or methodology, so called GIS expert can only reproduce the input map again through the sophisticated computer systems. The most significant purpose to introduce and develop the geographic database is to conduct the spatial data analysis to support the various planning works or to support the various management works. In order to avoid the duplicated investment and to best use of the existing GIS equipment, data and human resources, establishment of the System Information Center based on GIS technique shall be one option. In this Center, systematic training for the GIS operation, application system development, necessary data generation and information production could be conducted as a basic service for the whole BMA. Necessary discussion on this matter shall be waited.

APPENDIX 1: THE BEIP TRANSPORT SIMULATION MODEL

1. Back Ground

1.1 Introduction

The simulation model used for BEIP has been developed for the whole of the Bangkok Metropolitan Region, BMA plus the five adjacent provinces of Nonthaburi , Samut Prakarn , Pathun Thani, Nakorn Pathom and Samut Sakorn .However the presentation of the results will concentrate on the BMA .

This appendix describes the development of the simulation model. The appendix is divided into an additional 6 sections. The overall model development structure is shown in Fig.AP-1.1.

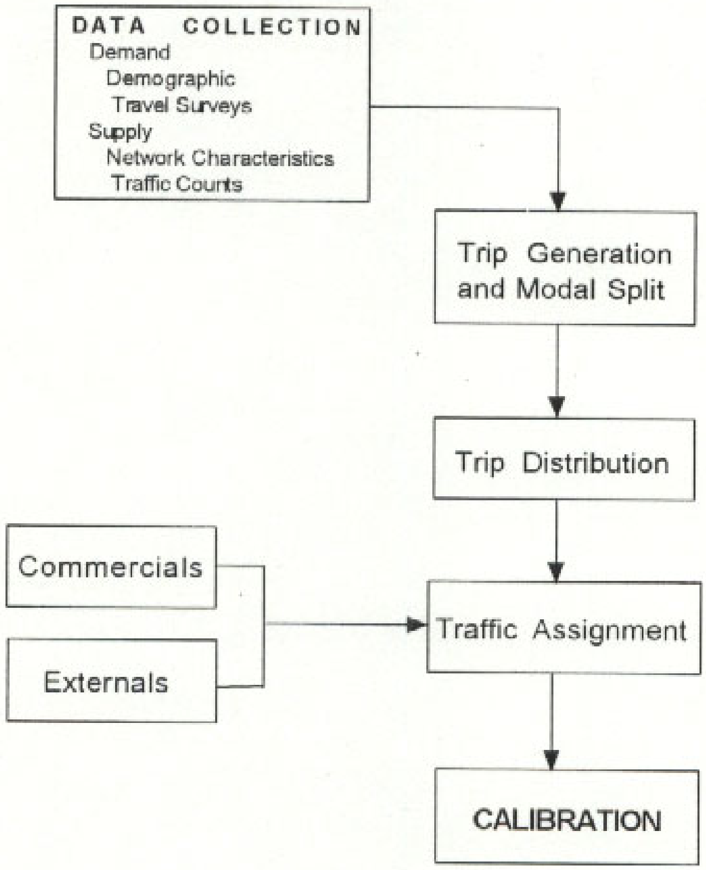


Fig. AP-1.1 Model Development Process

Section 2 describes the data collection procedure including the development of the traffic zone system, and the trip generation and attraction model including the initial production based modal split are detailed in Section 3.

The trip distribution for this model is discussed in Section 4. Section 5 describes the development of the commercial vehicle and external trip tables. The final model calibration / validation is given in Section 6.

In Section 7 the procedure for running the model to test different transport scenarios is documented for reference including the interface with GIS for presentation and environmental analysis. This section also describes the 10 cases analyzed in the development of the Transport Vision for BEIP. The final post distribution modal split for new network analysis is also described in this section .

2. Data Collection

2.1 Overview

The data collection for this study was jointly done with the Urban Transport Database Model (UTDM), a national government project being undertaken for OCMRT. In the past, transport studies in Bangkok have developed their own databases and zoning systems. Now for the first time a common approach is being used by two different major studies. Although some details are different the models developed in each project use a common database.

The UTDM project is designed to develop a model that will form the basis of transport modeling in Bangkok for some time, the BEIP simulation model is developed to evaluate overall transport strategies in Bangkok, rather than at the individual project level. In many respects the BEIP simulation model can be considered a sub model of UTDM.

2.2 Traffic Zoning System

For the first time in Bangkok ,the zone boundary is developed directly from the census boundaries. Each traffic zone was designed to consist as an aggregation of Census Enumeration Districts. The BMA is divided into over 4,000 enumeration districts each with approximately 500 households.

In the case of the BMA, it was divided into 332 zones with an average of 6,000 households per traffic zone. The whole BMR is divided into 505 zones. There are further 15 zones which are the external stations representing the locations where the major roads cross the study area boundary for the transport simulation model. The roads represented by the external stations are given in Table AP-1.1.

Table AP-1.1 External Stations

External Zones	Road Location	
506	Highway Route #	35
507	Highway Route #	4
508	Highway Route #	346
509	Highway Route #	321
510	Highway Route #	340
511	Highway Route #	3111
512	Highway Route #	3309
513	Highway Route #	1
514	Highway Route #	32
515	Highway Route #	3261
516	Highway Route #	305
517	Highway Route #	3312
518	Highway Route #	304
519	Highway Route #	34
520	Highway Route #	3

In the development of the zone boundaries within the BMR, three principles were adhered to namely:

- a zone boundary does not cross a district or sub-district boundary ;
- a zone is designated to be homogeneous in nature; and

- a zone is designated to represent a transport catchment area .

However overall the guiding control was that a zone is an amalgamation of census enumeration districts.

2.3 Home Interview Survey

The major data collection exercise for the transport model was the home interview survey. This was a joint survey with UTDM. UTDM undertook the first 4,000 surveys followed by an additional 4,000 by BEIP. The same survey staff was used in both sets of data together with a consistent technique for survey sample development. The survey sample expansion factors were developed for a combined sample. The sample selected from each province is given in Table AP-1.2

Table AP-1.2 Sample Distribution

Province	Sample	Total Households (x1000)
Bangkok	3,971	2,037
Samut Prakarn	1,459	242
Nonthaburi	1,022	163
Pathun Thani	723	147
Nakhon Pathon	225	172
Samut Sakhon	479	94
TOTAL	7,879	2,857

On the completion of the zoning system a zone to enumeration district equivalence table was prepared for use by NSO . NSO then reprocessed the census data and summarized selected census data on the basis of the 505 internal traffic zones for the BMR.

Other survey data collected by the UTDM project used in BEIP included:

- Roadside Interview Surveys
- Midblock Traffic Counts
- Turning Movement Counts
- Public Transport Passenger Interview Surveys
- Travel Time Delay Surveys
- Taxi Surveys

2.4 Demographic Data

The base year demographic data for 1995 was developed jointly with UTDM and has been thoroughly documented by that project data. The home interview data provided an additional check on the consistency of the base year. A summary of the planning data is given in TableAP-1.3 for the base year 1995 and the trend forecast year of 2011. The districts boundaries are shown in Fig. AP-1.2

Table AP-1.3 Summary of Demographic Data

District	Population		HH size		Avg. HH Income		Employment		Student	
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011
Phra Nakhon	106,334	107,190	4.49	4.02	27,580	44,048	158,370	301,928	69,542	71,075
Pom Prap Sattruphai	198,739	181,747	4.54	4.17	17,248	27,620	99,345	143,291	30,872	28,215
Samphanthawong	73,479	67,422	4.60	4.11	36,783	58,834	52,092	83,236	16,610	15,241
Bangkok Noi	251,535	308,989	4.22	3.90	15,497	24,819	41,509	59,973	50,816	60,519
Bang Phlat	247,004	301,047	4.18	3.81	19,902	31,448	77,430	125,852	39,977	49,097
Khlong San	144,402	167,473	4.61	4.12	18,591	29,736	77,766	105,743	15,749	18,254
Thonburi	296,430	343,068	4.42	3.95	15,074	24,114	85,862	115,151	48,637	56,143
Bangkok Yai	103,961	127,170	4.27	3.85	17,725	28,353	46,686	66,209	44,657	54,631
Dusit	283,042	282,910	3.99	3.67	22,671	36,260	84,911	124,549	115,323	115,296
Bang Rak	164,413	150,669	4.09	3.79	14,985	23,955	296,236	451,530	50,219	46,028
Bang Kho Leam	144,223	168,481	4.28	3.84	13,215	21,134	84,683	116,020	11,246	13,052
Bang Sue	338,730	404,365	3.93	3.58	23,138	37,222	85,456	109,689	40,195	50,403
Pathumwan	290,939	266,851	4.48	4.02	16,389	26,214	163,612	259,048	91,673	83,849
Phaya Thai	254,027	307,974	3.77	3.57	18,561	30,019	73,320	127,026	33,577	42,367
Yan Nawa	152,804	180,088	4.08	3.76	14,636	23,324	118,295	175,901	23,445	27,472
Ratchathewi	259,641	241,399	3.77	3.65	17,935	28,591	249,932	454,861	80,120	74,479
Sathon	136,963	161,532	4.12	3.72	17,351	27,764	113,728	206,506	57,427	67,280
Klong Toei	306,564	338,142	3.94	3.68	17,122	27,457	394,509	522,341	101,313	111,377
Chatu Chak	227,700	269,669	3.78	3.67	31,188	49,156	129,891	175,990	126,719	148,518
Don Muang	298,654	520,213	3.61	3.47	22,681	37,330	137,784	217,654	77,796	131,643
Bang Kapi	388,381	538,462	3.44	3.39	24,141	36,444	220,334	221,074	132,524	154,555
Bang Khen	377,261	420,802	3.58	3.42	24,217	37,406	70,325	68,640	58,269	64,553
Bung Kum	251,249	488,993	3.62	3.51	23,000	35,230	80,863	122,623	27,197	57,972
Phra Khanong	258,079	310,499	3.86	3.52	35,226	55,468	152,774	154,317	57,285	66,766
Suan Luang	161,910	282,459	3.86	3.55	26,416	45,022	62,365	80,631	22,036	44,631
Prawet	163,345	340,256	4.40	3.91	23,528	38,732	64,788	88,405	21,416	34,126
Huai Khwang	93,576	156,008	3.50	2.20	16,382	25,908	150,046	228,307	33,165	66,659
Lat Phrao	164,073	297,852	3.82	3.57	23,624	35,170	42,007	52,968	12,706	29,715
Din Daeng	261,227	242,888	3.85	3.57	16,546	26,607	123,923	116,320	72,077	66,973
Minburi	185,830	268,491	4.12	3.70	25,349	43,920	74,282	61,498	30,085	45,325
Latkrabang	123,696	160,370	3.96	3.76	14,690	23,638	83,922	42,813	34,061	42,149
Nong Chok	93,244	95,465	4.57	4.10	12,667	20,262	32,739	16,156	13,342	13,652
Chom Thong	199,282	306,122	4.21	3.80	15,502	24,739	69,117	81,862	22,082	35,963
Taling Chan	171,706	282,862	4.03	3.71	28,703	48,352	44,541	33,524	19,648	39,696
Bang Khun Thian	229,975	477,459	4.03	3.75	21,219	32,167	123,789	111,165	34,861	72,670
Phasi Charoen	314,860	438,888	4.15	3.76	12,607	19,697	173,720	199,421	77,663	128,752
Ratburana	264,724	325,158	4.32	3.95	24,738	40,327	75,270	53,839	40,968	48,866
Nong Khaem	144,123	186,520	3.92	3.65	28,041	44,872	122,102	91,834	36,160	41,408
BMA TOTAL	8,126,125	10,495,953	3.99	3.66	21,032	33,802	4,338,325	5,767,895	1,871,458	2,319,369
OTHER PROVICES										
Samut Prakarn	982,794	1,258,387	4.05	3.72	15,232	23,151	661,040	932,209	61,355	106,162
Nonthaburi	668,926	1,007,608	4.09	3.71	27,093	43,788	278,857	341,686	103,033	122,661
Pathun Thani	584,283	919,464	3.97	3.69	17,733	32,949	363,844	302,407	123,879	164,451
Nakhon Pathon	721,917	1,071,249	4.19	3.77	15,098	23,722	411,093	555,506	153,107	266,344
Samut Sakhon	367,689	473,211	3.92	3.64	12,997	21,323	296,559	430,049	42,793	30,374
GRAND TOTAL	11,451,734	15,225,872	4.01	3.67	20,094	32,452	6,349,718	8,329,752	2,355,625	3,009,360

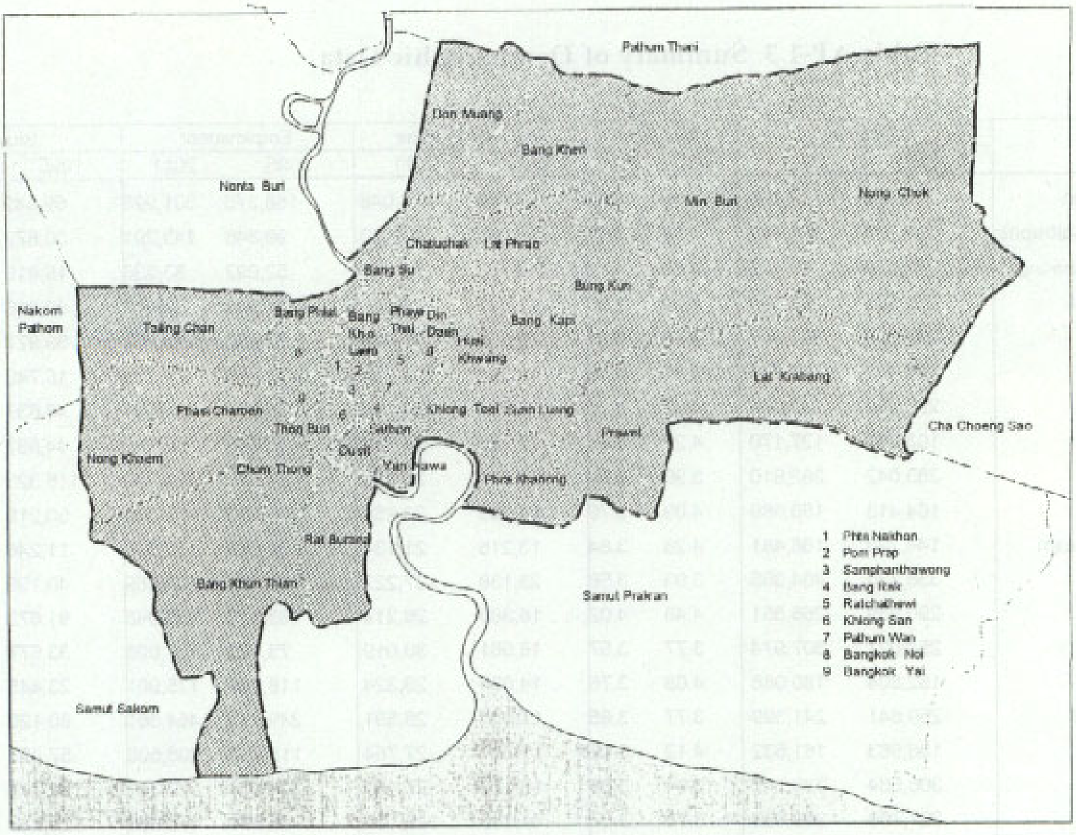


Fig. AP-1.2 Districts within the BMA

2.5 Network Development

The road network is a computerized simulation of the road system located within the study area. The network consists of numerous links (road segments) and nodes (intersection points), with each link being embedded with a unique set of indexes describing its operating capabilities. Two of the most important measures in this regard are speed and capacity.

There does not, at present, exist a manual in Thailand which quantitatively describes the relationship between speed, volume and capacity and road inventory under local conditions. In the past, these relationships have been developed in an ad hoc manner.

To adopt a scientific approach ,sources external to Bangkok and Thailand must therefore be employed for this purpose. It is the opinion of this project that link speed and capacity can adequately be developed based on recent findings of investigations conducted by UTDM and Indonesian Highway Capacity Manual.

It is judged that the application of these findings in a Bangkok context is more appropriate than the more traditional highway capacity manuals prepared for use in American , Japanese or Australian highway capacity techniques.

The use of a Thailand highway capacity manual is, of course, preferred once such a document is available and adopted on a uniform national scale. Since on the master inventory file there are data about road inventory such as locality, number of lanes and side friction new relationships derived in Thailand can readily be used in the future. This inventory to date has been based on the records of the BMA.

The study area road system, including all national, province, district roads and major through sois, a total of some 1,700 kilometers within the BMA. The level of detail with which the zone structure and highway network are built must be in balance; thus, not all existing roads need be included. Indeed, to provide linkage between all zones, a highway network embracing all nationally-owned, and principal BMA- and DOH-owned roads, is adequate.

The base-year (1995) network was therefore built via three steps:

- Digitization of the network, using the capabilities of ARC/INFO software, zone boundaries and relevant road network elements depicted on maps developed by Royal Thai Survey. Within the study area, base map scales varied between 1:20,000 for BMA and 1:50,000 for outside BMA.;
- Integration of field surveys and inventory data available via previous studies and our field survey conducted within the study area. This included a review of all inventory data held at the BMA within the Department of Public Works.; and
- Calculation of link parameters , the link parameters were calculated via a series of linked spreadsheets. (In retrospect if this procedure is used again it is strongly recommended that this procedure be redeveloped in a database framework.)

For the purpose of the development of a transport model ,the transport modeling software in this case, TRANPLAN[1] , highway network simulation programs require following parameters for each link:nodes, link distance,link capacity,and an assignment group code (capacity index in some software).

The A and B nodes are numeric values that identify the "from" and "to" ends of a link. Node locations are defined by their X and Y coordinates, which are derived from the digitizing process, and thus permit displays of network content, performance and operation via a graphical network editor in this case , NIS.

The Link distance defining the length of a link in kilometers ,this is measured directly from the GIS software.

Free flow speed, which is defined as the safe speed at which a vehicle would travel on a link in the absence of other traffic. The average free flow speeds are calculated based on equations used in the Indonesian Highway Capacity Manual, augmented by speed studies conducted throughout the study area.

Link capacity is defined in terms of practical capacity and assignment capacity. Practical capacity represents an absolute limit regarding the number of vehicles (pcu's) which can be accommodated on a given road section under realistic operational and terrain conditions.

Assignment capacity represents a trip-making threshold for modeling purposes at which alternative route choices (as possible) are likely. This is generally adopted as being synonymous with a Level of Service C/D[2] and uninterrupted flow condition[3].

[1] TRANPLAN (Transport Planning) and NIS (Network Information Systems)is an integrated set of computer programs offering , witin a single package , comprehensive planning and forecasting capabilities for both highway and transit systems. TRANPLAN/NIS is proprietary software distributed by the Urban Analysis Group , Danville , California ,USA and licensed for use by Pacific Consultants International.

[2] Lecel of Service as defined by the Highway Capacity Manual , Spedial Report 209 Transportation Research Board , USA 1985 (with subsequent updates)

Assignment capacity, free flow speed and traffic loadings are integrated via speed-decay curves which dynamically decrease link attractiveness (speed) as the volume to capacity ratio (V/C) increases.

Practical capacity is calculated in terms of hourly pcu's per lane or section, assignment capacity (about 80 percent of practical capacity) is generally expressed as daily link pcu's based on a specified percent peak hour factor.

Assignment group (ASG) code is used to identify links to which a common capacity restraint function is to be applied, that is, link speed is reduced by a pre-determined function as the link volume to capacity ratio increases.

Speed decay functions mirror the IHCM speed-flow relationships and depict speed decreasing from free-flow status as the V/C ratio increases. The change is particularly pronounced for narrow roads due to numerous avoidance maneuvers between directional traffic streams, as well as between traffic streams and roadside activities

Link type groupings are developed in accordance with relationship with the database and represent inventory items such as the agency ownership of the road.

3. TRIP GENERATION

3.1 Overview

Two concepts require definition when describing the structure of trip generation models. The first is the concept of trip productions and trip attractions; the second is trip stratification.

In this model also the initial modal split is applied at the generation stage. This stage focuses on predicting the absolute number of daily person trips generated by each of the study area's 505 zones by purpose by mode .

3.2 Definitions

(1) Trip Production / Attraction

In modeling terms there are two types of trip ends - productions and attractions. Trip productions are located at the trip maker's home (the majority of all urban trips begin or end at home). Trip ends 'produced' by the home are linked with the characteristics of the household producing the trips - the number of persons, workers and students in the household, the household income and the number and type of private vehicles available to household members.

Trip attractions on the other hand are trip ends located away from the trip maker's home and are estimated as a function of variables that 'attract' trips (persons) to that location (for example, the availability of jobs or educational places).

The 1995 household survey yields information describing the socioeconomic characteristics of potential tripmakers in a given zone. This information (household income, number of persons, workers and students in the household and the availability of private vehicles) is related to the number of trips produced by members of individual households.

Trip productions therefore are estimated as a function of a zone's residential development. The attraction, or non-home, end of trips is estimated as a function of the socioeconomic variables that tend to "attract" trips. Variables used for this purpose include employment (number of jobs) and school enrollment.

It is generally accepted that trip productions are estimated with more accuracy than trip attractions. Therefore, total trip productions are used to define a control total for aggregate travel in the study area. As the final step in the trip generation modeling procedure, trip attractions are therefore factored to equal trip productions.

(2) Trip Stratification

Trip makers travel to satisfy different objectives. In the study of travel behavior it has been found that it is possible to more accurately estimate the different kinds of trips separately than in total. In addition, the purpose for which a trip is made is often related to differences in several characteristics of the trip (the time of day, the mode of travel and the distance one is willing to travel to satisfy one's travel objective).

Trip characteristics, particularly vehicle ownership patterns, are strongly correlated with household income. Therefore, stratifying total trips by trip purpose, levels of income as well as vehicle ownership improves the accuracy of model components addressing these trip characteristics.

In the BEIP models four major trip purposes are used:

- Home-based Work (HBW) - Trips between residence and primary work location.
- Home-based Educational (HBE) - Trips between residence and school location.
- Home-based Other (HBO) - Trips between residence and all other locations (shopping, recreational, religious and personal business locations).
- Non-home-based (NHB) - Trips with neither end at home (for example, a trip between work place and restaurant).

In addition to these major trip purposes, two important characteristics of the tripmaker have been used to further stratify trip purpose; namely, vehicle ownership patterns and household income. Review of the 1995 home interview survey data found that trips made by different vehicle availability groups had different characteristics of trip length and mode choice.

To represent these differences in the model (and improve the accuracy of the forecasts) A total of sixteen purpose/vehicle availability group designations are used to represent these differences in the model (and improve the accuracy of the forecasts). These sixteen different categories of trips are processed separately by the trip generation and (later) trip distribution model components. For each of the four trip purposes listed above, four different levels of vehicle ownership are adopted; namely, households which own:

- Group 1: No vehicles;
- Group 2: At least one motorcycle (but no cars);
- Group 3: At least one car (and possibly a motorcycle); and
- Group 4: Two or more cars (and possibly a motorcycle).

As discussed in the following paragraph, household income is the single most important determinant of vehicle ownership. Results of the home interview survey yield typical household incomes; these were combined into four major groupings, with each grouping containing roughly one-fourth of study area households. These four groupings represent households with low, medium-low, medium-high and high incomes (Table AP-1.4)

Table AP-1.4 1995 Household Income Distribution: BEIP STUDY AREA

Income Group Number	Income Group Name	Income Range (Baht/Month)	Number of Households	Percent In Range	Percent In Group
1	Low	Less than 5,000	125,786	4.4	26.5
		5,000 - 9,999	631,787	22.1	
2	Low-Medium	10,000 - 14,999	754,714	26.4	26.4
3	Medium-High	15,000 - 19,999	431,674	15.1	22.7
		20,000 - 24,999	217,266	7.6	
4	High	25,000 - 29,999	214,407	7.5	24.4
		30,000 - 39,999	174,385	6.1	
		40,000 - 49,999	117,209	4.1	
		50,000 - 99,999	160,091	5.6	
		100,000 and up	31,446	1.1	
	Total		2,858,766	100.0	100.0

Source: 1995 BEIP Household Survey

3.3 Generation Model Development

Further review of home interview survey results confirmed, in addition to the previously defined stratification's, that considerable differences in vehicle ownership and trip making propensity exist between residents of the Bangkok Metropolitan Area (BMA) and persons residing outside of the BMA but within the Bangkok Metropolitan Region (BMR).

In terms of monthly household income (year 1995 Baht), differences are not overly pronounced. The BMA average is, for example, 20,600 Baht, and outside of BMA, 18,500 Baht . However, a BMA resident is more likely to own a vehicle than a person residing outside of Bangkok if incomes are reasonably similar. For example, some 60 percent of BMA households with an income of between 10,000 and 15,000 Baht are likely to own no vehicles, and slightly over 10 percent own a car (Fig. AP-1.3). In the case of households outside of the BMA with similar incomes, only some 40 percent own no vehicles and about 25 percent own one car (Fig. AP-1.4).

Thus , one additional stratification hierarchy by geographic entity (BMA, outside of BMA) was maintained throughout the production modeling process.

Two different mathematical techniques are used to construct the trip production and attraction models. The trip production models cross-classify households by income and vehicle availability category. Within each income/vehicle availability group an average rate of trip making for each of the household cross classifications is derived from the findings of the home interview survey .

These averages are then plotted and smooth curves are fitted to the individual points. The trip rate curves represent trips per worker for homebased work trips, trips per student for homebased school trips and trips per person for homebased other and non homebased trips. In some cases, aggregations in vehicle ownership categories proved possible due to similarities in trip making patterns. The adopted trip rates confirm that (Table AP-1.5):

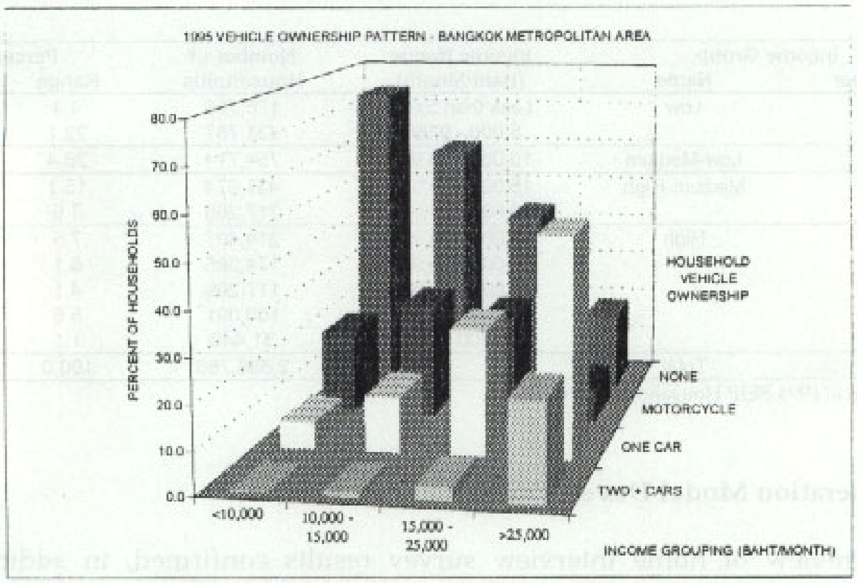


Fig. AP-1.3 Vehicle Ownership within BMA

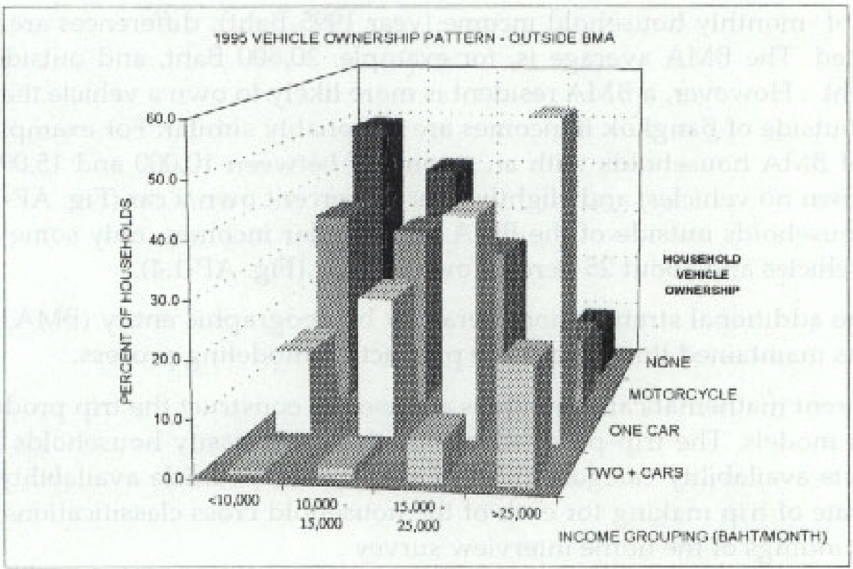


Fig. AP-1.4 Vehicle Ownership within BMR ,but outside BMA

- The unit trip production rate of BMA residents is higher for all trip purposes than the rate exhibited by persons residing outside of the BMA. These data confirm that urban study area residents travel away from the home more often than their rural compatriots.
- Trip production rates are, in the case of HBE trips, largely insensitive to income or vehicle ownership levels. The same pattern, although to a less pronounced degree, is observed for HBW trip productions by BMA residents. This suggests that non-discretionary trips (work, school) are accomplished regardless of the household's social strata.

- HBO and NHB trip production rates, two categories which can be viewed as being more discretionary in nature, exhibit marked increases (particularly so for persons residing outside of the BMA) as household income and/or relative levels of vehicle ownership increases . From the original home interview surveys there was a significant level of underreporting in these two categories . These trip rates were adjusted by cross checking against the larger sample frame of the SIMR home interview survey.

Table AP-1.5 Person Trip Rates

INCOME GROUP	TRIP PURP	VEH O'SHIP	TRIPS PER WORKR	TRIP PURP	VEH O'SHIP	TRIPS PER STUDNT	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON
WITHIN BANGKOK METROPOLITAN AREA												
1	HBW	1,2	1.70	HBE	2	2.15	HBO	1	0.20	NHB	1	0.05
		3,4	1.50		1,3,4	2.06		2	0.33		2	0.15
								3,4	0.44		3,4	0.26
2	HBW	1,2	1.80	HBE	2	2.20	HBO	1	0.21	NHB	1	0.07
		3,4	1.5		1,3,4	2.09		2	0.35		2	0.17
								3,4	0.45		3,4	0.27
3	HBW	1,2	1.80	HBE	2	2.20	HBO	1	0.22	NHB	1	0.08
		3,4	1.80		1,3,4	2.09		2	0.37		2	0.18
								3,4	0.46		3,4	0.29
4	HBW	1,2	1.80	HBE	2	2.20	HBO	1	0.22	NHB	1	0.10
		3,4	1.63		1,3,4	2.09		2	0.37		2	0.18
								3,4	0.46		3,4	0.32
OUTSIDE BANGKOK METROPOLITAN AREA (BMR LESS BMA)												
INCOME GROUP	TRIP PURP	VEH O'SHIP	TRIPS PER WORKR	TRIP PURP	VEH O'SHIP	TRIPS PER STUDNT	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON	TRIP PURP	VEH O'SHIP	TRIPS PER PERSON
1	HBW	1,2	1.30	HBE	1,2,3,4	1.67	HBO	1	0.07	NHB	1	0.02
		3,4	0.85					2	0.15		2	0.05
								3,4	0.25		3,4	0.17
2	HBW	1,2	1.37	HBE	1,2,3,4	1.70	HBO	1	0.09	NHB	1	0.03
		3,4	1.00					2	0.16		2	0.08
								3,4	0.27		3,4	0.19
3	HBW	1,2	1.43	HBE	1,2,3,4	1.70	HBO	1	0.10	NHB	1	0.04
		3,4	1.1					2	0.18		2	0.09
								3,4	0.27		3,4	0.20
4	HBW	1,2	1.49	HBE	1,2,3,4	1.70	HBO	1	0.12	NHB	1	0.05
		3,4	1.43					2	0.18		2	0.10
								3,4	0.28		3,4	0.22

Notes: (1) Income group definitions(all Baht/month/household)
1-less than10,000
2-10,000-15,000
3-15,000-25,000
4 -more than 25,000
(2) Vehicle Ownership definitions
1-households with no vehicles
2 - households owning at least one motorcycle
3-households owning at least one car
4-household own at least two cars

3.4 Trip Attraction Model Development

The trip attraction models employ linear regression analysis to calibrate the coefficients as shown in the following equation:

$$A_j = a_1 + b_1x_1 + b_2x_2 + b_nx_n$$

where:

A_j = Trip attractions in zone j;

$X_{1\text{-}n}$ = Socioeconomic variables describing zone j (employment, school enrollment, etc.); and,

$a_1, b_{1\text{-}n}$ = Constants and coefficients determined through calibration.

Results are presented in graphical form for homebased work trips (Fig. AP-1.5) and homebased educational trips (Fig. AP-1.6). In each plot, a comparison of observed and modeled attractions on a zonal basis is presented, as is the equation form and correlation coefficient (r^2). It is noted that all r^2 values are extremely high thus confirming (as expected) the strong correlation between HBW trips and employment, as well as between HBE trips and student places.

However, the regression analyses for homebased other trips and nonhomebased trips proved more problematic. These type of trip attractions are typically related to landuses such as commercial activity, retail development and religious institutions. Regretfully, zonal information which quantifies these data (such as square meters of retail/commercial activity, number of restaurant seats, number of theater seats, size of religious institutions) are not available from governmental sources, nor do the resource and temporal constraints of the current study permit development of such a database.

In light of this limitation, a series of regression runs were undertaken to evaluate the statistical relationship of available zonal variables with HBO and NHB trips. It was found that tertiary employment is the most appropriate surrogate indicator; unfortunately, the correlation coefficient is less than hoped for (Fig. AP-1.7 and AP-1.8).

To partially compensate for this shortcoming, the generation process was structured to maintain sensitivity toward both observed and empirical levels of demand. In other words, the application of base (1995) and future zonal socioeconomic variables resulted in the calculation of a relative rate of growth vis-à-vis observed conditions; that is,

$$T_F = T_B * \frac{T_{RF}}{T_{RB}}$$

where, for each zone,

T_F = Estimated future - year trips

T_B = Base - year trips

T_{RF} = Regression trip estimate derived from future socioeconomic variables

T_{RB} = Regression trip estimate derived from base - year socioeconomic variables

The final calculated attractions are, as indicated previously, balanced to calculated productions for the BMA and areas outside of the BMA.

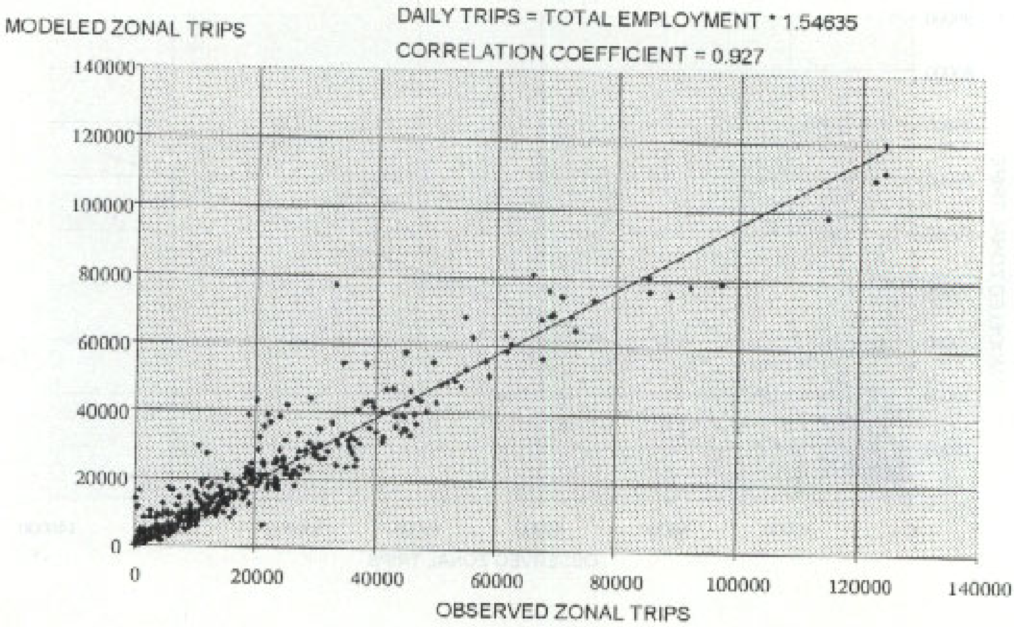


Fig. AP-1.5 Regression for Home Based Work (HBW)

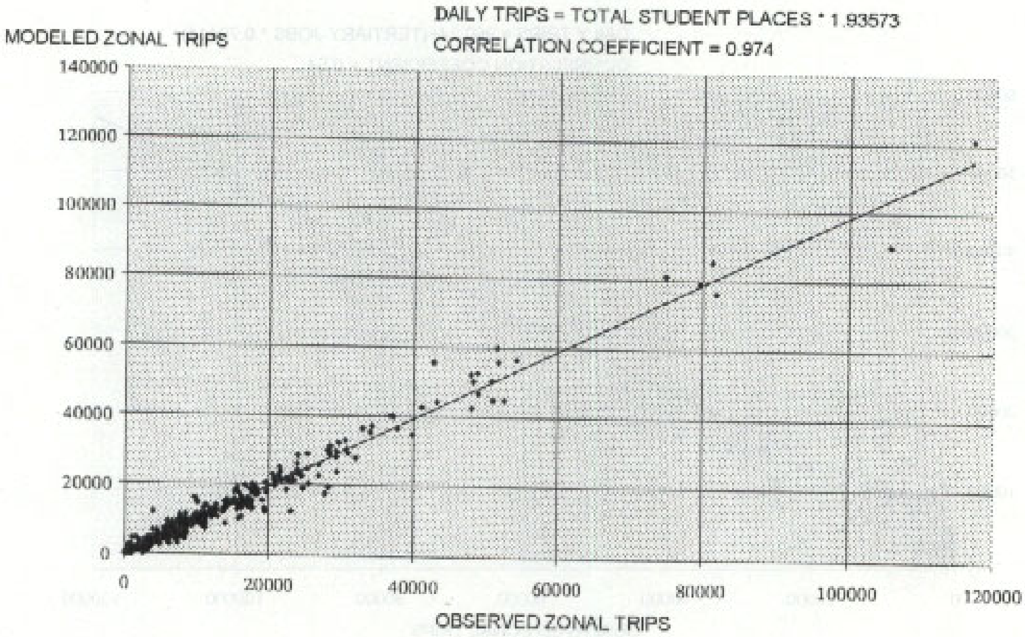


Fig. AP-1.6 Regression for Home Based Education (HBE)

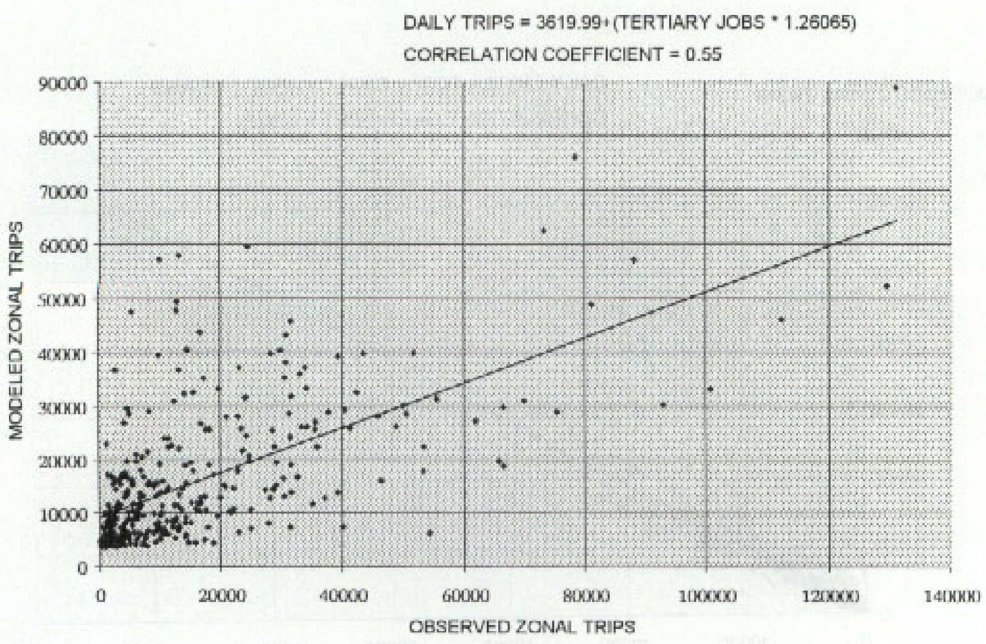


Fig. AP-1.7 Regression for Home Based Others (HBO)

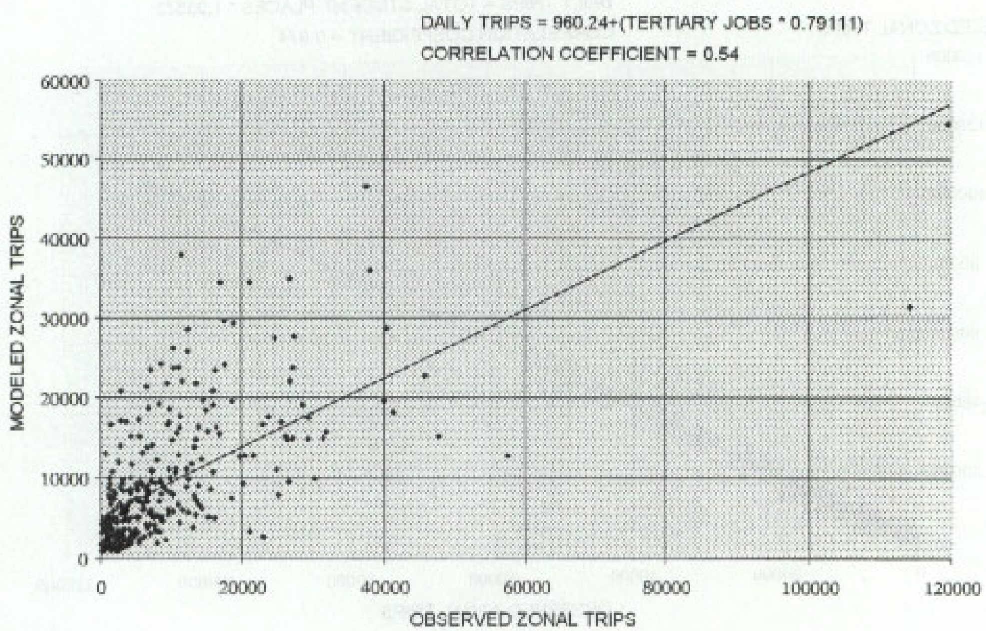


Fig. Ap-1.8 Regression for Non Home Based (NHB)

3.5 Pre Distribution Modal Split

A pre distribution modal split approach was adopted in this study for the base year analysis . In future years this was complimented with the modal split diversion curves derived during the SIMR study .(This is discussed further in Section 7 .) The modal split proportion factors were derived for each trip purpose and each vehicle ownership group from the 1995 home interview survey . These proportions are shown in Tables AP-1.6-AP-1.9 for each trip purpose .

Table AP-1.6 Modal Proportions for Home Based Work

Classification	Area	Income Group	Walk	M/C	Car	Public
HBW - 0 Veh	BMA	1	17.7%	8.0%	0.9%	73.5%
		2	17.5%	7.5%	1.3%	73.6%
		3	15.5%	5.2%	0.8%	78.4%
		4	7.0%	3.2%	3.3%	86.5%
	BMR	1	10.6%	7.8%	2.2%	79.4%
		2	8.4%	8.3%	0.5%	82.8%
		3	14.0%	8.8%	0.5%	76.7%
		4	6.5%	1.8%	3.9%	87.8%
HBW - M/C	BMA	1	8.0%	82.5%	0.3%	9.3%
		2	13.1%	67.8%	1.1%	18.0%
		3	9.1%	54.9%	0.6%	35.3%
		4	7.6%	42.7%	1.6%	48.1%
	BMR	1	4.0%	88.2%	0.9%	6.9%
		2	7.8%	77.6%	2.1%	12.5%
		3	6.5%	55.8%	3.6%	34.1%
		4	5.3%	57.9%	0.3%	36.4%
HBW - CAR	BMA	1	6.2%	12.1%	61.6%	20.1%
		2	4.1%	3.8%	74.8%	17.2%
		3	5.2%	5.6%	66.4%	22.8%
		4	3.1%	6.6%	62.2%	28.1%
	BMR	1	0.2%	11.4%	81.2%	7.2%
		2	3.7%	15.1%	69.4%	11.7%
		3	5.4%	12.8%	63.3%	18.6%
		4	3.7%	12.3%	68.6%	15.5%
HBW - CAR 2 +	BMA	1	1.4%	2.1%	83.5%	12.9%
		2	1.4%	2.1%	83.5%	12.9%
		3	1.4%	2.1%	83.5%	12.9%
		4	1.4%	2.1%	83.5%	12.9%
	BMR	1	5.0%	4.2%	78.2%	12.5%
		2	5.0%	4.2%	78.2%	12.5%
		3	5.0%	4.2%	78.2%	12.5%
		4	5.0%	4.2%	78.2%	12.5%

Table AP-1.7 Modal Proportions for Home Based Education

Classification	Area	Income Group	Walk	M/C	Car	Public
HBE - 0 Veh	BMA	1	33.3%	5.8%	0.8%	60.2%
		2	28.5%	3.4%	0.2%	67.8%
		3	21.9%	1.9%	2.0%	74.2%
		4	14.4%	5.9%	1.6%	78.0%
	BMR	1	29.7%	5.3%	2.0%	63.0%
		2	28.5%	5.9%	4.5%	61.1%
		3	15.7%	1.1%	8.3%	74.9%
		4	15.7%	1.1%	8.3%	74.9%
HBE - M/C	BMA	1	24.6%	21.6%	0.7%	53.1%
		2	24.6%	21.6%	0.7%	53.1%
		3	29.2%	19.6%	0.8%	50.5%
		4	29.2%	19.6%	0.8%	50.5%
	BMR	1	14.6%	36.5%	1.5%	47.4%
		2	23.2%	23.7%	4.0%	49.1%
		3	22.2%	22.8%	0.9%	54.1%
		4	22.2%	22.8%	0.9%	54.1%
HBE - CAR	BMA	1	10.4%	15.8%	30.0%	43.8%
		2	21.8%	10.9%	7.4%	59.9%
		3	15.7%	7.9%	17.8%	58.7%
		4	9.2%	4.4%	20.2%	66.2%
	BMR	1	20.2%	3.9%	15.4%	60.5%
		2	13.5%	16.1%	19.4%	51.0%
		3	18.3%	4.9%	13.9%	62.9%
		4	12.5%	16.3%	15.6%	55.6%
HBE - CAR 2 +	BMA	1	6.7%	2.4%	45.5%	45.4%
		2	6.7%	2.4%	45.5%	45.4%
		3	6.7%	2.4%	45.5%	45.4%
		4	6.7%	2.4%	45.5%	45.4%
	BMR	1	2.5%	3.0%	72.4%	22.2%
		2	2.5%	3.0%	72.4%	22.2%
		3	13.1%	6.9%	27.0%	53.0%
		4	9.2%	3.3%	42.0%	45.6%

Table AP-1.8 Modal Proportions for Home Based Other

Classification	Area	Income Group	Walk	M/C	Car	Public
HBO - 0 Veh	BMA	1	34.0%	5.0%	1.0%	60.0%
		2	34.0%	5.0%	1.0%	60.0%
		3	34.0%	5.0%	1.0%	60.0%
		4	15.4%	6.5%	14.8%	63.3%
	BMR	1	34.0%	5.0%	1.0%	60.0%
		2	34.0%	5.0%	1.0%	60.0%
		3	34.0%	5.0%	1.0%	60.0%
		4	15.5%	4.5%	8.9%	71.1%
HBO - M/C	BMA	1	29.0%	50.0%	1.0%	20.0%
		2	29.0%	50.0%	1.0%	20.0%
		3	29.0%	50.0%	1.0%	20.0%
		4	29.0%	50.0%	1.0%	20.0%
	BMR	1	29.0%	50.0%	1.0%	20.0%
		2	29.0%	50.0%	1.0%	20.0%
		3	29.0%	50.0%	1.0%	20.0%
		4	29.0%	50.0%	1.0%	20.0%
HBO - CAR	BMA	1	35.0%	15.0%	30.0%	20.0%
		2	35.0%	15.0%	30.0%	20.0%
		3	35.0%	15.0%	30.0%	20.0%
		4	35.0%	15.0%	30.0%	20.0%
	BMR	1	35.0%	15.0%	30.0%	20.0%
		2	35.0%	15.0%	30.0%	20.0%
		3	35.0%	15.0%	30.0%	20.0%
		4	35.0%	15.0%	30.0%	20.0%
HBO - CAR 2 +	BMA	1	30.0%	10.0%	50.0%	10.0%
		2	30.0%	10.0%	50.0%	10.0%
		3	30.0%	10.0%	50.0%	10.0%
		4	30.0%	10.0%	50.0%	10.0%
	BMR	1	30.0%	10.0%	50.0%	10.0%
		2	30.0%	10.0%	50.0%	10.0%
		3	30.0%	10.0%	50.0%	10.0%
		4	30.0%	10.0%	50.0%	10.0%

Table AP-1.9 Modal Proportions for Non Home Based

Classification	Area	Income Group	Walk	M/C	Car	Public
NHB - 0 Veh	BMA	1	18.4%	9.3%	24.4%	47.9%
		2	31.0%	15.8%	11.4%	41.8%
		3	23.2%	39.6%	5.6%	31.6%
		4	12.7%	4.5%	22.9%	59.9%
	BMR	1	6.9%	66.3%	7.7%	19.1%
		2	48.2%	5.9%	11.7%	34.2%
		3	40.0%	10.0%	10.0%	40.0%
		4	40.0%	10.0%	10.0%	40.0%
NHB - M/C	BMA	1	30.0%	20.0%	10.0%	40.0%
		2	30.0%	20.0%	10.0%	40.0%
		3	30.0%	20.0%	10.0%	40.0%
		4	30.0%	20.0%	10.0%	40.0%
	BMR	1	30.0%	20.0%	10.0%	40.0%
		2	30.0%	20.0%	10.0%	40.0%
		3	30.0%	20.0%	10.0%	40.0%
		4	30.0%	20.0%	10.0%	40.0%
NHB - CAR	BMA	1	20.0%	10.0%	50.0%	20.0%
		2	20.0%	10.0%	50.0%	20.0%
		3	20.0%	10.0%	50.0%	20.0%
		4	20.0%	10.0%	50.0%	20.0%
	BMR	1	20.0%	10.0%	50.0%	20.0%
		2	20.0%	10.0%	50.0%	20.0%
		3	20.0%	10.0%	50.0%	20.0%
		4	20.0%	10.0%	50.0%	20.0%
NHB - CAR 2 +	BMA	1	20.0%	10.0%	60.0%	10.0%
		2	20.0%	10.0%	60.0%	10.0%
		3	20.0%	10.0%	60.0%	10.0%
		4	20.0%	10.0%	60.0%	10.0%
	BMR	1	20.0%	10.0%	60.0%	10.0%
		2	20.0%	10.0%	60.0%	10.0%
		3	20.0%	10.0%	60.0%	10.0%
		4	20.0%	10.0%	60.0%	10.0%

3.6 Adjustment for Under Reporting

In all home interview surveys there is a general tendency to under report non regular trips, trips that are made on the day of the survey but are trips that the interviewee does not normally make on that day. These trips are most likely to be non work or non educational trips. The trips that are typically under reported are therefore Homebased Other and Non Homebased trips. The home interview survey , can thus be biased towards work and educational trips from the home .

However in this project roadside interviews were also conducted at fourteen sites within the study area. These surveys which resulted in a random sample of vehicles being stopped are unlikely to be biased towards any trip purpose. The difference in the different percentage distribution of the four trip purpose was used to estimate purpose expansion factors. The purpose expansion factors were developed for Homebased Other and Nonhome Based. These factors were used in the trip generation analysis and appended to the home interview survey files. The values derived in this way are 2.8 and 3.2 for Homebased Other and Nonhome Based respectively. (Trip Rates presented in Table 5 includes these factors)

4. Trip Distribution

The trip distribution models take zonal productions and attractions produced in earlier phases of the model, and link them to form a trip matrix of zone-to-zone movements. A total of 16 models were built; 12 for private vehicle modes (four purposes by three vehicle availability groups) and four for public transport modes (four purposes) .

The public transport distribution has basically been developed in detail as part of the UTDM process and is documented in their Interim Report (Sept. ,1996) and is not discudssed in detail further. The basic reason for this is the detail development of the public transport network was undertaken by UTDM whilst the major development of the road network was prepared by BEIP.

4.1 Overview

A gravity model is used to achieve the trip distribution and is expressed as:

$$T_{(i,j)} = \frac{P_i \ A_j \ F_{t(i,j)} K_{(i,j)}}{\sum_{x=1}^{n} A_x \ F_{t_{(i,x)}} \ K_{(i,x)}}$$

Where $T_{(i,j)}$ = trips produced in zone i and attracted to zone j

P_i = trips produced in zone i

A_j = trips attracted to zone j

$t_{(i,j)}$ = travel time between zone i and zone j

$F_{t_{(i,j)}}$ = empirically derived travel time factor that expresses the average area-wide effect of spatial separation on trip interchange between zones that are t(i,j) apart

$K_{(i,j)}$ = specific zone-to-zone adjustment factor to allow for the incorporation of spatial/geographic influences upon travel patterns

Distribution functions for each zone pair are prepared using as input public and private vehicle generalized cost skims and the calibrated distribution function. Subsequently, these distribution function values and an observed modal split matrix are applied to zonal trip productions and trip attractions to generate private and public person trip matrices. These two steps are conducted separately for each of the four trip purposes - home-based work, home-based school, home-based other and non-home-based.

4.2 Details of the Model

For private vehicle trips, generalized cost is calculated using the following equation:

$$GC = t_{ij} + \left[(R \times d_{ij}) / V\right] + (C / V)$$

Where GC = Generalized cost expressed in minutes

t_{ij} = access/trip time for movement from zone i to zone j

R = cost per kilometer, taken as 0.72 Baht

d_{ij} = distance from zone i to zone j

V = value of time, which is different for each mode of public transport , related to the average income of the user by mode. It is taken as 57 Baht/hour for the private person trip by private vehicle.

C = out-of-pocket trip cost (parking, tolls)

For public transport trips, generalized cost is calculated as:

$$GC = t_{ij} + (F_{ij} / V)$$

Where,

GC = Generalized cost expressed in minutes

$t_{i,j}$ = Access/wait/trip time for movement from zone I to zone j

F_{ij} = fare for movement from zone I to zone j

V = Value of time, taken as 28 Baht/hour (Average over all public transport modes)

For both private and public transport trips, intrazonal generalized costs were estimated by taking half the value of the cost to the nearest three zones. For private transport trips, terminal times were also added at each and of the trip. The terminal times estimated for the base year are five minutes for CBD zones, two minutes for all other zones.

The criteria used in defining the distribution function is that, when applied, it should return a trip length distribution (TLD) as close as possible to the observed TLD. The TLD gives for each cost increment the percentage of trips occurring at that cost. The observed TLD was created by taking the observed trip matrix, together with the associated generalized cost, and tabulating the number of trips, and thus the percentage, for each cell with a given cost.

Typically, a TLD rises quickly from zero to a peak and then drips off gradually, finally becoming ragged as observations become sparse. All trips with both trip-ends within the study area (zones 1-505) were included in the observed trip matrix (and trip length distribution). The resultant TLD is then input to the gravity model calibration program together with an initial estimate of the distribution function. TRANPLAN uses an iterative technique to adjust the input distribution function in an effort to match the observed TLD; this is generally achieved after about five or ten iterations.

The iterative procedure uses a weighting factor of the percentage of trips for each interval thereby ensuring that the curves are fitted closest for the intervals which contain the greatest number of trips. The use of such an approval yields trip distribution functions which are reasonably free from irregularities caused by sampling errors and other errors inherent in survey data.

Models were calibrated for private vehicle trips by purpose (HBW, HBE, HBO, NHB) by vehicle availability group (none, motorcycle, car); for public transport trips, models were calibrated for each purpose. Resultant frequency curves (F - factors) for the Hone Based Work private person trip are depicted in Table AP-1.10 as an example.

Average trip lengths vary, as expected, with longest trips typically increased by public transport trips, and shortest trips being those mode by households not owning a vehicle.(see Table AP-1.11)

As a final check , person trip matrixes derived by the distribution model were converted to vehicle trips, assigned to the road network, and compared to observed traffic counts for private person trips . At this stage a set of K factors or geographical refinement factors were also developed to fine tune the trip tables and to correctly replicate the travel patterns as a result of geographical barriers such as the river .(This is discussed furher in model calibration.)

Table AP-1.10 F Factors for Home Base Work

TIME (1) (MINUTES)	PRIVATE TRIPS (2) BY VEHICLE OWNERSHIP GROUP NONE	M'CYCLE	CAR	TIME (1) (MINUTES)	PRIVATE TRIPS (2) BY VEHICLE OWNERSHIP GROUP NONE	M'CYCLE	CAR
1	640116	1454017	130553	61	331	3205	3629
3	393620	1092557	112962	63	304	2794	3297
5	247221	826629	97935	65	280	2444	2998
7	158507	629667	85072	67	260	2143	2730
9	103689	482822	74041	69	242	1884	2489
11	69168	372633	64563	71	226	1661	2271
13	47025	289426	56403	73	211	1468	2076
15	32567	226202	49367	75	198	1300	1899
17	22962	177869	43287	77	187	1153	1739
19	16474	140699	38024	79	176	1025	1594
21	12020	111947	33461	81	166	913	1463
23	8915	89579	29496	83	156	815	1344
25	6717	72080	26047	85	147	728	1236
27	5139	58315	23040	87	138	652	1137
29	3989	47429	20415	89	130	584	1048
31	3141	38774	18118	91	122	524	966
33	2507	31859	16106	93	114	471	892
35	2028	26305	14341	95	106	423	824
37	1661	21824	12789	97	99	381	762
39	1377	18189	11423	99	92	343	705
41	1154	15229	10219	101	84	309	653
43	978	12806	9155	103	77	278	605
45	838	10814	8215	105	70	251	561
47	725	9169	7381	107	64	226	521
49	633	7806	6642	109	57	204	484
51	557	6670	5985	111	51	184	450
53	495	5721	5401	113	45	165	418
55	443	4925	4880	115	40	149	389
57	399	4254	4416	117	35	134	363
59	363	3686	4001	119	30	121	338
60	346	3436	3810	120	28	114	326

(1) Includes costs associated with trip time, trip distance and out-of-pocket costs converted to equivalent minutes.

(2) Trips made by private means of mechanized transport (car, motorcycle). Vehicle ownership group relates to household characteristics . Maxmum trip lengths by household ownership grouping: None - 146 minutes; Motorcycle -177 Minutes ; Car - 218 minutes.

Table AP-1.11 Average Trip Length Distribution

TRIP PURPOSE	HOUSEHOLD VEHICLE OWNERSHIP	Average Trip Length (Equivalent Minutes) PRIVATE
HBW	None	29.6
	Motorcycle	31.5
	Car	43.9
HBE	None	40.5
	Motorcycle	42.3
	Car	38.8
HBO	None	27.8
	Motorcycle	25.0
	Car	37.7
NHB	None	26.7
	Motorcycle	30.5
	Car	41.6

The final calibration process is discussed in Section 6 .

5 . Non-Person Trips

In any city there are other types of trips being made at any one time besides internal person trips . In particular there are two major categories namely external trips and commercial vehicle trips . The development of the trip tables for these two categories of trips is presented in this section.

5.1 External Trip Table

The major home interview surveys undertaken during this project does not record trips being made by people from outside the study area to inside the study area or those trips that pass through the study area . This is termed the external cordon and the crossing points or external station locations are described in Section 2.

This external trip table was developed in three stages :

- Development of External-Internal Trip Table ;
- Development of External-Internal Trip Table ; and
- Allocation of Buses (Bus Passengers were not interviewed at the Cordons).

A flowchart depicting the process is given in Fig. AP-1.9

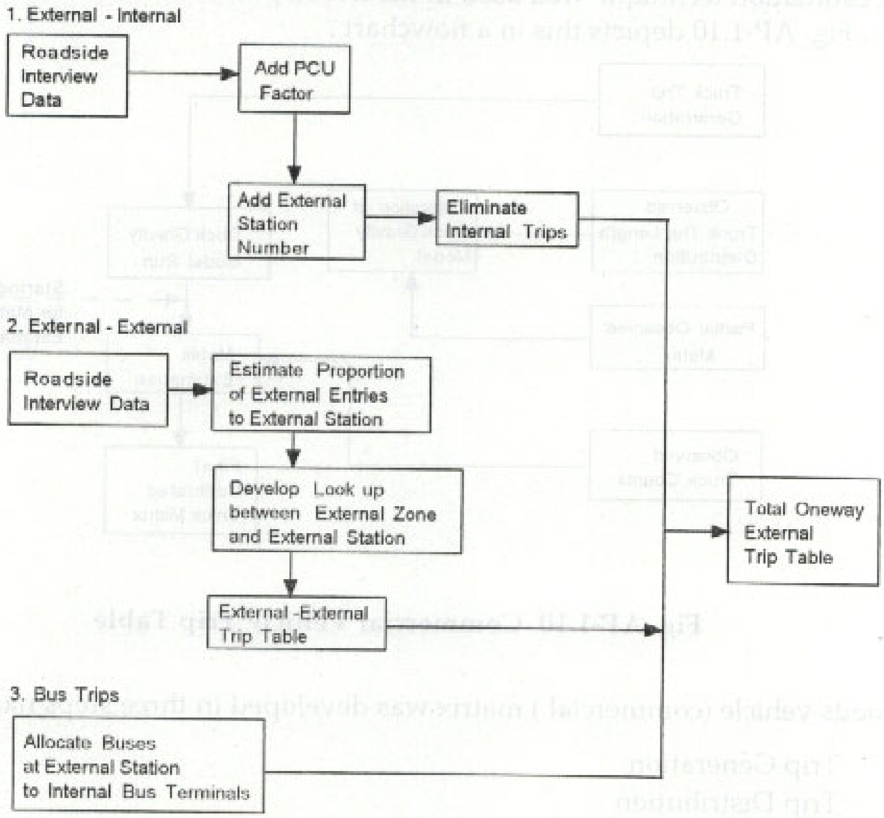


Fig. AP-1.9 External Trip Table Development

The development of the External to Internal Table is relatively simple . It is the observed external station (506-520) to the internal zone (1-505).

The external to external trip table involves linking the external zones (up to 812) as defined for the roadside interview . The procedure was as follows :

- Build the full trip table from the roadside surveys (zones 1 - 812).
- Allocate each combination of External Station to External Zone to have a temporary destination zone i.e. matrix expansion procedure.
- These temporary destination zones are then associated with an external station.
- The matrix is then squeezed back to a 520 X 520 matrix .

The buses was then allocated to the three intercity bus terminals.
This external matrix was developed from the beginning as an all day pcu matrix .

5.2 Commercial Vehicles

The commercial vehicle model for the study area was developed for truck movements within the BMR . The external matrix discussed above includes the external truck movements. There is little data available on commercial vehicle movements in Bangkok . The best source of data is from traffic count information. For that reason a matrix estimation technique was used in the development of the commercial vehicle matrix . Fig. AP-1.10 depicts this in a flowchart .

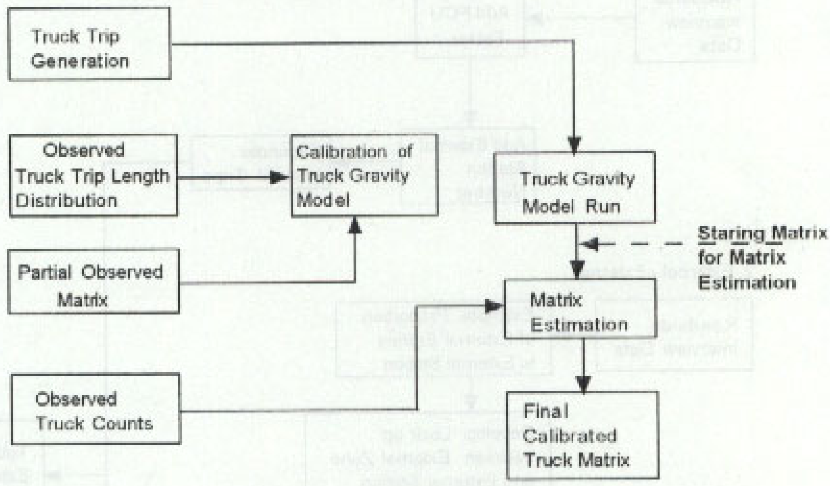


Fig. AP-1.10 Commercial Vehicle Trip Table

The goods vehicle (commercial) matrix was developed in three steps namely :

- Trip Generation
- Trip Distribution
- Trip calibration , Matrix Estimation.

It is important to note that the generation and distribution used in the development are really used simply to improve the starting matrix for the matrix estimation procedure .The truck trip generation equations have been adopted from the earlier SPURT study namely:

Truck Trip Generation in a zone

= (0.009*Zonal Employment) + (0.01*Zonal Households)

The gravity model for trip distribution is calibrated against the observed truck trip length distribution from the internal roadside interview locations . In this case the F factors derived from the gravity model take the form of a Gamma function as described below :

$$F(C_{ij})=C_{ij}^{X1}*\exp(X2*C_{ij})$$

where

F(Cij) is the F factor curve

Cij is the generalized cost of travel

X1 and X2 are calibration constants with the value of

X1=-1.5

X2=0.00163

This results gives good correspondence between the observed and the estimated mean trip length of 176.8 for the observed and 180.1 for the estimated .These F Factors are the used in a full run of the gravity with the trip generations discussed above to produce a starting matrix for matrix estimation .

The matrix estimation uses as input traffic count data from over 150 sites to produce the best estimate of a goods vehicle matrix.

6. Traffic Assignment and Calibration

6.1 Overview

Prior to the assignment of the trip tables to the network it is necessary to develop the peak hour pcu trip table from the total daily person trip tables and from the external trip table and the commercial vehicle trip table. This will then able the assignment of the vehicle peak hour trip table to the road network.

6.2 Development of Peak Hour Private Trip Table

The person trip tables as output from the gravity models are not in a suitable format for traffic assignment . These tables need to be converted to a peak hour origin destination matrix from the production / attraction format as output from the gravity model .The following formula is used in the first step :

$$ODij = a*PAij + b*TR\{PAij\}$$

where ODij is the matrix in origin destination format

PAij is the matrix in production attraction format

TR{} is the mathematical matrix transpose function

a,b are constants used to develop the morning peak hour

(see Table AP-1.12)

Table 12 Peak Hour Factors

Factor	Trip Purpose			
	HBW	HBE	HBO	NHB
a	0.15	0.15	0.04	0.02
b	0.01	0.01	0.04	0.02

This is still in the form of a person trip table , these are then converted to vehicle format with two sets of factors namely :

- Passenger Car Unit (pcu) factor
- Vehicle Occupancy Factor

These are presented in Table AP--1.13. The peak factors for goods vehicles and external vehicles are also presented in this table .

Table AP-1.13 Vehicle Occupancy and PCU factor

Vehicle Type	Peak	PCU	Trip Purpose Occupancy Factor			
	Hour Factor	Factor	HBW	HBE	HBO	NHB
Car	-	1	1.73	2.32	2.08	1.97
Motorcycle	-	0.25	1.38	1.6	1.22	1.47
Goods Vehicle	0.03	2.3	-	-	-	-
External Vehicle	0.05	-	-	-	-	-

The peak hour trip table for traffic assignment is the addition of the three pcu tables namely person , external and commercial trip tables.

6.3 Traffic Assignment

The purpose of the trip assignment process is to replicate the amount of traffic on the road system. Thus, the content of trip matrixes (peak hour trips) is "loaded" onto the roadway network where trip origin-destination patterns are permitted to interact with embedded network parameters (distance, time, speed, capacity and other user-specified criteria such as road toll).

Since route choice, travel time and congestion impacts are important considerations, an equilibrium assignment algorithm is considered appropriate. Equilibrium, in the context of transportation assignments, occurs when no trip can be made by an alternative path without increasing the total travel time of all trips in the network. Equilibrium assignment consists of an iterative series of all-or-nothing traffic assignments with an adjustment of link capacity/speed reflecting congestion encountered in each associated iteration.

The load from each assignment after the first iteration is combined with the previous load in such a way as to minimize the impedance of each trip and thus reducing the number of iterations to find the equilibrium loads. Equilibrium assignment is multipath because the final loads are a linear combination of the all-or-nothing loads of each iteration. These loads may be assigned to different paths because of the time adjustments after each iteration.

For the BEIP project these assignment paths are bases on a generalized cost derived in equivalent minutes for the path between each zone pair and takes the form of:

$$GCij = a^*Tij + b^*Dij + c^* Aij$$

where GCij is defined as generalized cost in equivalent minutes

Tij is the travel time

Dij is the distance

Aij is the additional cost such as expressway tolls in units of 10 Baht

a,b,c are constants defined as: a = 1.0 , b = 0.76 and c = 6.58

The other parameters input into the road traffic assignment include the preload volumes developed in the bus passenger assignments which as discussed in previous sections are not discussed in this technical appendix .

6.4 Calibration / Validation

When the traffic assignment procedure is complete , the results are then compared with the on ground counts . If there is a good comparison then there is no need to do any review of the parameters . This is not usually the case . Indeed this is now considered an important step in model development , the calibration or validation procedure .(See Fig. AP-1.11)

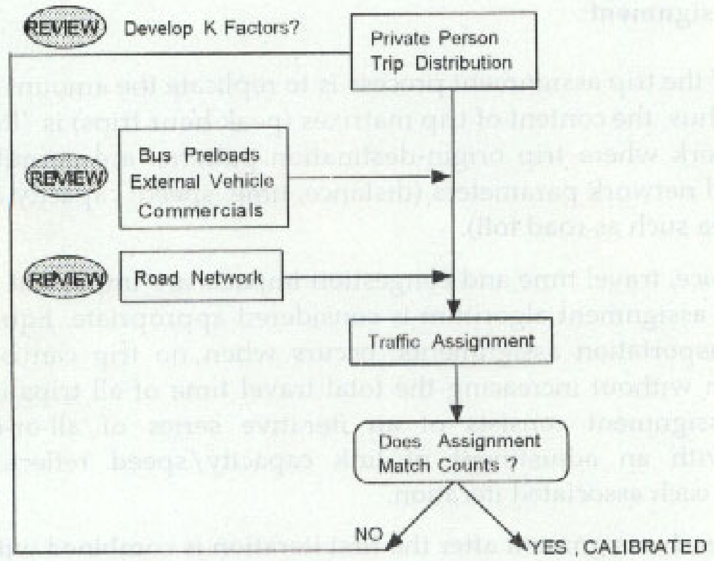


Fig. AP-1.11 Model Validation Procedure

Indeed during the BEIP to calibrate the model it was necessary to both make modification to the network , change the initial speed coded on links or in some cases make network corrections as well as develop K Factors or geographical calibration factors . The relationship of these factors to the gravity model is presented in Section 4.

The model was considered calibration in the final validation against screenlines (see Table 14) and in detail along the river screenline for the morning peak hour in Table AP-1.15.

Table AP-1.14 Screenline Calibration

SCREENLINE	NUMBER OF STATIONS	DAILY PRIVATE TRIPS Observed	Estimated	Ratio
Railway	19	965,233	995,573	1.03
River Bridges	12	735,391	774,722	1.05
CBD	25	1,584,664	1,725,085	1.09
East	17	611,826	549,296	0.90
North	10	251,758	249,659	0.99
West	9	171,108	194,390	1.14
Total	92	4,319,980	4,488,725	1.04

Table AP-1.15 River Screenline Morning Peak PCU Comparison

Link	Location Name	Direction	COUNT	ASSIGNMENT
R1	PATHUMTHANI BRIDGE	EB	1,513	1,147
R2	NONTHABURI BRIDGE	EB	1,643	1,069
R3	PHRA NANG KLAO BRIDGE	EB	2,629	1,017
R4	RAMA VII BRIDGE	NB	2,967	2,260
R5	KRUNG THON BRTIDGE	EB	2,759	4,592
R6	PHIRA PIN KLAO BRIDGE	EB	6,492	5,328
R7	MEMORIAL BRIDGE	NB	2,937	2,829
R8	PHRA POK KLAO BRIDGE(New Memorial)	NB	3,556	4,505
R9	TAKSIN BRIDGE	EB	4,512	6,325
R10	KRUNGTHEP BRIDGE	EB	2,522	3,226
R11	RAMA IX BRIDGE	EB	2,058	3,120
R12	POO CHAO SAMING PRAI FERRY	EB	430	
	TOTAL		34,018	35,418
			% Difference =	4.1%
R1	PATHUMTHANI BRIDGE	WB	1,549	1,588
R2	NONTHABURI BRIDGE	WB	1,500	866
R3	PHRA NANG KLAO BRIDGE	WB	2,397	1,305
R4	RAMA VII BRIDGE	SB	3,111	2,443
R5	KRUNG THON BRLDGE	WB	1,506	1,677
R6	PSRA PIN KLAO BRIDGE	WB	3,015	2,204
R7	MEMORIAL BRIDGE	SB	280	1,721
R8	PHRA POK KLAO BRIDGE	SB	2,601	3,180
R9	TAKSIN BRIDGE	WB	2,185	2,715
R10	KRUNGTHEP BRIDGE	WB	1,831	941
R11	RAMA IX BRIDGE	WB	2,610	1,178
R12	POO CHAO SAMING PRAI FERRY	WB	279	
	TOTAL		22,864	19,818
			% Difference =	-13.3%
	GRAND TOTAL		**56,882**	**55,236**
			% Difference =	**-2.9%**

7. Model Runs - 10 Simulation Cases

7.1 Overview

A full model run requires that the starting point is the demographic spreadsheets established for the trip production and attraction sub models. In most cases the model run is started after the production and attraction development . The flowchart for a full future model run is shown in Fig. AP-1.12 . For BEIP ten full simulation cases were run in the development of the BEIP Transport Vision for Bangkok .

The major parameters in these case are network changes and demographic changes . Two future year demand scenarios are tested each with a different set of demographic data . Various networks are tested including changes in public transport which in some cases is reflected tested by modifying the road network . The changes are applied to the private person triptable which is then used to perform a new highway assignment. The basis of the analysis is that the initial private person trip table is changed as a result of modifications in the networks .

7.2 Person Trip Table

There are three base demand trip tables namely :

- Calibrated 1995 Person Trip Table ;
- 2011 Trend Person Trip Table ;
- 2011 New (Sub-Center Led) Person Trip Table

The demographic data used in the first two is tabulated by district in Table AP-1.2. The demographic data for the New 2011 changes only within the BMA as a result of the three sub-center developments at Lat Krabang/Minburi , Taling Chan and Bang Kungthian (see Table AP-1.16) .

7.3 Post Distribution Modal Split

The pre distribution mode splits were sufficient for the base year where the modal choice is not necessarily sensitive to changes in travel times between private and public modes . This is not sufficient to test major changes in either the public or private sector . For this reason modal diversion curves needed to be produced for this study . The previous modal diversion curves of SIMR were reviewed and accepted for BEIP .

The modal distribution curves used take the following format :

$$p = 1/(1 + \exp(A + B^*\Delta T + C^*\Delta + D^*N))$$

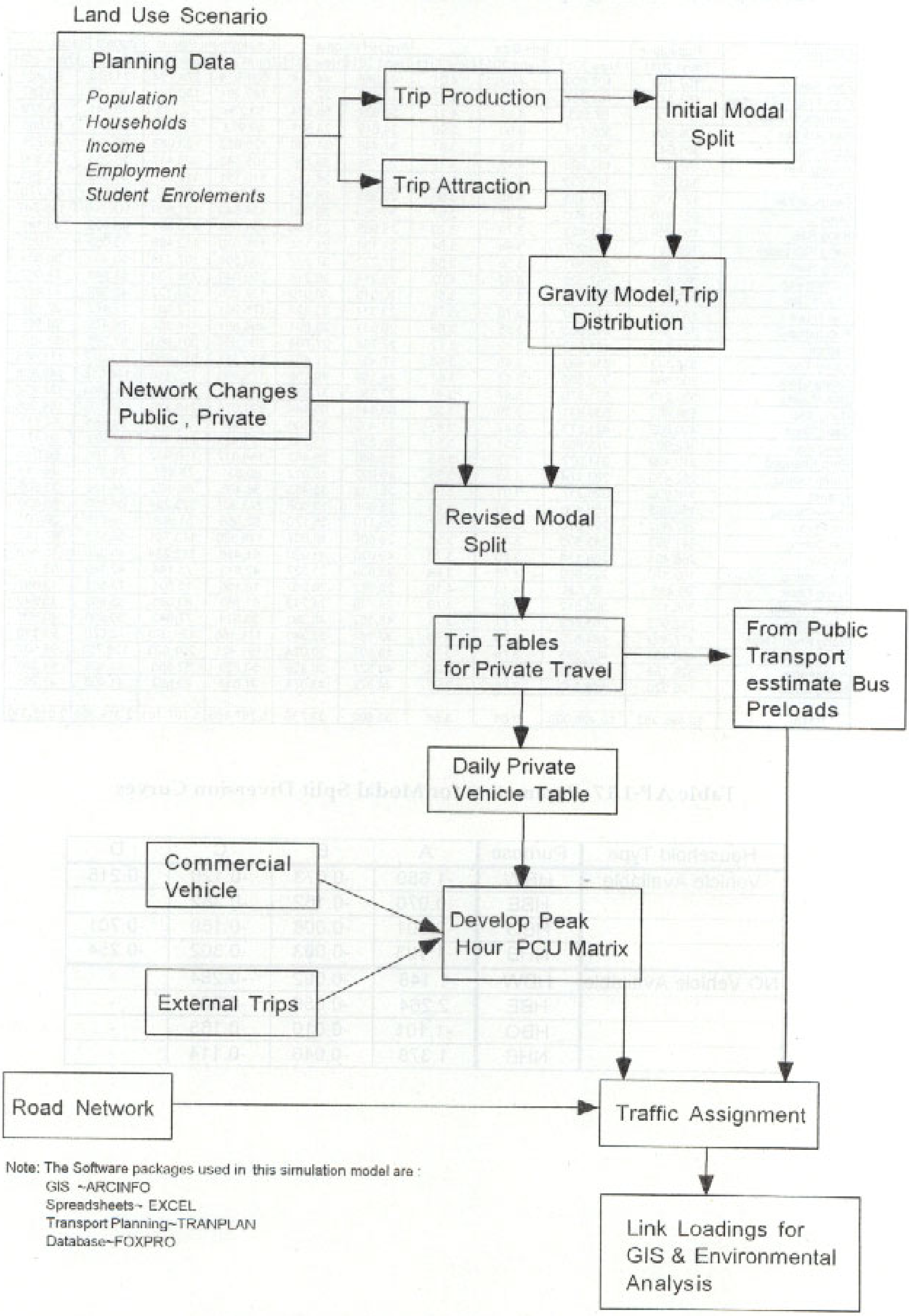
where p is the share of private mode

ΔT is the Travel Time Difference(Public-Private in minutes)

ΔC is the Travel Cost Difference(Public-Private in minutes)

N is the number of Interchanges

The parameter values are given in Table AP-1.17 and examples of the curves themselves are given in Fig. AP-1.13 & 1.14.



Note: The Software packages used in this simulation model are :
GIS ~ARCINFO
Spreadsheets~ EXCEL
Transport Planning~TRANPLAN
Database~FOXPRO

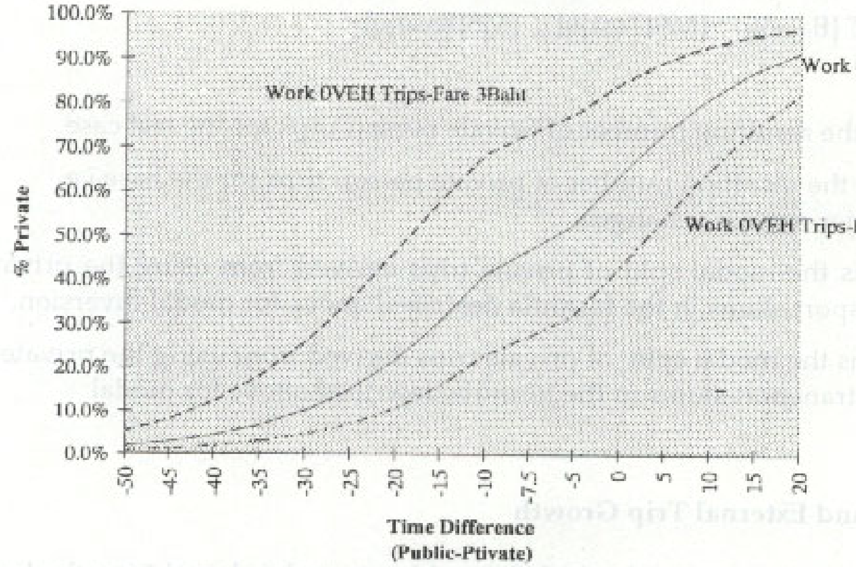
Fig. AP-1.12 BEIP Similation Model Run

Table AP-1.16 Demographic Differences between trend-2011 and new-2011

DISTRICT	Population		HH Size		Avg HH Income		Employment Places		Student Places	
	Trend 2011	New 2011	Trend 2011	New 2011	Trend 2011	New 2011	Trend 2011	New 2011	Trend 2011	New 2011
Phra Nakhon	107,190	107,009	4.02	4.01	44,048	44,114	301,928	274,754	71,075	69,984
Pom Prap Sattruphai	181,747	182,207	4.17	4.17	27,620	27,620	143,291	130,395	28,215	28,287
Samphanthawong	67,422	67,593	4.11	4.11	58,834	58,834	83,236	75,745	15,241	15,279
Bangkok Noi	306,989	305,721	3.90	3.90	24,819	24,821	59,973	58,653	60,519	60,566
Bang Phlat	301,047	301,808	3.81	3.81	31,448	31,448	125,852	123,083	49,097	49,221
Khlong San	167,473	167,898	4.12	4.12	29,736	29,736	105,743	103,417	18,254	18,300
Thonburi	343,068	343,938	3.95	3.95	24,114	24,114	115,151	112,617	56,143	56,285
Bangkok Yai	127,170	127,493	3.85	3.85	28,353	28,353	66,209	64,752	54,631	54,770
Dusit	282,910	283,600	3.67	3.67	36,260	36,260	124,549	121,809	115,296	115,549
Bang Rak	150,669	151,052	3.79	3.79	23,955	23,955	451,530	410,892	46,028	46,145
Bang Kho Leam	168,481	168,907	3.84	3.84	21,134	21,134	116,020	113,468	13,052	13,085
Bang Sue	404,365	405,391	3.58	3.58	37,222	37,222	109,689	107,276	50,403	50,531
Pathumwan	266,851	267,529	4.02	4.02	26,214	26,214	259,048	235,734	83,849	84,062
Phaya Thai	307,974	308,758	3.57	3.57	30,019	30,019	127,026	124,232	42,367	42,474
Yan Nawa	180,086	179,052	3.76	3.76	23,324	23,324	175,901	172,031	27,472	27,418
Ratchathewi	241,399	242,003	3.65	3.65	28,591	28,591	454,861	444,854	74,479	74,666
Sathon	161,532	161,942	3.72	3.72	27,764	27,764	206,506	201,963	67,280	67,451
Klong Toei	338,142	338,982	3.68	3.68	27,457	27,457	522,341	510,850	111,377	111,655
Chatu Chak	269,669	270,356	3.67	3.67	49,156	49,156	175,990	172,118	148,518	148,898
Don Muang	520,213	521,379	3.47	3.47	37,330	37,333	217,654	212,865	131,643	131,958
Bang Kapi	538,462	539,831	3.39	3.39	36,444	36,444	221,074	216,210	154,555	154,968
Bang Khen	420,802	421,873	3.42	3.42	37,406	37,406	68,640	67,130	64,553	64,717
Bung Kum	488,993	478,653	3.51	3.50	35,230	35,232	122,623	119,925	57,972	55,477
Phra Khanong	310,499	311,077	3.52	3.53	55,468	55,482	154,317	150,922	66,766	66,918
Suan Luang	282,459	283,174	3.55	3.55	45,022	45,022	80,631	78,857	44,631	44,744
Prawet	340,256	326,217	3.91	3.91	38,732	38,453	88,405	86,460	34,126	33,605
Huai Khwang	156,008	156,406	2.20	2.20	25,908	25,908	228,307	223,284	66,659	66,830
Lat Phrao	297,852	298,610	3.57	3.57	35,170	35,170	52,968	51,802	29,715	29,791
Din Daeng	242,888	243,506	3.57	3.57	26,607	26,607	116,320	113,761	66,973	67,143
Minburi	268,491	269,174	3.70	3.70	43,920	43,920	61,498	112,284	45,325	45,440
Latkrabang	160,370	222,989	3.76	3.89	23,638	23,827	42,813	75,144	42,149	52,168
Nong Chok	95,465	95,706	4.10	4.10	20,262	20,262	16,156	15,801	13,652	13,687
Chom Thong	306,122	305,512	3.80	3.79	24,730	24,712	81,862	80,061	35,963	35,949
Taling Chan	282,862	293,669	3.71	3.71	48,352	48,392	33,524	77,842	39,696	40,806
Bang Khun Thian	477,459	484,525	3.75	3.75	32,167	32,346	111,165	179,078	72,670	91,219
Phasi Charoen	438,888	407,263	3.76	3.76	19,697	20,024	199,421	201,693	128,752	98,507
Ratburana	325,158	286,988	3.95	3.94	40,327	38,459	53,839	52,655	48,866	44,980
Nong Khaem	166,520	168,240	3.65	3.68	44,872	43,978	91,834	92,682	41,408	42,791
TOTAL	10,495,953	10,496,009	3.66	3.66	33,802	33,738	5,767,895	5,767,101	2,319,369	2,316,330

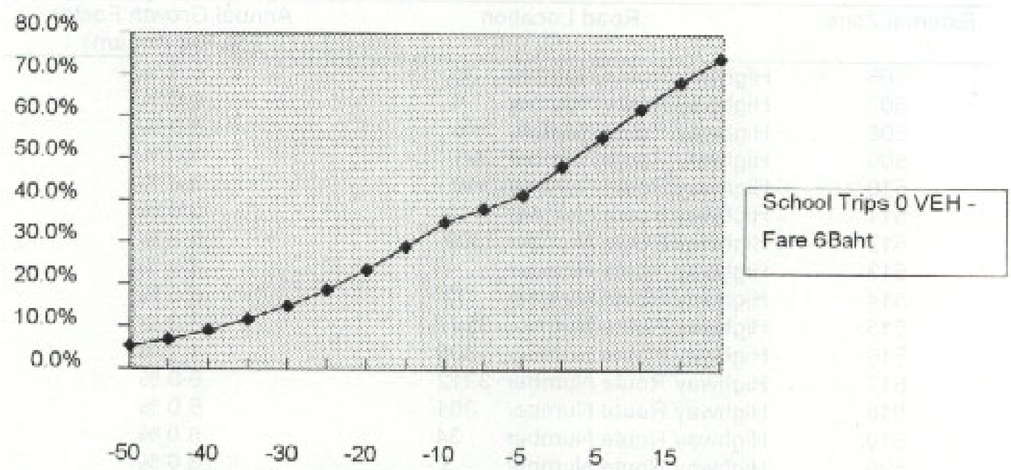
Table AP-1.17 Parameters for Modal Split Diversion Curves

Household Type	Purpose	A	B	C	D
Vehicle Available	HBW	-1.689	-0.073	-0.120	-0.215
	HBE	-0.070	-0.162	-0.382	-
	HBO	-2.601	-0.008	-0.169	-0.701
	NHB	-1.103	-0.093	-0.302	-0.254
NO Vehicle Available	HBW	1.148	-0.092	-0.284	-
	HBE	2.264	-0.056	-0.366	-
	HBO	-1.101	-0.010	-0.165	-
	NHB	1.378	-0.046	-0.114	-



Fare difference : Three Fares as shown
No Interchange

Fig. AP-1.13 Modal Diversion Curve for HBW No Vehicle Available



Fare difference : Fares as shown
No Interchange

Fig. AP-1.14 Modal Diversion Curve for HBE No Vehicle Available

These modal diversion curves which are basically exponential curves had to be programmed into the transport modeling software package TRANPLAN .

The basic formula was of the following form for each test case:

T{Test}ij = T {Base}ij * [MS{Test}ij] / [MS{Base}ij]

where

T{Test}ij is the resulting number of private person trips for the test case.

T {Base}ij is the resulting number of private person trips for the base i.e. without major network changes.

MS{Test}ij is the modal split of private trips derived from using the private and public transport skims in the formula described above for modal diversion.

MS{Base}ij is the modal split of private trips derived from using the private and public transport skims in the formula described above for modal diversion.

7.4 Commercial and External Trip Growth

The future external and commercial vehicle trip tables were developed from the base year using the mathematical growth model known as Fratar . A set of expansion factors were developed for each trip type . In the case of the external stations these growth factors were developed from a review of trends in Department of Highway counts . The final factors are presented in Table AP-1.18

Table AP-1.18 External Growth Factors

External Zone	Road Location	Annual Growth Factor (% Per Annum)
506	Highway Route Number 35	6.0 %
507	Highway Route Number 4	6.0 %
508	Highway Route Number 346	6.0 %
509	Highway Route Number 321	3.0 %
510	Highway Route Number 340	3.0 %
511	Highway Route Number 3111	6.0 %
512	Highway Route Number 3309	6.0 %
513	Highway Route Number 1	3.0 %
514	Highway Route Number 32	6.0 %
515	Highway Route Number 3261	3.0 %
516	Highway Route Number 305	4.0 %
517	Highway Route Number 3312	6.0 %
518	Highway Route Number 304	6.0 %
519	Highway Route Number 34	6.0 %
520	Highway Route Number 3	6.0 %

For commercial vehicles trips the growth factors were developed from the trip generation equations described in earlier sections of the appendix with an overall growth of 5 % per annum. This compares with a growth rate of 3 % per annum for mechanized trips (public plus private). However in the so called do nothing scenario with no improvements to public transport and continual congestion there is expected to be a growth in private pcu vehicle trips of 5.4 % per annum in the morning peak hour .

It should also be remembered that the controlling number of trips in the peak hour assignment are the private vehicle trips which make up some 90% of all peak hour vehicle trips excluding public transport vehicles .

7.5 Ten Simulation Cases

For this project ten simulation cases were prepared in an attempt to clarify and refine the BEIP transport vision for Bangkok . The simulation cases have been devised to analyze policies rather than evaluate any of the individual road project put forward by individual agencies in the formulation of the 8 th national plan . The 10 cases are described in Table 19.

Table AP-1.19 Ten Simulation Cases

	DEMAND			SUPPLY			SPECIAL POLICY
	1995	TREND 2011	NEW 2011	1995	8th plan road	MRT	
CASE 1	•			•			
CASE 2	•			•	•		
CASE 3	•			•	•	•	
CASE 4		•		•			
CASE 5		•		•	•		
CASE 6		•		•	•	•	
CASE 7		•		•	•	•	BUS PRIORITY
CASE 8		•		•	•	•	ROAD CAPACITY INCREASE
CASE 9		•		•	•	•	AREA RESTRAINT
CASE 10			•	•	•	•	SUB CENTER DEVELOPMENT

The difference between the two demographic projections is presented earlier in this appendix . The different trip making characteristics between 1995 and 2011 are shown in Table 20. The 8 th National Plan is described in detail in the main report. The MRT referred to in the above table is the mass transit master plan prepared by the CMIP team .

In all ten cases the simulation is done as in Fig. AP-1.14. The only exception being case 10 which also includes the redevelopment of trip generation with the New 2011 demographic data .

Table AP-1.20 Demographic Assumptions

	BMA		BMR	
Year	1995	2011	1995	2011
Population (x 1,000)	8,126	10,495	11,453	15,227
Households (x 1,000)	2,037	2,870	2,858	4,145
HH Size	3.99	3.66	4.01	3.67
Mechanized Trip per household	6.79	7.80	6.29	6.97
Average HH Income (Bahts / Month)	21,032	33,802	20,081	32,437
Household Vehicle Ownership				
NONE	42.5 %	25.3 %	38.9 %	22.9 %
M/C	21.8 %	12.9 %	23.5 %	15.3 %
1 CAR	29.4 %	44.6 %	31.1 %	45.7 %
2 CAR	6.3%	17.2 %	6.5%	16.1 %

For Cases 6-9 the simulation is based on certain assumptions to estimate the effect of particular policies . The mathematical assumptions to test the policies are as follows :

- Case7- The effect of increasing bus priority by giving over more road space to buses will increase private vehicle travel time.The simulation is to increase private travel time by 20 % . This is equivalent to decreasing the road space available to the private vehicle by 20%.
-
- Case 8- The effect of increasing road space by 20% is achieved by increasing the capacity of all non expressway links by 20%.
-
- Case 9- The policy of area restraint is tested by adding a toll on all links crossing the area bounded by the MRR on the east and the river on the west, equivalent to the toll on the First Stage Expressway toll .

The results from the analysis of the ten cases is presented in Table 21 in the form of the road congestion index by case whilst the major findings are summarized in Table AP-1.22. The interpretation of these results has helped in the clarification of the BEIP transport vision for BMA which can be summarized as follows:

- People movement is the Priority -Even if all the new roads are built with MRT by2011(Case 6) this will not be sufficient without bus priority (Case 7) or Area Restraint (Case 9) or Structural Change (Case 1).
- Many more roads are not the Answer Alone -In Case 8 , where additional road space is added without additional supporting public transport , the shift to the private mode does not match the increase in supply.
- New Road Development with Mass Transit and Improved Public Transport (All the analysis support this,to encourage the use of public
- Transport it may require area restraint in the form of central area restraint or changes in parking in the center(Case 9).

Table AP-1.21 Results of Simulation Analysis: Congestion Ranking for Roads within BMA (% distribution of roads in morning peak hour)

LEVEL	1	2	3	4	5	6	7	8	9	10
SATURATED	13.2	3.4	1.5	62.2	35.5	23.8	10.1	32.0	16.8	18.2
HEAVILY CONGESTED	15.7	6.0	3.8	13.2	14.6	13.8	14.1	13.2	14.8	13.3
CONGESTED	9.4	5.5	4.0	5.8	8.4	8.6	9.0	7.2	9.1	9.3
Sub -Total (km)	**38.3 (663)**	**14.9 (354)**	**9.3 (219)**	**81.2 (1406)**	**58.5 (1389)**	**46.2 (1100)**	**33.2 (789)**	**52.4 (1246)**	**40.7 (965)**	**40.8 (971)**
C.I.	**100**	**39**	**24**	**212**	**152**	**121**	**87**	**137**	**106**	**106**
ACCEPTABLE	12.6	10.1	8.0	5.8	10.4	10.3	11.5	9.8	11.9	11.5
UNDER CAPACITY	49.1	75.0	82.7	13.0	31.1	43.5	55.3	37.8	47.4	47.7
TOTAL	100	100	100	100	100	100	100	100	100	100
LENGTH	1732	2376	2376	1732	2376	2376	2376	2376	2376	2376

Note C.I. : Congestion Index (Based on Percentage of Congested Roads in 1995=100)

Table AP-1.22 Major Findings from the Simulation Analysis

CASE	C.I.	% PT	COMMENTS
1	100	55	The Existing Situation
2	39	50	If all the roads of the 8th plan were to built in 1995, the C.I. decreases to 39
3	24	60	If Mass Transit were in place in 1995, the C.I. drops further as the modal chsre of public transport increases.
4	212	55	The "Do Nothing Case" by 2011 If nothing is done, the C.I increases significantry
5	152	43	The roads of the 8th plan in place by 2011, the C.I. decreases but not below 1995 level. Mmore road construction leads to decrease of public transport (PT) share.
6	121	58	Case 5 with the Mass Transit, C.I decreases but still above 1995 level.
7	87	63	In addition, "BUS PRIORITY" is added, C.I. becomes close to the existing level.
8	137	48	It was assumed more road space could be created at the local street level. This leads to a decrease of public transport (PT) share and increase of C.I.
9	106	61	With central area restraint (the Middle Ring Road in this case), public transport (PT) share and C.I. decreases.
10	106	58	With the sub-center development case, C.I. decreases in comparison with case 6.

Fig. AP-1.15 Level of Congestion

Level of Road Traffic Congestion (case1)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

N
W E
S

SCALE 1:235000

6 0 2 4 6 8 10

KILOMETERS

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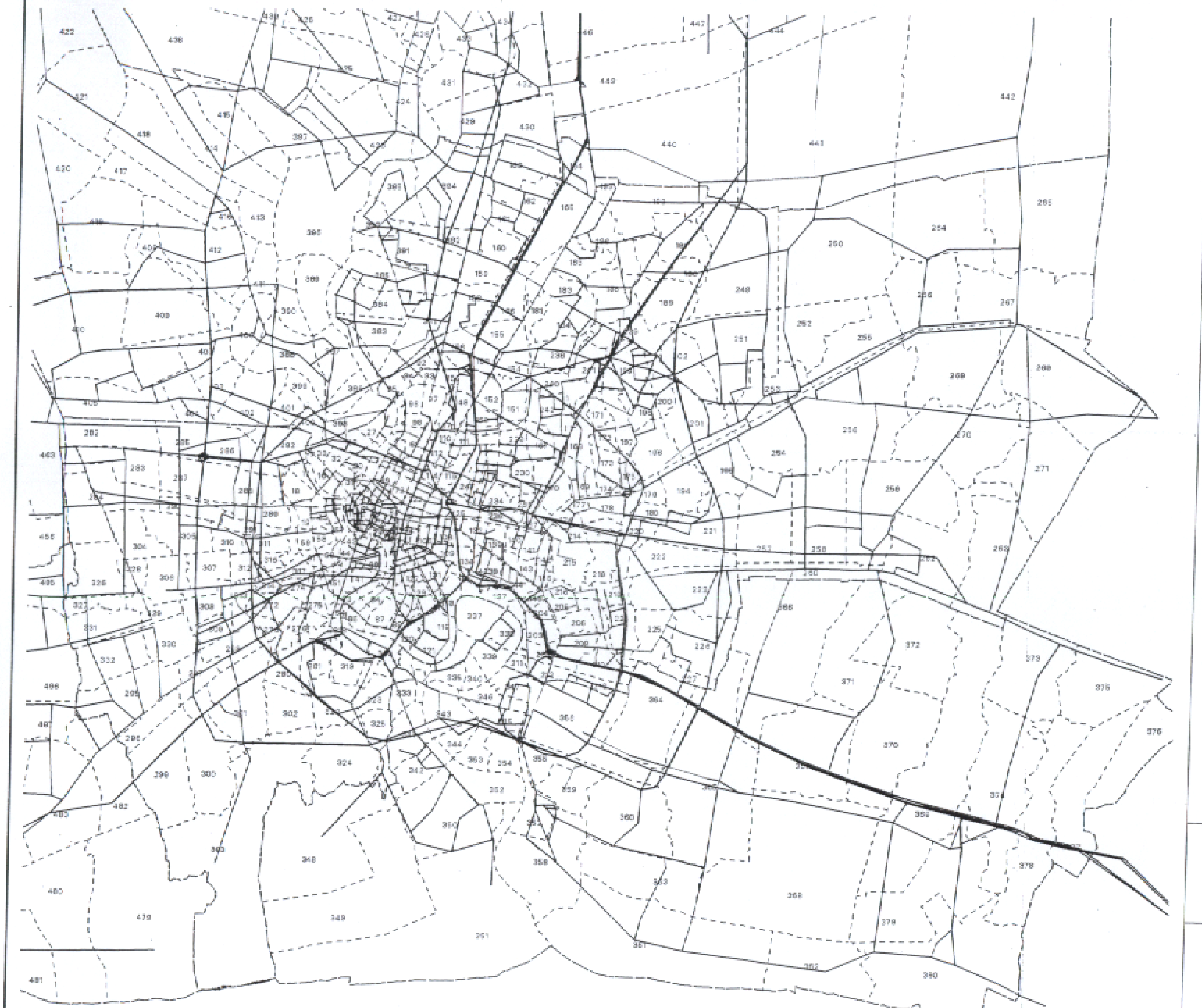
Fig. AP-1.16 Level of Congestion



Level of Road Traffic Congestion (case2)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

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Fig. AP-1.17 Level of Congestion

Level of Road Traffic Congestion (case3)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

SCALE 1:235000

5 0 2 4 6 8 10

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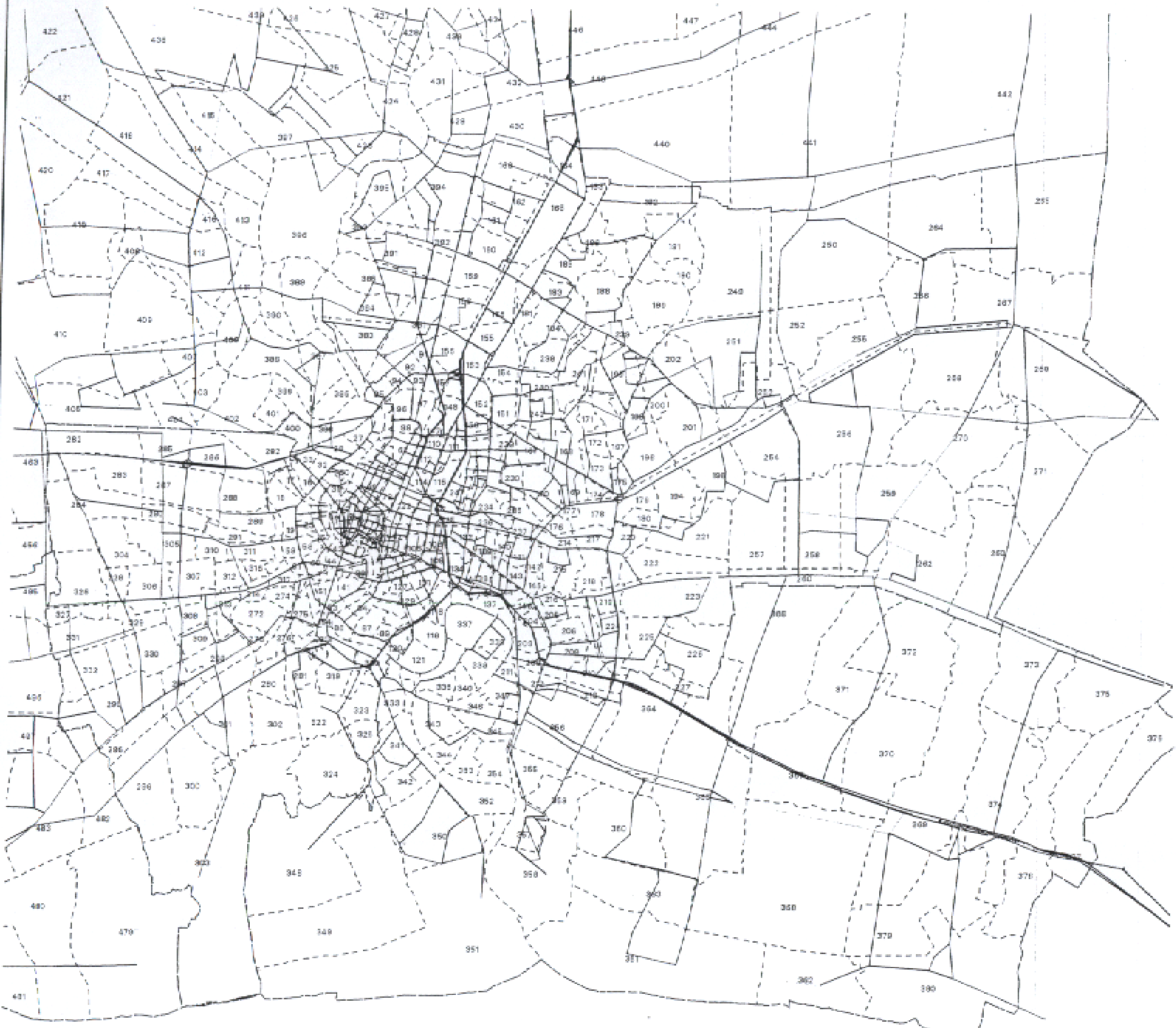
Fig. AP-1.18 Level of Congestion



Level of Road Traffic Congestion (case4)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

SCALE 1:235000

5 0 2 4 6 8 10

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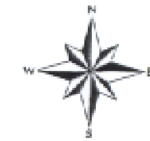
Level of Road Traffic Congestion (case5)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity



SCALE 1:235000

5 0 2 4 6 8 10

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Fig. AP-1.20 Level of Congestion

Level of Road Traffic Congestion (case6)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

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SCALE 1:235000

6 0 2 4 6 8 10

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Fig. AP-1.21 Level of Congestion

Level of Road Traffic Congestion (case7)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

N W E S

SCALE 1:235000

5 0 2 4 6 8 10

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Fig. AP-1.22 Level of Congestion

Level of Road Traffic Congestion (case8)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

N
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SCALE 1:235000

6 0 2 4 6 8 10

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Fig. AP-1.23 Level of Congestion

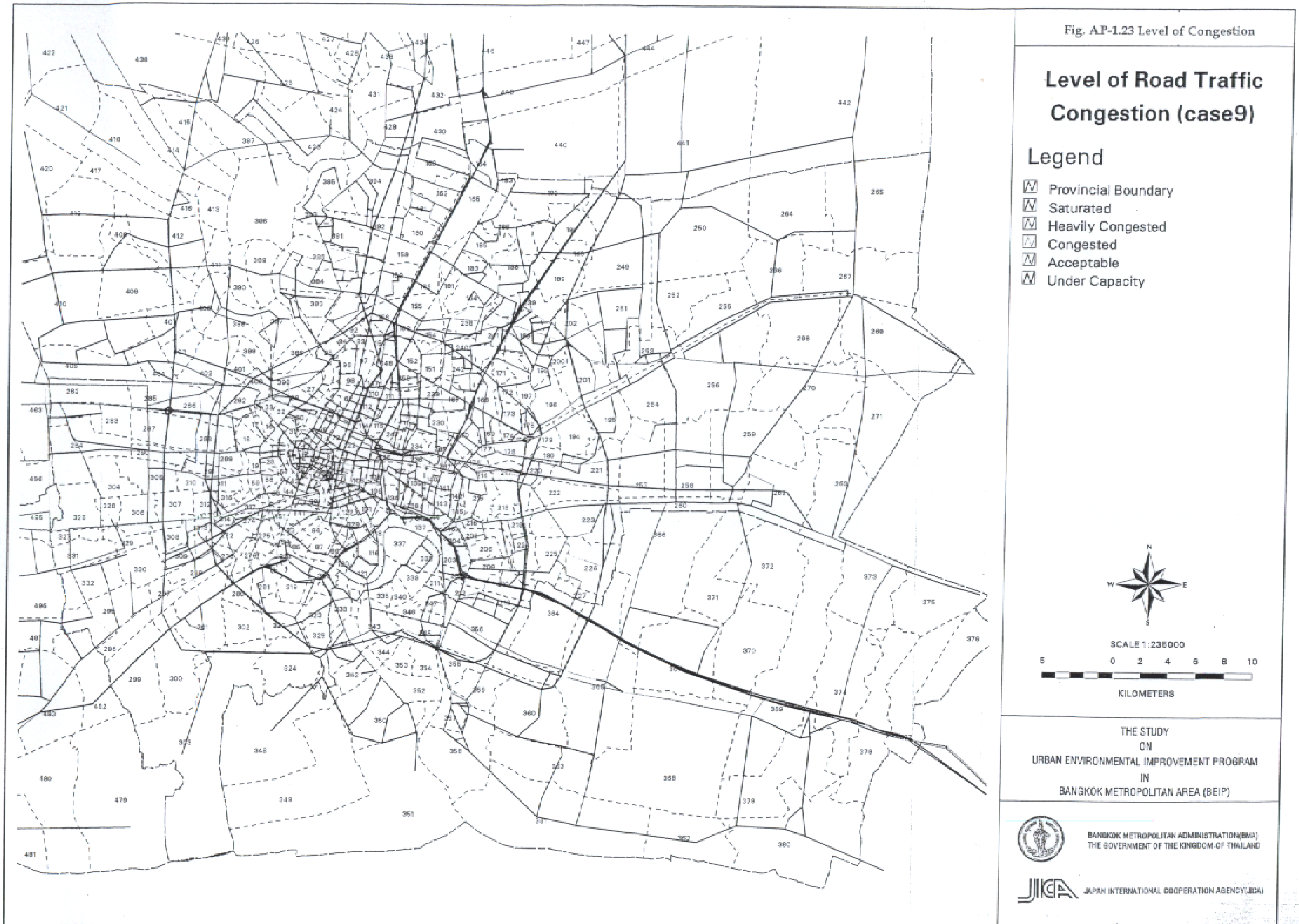

Fig. AP-1.24 Level of Congestion

Level of Road Traffic Congestion (case10)

Legend

- Provincial Boundary
- Saturated
- Heavily Congested
- Congested
- Acceptable
- Under Capacity

N W E S

SCALE 1:236000

8 0 2 4 6 8 10

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7.6 Down Loading to GIS and Environmental Analysis

For additional analysis and environmental simulation , the output from the transport assignment program was dumped into an ASCII format and combined with selected items from the road inventory network databases to produce input data files into GIS software and the environmental package .

For further GIS analysis the link volume,volume capacity ratio ,the link rank (a function of the volume capacity ratio) were merged into a database file.

For input into the environmental program the link volume and link speeds from the peak hour pcu assignments broken down into several vehicle type by different time periods . The factors used in this process were developed from existing traffic counts and route choice speed surveys undertaken as part of UTDM.

7.7 Sample Run Procedure

A full run procedure with file names and instructions is presented in Table 23

Table AP-1.23 Model Run Procedure for Case 7

PROGRAM NAME	TASK DESCRIPTION	INPUT FILES	DESCRIPTION	OUTPUT FILES
FUT12CA7.IN (TRANPLAN)	Run Gravity Model	FUTSKIM.BIN GFUT9.DAT GFUT10.DAT	Future Skim Matrix Future production & attraction files derived from modal split spreadsheets, MOD2011X.XLS	HBW11CA7.BIN HBE11CA7.BIN HBO11CA7.BIN NHB11CA7.BIN
CA7HBW11.IN CA7HBE11.IN CA7HBO11.IN CA7NHB11.IN (TRANPLAN)	Modal Split Run for 4 purposes (Note program is currently set to use Case 6 as starting point. To change edit 'new.mip' to 'ca7.bin')	PRSKMNEW.MAT PRSKMOLD.MAT PTSKMNEW.MAT PTSKMNEW.MAT HBW11CA7.BIN HBE11CA7.BIN HBO11CA7.BIN NHB11CA7.BIN	Old & new private skims Old & new public skims Output matrices from Gravity Model Run	HBW11NEW.CA7 HBE11NEW.CA7 HBO11NEW.CA7 NHB11NEW.CA7
CA714NEW.IN (TRANPLAN)	Develop Daily Trips ~Split private trips between car and m/c .	FRATHBW.DAT FRATHBE.DAT FRATHBO.DAT FRATNHB.DAT HBW11NEW.CA7 HBE11NEW.CA7 HBO11NEW.CA7 NHB11NEW.CA7	Private person split factors for car and motorcycle Trip tables as output from the modal split procedure	DAY11NEW.CA7
CA715NEW.IN (TRANPLAN)	Peak hour PCU matrix for traffic assignment	DAY11NEW.MAT	Daily private matrix as output from previous step	HR11NEW.CA7
C7_11_01.IN (TRANPLAN)	Case 7 Assignment Loads 2011 triptable onto 2001 network	HR1111NEW.CA7 2001HW.NET BEIEX11A.MAT TRUCK11.MAT TRANSIT.DAT TURN_BAN.TXT	Peak Hour Private-2011 Network - 2001 Externals - 2011 Commercials - 2011 Bus Preloads Turn ban file	CA711_01.LOD (Loaded network for Case 7)
NETCARD (TRANPLAN)	Dump for GIS Options: Dump 2 way Rounded speeds Speed Factor-1 Output Cap1 in cap 2 field-no , with last iteration .	CA711_01.LOD	Loaded network for Case 7	CA711_01.TXT
TRANLOD.PRG (FOXPRO)	Procedure for GIS Program requires editing of input and output filenames. Edit CA7 to new case number	CA711_01.TXT	Dumped network in text format	CA711_01.DBF (database file for input into ARCINFO)
ENVIRON.PRG (FOXPRO)	Converts to environmental format Dump to text format using NETCARD but choose 1 way option.	Use this text file dumped from loaded network , Open file TRAN_LOD.DBF, then zap. Append text file. Then run program.		TRAN_FIN.DBF (Dump this file to text to transfer to environmental group for analysis)
PR_SKIM.IN PU_SKIM.IN PR_NEW.IN PU_NEW.IN ACC_SKIM.IN	Develops start private skim Develops start public skim Develops new private skim Develops new public skim Develops time skims for 10 cases for accessibility analysis			

APPENDIX 2: THE BEIP SIMULATION MODEL FOR AIR POLLUTION

1. Objectives of the BEIP Simulation Model for Air Pollution

The BEIP Simulation Model for Air Pollution is a simulation model modified to emulate the air pollution of Bangkok, as the BEIP Study Team developed it by checking the simulation results with the actual ambient monitoring results.

The targets of the model are as follows;

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

2. Methodology

The outline of the model is as follows:

- Meteorological data observed at ONEB Station in 1988 by JICA;
- CONCAWE Equation (CONCAWE, 1966) and Briggs Equation (Briggs, 1969) for the height of the plume rise;
- Gaussian Plume Equation and Gaussian Puff Equation for the dispersion model; and
- Monitoring results of CO were used for model improvement.

The simulation procedure is shown in Fig. AP-2.1.

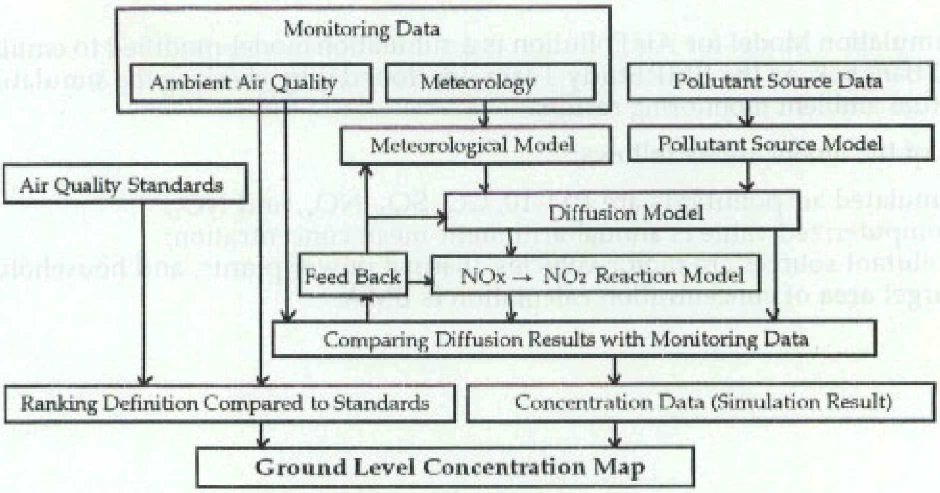


Fig. AP-2.1 Flow Chart of Diffusion Simulation

3. Target of the BEIP Simulation Model for Air Pollution

3.1 Target Years

The target year of present case is 1995, and 2011 for future case.

3.2 Air Pollutants Covered

Recently, PM-10 and CO are said to be important problems in Bangkok. SO_2 and NO_2 are potential important problems according to other countries experiences. So, concentration of primary PM-10, CO, SO_2, NOx and NO_2 are targets of this simulation model.

PM-10 consists of Primary PM-10 and Secondary PM-10. Primary PM-10 means PM-10 emitted originally from stacks and exhaust pipes. Secondary PM-10 means formulated PM-10 in the air from other air pollutants after emission from stack or exhaust pipe. Only primary PM-10 was simulated because PM-10 mainly consists of primary PM-10. Secondary PM-10 model also should be included to the simulation model if there are more available data enough to establish secondary PM-10 formulating model.

The quantity of SPM emitted from stack or exhaust pipe is assumed to be the amount of PM-10 although the definition of SPM sometimes may include larger particulate.

3.3 Averaging Time of Concentration

Long-term average (one year arithmetic mean) of concentration is calculated to omit hourly, daily and seasonally drifts and errors.

To simulate concentration of annual average, first, the meteorological information are grouped by matrix of 16 wind-directions, 8 ranks of wind-speed and 11 stability classifications, as described in Section AP2-4.4 for each matrix of three (3) seasons and four (4) time zones. Second, dispersion of pollutants per source is calculated for average condition of each matrix. Third, it is summarized to average concentration by each season-time zone. Finally, one (1) year arithmetic mean is calculated.

$$C_y = \sum_t \left(\sum_s \left(\sum_{rm} F(Q_s, W_{rm}) \cdot f_{rm} \right) \cdot f_t \right)$$

where

- Cy: Yearly average of concentration
- t: Matrix of Season and Time zone
- s: Pollutant source
- rm: Representative meteorology
- F (): Dispersion equation
- Qs: Quantity of pollutant from each source
- Wrm: Meteorological information of each representative meteorology
- frm: Frequency of each representative meteorology compared with each season and time zone
- ft: Ratio of each time zone compared with one year

On the other hand, Simulation for short term, e.g., 1 hour average of concentration, is also necessary for the simulation under specified condition, e.g., analysis of high TSP concentration at Saphan Kwai monitored at temporally station in 1995. For this purpose, further study is required.

3.4 Pollutants Sources

Pollutants from motor vehicles and household were originally simulated because the study focuses the air pollution of Bangkok City. After the analysis of air pollutant sources in and around Bangkok, pollutants from thermal power plants in and near from Bangkok are found to be much important than those from household. So, emission from vehicles, household and power plants (South Bangkok Power Plant and North Bangkok Power Plant) are taken into account in this study.

3.5 Area of simulation

Area of simulation is whole area inside BMA (66 km in east-west direction and 52 km in north-south direction). Calculated points are nearly 4000, which are;

- 2m high at PCD's Monitoring Points;
- 1.5m high at 500m x 500m grid centers of inner Bangkok (West end is nearly Thanon Wongwan Rob Nok and east end is nearly Thanon Sinakarin, 2988 points); and
- 1.5m high at 1 km x 1 km grid centers of outer Bangkok (961 points).

The area of 500m grid cells is hatched area in Fig. AP-2.2, and the area of 1 km grid cells is other enclosed area.

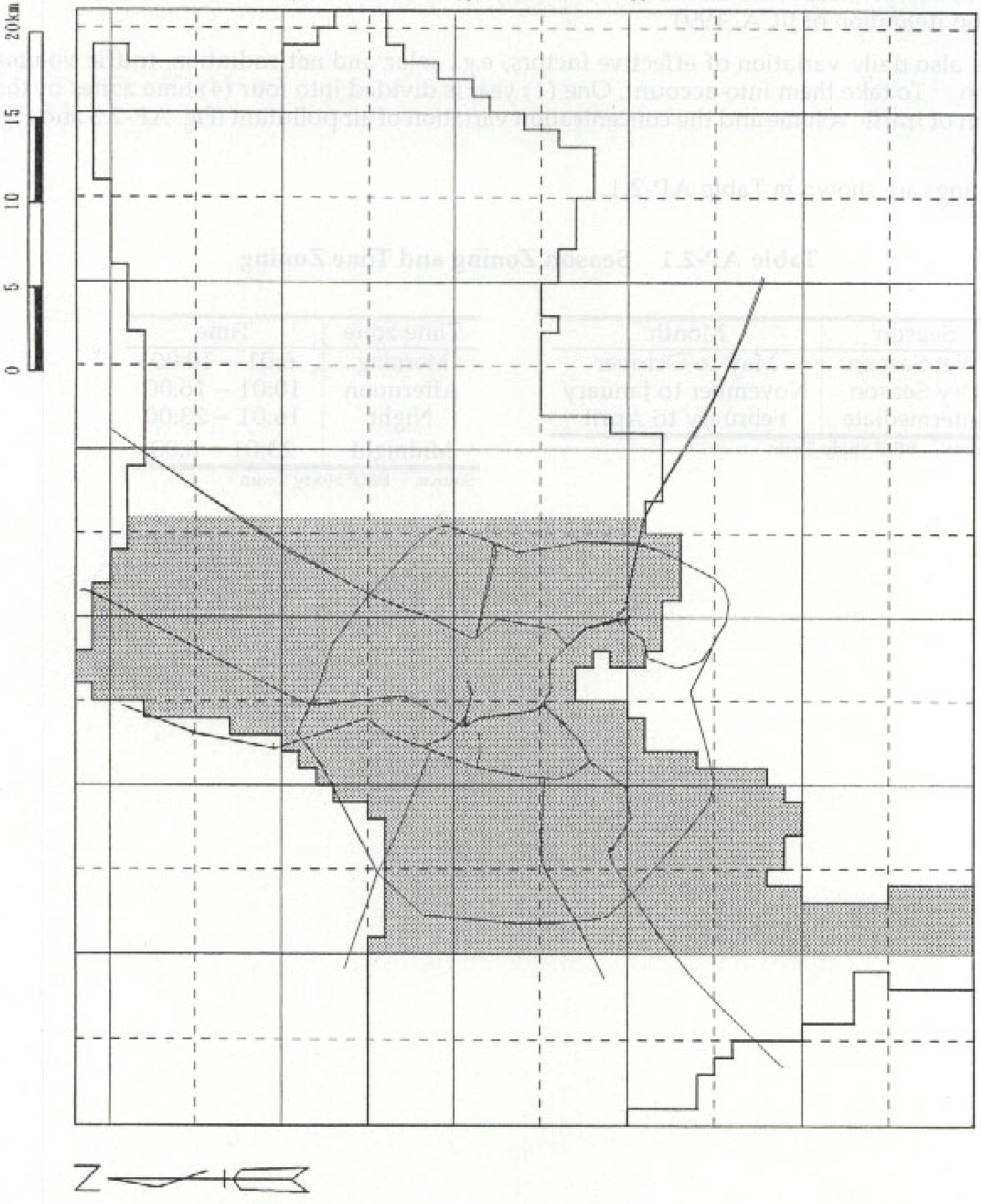


Fig. AP-2.2 Simulation Area

Note: Hatched area means the area of 500 m grid cells.
Other enclosed area means the area of 1 km grid cells.

3.6 Season and Time Zoning

Season was defined in order to consider the seasonal variation of effectual factors for diffusion, e.g., primary wind direction. One (1) year is divided into three (3) seasons as same as season definition of JICA, 1991.

There is also daily variation of effective factors, e.g., solar and net radiation, traffic volume variation. To take them into account, One (1) year is divided into four (4) time zones by the variation of traffic volume and the concentration variation of air pollutant (Fig. AP-2.3 and Fig. AP-2.4).

The zonings are shown in Table AP-2.1.

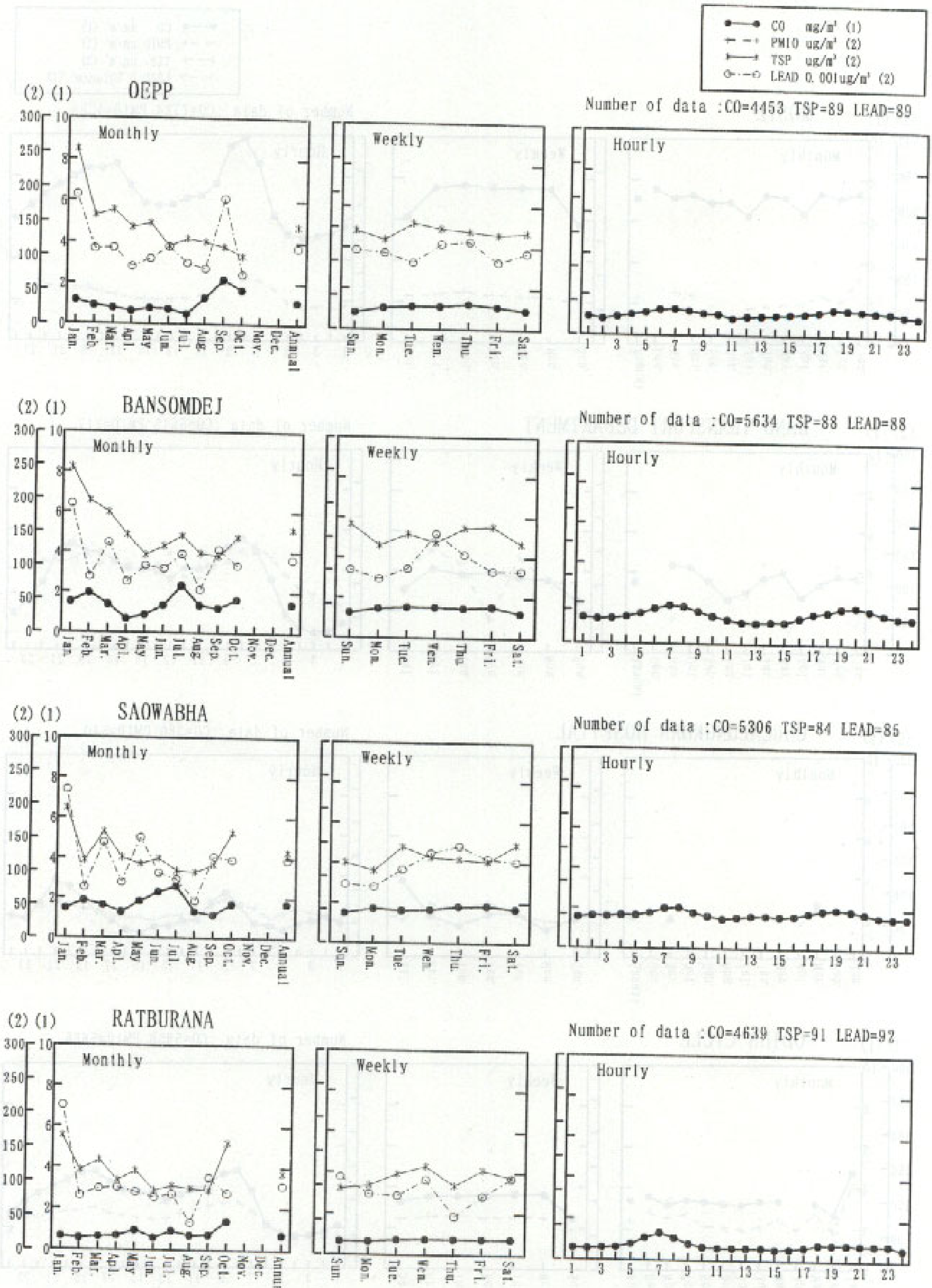
Table AP-2.1 Season Zoning and Time Zoning

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

Source: BEIP Study Team

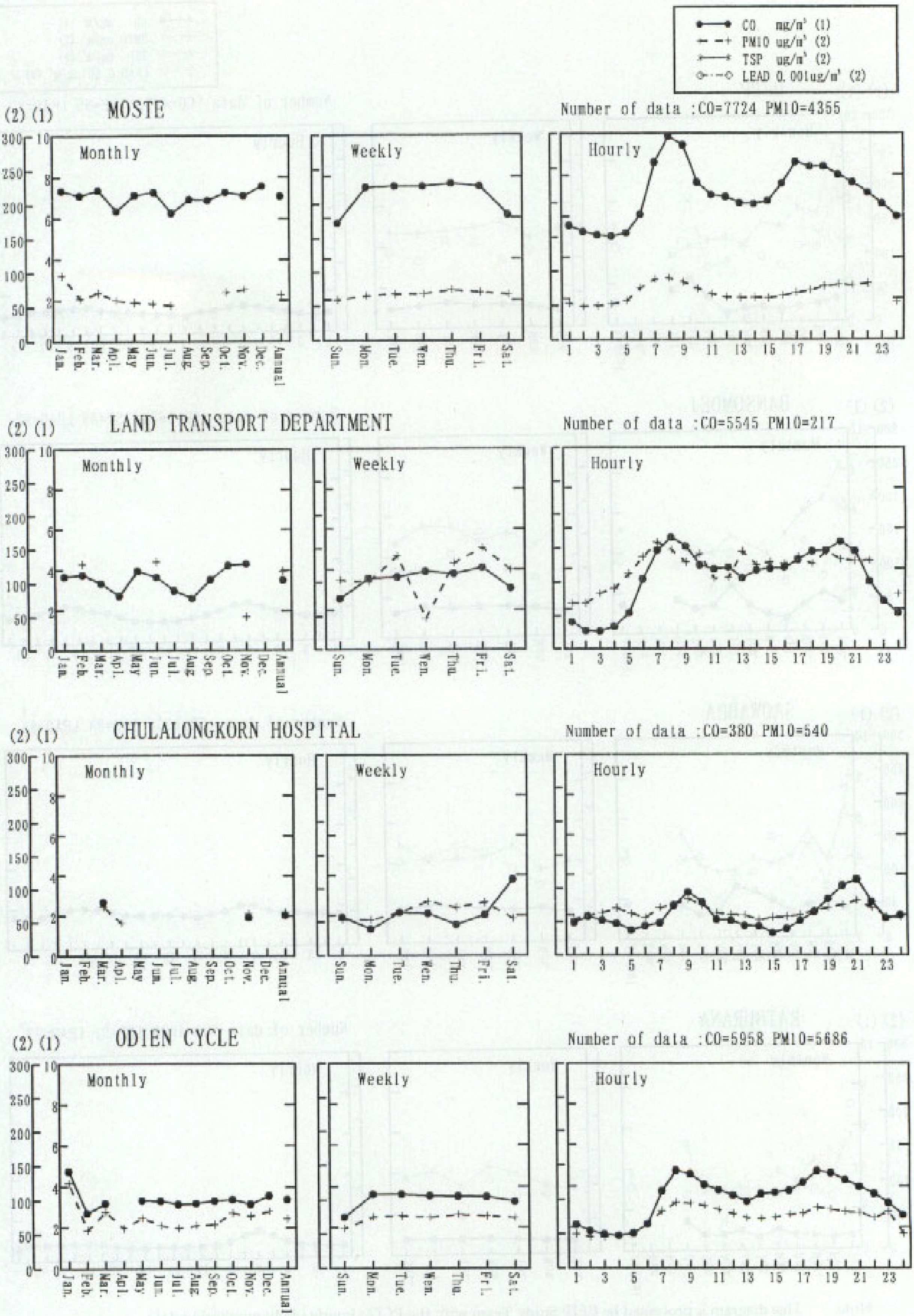
Time zone	Time
Morning	6:01 ~ 10:00
Afternoon	10:01 ~ 16:00
Night	16:01 ~ 23:00
Midnight	23:01 ~ 6:00

Source: BEIP Study Team



Note: This diagram is processed by BEIP Study Team with the PCD's hourly / daily monitoring data
TSP and LEAD are originally daily data

Fig. AP-2.3 Variations of Air Quality Concentration, 1994 (2537), General Stations



Note: This diagram is processed by BEIP Study Team with the PCD's hourly / daily monitoring data

Fig. AP-2.4 Variations of Air Quality Concentration, 1994 (2537), Roadside Stations

4. Meteorological Modeling

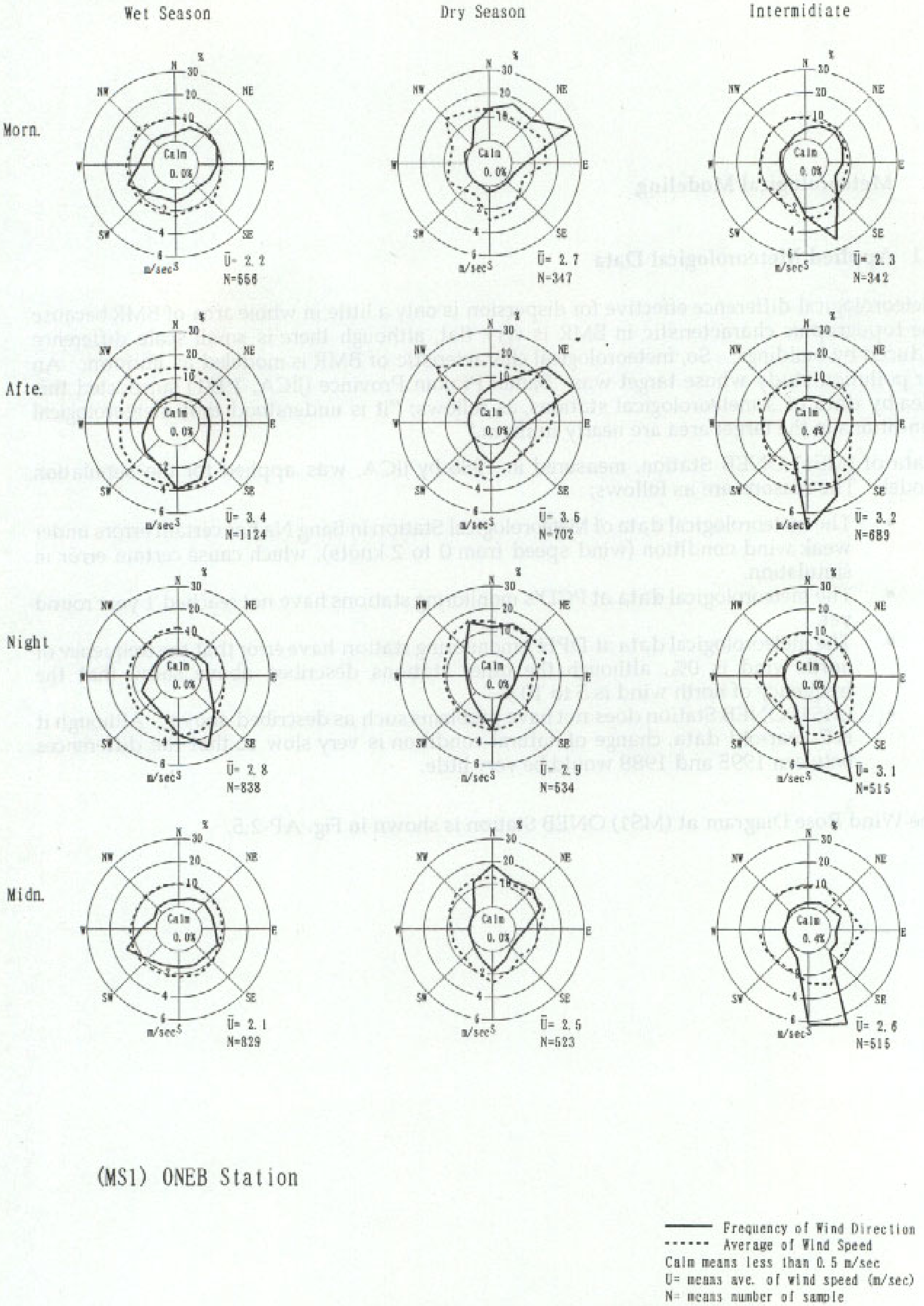
4.1 Applied Meteorological Data

Meteorological difference effective for dispersion is only a little in whole area of BMR because the topographic characteristic in BMR is very flat, although there is small scale difference induced by buildings. So, meteorological characteristic of BMR is modeled as uniform. An air pollution study whose target was Samut Prakan Province (JICA, 1991) supported this idea by data of 3 meteorological stations, as follows; "it is understood that meteorological conditions in the target area are nearly uniform."

Data of (MS1) ONEB Station, measured in 1988 by JICA, was applied for the simulation model. The reasons are as follows;

- The meteorological data of Meteorological Station in Bang Na has certain errors under weak wind condition (wind speed from 0 to 2 knots), which cause certain error in simulation.
- The meteorological data at PCD's monitoring stations have not reached 1 year round yet.
- The meteorological data at DPH's monitoring station have error that the frequency of north wind is 0%, although the other stations described above show that the frequency of north wind is 5 to 10 %.
- (MS1) ONEB Station does not have problems such as described above. Although it is 7-year-old data, change of natural condition is very slow so that the differences between 1995 and 1988 would be very little.

The Wind Rose Diagram at (MS1) ONEB Station is shown in Fig. AP-2.5.



Note: This diagram is processed by BEIP Study Team with the hourly/daily monitoring data of JICA, 1991

Fig. AP-2.5 Wind Rose Diagrams of Applied Meteorological Data

4.2 Atmospheric Stability

Pasquill's Stability Classification is generally prevalent to evaluate the atmospheric stability. Pasquill's Stability Classification redefined by Gen-an-kyo, 1982, as shown in Boxed Item, is adopted in this BEIP study because the available data were solar radiation, net radiation and wind speed.

Appearance frequency of atmospheric stability at (MS1) ONEB Station is shown in Fig. AP-2.6.

Boxed Item: Definitions of Pasquill's Stability Classification

1. Pasquill's Stability Classification (Original)

Atmospheric stability was originally classified by the vertical profile of atmospheric temperature. However, it is difficult to make continuous measurements (up to an altitude of 1000 m above the ground) of the vertical distribution of atmospheric temperature. Also, smoke plume diffusion is greatly influenced not only by the vertical distribution of atmospheric temperature, but also by wind velocity, and is related to other factors as well. Therefore, Pasquill proposed a method of classifying the atmospheric stability into A through F, from simple meteorological observations, with respect to wind velocity, solar radiation and cloud amount, and this method had been adopted by the Meteorological Agency of England. Pasquill's stability classificationis shown in Table 1.

Table 1 Pasquill's Stability Classification, Pasquill, 1961

Surface wind	Daytime			Nighttime	
	Insolation			Thinly overcast	
Speed (m/sec)	Strong	Moderate	Slight	or >=4/8 cloudiness	<= 3/8 cloudiness
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Note: Strong insolation corresponds to sunny midday in midsummer in England, slight insolation to similar conditions in midwinter. Night refers to the period from 1 hour before sunset to 1 hour after dawn. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night, and for any sky conditions during the hour preceding or following night as defined above.

Source: Pasquill, 1961

Gifford added the G rank for blank area of the original Pasquill's classification.

2. Types of Redefined Pasquill's Stability Classification

Solar radiation was not given quantitatively and nighttime classifications were dependent on the cloud volume in these classifications. But due to the progress of the measuring instrument, solar radiation and net radiation flux are easily obtainable, and Pasquill's stability classifications are redefined with available data. Many classifications have been proposed.

Three major classifications are mainly used nowadays, depending on the available data, shown in Table 2. The data made by three methods should not be equal because the using data are different. So, the Pasquill's classification data should be treated with the method information.

Table 2 Major Pasquill's classifications in related with the data

Method	Table	Day time: Solar radiation	Day time: Net radiation	Night time: Cloudiness	Night time: Net radiation
JEA, 1993	3	O	-	O	-
Senshu, 1977	5	-	O	-	O
Gen-an-kyo, 1982	6	O	-	-	O

Source: JEA, 1993 and JEA, 1982

3. Redefined Pasquill's Stability Classification (JEA, 1993)

Table 3 shows the Pasquill's stability classifications of JEA, 1993, which is used when solar radiation and decimal cloudiness data are available. This classification can be used for the Meteorological Station's data in Bangkok.

Table 3 Pasquill's Stability Classification, JEA, 1993

Surface wind Speed (m/sec)	Daytime, Solar radiation (T, kW/m^2): T >=0.60	0.60>T >=0.30	0.30>T >=0.15	0.15>T	Nighttime, Cloudiness (0 ~ 10): 8 ~ 10	5 ~ 7	0-4
U<2	A	A-B	B	dD	nD	G	G
2<=U<3	A-B	B	C	dD	nD	E	F
3<=U<4	B	B-C	C	dD	nD	nD	E
4<=U<6	C	C-D	dD	dD	nD	nD	E
6<=U	C	dD	dD	dD	nD	nD	E

Note: Daytime means the time when the solar radiation is plus. The fist and the last hour of the Nighttime are defined as D, even if the cloudiness is less than 8/10.

Source: JEA, 1993 and JEA, 1982

4. Redefined Pasquill's Stability Classification (Senshu, 1977)

Table 4 shows the Pasquill's stability classifications of Senshu, 1977, which is used when net radiation data is available and solar radiation data is not available. This classification can be applied for the PCD's Rangsit Station data.

Table 4 Pasquill's Stability Classification, Senshu, 1977

Surface wind Speed (m/sec)	Daytime: Net radiation (γ, cal/cm^2/h) γ >=30	30>γ >=15	15>γ >=7.5	7.5>γ >=0	Nighttime: 0>γ >=-1.8	-1.8>γ >=-3.6	-3.6>γ
U<2	A	A-B	B	dD	nD	G	G
2<=U<3	A-B	B	C	dD	nD	E	F
3<=U<4	B	B-C	C	dD	nD	nD	E
4<=U<6	C	C-D	dD	dD	nD	nD	E
6<=U	C	dD	dD	dD	nD	nD	E

Source: JEA, 1982

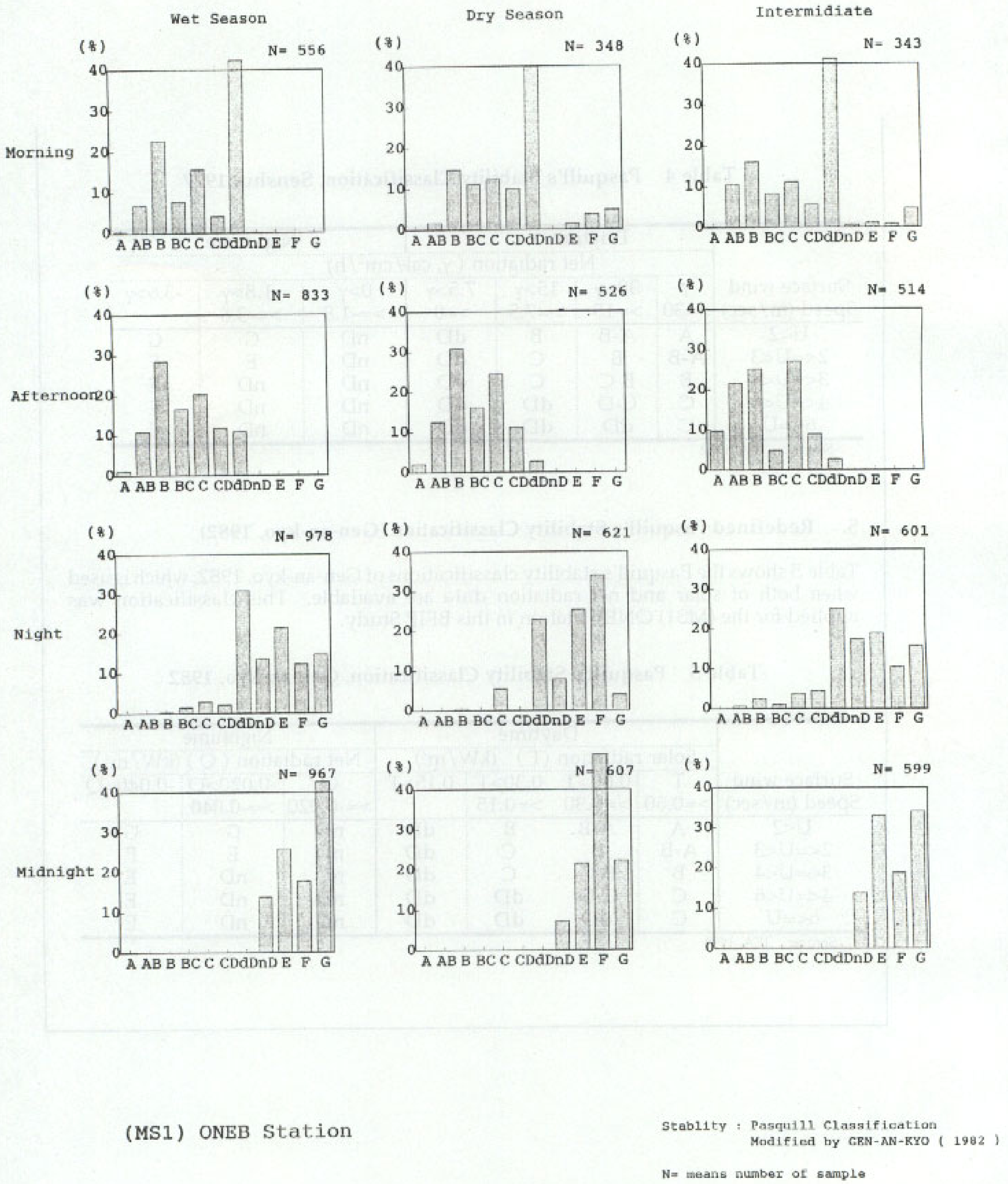
5. Redefined Pasquill's Stability Classification (Gen-an-kyo, 1982)

Table 5 shows the Pasquill's stability classifications of Gen-an-kyo, 1982, which is used when both of solar and net radiation data are available. This classification was applied for the (MS1) ONEB Station in this BEIP Study.

Table 5 Pasquill's Stability Classification, Gen-an-kyo, 1982

Surface wind Speed (m/sec)	Daytime: Solar radiation (T) (kW/m^2) T >=0.60	0.60>T >=0.30	0.30>T >=0.15	0.15>T	Nighttime: Net radiation (Q) (kW/m^2) Q >=-0.020	-0.020>Q >=-0.040	-0.040>Q
U<2	A	A-B	B	dD	nD	G	G
2<=U<3	A-B	B	C	dD	nD	E	F
3<=U<4	B	B-C	C	dD	nD	nD	E
4<=U<6	C	C-D	dD	dD	nD	nD	E
6<=U	C	dD	dD	dD	nD	nD	E

Source: JEA, 1993



Note: This diagram is processed by BEIP Study Team with the hourly/daily monitoring data of JICA, 1991

Fig. AP-2.6 Frequency of Atmospheric Stability of Applied Meteorological Data

4.3 Vertical Zoning and Estimation of Upper Layer Wind

Generally, the wind speed tends to increase with height from the ground surface. The diffusion field was divided into three fields in the vertical direction as shown in Table AP-2.2.

Table AP-2.2 Vertical Zoning

	Diffusion Zone	Type of Source	Height of Source	Representative Height of Diffusion Field
1	Surface	Vehicle	5 ~ 15m	3m
2	Lower	Household	30m	30m
3	Upper	Power Plants	70 ~ 110m	100m

Source: BEIP Study Team

The data at (MS1) ONEB were observed at 30m high and directly used for the simulation of air pollutants from household. Equation of G. A. De Marais, 1959, was applied to estimate the wind speed of other fields. The equation is;

$$U_z = U_s\left(\frac{Z}{Zs}\right)^p$$

where;

Uz: Estimated wind speed at height Z(m)
Us: Measured wind speed at height Zs(m)
p: Factor, as shown in Table AP-2.3.

Table AP-2.3 Factor p

Stability	A	AB-B	BC-C	CD-D	E	F & G
P	0.1	0.15	0.2	0.25	0.25	0.3

Source: G. A. De Marais, 1959

4.4 Meteorological Classification

The original classification of wind direction (16 direction and calm) and atmospheric stability (11 rank, A to G) was also utilized for simulation modeling.

Wind speed data were classified as Table AP-2.4 and the average speed of each rank is used as representative wind speed.

Table AP-2.4 Wind Speed Classification

Rank	Wind Velocity	Representative Wind Velocity
Calm	0.0 ~ 0.4m/s	
Windy-1	0.5 ~ 0.9m/s	
Windy-2	1.0 ~ 1.9m/s	
Windy-3	2.0 ~ 2.9m/s	
Windy-4	3.0 ~ 3.9m/s	Yearly Average of each Rank
Windy-5	4.0 ~ 5.9m/s	
Windy-6	6.0 ~ 7.9m/s	
Windy-7	8.0 m/s~	

Source: BEIP Study Team

5. Source Modeling

5.1 Source Type

Sources with quantitative air pollutants were modeled as point or line source individually. Sources with small pollutants were compiled to area sources. The definition of modeling is shown in Table AP-2.5.

Table AP-2.5 Source Type

Source		Type
• Vehicle	• Freeway • Fly over • Other major road from which SPM is emitted more than or equal 10 kg/km/h (cases using emission factor for 1992) or 2 kg/km/h (cases using emission factor for future)	Line
	• Other minor road	Area
• Thermal Power Plant		Point
• Household		Area

Source: BEIP Study Team

5.2 Variation of Emission

The daily and seasonally variation of emission amount from each source are estimated as follows;

- Vehicle: The daily variation of traffic volume and travel speed was taken into account. These variation data are output of the transport analysis of this BEIP Study Team;
- Thermal Power Plant: It is assumed that emission volume is constant; and
- Household: Fuel consumption ratio by time zone was summarized by the field survey as shown in Table AP-2.6.

Table AP-2.6 LPG Consumption Ratio of Household

Time Zone	Morning	Afternoon	Night	Midnight
Ratio	0.366	0.066	0.568	0.000

Source: Questionnaire survey of fuel consumption, BEIP Study Team

6. Diffusional Modeling

6.1 Effective Stack Height

Effective Stack Height was set or calculated as shown in Table AP-2.7.

Table AP-2.7 Effective Stack Height

Source	Source Type	Windy	Calm
Vehicle	Expressway	15m	20m
	Flyover	10m	15m
	Others	5m	10m
Households		20m	20m
Power Plants		CONCAWE	Briggs

Source: BEIP Study Team

The CONCAWE equation (CONCAWE, 1966) is

$$H_e = H_0 + 0.175 \cdot Q_H^{\frac{1}{2}} \cdot u^{-\frac{3}{4}}$$

where;

He: Effective stack height (m)
H_0: Actual stack height (m)
Q_H: Released heat (cal/s)

$$Q_H = \rho \cdot C_p \cdot Q \cdot (T_G - T_A)$$

where;

ρ: Air density at 0°C (1.293×10^3 g/m^3)
C_p: Isopiestic specific heat (0.24 cal/K/g)
Q: Volume of emitted gas (m^{3}N/s)
T_G: Temperature of exhaust gas (°C)
T_A: Temperature of atmosphere (28 °C)
u: Wind speed at stack top (m/s)

The Briggs equation (Briggs, 1969) is

$$H_e = H_0 + 1.4 \cdot Q_H^{1/4} \cdot (d\theta / dz)^{-3/8}$$

where;

dθ/dz: Temperature gradient (Daytime: 0.005 °C/m, Nighttime: 0.010 °C/m)

Stack information for calculation of effective height of the thermal power plants are shown in Table AP-2.8.

Table AP-2.8 Stack Information of the Thermal Power Plants

Stack		Stack Height (m)	Temperature (C°)	Exhaust gas (10^3 m^3N/h)
South Bangkok P.P.	1	76	140.0	493
	2	76	140.0	493
	3	84	135.0	740
	4	110	135.0	740
	5	110	150.0	740
North Bangkok P.P.	1	70	140.0	207
	2	70	140.0	207
	3	70	140.0	241

Source: JICA, 1991 (Stack Height and Temperature of South Bangkok P. P)
Estimated by BEIP Study Team (Stack Height and Temperature of North Bangkok P. P.)
PCD, 1994 (Fuel Consumption)
Exhaust gas volume was estimated as
$V = W \times K / 8760$
where;
V: Exhaust gas volume (m^3N/h)
W: Fuel Consumption (ton/y)
K: Exhaust gas factor for heavy fuel oil (12,000 m^3N/ton)

6.2 Diffusion Formulas

Gaussian plume model equation and gaussian puff model equation are selected for diffusion formulas, as shown in Table AP-2.9.

Table AP-2.9 Diffusion Formulas

Source	Windy	Calm
Point	Simplified Gaussian Plume Equation	Simplified Gaussian Puff Equation
Line	Simplified Gaussian Plume Equation	Simplified Gaussian Puff Equation
Area	Simplified Gaussian Plume Equation	Simplified Gaussian Puff Equation

Source: BEIP Study Team

(1) Gaussian Plume Equation

Original formula of gaussian plume model is as follows:

$$C(x,y,z) = \frac{Q_p}{2\pi\sigma_y\sigma_z u} \cdot \exp\left(-\frac{y^2}{2\sigma_y^{\,2}}\right) \cdot F$$

where;

$$F = \left\{\exp\left[-\frac{(z-He)^2}{2\sigma_z^{\,2}}\right] + \exp\left[-\frac{(z+He)^2}{2\sigma_z^{\,2}}\right]\right\}$$

C: Concentration at calculation point.
x: Distance from source to calculation point along wind direction (m).
y: Distance from source to calculation point upright to wind direction (m).
z: Height of calculation point (m).

Qp: Emission rate of pollutant (m^3N/sec).
u: Wind speed (m/sec).
He: Effective stack height
σ_y: Diffusion width upright to wind direction (m)
σ_z: Vertical diffusion width (m)

Because the original formula is time consuming in the practical use, this formula was simplified by Holland 1953 with the assumption that frequency inside each 16 wind direction rank is constant, which is applied for the BEIP simulation model.

$$C(R,z) = \sqrt{\frac{1}{2\pi}}\frac{Q_p}{\frac{\pi}{8}R\sigma_z u}\cdot F$$

where;

R: Distance from source to calculation point (m)

(2) Gaussian Puff Equation

On the other hand, Formula of original gaussian puff model is as follows:

$$C(x,y,z) = \frac{Q_p}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z}\cdot \exp\left(-\frac{(x-ut)^2}{2\sigma_x^{\ 2}} - \frac{y^2}{2\sigma_y^{\ 2}}\right)\cdot F$$

where;

t: Time from stack or exhaust gas pipe (sec)
Others: same as the Plume Equation Section

It is also time consuming in the practical use and simplified equation, which was used in BEIP simulation model, is as follows;

$$C(R,z) = \frac{Q_p}{(2\pi)^{3/2}\gamma}\cdot\left\{\frac{1}{R^2+\frac{\alpha^2}{\gamma^2}(He-z)^2} + \frac{1}{R^2+\frac{\alpha^2}{\gamma^2}(He+z)^2}\right\}$$

where;

$\alpha = \sigma_x / t = \sigma_y / t$ (t: 3600 sec)
$\gamma = \sigma_z / t$ (t: 3600 sec)

6.3 Diffusion Width

(1) Diffusion Width for Plume Equation

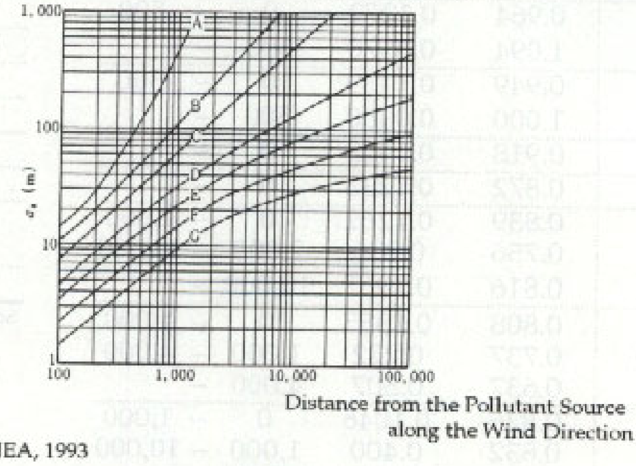
JEA Equation which simulating Pasquill - Gifford Chart (Fig. AP-2.7) was used for plume equation. The equation is;

$$\sigma_z(x) = \gamma_z \cdot x^{\alpha_z} + \sigma_{z0}$$

where;

γ_z, α_z: Constants depending atmospheric stability (Table AP-2.10).
x: Distance from source along wind direction (m).
σ_{z0}: Original Diffusion Width
Line source of vehicle: Road width for each direction (m)
Power Plant: 0m
Area sources: 5m

Fig. AP-2.7 Pasquill - Gifford Chart



Source: JEA, 1993

(2) Diffusion Width for Puff Equation

JEA Table leaded from Turner Chart was used for puff equation (Table AP-2.11).

Table AP-2.10 Constant for σ_z

Stability	α_z	γ_z	x (m)
A	1.122	0.0800	0 ~ 300
	1.514	0.00855	300 ~ 500
	2.109	0.000212	500 ~
AB	1.024	0.1100	0 ~ 300
	1.278	0.0259	300 ~ 500
	1.601	0.00347	500 ~
B	0.964	0.1272	0 ~ 500
	1.094	0.0570	500 ~
BC	0.949	0.1139	0 ~ 500
	1.000	0.0800	500 ~
C	0.918	0.1068	0 ~
CCD	0.872	0.1233	0 ~
CD	0.839	0.1262	0 ~ 2,000
	0.756	0.236	2,000 ~ 10,000
	0.816	0.1367	10,000 ~
CDD	0.808	0.1355	0 ~ 1,000
	0.737	0.222	1,000 ~ 4,000
	0.637	0.507	4,000 ~
D	0.826	0.1046	0 ~ 1,000
	0.632	0.400	1,000 ~ 10,000
	0.555	0.811	10,000 ~
DE	0.777	0.1118	0 ~ 2,000
	0.572	0.529	2,000 ~ 10,000
	0.499	1.038	10,000 ~
E	0.788	0.0928	0 ~ 1,000
	0.565	0.433	1,000 ~ 10,000
	0.415	1.732	10,000 ~
EF	0.791	0.0733	0 ~ 1,000
	0.547	0.395	1,000 ~ 10,000
	0.366	2.09	10,000 ~
F	0.784	0.0621	0 ~ 1,000
	0.526	0.370	1,000 ~ 10,000
	0.323	2.41	10,000 ~
FG	0.789	0.0481	0 ~ 1,000
	0.582	0.202	1,000 ~ 2,000
	0.479	0.442	2,000 ~ 10,000
	0.273	2.954	10,000 ~
G	0.794	0.0373	0 ~ 1,000
	0.637	0.1105	1,000 ~ 2,000
	0.431	0.529	2,000 ~ 10,000
	0.222	3.62	10,000 ~

Source: JEA, 1993

Table AP-2.11 JEA Table for Puff Equation

Stability	α	γ
A	0.948	1.569
AB	0.859	0.862
B	0.781	0.474
BC	0.702	0.314
C	0.635	0.208
CCD	0.589	0.181
CD	0.542	0.153
CDD	0.506	0.133
D	0.470	0.113
DE	0.455	0.090
E	0.439	0.067
EF	0.439	0.058
F	0.439	0.048
FG	0.439	0.039
G	0.439	0.029

Source: JEA, 1993

6.4 Atmospheric Stability and Stability for Diffusion Width

Table AP-2.12 is showing the relationship setting in the BEIP Simulation Model, between Pasquill's Atmospheric Stability Classification and the stability for Diffusion Width table.

Table AP-2.12 Relationship between Atmospheric Stability and Stability for Diffusion Width

Season	Time Zone	Source	A ~ B	BC ~ C	CD ~ dD	nD	E ~ G
Wet Season May ~ Oct.	Morning	Surface & Lower	A	A	B	C	CD
		Upper	BC	CD	CD	D	D
	Afternoon	Surface & Lower	A	A	B	C	CD
		Upper	BC	CD	CD	CD	D
	Night	Surface & Lower	A	B	BC	C	CD
		Upper	BC	CD	CD	CD	D
	Midnight	Surface & Lower	B	C	CD	D	E
		Upper	BC	CD	CD	D	E
Dry Season Nov. ~ Jan.	Morning	Surface & Lower	A	B	C	CD	CD
		Upper	BC	CD	CD	D	D
	Afternoon	Surface & Lower	A	B	BC	C	D
		Upper	BC	CD	CD	CD	D
	Night	Surface & Lower	A	B	C	CD	CD
		Upper	BC	CD	CD	CD	D
	Midnight	Surface & Lower	B	C	CD	D	E
		Upper	BC	CD	CD	D	E
Intermediate Feb. ~ Apr..	Morning	Surface & Lower	A	B	C	CD	CD
		Upper	BC	CD	CD	D	D
	Afternoon	Surface & Lower	A	B	BC	C	CD
		Upper	B	C	CD	CD	D
	Night	Surface & Lower	A	B	C	CD	CD
		Upper	BC	CD	CD	D	D
	Midnight	Surface & Lower	B	C	CD	D	E
		Upper	BC	CD	CD	D	E

Source: BEIP Study Team

6.5 Reaction Model from NOx to NO_2

Reaction Model from NOx to NO_2 follows the model of Yamamoto, Yokoyama, et al. (1978). The equation is;

$$[NO_2] = [NOx]_D \cdot \left[1 - \frac{\alpha}{1+\beta} \left\{ \exp(-Kt) + \beta \right\} \right]$$

where;

$K = 0.208 \cdot u \cdot [O_3]_B \cdot k$: Vehicle and Household

$K = 0.0062 \cdot u \cdot [O_3]_B \cdot k$: Power Plants

$[NO_2]$, $[NOx]_D$: Concentration of NO_2 and NOx

α: Factor (=0.9)
β: Factor (=0.3)
u: Wind Speed (m/s)
t: Time from stack/ exhaust gas pipe (sec)
$[O_3]_B$: Back Ground Concentration of O_3, shown in Table AP-2.13
k: O_3 Back Ground Factor, shown in Table AP-2.13

Table AP-2.13 Back Ground Concentration of O_3 (MS1: ONEB Station in 1988) and O_3 Back Ground Factor

Time Zone	Daytime		Nighttime	
Stability	A ~ CD	D	D	E ~ G
$[O_3]_B$	0.014	0.010	0.005	0.005
k (Parallel wind to line source)	0.55	0.55	0.33	0.33
k (other cases)	1	1	1	1

Note: If the source is line source and the azimuth between the direction of line and the wind direction is less than or equal 30 degree, k is 0.55 at daytime and is 0.33 in nighttime. k is 1.0 in other cases.

Source: JICA, 1991

7. Reproducibility of the BEIP Simulation Model for Air Pollution

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. AP-2.8. 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.

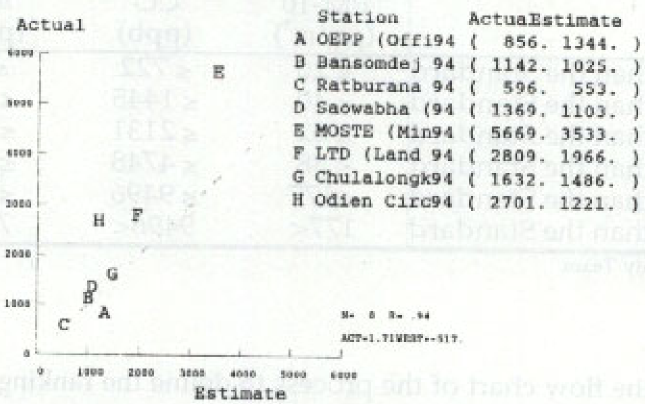


Fig. AP-2.8 Scatter Diagram Comparing the Simulation Result (Estimate) and the Monitoring Result in 1994 (Actual) (CO, ppb)

8. Comparison of Simulated Annual Average to Air Standards

There are various ambient air standards, that is 1 hour, 8 hours, 24 hours, monthly and geometric annual mean. To evaluate the simulated annual average concentration by these standard, ranking table compared to the ambient air standards were prepared, as shown in Table AP-2.14.

Table AP-2.14 Ranking of Annual Arithmetic Average of Air Pollutant Concentration,

	PM-10 ($\mu g/m^3$)	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

Fig. AP-2.9 shows the flow chart of the process to define the ranking.

First, maximum of 1 hour data, maximum of 8 hours, 24 hours and monthly average and geometric annual mean (hereinafter, refereed as Mi), and arithmetic mean (hereinafter, Ma) were calculated for each station. JICA's monitoring results in 1988 in Samut Prakan area were included to this process because the PCD's monitoring stations in 1994 din't have a station to monitor SO2 and NO2.

Second, the ratios (hereinafter, Ri) of Ma/Mi are calculated for each station.

Third, the standards are converted to equivalent annual means (hereinafter, Ei) by Ri and Ambient Air Standards (Si).

Forth, the most strict value among the standards were selected (hereinafter, Es), which are the lowest value of Ei.

Fifth, the most strict value among the stations (Es.min) is defined as the limit of "Lower than the Standard" and "Possibly Lower than the Standard," while the half of Es.min is the limit of "Lower than the Standard" and "Much Lower than the Standard."

The average of Es(j) is defined as the limit of "Possibly Lower than the Standard" and "Possibly Higher than the Standard."

The highest value of Es(j) (hereinafter, Es.max) is the limit of "Higher than the Standard" and "Possibly Higher than the Standard." Double of Es.max is the limit of "Higher than the Standard" and "Extremely Higher than the Standard."

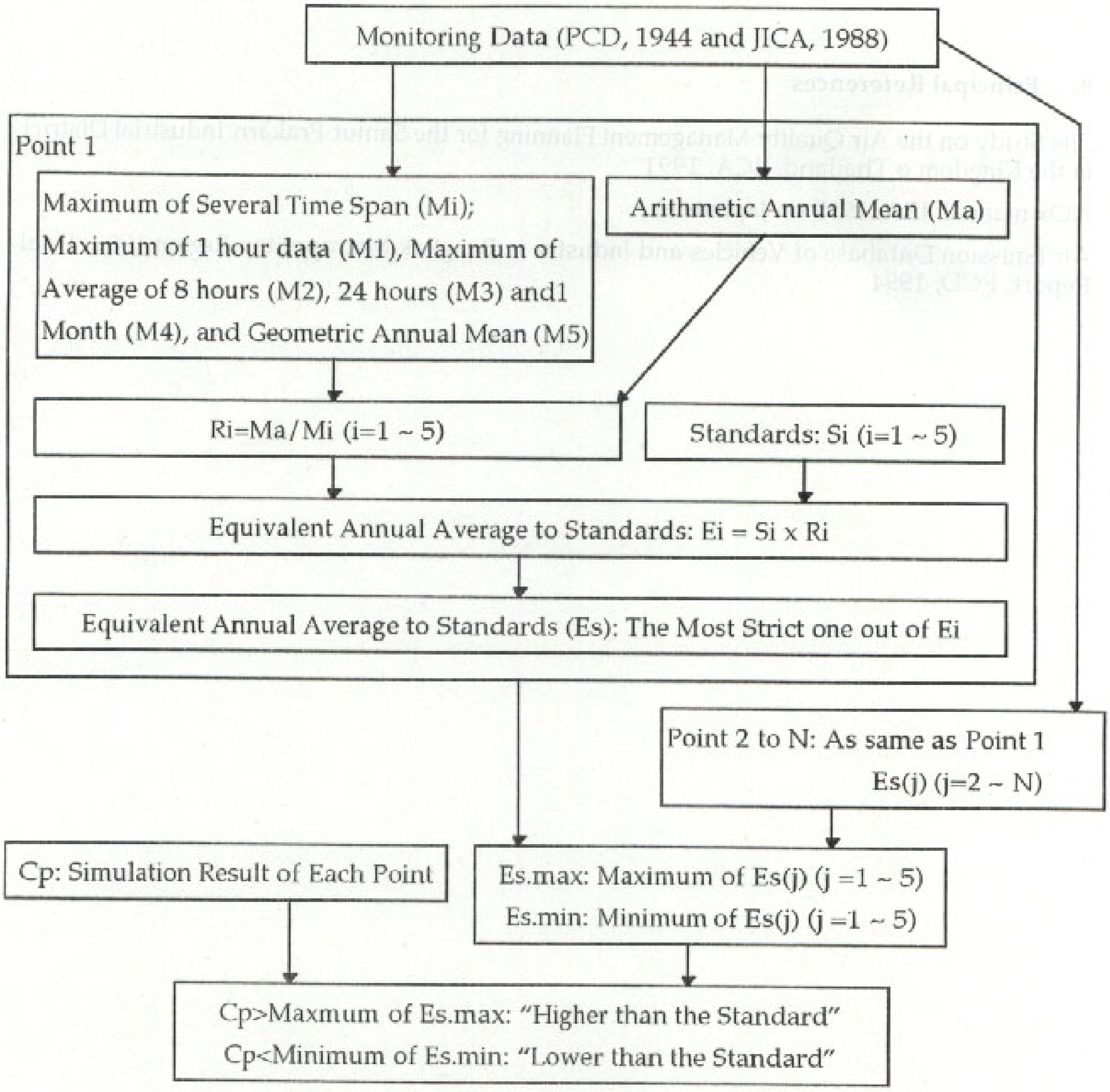


Fig. AP-2.9 Flow Chart of Comparison of Simulated Annual Average to Air Standards

9. Principal References

The Study on the Air Quality Management Planning for the Samut Prakarn Industrial District in the Kingdom o Thailand, JICA, 1991

NOx manual, JEA, 1993 (in Japanese)

Air Emission Database of Vehicles and Industry in Bangkok Metropolitan Region 1992, Final Report, PCD, 1994

JICA