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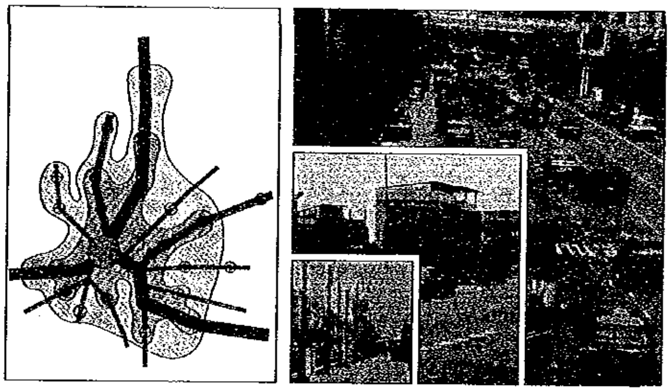
THE STUDY ON MEDIUM TO LONG TERM IMPROVEMENT/MANAGEMENT PLAN OF ROAD AND ROAD TRANSPORT IN BANGKOK IN THE KINGDOM OF THAILAND

FEASIBILITY STUDY ON AREA TRAFFIC CONTROL SYSTEM

MAIN REPORT



MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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FEASIBILITY STUDY ON AREA TRAFFIC CONTROL SYSTEM MAIN REPORT
MARCH 1990
JAPAN INTERN. COOPERATION

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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Study on Medium to Long-term Improvement/Management Plan of Road and Road Transport in Bangkok and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Dr. Juro Kodera, and comprising of members from Yachiyo Engineering Co., Ltd., International Engineering Consultants Association and Almec Corporation from November, 1988 to March, 1989 and from May, 1989 to January, 1990.

The team held discussions with concerned officials of the Government of Thailand, and conducted field surveys. 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 realization of the project and the enhancement of friendly relations between our two countries.

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

March, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

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INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background

The Bangkok Metropolitan Area which covers approximately 1,600 square kilometers of land is basically serving as the socio-economic center of Thailand. Its population in 1989 stands at 6.29 million which corresponds to 10% of the national population and is growing at an annual rate of about 2.8%.

In parallel with the rapid urban growth, the motorization of Bangkok progressed at a fast pace from the 1970's. At present there are 820,000 motorcycles and 970,000 automobiles in the Bangkok Metropolitan Area, and these figures are forecast to increase by 2.0 and 2.3 times respectively in the year 2006.

On the other hand, the road network development cannot keep abreast of the growing motorisation and, consequently chronic traffic congestion is observed at CBD and on arterials despite the efforts to construct elevated roads and grade separated intersections.

Roughly 200 intersections in the Bangkok Metropolitan Area-- including all major intersections-- are currently signal-controlled. Of these, 47 intersections, most of which are located in the Old City, are subject to a computer-controlled ATC system. Although the OCMRT had been operating the ATC system since March 1979, responsibility for the operation of the system was subsequently transferred to the BMA. Simply extending this system to the entire Bangkok Metropolitan Area, where signals are currently manually controlled, is expected to have little effect in improving traffic flow in the area, as the existing system are considered to be unsuitable for the purpose.

Meanwhile, since the existing road network is cause and believed to be inadequate for alleviating traffic congestion in Bangkok, the construction of additional roads is believed to be necessary. At the same time, it should be possible to alleviate congestion still further by applying more efficient traffic control plans to the new road network that will result from the completion of ongoing projects.

For these reasons, it would be desirable to make a fresh study of traffic systems and control concepts in order to introduce the most effective techniques for managing traffic in the Bangkok Metropolitan Area.

In response to the request of the Kingdom of Thailand, to try to improve the circumstances described above, the Government of Japan has decided to extend technical cooperation for the Feasibility Study on Area Traffic Control System in Bangkok (hereinafter referred to as the Study). The Japan International Cooperation Agency (hereinafter referred to as JICA), which is the official agency responsible for the implementation of the technical cooperation programs of the Japanese Government, sent a preliminary survey mission in April 1988 to conduct a reconnaissance survey and to conclude the scope of works for the Study, which was subsequently agreed upon between the Bangkok Metropolitan Administration (hereinafter referred to as BMA) and JICA. The Study Team commenced the Study in November, 1988.

1.2 Objective

The objective of this Study is to formulate a plan for the improvement and expansion of the Area Traffic Control System (ATC System) coping with the heavy traffic congestion in the urban road network of Bangkok.

The Study area consists mainly of the area within the Middle Ring Road, as shown in Fig. 1.2.1.

1.3 Study Approach

This Study was carried out in two (2) Stages for a total of ten (10) months. The work flow is shown in Fig. 1.3.1, and the activities are briefly described below;

1) Stage 1

In this stage, by reviewing available data, making observations on current conditions and analyzing traffic survey results, the problems related to the ATC system in particular were evaluated and organized in a relevant manner.

The area to be covered by the ATC system and the intersections to be controlled by the ATC system were selected by taking into account future growth of the metropolitan area and the expected increase of congested sections.

Based on the current traffic conditions and problems identified, a traffic control plan and a basic ATC system concept were formulated.

2) Stage 2

During the second stage of the Study, the overall composition of the ATC system was studied in terms of the equipment required to fulfill the functions determined by the basic concept. A preliminary design of the system was planned on the basis of the basic concept.

The project cost was estimated on the basis of the preliminary design, and implementation methods were studied.

In order to evaluate the effectiveness of the ATC system in controlling traffic, the total vehicle operating cost (VOC) and travel time cost (TTC) were estimated. In addition, an implementation program for the recommended plan was evaluated on the basis of economic analyze.

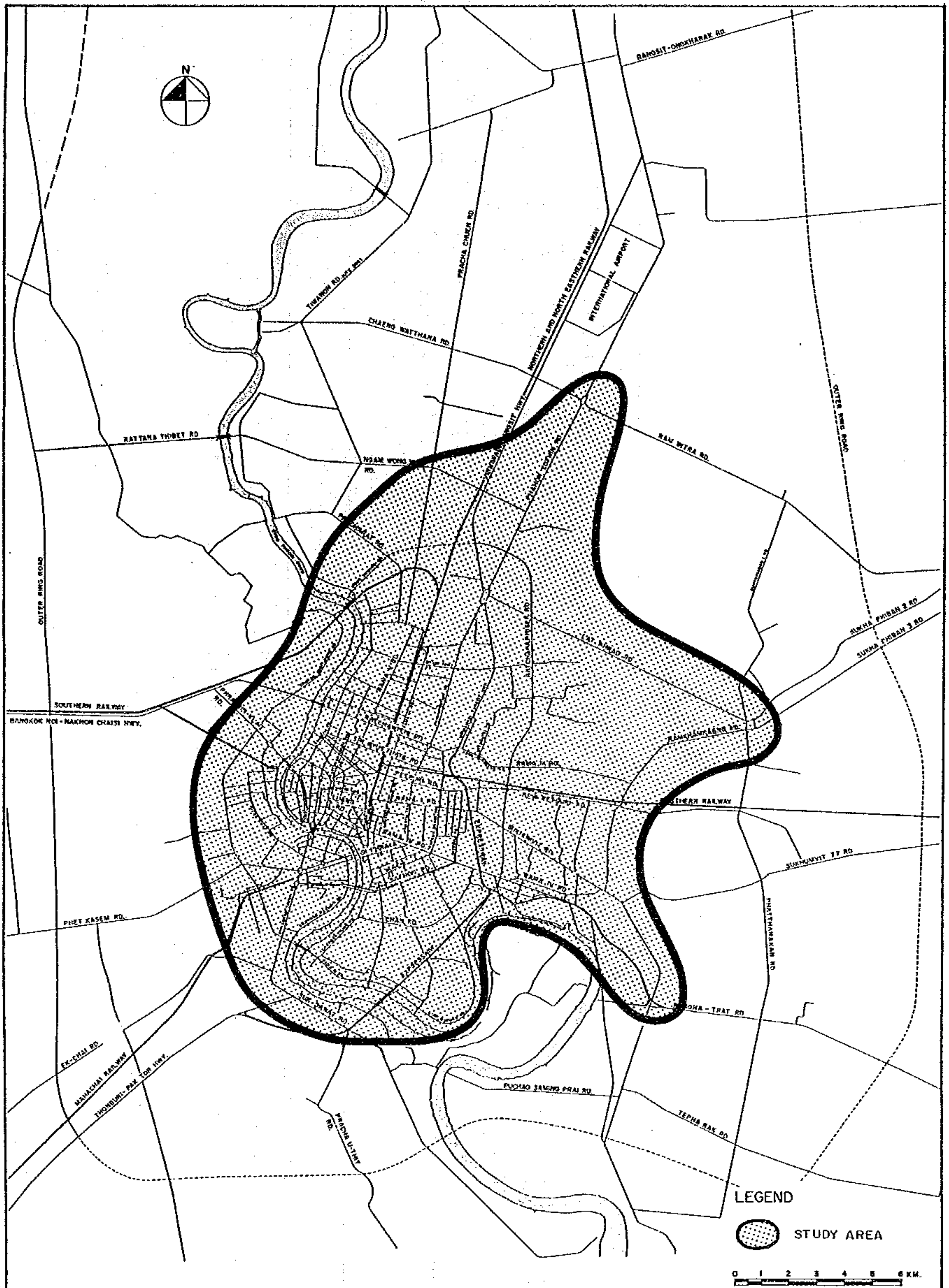

Fig. 1.2.1 Study Area

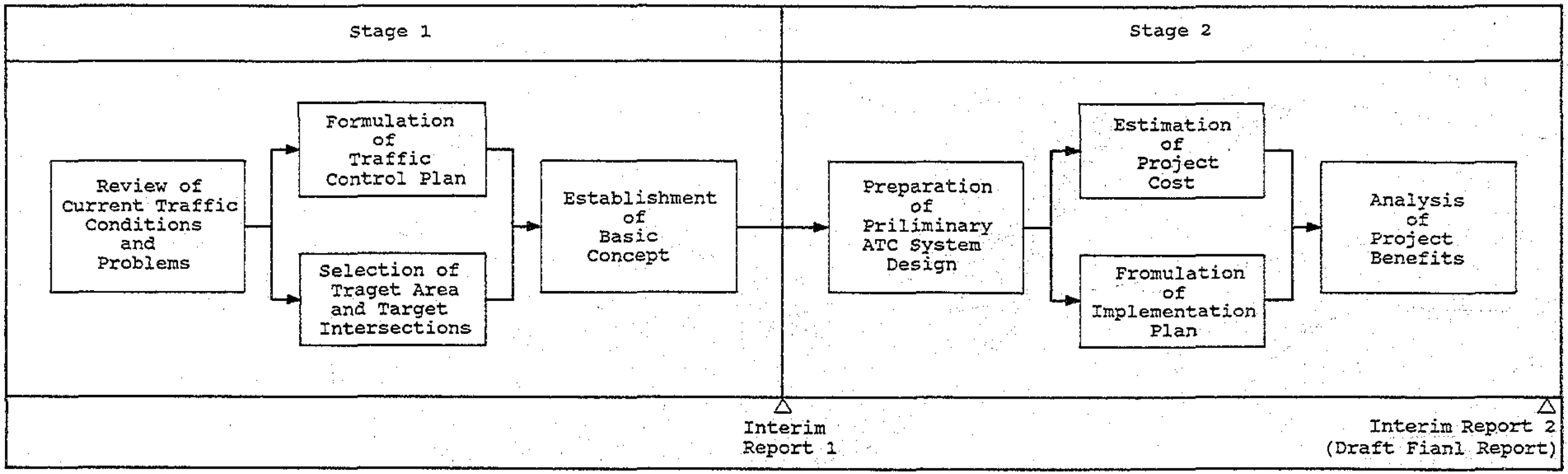

Fig. 1.3.1 Work Flow of the Study

1.4 Study Organization

The Study was carried out in Thailand jointly by JICA and the related agencies of the Government of the Kingdom of Thailand.

The Study organization is shown below. (Fig. 1.4.1)

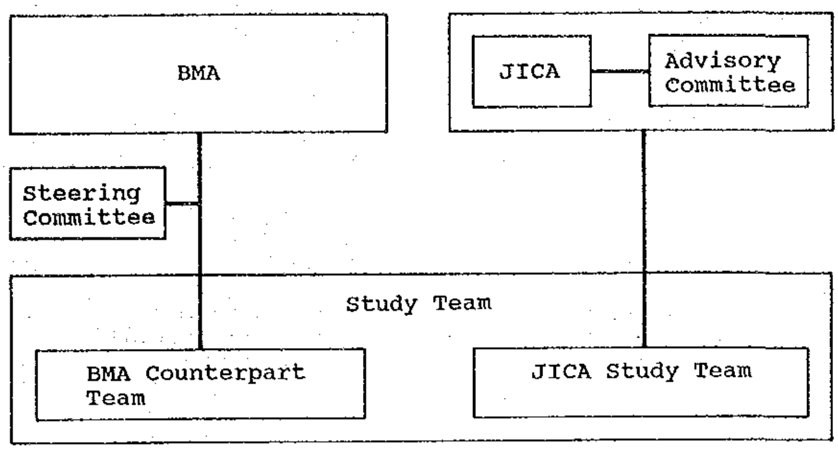

Fig. 1.4.1 Study Organization

Table 1.4.1 List of Members for the Study

<THAI SIDE>

Steering Committee (SIMR)

Dr. Wicha Jiwalai	Deputy Governor, BMA
Mr. Prasert Samalapa	Deputy Permanent Secretary, BMA
Mr. Bamphen Jatoorapreuk	Director, PWD, BMA
Mr. Chalit Sathon	Deputy Director, PWD, BMA
Mr. Charuay Chantavali	Deputy Director, PWD, BMA
Mr. Suwat Wanisubut	Chief, PTSD, NESDB
Mr. Pallop Onkcharoen	Director, ED, DTCP
Dr. Kitipol Asaparporn	Director, TED, DOH
Mr. Rapin Charudul	Civil Engineer, OPP, MOI
Mr. Anuchit sotsathit	Director, PPD, BMA
Pol.Maj.Gen.Charoen Chottidamrong	Metropolitan Police Bureau
Dr. Teerapong Attajarusit	Director, TD, ETA
Mr. Worawit Lertlaksana	Deputy Director-General, PWD, MOI
Mr. Prakob Iumdilokwong	Director, TPD, DLT
Mr. Wanich Pansuwan	Deputy Chief, SRT
Dr. Visnu Palayanon	Electrical Engineer, MEA
Mr. Chamras Sindhuwongse	Director, PD, MWA
Mr. Ong-Aj Pulthavee	Chief, NSED, TOT
Mr. San Trachoo	Director, PWD, BMA
Miss Aporn Chancharoensuk	Director, CPD, BMA
Mr. Boonyawat Tiptus	Director, TED, BMA
Mr. Wisut Panutat	Director, PWD, BMA
Mr. Nikhom Prachnakorn	Director, PWD, BMA
Mr. Thanit Srichoo	Civil Engineer, PWD, BMA
Mr. Suphot Phongkidakarn	Director, PWD, BMA
Mr. Orawit Hemachudha	Civil Engineer, PWD, BMA
Mr. Chailert Panchathewakup	Civil Engineer, PWD, BMA

* As of January 1990, Professor Krisda Arunvong participated upon succeeding Dr. Wicha Jiwalai as Deputy Governer.

Road Network Sub-Committee (MP)

Mr. Bamphen Jatoorapreuk	Director, PWD, BMA
Mr. Chalit Sathon	Deputy Director, PWD, BMA
Mr. Worawit Lohthong	Director, PWD, BMA
Mr. Wisut Panutat	Director, PWD, BMA
Mr. Sa-Ngium Mingmani	Civil Engineer, DTCP
Dr. Suwat Wanisubut	Chief, PTSD, NESDB
Mr. Worawit Lertlaksana	Deputy Director-General, PWD, MOI
Mr. Prachum Tanticharoen	Engineering Division, SRT
Mr. Vichit Vatcharin	Director, TPD, ETA
Mr. Bancha Vadhanasindhu	Civil Engineer, Planning Division,DOH
Mr. Pramote Suriya	Civil Engineer, OPP, MOI
Mr. San Trachoo	Director, DDS, BMA
Mr. Kasamesanta Suwannarath	Director, DPP, BMA
Mr. Boonyawat Tiptus	Director, TED, BMA
Miss Aporn Chancharoensuk	Director, CPD, BMA
Dr. Wongchai Charoensawan	Civil Engineer, DOH
Mr. Thanit Srichoo	Civil Engineer, PWD, BMA
Mr. Oravit Hemachudha	Civil Engineer, PWD, BMA
Mr. Suphot Raveesaengsoon	Civil Engineer, PWD, BMA

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Pol. Col., Sanong Kittayaban	Metropolitan Police Bureau
Assoc. Prof. Kanchit Phewnuan	Chulalongkorn University
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Dr. Teerapong Attajarusit	Director, TD, ETA
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Mr. Suppachai Tangsriwong	Chief, TED, BMA
Mr. Orawit Hemachuda	Civil Engineer, PWD, BMA

Common Utility Duct Sub-Committee

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Pol.Maj.Gen. Narong Rianthong	Deputy Commissioner, MPB
Mr. Jim Phanthumkomol	Chief, PWD, BMA
Mr. Wisut Panutat	Director, BMA
Mr. Samak Thanwanon	Chief, PWD, BMA
Mr. San Trachoo	Director, DDS, BMA
Mr. Palakorn Suwannarath	OPP,MOI
Mr. Kasamesanta Suwannarath	Director, DPP, BMA
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Mr. Ong-Aj Pultavee	Chief, NSED, TOT
Mr. Suthi Paritpokee	Director, NGTSD, PAT
Mr. Seksun Loylapcharoenporn	Assistant Director, DPD, CAT
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Mr. Niphon Noeymuangpak	Civil Engineer, PWD, BMA

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Mr. Hideaki Araki	Ministry of Construction
Mr. Shin-ichi Ishikawa	Ministry of Construction
Mr. Naofumi Takeuchi	Ministry of Construction
Mr. Michimasa Ikeda	Ministry of Construction

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Dr. Juro Kodera	Team Leader
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Mr. Tetsuo Wakui	Transport Planning
Mr. Masato Kotoh	Public Transport Planning
Mr. Katsumi Imamura	Transport Survey (I)
Mr. Tetsuo Horie	Transport Survey (II)
Mr. Kimio Kaneko	Traffic Management (I)
Mr. Seichi Horie	Traffic Management (II)
Mr. Kenji Takenaga	Signal Control
Mr. Yoshio Yoshida	System Analysis
Mr. Saburo Shimauchi	Systems Design/Cost Estimate
Mr. Shizuo Iwata	Road Planning
Mr. Tsutomu Horie	Road Design
Mr. Katsunori Fuse	Structure Planning/Design (I)
Mr. Kenji Miwa	Structure Planning/Design (II)
Mr. Iwane Mizuno	Economic Analysis
Mr. Akio Miyachi	System Planning
Mr. Setsuo Ninomiya	Common Utility Duct Planning

Table 1.4.2 List of Abbreviations

ROAD PLAN

BB	Budget Bureau
BCD	Building Control Division
BMA	Bangkok Metropolitan Administraion
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Mass Transit Authority
BTS	Bangkok Transportation Study in 1975
BTSS	Bangkok Transit System Study in 1986
B/C	Benefit Cost Ratio
CAB	Cabinet
CCSD	Construction Control and Supervision Division
CMD	Construction and Maintenance Division
CMRT	Committee for the Manegement of Road Traffic
CPD	City Planning Division
DD	Design Division
DLT	Department of Land Transport
DOH	Department of Highway
DPP	Department of Policy and Planning
DPW	Department of Public Works
DTCP	Department of Town and Country Planning
ETA	Expressway and Rapid Transit Authority of Thailand
ETO	Express Transportation Organization of Thailand
FSE	First Stage Expressway
GDP	Gross Domestic Product
GRP	Gross Regional Product
HD	Harbor Department
HRT	Heavy Rail Transit
KSS	Elevated Toll Road above Klong Saen Saep
LRT	Light Rail Transit
LTCB	Land Transport Control Board
LTPC	Land Transport Polocy Committee
MOC	Ministry of Communication
MOF	Ministry of Finance
MOI	Ministry of Interior
MPB	Metropolitan Plice Bureau
MSTE	Ministry of Science, Technology and Energy
NESDB	National Economic and Social Development Board
NPV	Net Present Value
NSC	National Safety Council
OCMRT	Office of the Committee for the Management for Road Traffic
OFP	Office of Fiscal Policy
ONEB	Office of the National Environmental Board
OPM	Office of the Prime Minister
OPP	Office of the Policy and Planning
OPS	Office of the Permanent Secretary (BMA)
PCU	Passenger Car Unit
PD	Police Department
PT	Person Trip
PWD	Public Works Department
RWLD	Right of Way and Land Acquisition Division
SRT	State Railway of Thailand
SSE	Second Stage Expressway
STTR	Bangkok Metropolitan Short Term Transport Review
TD	Treasury Department
TED	Traffic Engineering Division
TPD	Traffic Police Division
TSES	Third Stage Expressway System
TTC	Travel Time Cost
VOC	Vehicle Operationg Cost

ATC SYSTEM

ATC	Area Traffic Control
BMA	Bangkok Metropolitan Administration
CCU	communication Control Unit
DET	Vehicle Detector
ETA	Expressway and Rapid Transit Authority of Thailand
FHWA	Federal Highway Administration
FSR	Frequency Shift Keying
GRM	Synchrinous Response Mode
MDF	Main Distribution Frame
MEA	Metropolitan Electricity Authority
OCMRT	Office of the Committee for the Management for Road Traffic
PCM	Pulse Code Modulation
PP	Pre-Processor of Vehicle Detector
PSK	Phase Shift Keying
SCAT	Sydney Highway Administration
TOT	Telephone Organization of Thailand
TTC	Travel Time Cost
TTR	Terminal Transmitter-Receiver
UTCS	Urban Traffic Control System
VA	Vehicle-Actualed
VOC	Vehicle Operating Cost

CUD SYSTEM

AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standard Code for Pressure Piping
BMA	Bangkok Metropolitan Administration
CAB	Cable Box
CAT	Communication Authority of Thailand
CBD	Central Business District
CMD	Cubic Meter per Day
CUD	Common Utility Duct System
DDS	Department of Drainage and Sewerage, BMA
EGAT	Electricity Generating Authority of Thailand
ETA	Expressway and Rapid Transit Authority of Thailand
KV	Kilovolt
MEA	Metropolitan Electricity Authority
MTS	Mass Transit System
MVA	Megea-Volt Ampere
MWA	Metropolitan Water Works Authority
NESDB	National Economic and Social Development Board
PTT	Ptroleum Authority of Thailand
PVC	Polyvinylchloride
SRT	State Railway of Thailand
TOT	Telephone Organization of Thailand

2

CURRENT TRAFFIC CONDITION

CHAPTER 2 CURRENT TRAFFIC CONDITIONS

2.1 Field Surveys Outline

2.1.1 Types of Surveys Conducted

In connection with the Traffic Management Plan and ATC System Plan, the following field surveys were conducted in order to obtain basic data needed to understand current traffic conditions and to plan for improvements:

a) Intersection and road cross section vehicular traffic volume survey
b) Travel time survey
c) Queue length survey
d) Parking survey
e) Saturation flow survey
f) Intersection and traffic control facility survey

2.1.2 Survey Outline and Purpose

The surveys listed above were conducted as outlined in Table 2.1.1, at the locations indicated in Fig. 2.1.1. The main objectives of these surveys are described below.

Table 2.1.1 Field Survey

Type of survey	Content	Area & Location	Method
Traffic Road side	. Vehicle type(8)	18 Locations	14 Hour:16 Locations
Volume	. Directions		24 Hour:2 Locations
Survey Intersection	. Vehicle type . Directions	20 Intersections	14 Hour:19 Intersections 24 Hour:1 Intersections
Queue Length Survey	. Queue length at intersection	20 Intersections	7:00-9:00 16:00-18:00
Travel Time Survey	. Link travel time . Peak hour . Average time of 3 round trips	31 Routes	7:00-9:00 16:00-18:00
Parking Survey	. No. of on-street parking vehicle . By hour	All old town	

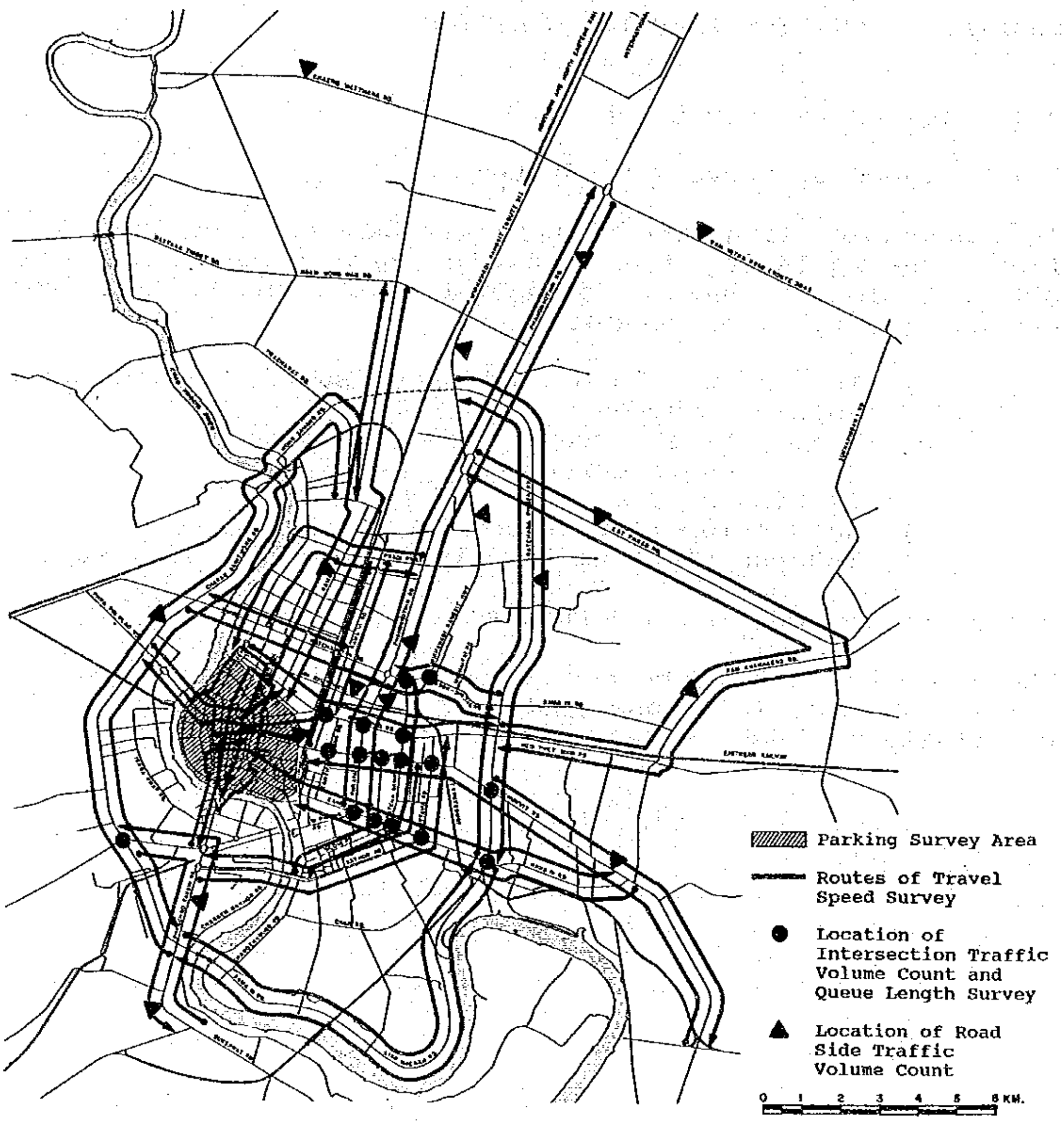


Fig. 2.1.1 Survey Location

a) Intersection and Road Cross Section Vehicular Traffic Volume Survey

This survey was conducted to obtain data on vehicular traffic volumes at major intersections and road cross sections. Its main purpose was to provide data for comparison with the 1985 JICA Study and to investigate any increases in traffic volume. Items studied include traffic volume, hourly fluctuation, vehicle type composition, and turning movement.

b) Travel Time Survey

This survey was conducted to obtain data on travelling speeds on major roads. It main purpose, as in the traffic volume survey, was to provide data for comparison with the 1985 JICA Study and to investigate the speed distribution. Items studied include reasons for congestion and/or stoppage.

c) Queue Length Survey

This survey was conducted to obtain data on queue lengths at major intersections. It covered those intersections where major changes are recognized to have occurred since the last JICA Study--i.e. major intersections on one-way east-west arterial roads. Items studied include maximum queue length by time period.

d) Saturation Flow Survey

This survey was conducted as a basis for studying control logic, one-way systems and other matters. Data were collected through video recordings in order to simulate saturation flow rates and other conditions at intersections. Items studied include simulation parameters.

e) Intersection and Traffic Control Facility Survey

This survey was conducted as a basis for studying flow control including one-way systems. Items studied include signal phasing and number of lanes at major intersections and traffic regulations and safety facilities within the Study Area.

2.2 Road Network

Fig. 2.2.1 shows the current network of major roads in the Bangkok Metropolitan Area. Several arterial roads radiate outwards from the city center, which is served by a grid pattern network of roads. These radial roads are traversed by the Middle Ring Rd and the Outer Ring Rd The 4.5km section at the northern tip of the Middle Ring Rd (about 8.5km east to west and 14km north to south) and its 2.7km section in the southwestern area have not been completed as yet. The remaining sections are in operation as a circumferential road serving traffic in the urban area.

There are five east-west arterial routes and seven north-south arterial routes that serve traffic within the area circumscribed by the Middle Ring Rd The east-west arterials are Ratchawithi Rd- Asok Din Daeng Rd, Phetcha Buri Rd- New Phetcha Buri Rd, Sukhumvit Rd, Rama IV Rd and Sathon Rd. The north-south arterials are Vibhavadi Rangsit Rd, Ratchadamri Rd-Ratchaprarop

Rd, Phaya Thai Rd-Phahon Yothin Rd, Charu Muang Rd-Rama VI Rd, Sawankhalok Rd-Pracha Ahuen Rd, Rama V Rd, and Somdet Phra Chao Taksin Rd-Ratchadamnoen Nok Rd In addition, the ETA Expressway spreads northward and southward from the city center.

Road network in the urban area is composed largely of arterial roads. There are only a few semi-arterial roads giving access to areas between these arterials, while there are a large number of small streets called soi that run parallel to the arterials and end in deadends. Owing to the sparsity of roads comprising the network, links between intersections tend to be long.

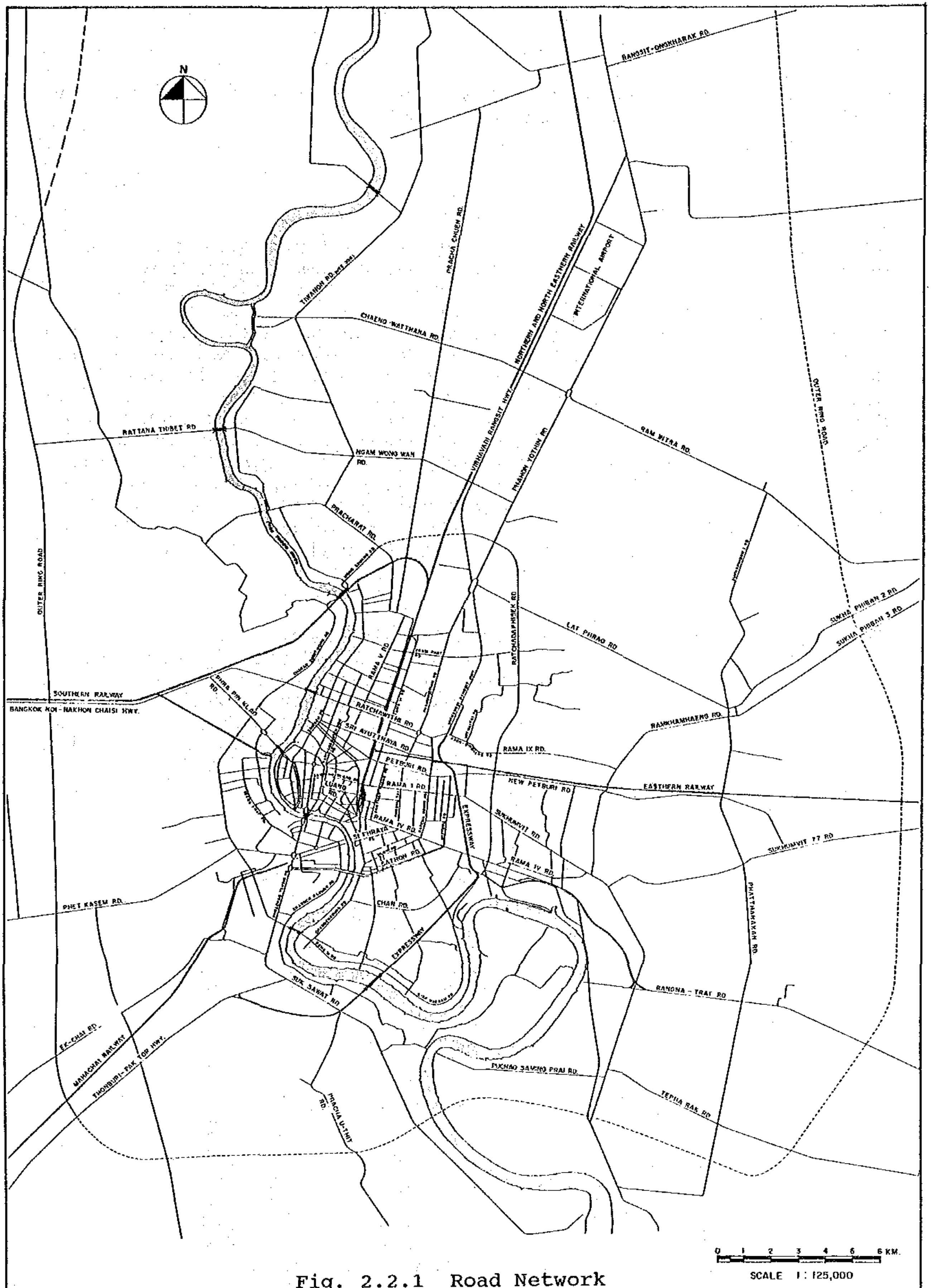


Fig. 2.2.1 Road Network

2.3 Vehicular Traffic Flow

Conditions pertaining to the flow of vehicular traffic within the Study Area in 1989 are discussed below.

2.3.1 Traffic Volume

1) 12-hour Volume

As shown in Table 2.3.1, two-way traffic volumes during a 12-hour period on arterial roads in the Planning Area range from 30,000 to 126,000 pcu. Vibhavadai Rangsit Rd has the highest volume, at about 126,000 pcu. The next highest volumes are seen on the roads that comprise the arterial road network in the city center--Din Daeng Rd, Petburi Rd, Rama IV Rd, Sukhumvit Rd, Phaya Thai Rd, and Ratcha Damnoen Klang Rd--at 70,300 - 81,600. In addition, Sathon Rd, Phahon Yothin Rd, Rama VI Rd, and Ratchaprarop Rd have volumes ranging from 42,900 to 65,500. Two-way 12-hour volume on the Middle Ring Rd, which circumscribes the city center, is 25,000 - 60,500--which is relatively low owing to the existence of several sections that have not been built yet. Thus, it can see that a large volume of vehicular traffic converges on the area surrounded by Rama IV Rd, the Middle Ring Rd, Din Daeng Rd, Ratchawithi Rd, and Chao Phraya River.

2) Peak-hour Volume

Two-way traffic volumes during a morning peak hour on arterial roads in the Planning Area vary between 2,500 and 12,000 pcu, as shown in Table 2.3.1. The highest volume (12,000) is seen on Vibhavadi Rangsit Rd, which is an expressway for exclusive motor vehicle use. Peak-hour volume per lane is roughly 1,500 pcu. Two-way peak-hour volumes on arterial roads serving the city center range between 3,300 and 7,700, with peak-hour volume per lane as high as 600 - 900 pcu, indicating conditions of saturation.

Table 2.3.1 Traffic Volume on Major Roads (1989)

PCU/12H for both directions

Road	Range of Volume 12 Hour	Range of Volume Peak Hour
Vibhavadi Rangsit	116,300 - 126,300	9,300 - 12,000
Petburi	23,400 - 81,600	2,200 - 7,200
Rama IV	43,600 - 80,900	3,900 - 6,800
Sukhumvit	38,500 - 79,100	3,200 - 7,700
Din Daeng	53,900 - 73,700	4,800 - 7,700
Phaya Thai	41,300 - 72,800	3,000 - 7,000
Ratchadamnoen Klang	70,300	6,700
Sathon	65,500	4,600
Ratchadaphisek	49,200 - 60,500	2,900 - 3,900
Phahon Yothin	40,700 - 57,100	2,900 - 4,700
Somdet Phra Chao Taksin	- 54,500	4,700
Rama VI	37,900 - 54,000	3,200 - 4,100
Suksawat	- 55,000	4,900
Charan Sanitwongse	- 52,000	6,600
Ratchaprarop	42,400 - 50,200	3,300 - 3,700
Witthayu	32,000 - 49,500	2,400 - 4,600
Sukhumvit 21	31,700 - 48,200	2,400 - 3,200
Ratchawithi	31,400 - 43,200	2,600 - 3,300
Lat Phrao	- 42,900	3,300
Henri Dunant	33,900 - 38,900	3,000 - 3,100
Rama V	- 29,900	2,500

SOURCE: SIMR

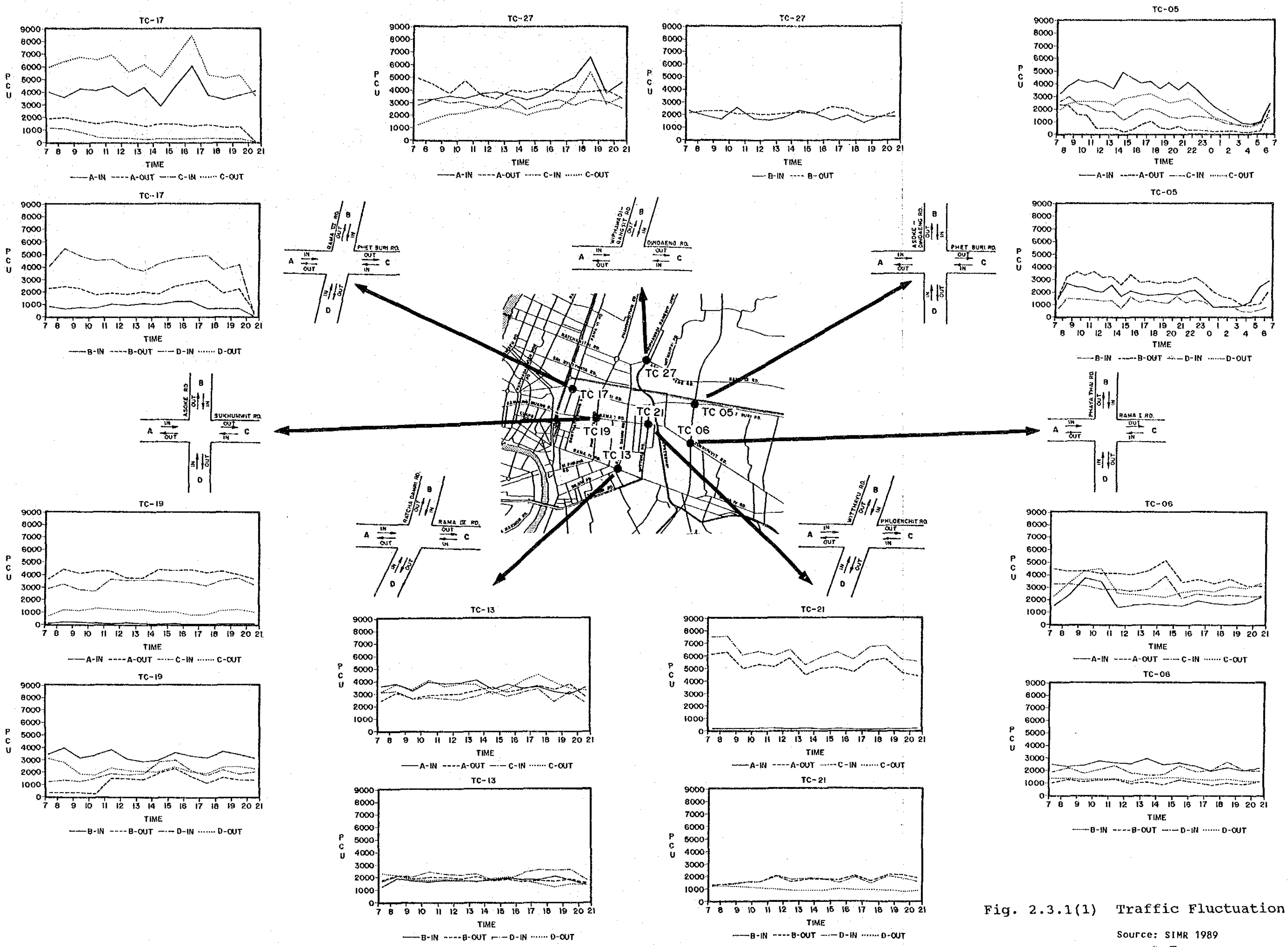


Fig. 2.3.1(1) Traffic Fluctuation

Source: SIMR 1989

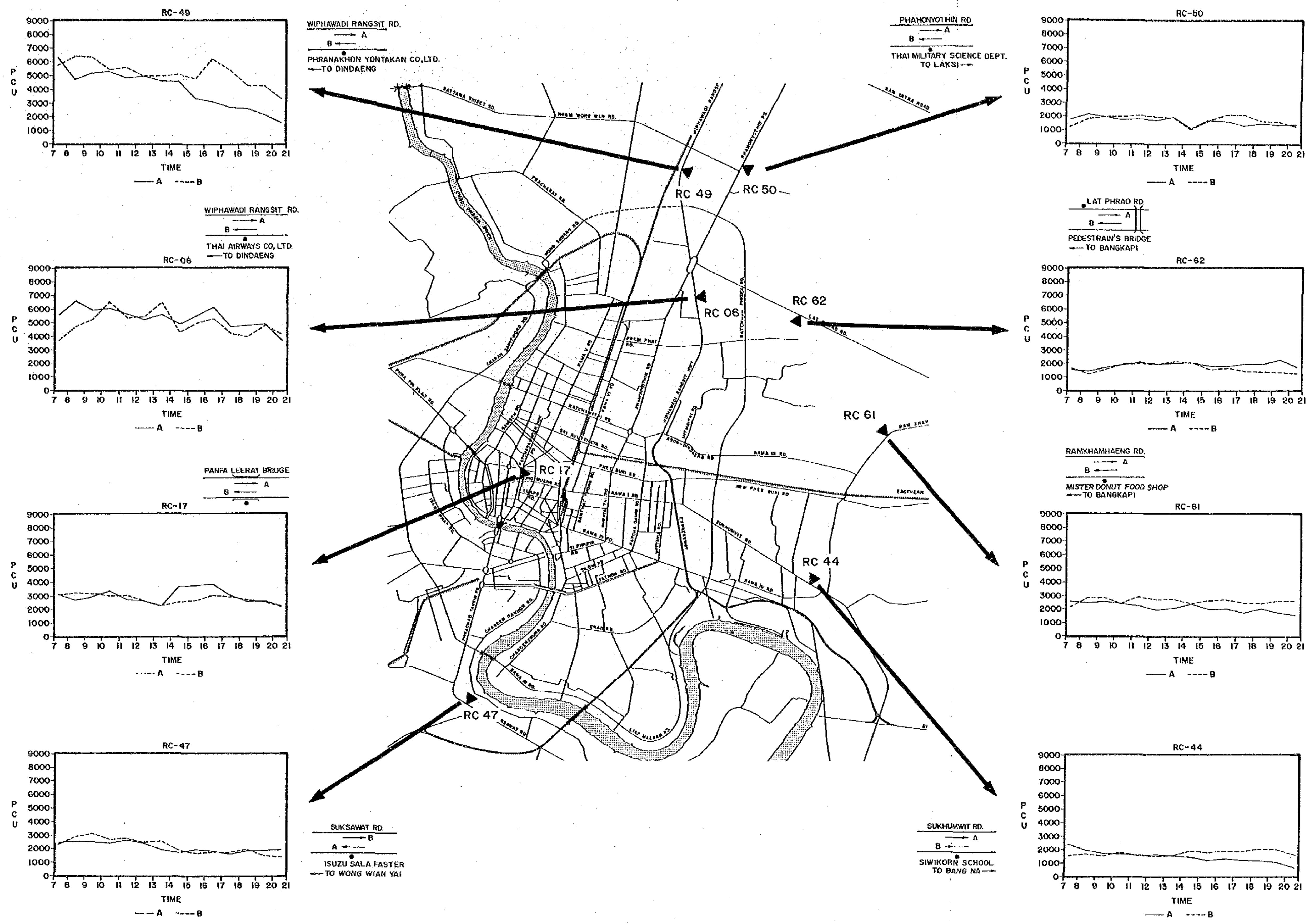


Fig. 2.3.1(2) Traffic Fluctuation

Source: SIMR 1989

3) Hourly Fluctuation

Fig. 2.3.1 shows the hourly fluctuations of traffic volumes on major roads in the Planning Area. The fluctuation patterns shown in the figure are complicated and vary widely. Peak hours generally occur during 7:00 - 9:00 in the morning, 13:00 - 14:00 in the afternoon, and 16:00 - 18:00 in the evening. Especially large fluctuations are seen from morning to afternoon owing to changes in traffic congestion that occur during business hours.

To see how traffic volumes fluctuate during a week, quarter-hourly fluctuations of traffic volume on ETA - Soi 3 section of Sukhumvit Rd during the morning peak hours were charted for each day of the week as shown in Fig. 2.3.2. As the figure indicates, traffic volumes vary greatly depending on the day of the week. A highly effective way of controlling traffic flow on roads where volume fluctuates in such a complicated manner would be the responsive signal control by detecting changes as they occur and adopting the control method that best suits the condition at hand.

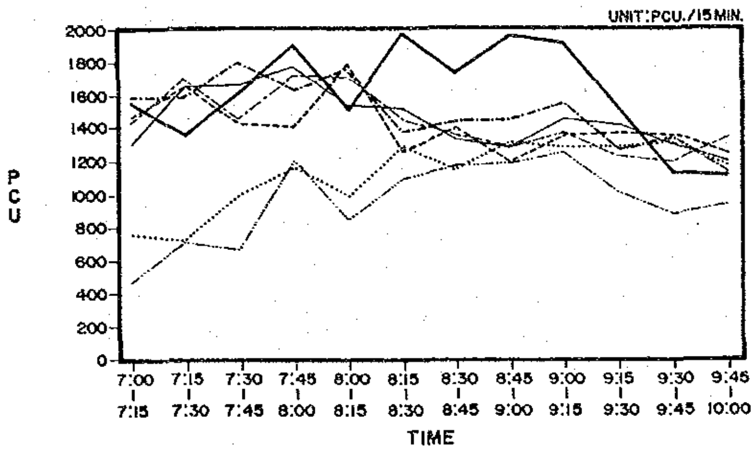


Fig. 2.3.2 Traffic Fluctuation During A Week (1)
(Section ETA-Soi3 on Sukhumvit Road, Inbound)

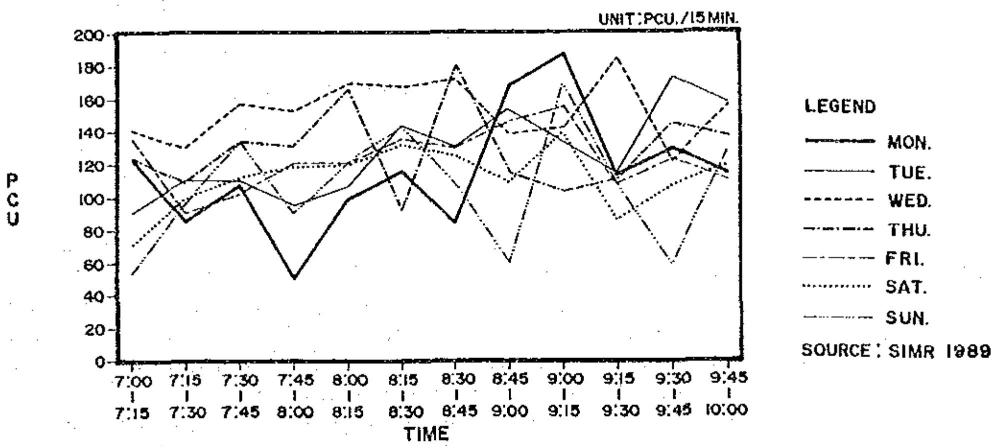


Fig. 2.3.2 Traffic Fluctuation During A Week (2)
(Section ETA-Soi3 on Sukhumvit Road, Outbound)

4) Intersection Saturation Degree

Fig. 2.3.3 shows the saturation degree of intersections covered by the recent intersection traffic volume survey. Of the 20 intersections surveyed, intersections other than Middle Ring Rd - Petburi intersection (TC05), Middle Ring Rd - Rama IV intersection (TC09), the Rama IV - Phaya Thai intersection (TC14), Rama IV - Sathon intersection (TC12), Rama IV - Silom Rd intersection (TC13), Petburi - Rama VI intersection and Ratchada - Phet Kasem intersection (TC 29) all showed saturation degrees of more than 1.0. The values ranged from 1.02 to 1.71, indicating that these intersections are oversaturated.

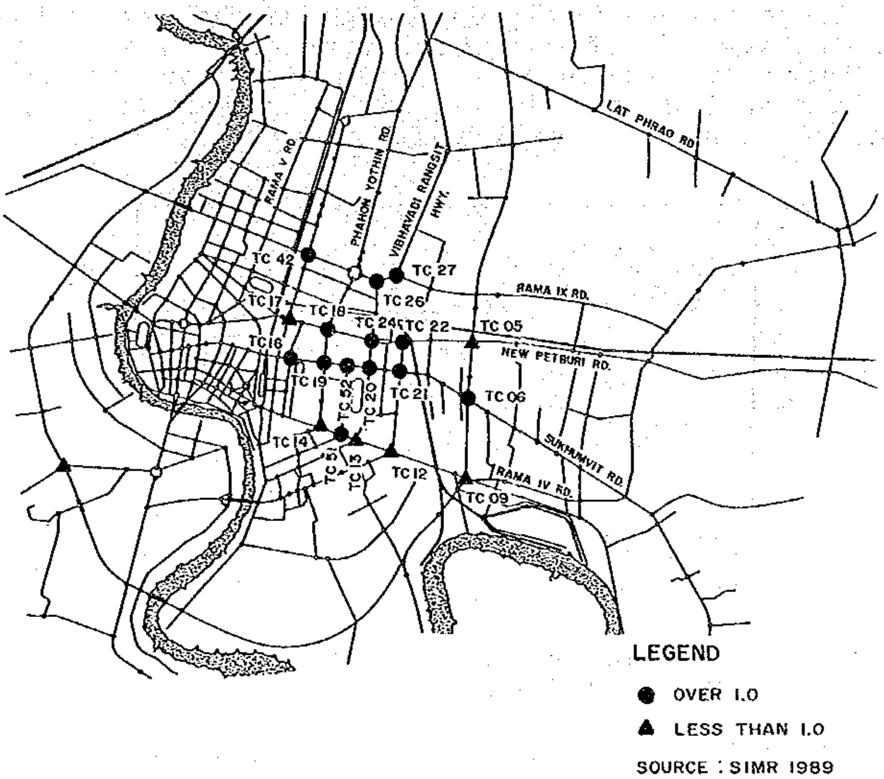
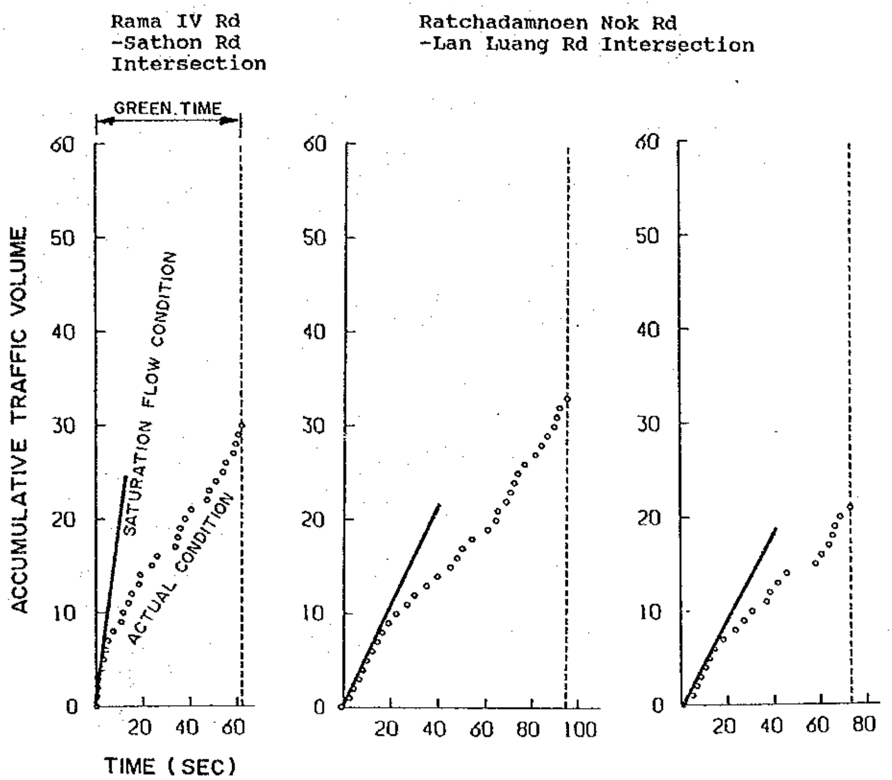


Fig. 2.3.3 Saturation Degree

5) Saturation Flow

At present, nearly all signalized intersections are controlled manually by traffic policemen. Under this method, it is difficult to respond effectively to slight changes in traffic conditions and waiting time is increased at many intersections. Fig. 2.3.4 shows a sample result of a video analysis conducted on traffic flow at signalized intersections which are thought to be saturated. In the analysis, the headway of vehicles passing through the intersection stop line was recorded by approach and by cycle length and compiled into a time-cumulative volume curve.

The results indicate that the allotted green time is not being used efficiently, and it should be possible to correct this situation by adjusting the signal split such as split control mehod, thus improving the overall capacity of the intersection. The current signal control system can be improved in these and various other ways. It is believed that capacity can be increased by detecting changes in traffic conditions on an ongoing basis and adapting signal control to the condition at hand.



Source: *SIMR 1989*

Fig. 2.3.4 Sample Result of Video Analysis Conducted on Traffic Flow

6) Growth Factor in Traffic Volume

To see how traffic volumes have increased over the past four years, the results of the 1985 JICA Study and those of the 1989 field survey were compared. Growth factors on major road in and around the Planning Area are shown in Fig. 2.3.5. Growth factors in Old Bangkok, which is bordered by Krung Kasem Rd and Chao Phraya River, and in the Thonburi district are roughly 0.9 each, indicating that traffic volumes have decreased. The congested area bordered by Chao Phraya River, Thahran Rd, Sutthisan Winit Chai Rd, Middle Ring Rd and Satoh Rd shows an increase factor of roughly 1.1, indicating that traffic volume has grown by 10%. The highest increase factor, 1.50, is seen in the city's northern area near the Middle Ring Rd, while the western area on the outside of the Middle Ring Rdand the eastern area show increase factors of 1.2 and 1.3 respectively. Thus, traffic volume in the area where congestion is the most severe has not increased appreciably over the past four years.

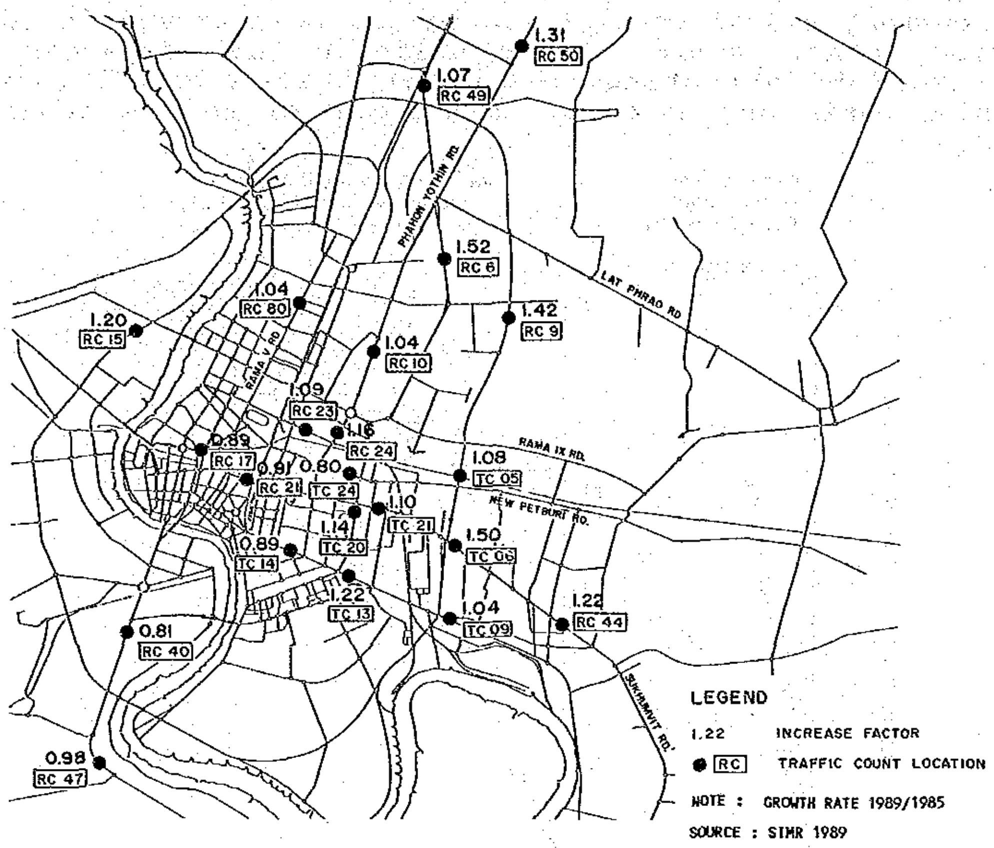


Fig. 2.3.5 12 Hours Traffic Growth Factor

2.3.2 Travel Speed

Fig. 2.3.6 shows the distribution of travel speed by road section during the morning and evening peak hours.

1) Morning Peak Hours

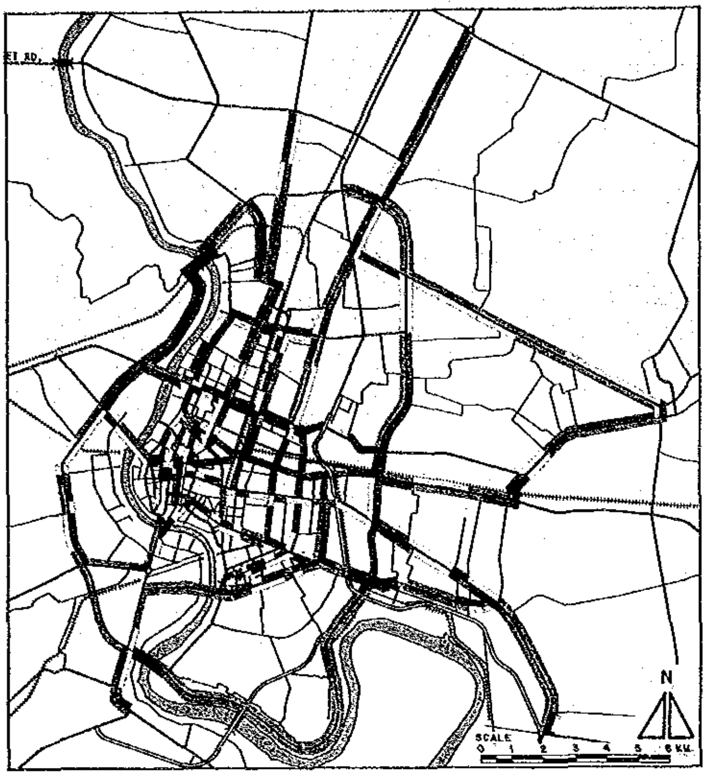
Sections with travel speeds of 10 km/h or less, which indicates congestion, are heavily concentrated in the city center bordered by Charun Sanit Wong Rd, Thawarn Rd, Phahon Yothin Rd, Din Daeng Rd, Middle Ring Rd (Asok), Rama IV Rd, Phaya Thai Rd, and Bamrung Muang Rd Separated from this major area of congestion, sections with travel speeds of 10 km/h or less are seen in and around areas where a major road intersects the Middle Ring Rd These sections are located on Mahai Sawan Rd, Suk Sawat Rd, Lat Phrao Rd, Phahon Yothin Rd, Prachachun Rd and Prachart Rd In addition, low speeds were observed in the vicinity of the Rama IV - Sukhumvit intersection, the Sathon - Charoen Krung intersection, the New Petburi - Ramkhamhaeng intersection and the Ramkhamhaeng - Lat Phrao intersection.

Thus, the area covering approximately 20 sq.km. centering on Ratchawithi Rd, Din Daeng Rd, Phahon Yothin Rd, Phaya Thai Rd, Ratchaprarop Rd and Rama IV Rd is heavily congested.

2) Evening Peak Hours

Sections with low travel speeds in the evening peak hours are more or less the same as in the morning peak hours. However, the congested area extends further northward and southward than in the morning. The area covering approximately 30 km2 centering on Ratchawithi Rd,Din Daeng Rd, Petburi Rd, Phahon Yothin Rd, Phaya Thai Rd, Ratchaprarop Rd, Rama IV Rd, Soi Asok Rd and Silom Rd is heavily congested.

Morning Peak Hour



Evening Peak Hour

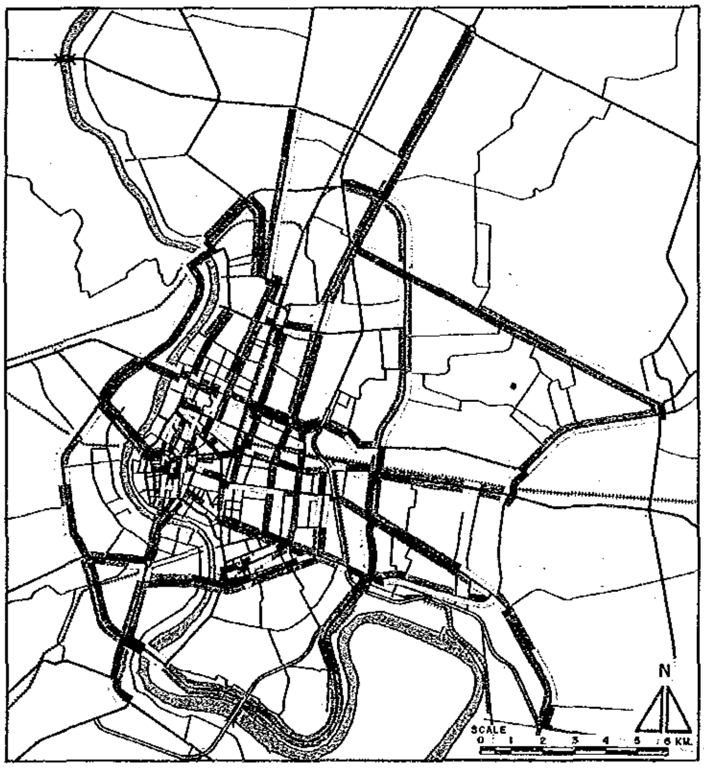


Fig. 2.3.6 Average Travel Speed

2.3.3 Traffic Accidents

1) Number of Accidents

Table 2.3.2 gives the number of traffic accidents that occurred in the Bangkok Metropolitan Area during the past 10 years (1979 - 1988). A downward trend was seen in 1981, but the number increased gradually over the following years and rose sharply in 1987 and 1988, resulting in a 2.6-fold increase in traffic accidents during the past decade. However, the number of accidents per 100 vehicles registered declined by close to 50% during the same period, from 3.4 accidents to 1.9, apparently indicating the effectiveness of traffic safety measures.

Table 2.3.2 Traffic Accident & Registered Vehicle

Year / Description	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Number of Accident	12,045	11,190	11,802	9,794	13,674	14,092	14,295	16,069	19,745	31,175
Number of Registered Vehicle in Bangkok	350,970	438,128	490,988	563,543	606,806	694,101	760,257	-	-	1,050,033
Accident/100 Registered Vehicle in Bangkok	3.4	2.6	2.4	1.7	2.3	2.0	1.9	-	-	1.9

Source : Department of Land Transport
Dec. 1988

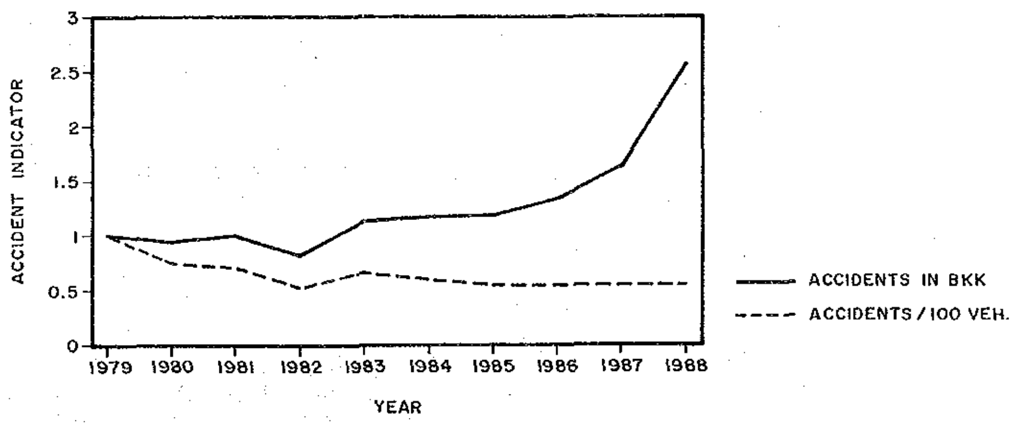


Fig. 2.3.7 Traffic Accident & Registered Vehicle

2) Accident Analysis

Fig. 2.3.8 shows where accidents occur at a high frequency within the area bordered by the Middle Ring Rd There is a tendency toward high accident frequency in the city center, particularly on Rama IV Rd, Sukhumvit Rd, Petburi Rd, Phaya Thai Rd and Sri Ayutthaya Rd, where congested is severe.

Of the total number of traffic accidents, a substantial 76% were vehicle-to-vehicle accidents (including motorcycles), while 20% involved pedestrians. Of the total number of vehicle-to-vehicle accidents, rear-end collisions represented 25%, side collisions during turning movements, 20%, and scraping, 17%. Of the total number of vehicle-to-pedestrian accidents, 11% occurred while the pedestrian was crossing a street where there is no crosswalk.

By cause of accident, close to half (47%) the total number was caused by improper driving speed. This was followed by improper overtaking at 27% and improper turning movement at 24%.

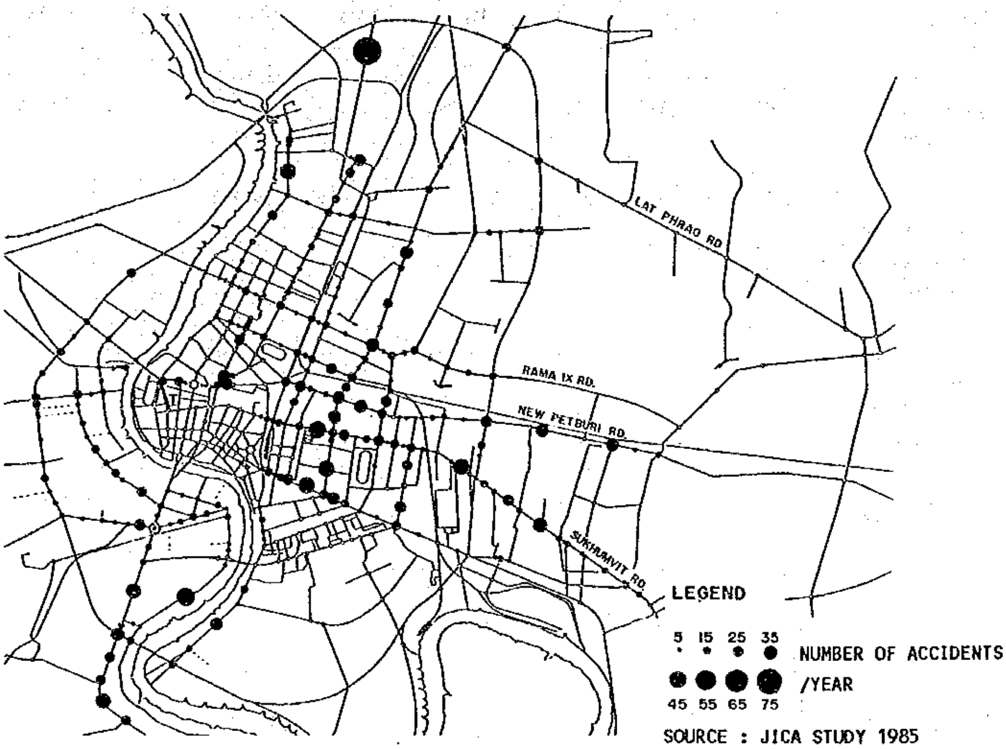


Fig. 2.3.8 High Accident Frequency Points

2.4 Traffic Signal Facilities

1) Existing ATC System Facilities

The central facilities of the existing ATC system are housed in the OPP building. Local controllers cover the Old City and the government office district located directly to the north of the Old City. The system was installed in 1979.

An outline of the existing ATC system is given below.

(a) Control System

A time-fixed control system, established by TRANSYT-7, that applies four patterns of timing plans to five time periods.

(b) Number of Intersections Controlled

The maximum capacity is 64 intersections, but currently only 47 intersections are covered.

(c) Communication System

A half duplex TDM system with a 1:N multidrop circuit configuration. The maximum value of N is 8. The system can accept eight modems, but is currently equipped with only 6.

(d) Monitoring Functions

Indications of "on-line," "permitted manual," "independent operation (poor communication or unpermitted manual)" and "major road green" appear on the graphic panel. Based on observation at 10:00 on a weekday, about 20% are estimated to be in an on-line status and 80% in other status. Print-outs of errors and control parameter changes are also provided.

2) Existing ATC System Operation

The existing ATC system is being operated as follows:

(a) During the 10 years since the ATC system was introduced, its control parameters were renewed twice. When renewing the parameters, traffic survey data were sent to an overseas organization and newly-calculated parameters were obtained by return mail, which were then fed into the computer.

(b) As mentioned above, there are four patterns of timing plans. Of these, three have cycle lengths of 60, 90 and 120 seconds respectively.

(c) Circuit conditions are poor during the rainy season. There are no data on the actual reliability of TOT circuits. The only information available is that restoration work targets "80% recovery within 24 hours and 99% within seven days."

(d) The TOT circuit leads directly into the ATC local controller.

3) Existing Signal Control Facilities and Operation

Signal control facilities in current use and their operations are as follows:

(a) Nearly all signalized intersections are manually controlled at site by traffic policemen. According to observations, manual cycles are about 2.5 - 8 minutes. However, there is no concept on cycles owing to skipping and backtracking of phases. Manual operations are based on assessments of spot conditions as indicated by visual observations by traffic policemen and/or information received via transceivers.

(b) Some of the traffic signals are mounted on high poles and have small lenses of approximatly 20 cm in diameters. Signal illumination tends to be dark. Electric power (about 12V, 50W) is supplied via transformers.

(c) Each traffic signal is connected directly to the local controller by a single cable; no relays are used.

4) Maintenance

Maintenance of ATC facilities and pre-timed signal equipment is handled by contractors and a staff of 17 members including ATC operators. The staff works in shifts, with 4 members at their posts in the afternoon and 8 at night. The afternoon staff is small because the members also undertake office work.

2.5 Problems Concerning Current Traffic Conditions and Current Signal Facilities

Problems concerning current traffic flow and current signal facilities which have a bearing on the ATC System are discussed below.

2.5.1 Traffic Flow Problems

The following problems concerning traffic flow were identified from field survey results and from available reference data:

1) Within the area that constitutes the city's business and commercial center, a substantial volume of traffic is concentrated in the area bordered by Rama IV Rd, Middle Ring Rd, Din Daeng Rd, Ratchawithi Rd, and Chao Phraya River, causing chronic congestion within the area.

2) Congestion in the abovementioned area is severe during peak hours, when major signalized intersections become saturated, as indicated by hourly traffic volume per lane. Moreover, travel speeds during the morning and evening peak hours fall to less than 10 km/h, and nearly all stoppages are caused by intersection waiting time or spill back.

3) A large number of major signalized intersections have saturation degree of more than 1.0, indicating that these intersections are oversaturated.

4) Traffic volumes on major roads fluctuate in complicated and diverse patterns during a day, with especially large fluctuations seen during business hours. There are also wide fluctuations from day to day. Owing to these factors, it is extremely difficult to control such as traffic volume by pre-timed signal control.

5) Within the area mentioned above, especially heavy congestion is seen on one-way arterial roads. The high concentration of traffic on these roads is partly attributed to the fact that trip lengths become of longer owing to the one way scheme in the sparse network of roads in the area, which results in longer detour trips.

6) There is a tendency toward high accident frequency on Rama IV Rd, Sukhumvit Rd, Petburi Rd, Phaya Thai Rd, and Sri Ayutthaya Rd, where congestion is severe. The rate of rear-end collisions is high.

7) In consideration of frequency of traffic flow interruption caused by the official events a green band control system should be considered.

2.5.2 Signal Facility Problems

The following problems concerning traffic signal facilities were identified from field survey results and from collected reference data:

1) The existing ATC system has several problems related to its operation as follows:

   (a) During the 10 years since the ATC system was introduced, its control parameters were renewed only a few times; thus, changes in traffic conditions are not being responded to quickly and effectively enough.

2) Problems related to existing signal control facilities are as follows:

   (a) Nearly all signalized intersections are manually controlled by traffic policemen. This means that the intersection capacity is decreased by no coordinated situation and too long cycle time.

   (b) The most of traffic lights are mounted on low poles and have small lenses, resulting to poor visibility.

   (c) The maintenance setup seems inadequate owing to the very small number of staff, lack of spare parts and other problems.

3

FRAMEWORK FOR ATC SYSTEM PLAN

CHAPTER 3 FRAMEWORK FOR ATC SYSTEM PLAN

A framework for the ATC System Plan was established as described below.

3.1 Target Year

Since the ATC System is a short-term traffic management objective, the target year for its construction should be within five years. Furthermore, taking into consideration the influence that a part of the ETA's Second Stage Expressway will have on the road network within the ATC System Planning Area, the target year is established as 1993, when the Expressway will be completed.

3.2 Future Road Network and Ongoing Projects

At present, a number of road transport projects are being pursued by the BMA, DOH, ETA and other government agencies. Of these, the projects shown in Fig. 3.2.1 are slated for completion by 1993 (for detailed information, refer to the separate discussion on the future network plan for the Medium- to Long-Term Plan). When determining the road network to be covered by the ATC System, these projects were taken into account as preconditions. The project names are listed in Table 3.2.1.

Table 3.2.1 Project by Public Agency

Project	Public Agency
1) ETA projects	a. Second stage expressway
	b. Ekkamai - Ram Intra expressway
2) BMA projects	a. Flyover, Din Daeng - Ratchaprarop
	b. Flyover, Ngam Wong Wan - Pracha Chuen
	c. Flyover, Middle Ring - Pracha Rat
	d. Flyover, Rama IV - Sukhumvit
	e. Flyover, Sri Ayutthaya - Ratchadamri
	f. Flyover, Middle Ring - Lat Phrao
	g. Flyover, Middle Ring - Rama IV
	h. Flyover, Middle Ring - Pracha Chuen
	i. Flyover, Phatthanakan - Ramkhamhaeng
	j. Flyover, Somdet Phra Pin Klao - Charan Sanit Wong
	k. Flyover, Inthraphithak - Charan Sanit Wong
	l. Flyover, Middle Ring - Phahon Yothin
	m. Flyover, Phahon Yothin - Sutthisan
	n. Flyover, Rama IV
	o. Elevated road, Soi Asok
	p. Improvement intersection, Rama IV - Ari
	q. Extension, Pracha Rat
	r. New road & Improvement, Mahaisawan
	s. New road & Improvement, Itsaraphap
	t. New road & Improvement, Ratchadaphisek
	u. New road & Improvement, Route 343
	v. New road & Improvement, Klong Chong Nonsi
3) DPW projects	a. Extension, Sathon
	b. Bridge, Rama VI bridge & approach
4) DOH projects	a. New road, Route 35
	b. New road, Route 343
	c. New road, Route 45
	d. New road, Phahon Yothin - Sukhaphiban

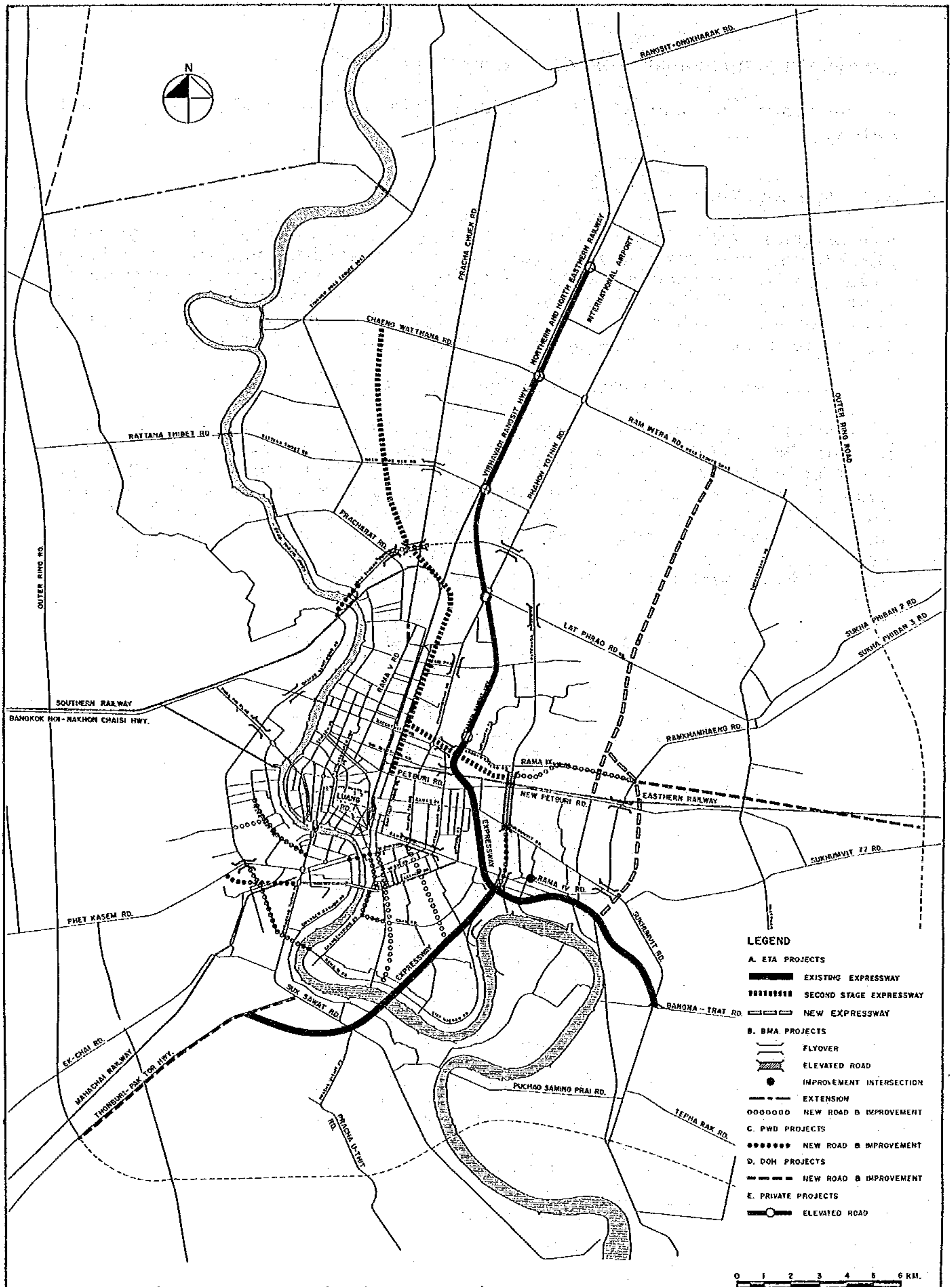


Fig. 3.2.1 Existing Plan in ATC System Area

3.3 ATC Planning Area

3.3.1 Selection Criteria

The relationship between traffic volume and link length, current traffic congestion and the future road network were used as criteria for selecting the ATC Planning Area. The minimum or maximum values applicable to these criteria are shown in Table 3.3.1.

In order to achieve the maximum operational efficiency of the ATC System, the relationship between traffic volume and link length on major roads in the Bankgkok Study Area was chosen as the primary selection criteria. In general, an ATC system has greater impact on links with smaller lengths or heavier traffic. Therefore, the ratio of traffic volume to link length (V/L) was used as an index to initially determine which links to include in the Planning Area. By removing links with the lowest V/L values, the overall network was divided into several areas. Based on the results of this procedure, an outline of the ATC Planning Area was determined by taking into account the congestion indices of travel speed and queue length obtained from field surveys, as well as the future network.

Fig. 3.3.1 gives the percentile value distribution for V/L, Fig. 3.3.2 shows where V/L is equal to or greater than 4.0, Fig. 3.3.3 indicates where travel speeds are under 10 kilometers per hour, and Fig. 3.3.4 shows queue lengths at major intersections.

Table 3.3.1 Evaluation Criteria for Sellection of ATC Planning Area

Item	Criteria	Ramarks
1. Relationship between traffic volume and link length	$V/L \geqq 4.0$	V=Traffic volume (PCU/P.H.) L=Link length (M) (Source:OD trips 1988)
2. Travel speed	$V \leqq 10$ Km/H	V=travel speed(Km/H) (Source:Travel time survey 1989)
3. Queue length	$L \geqq 100M$ (Max)	L=Queue length(M) (Source:Traffic congestion survey 1985&1989)
4. Future road network		

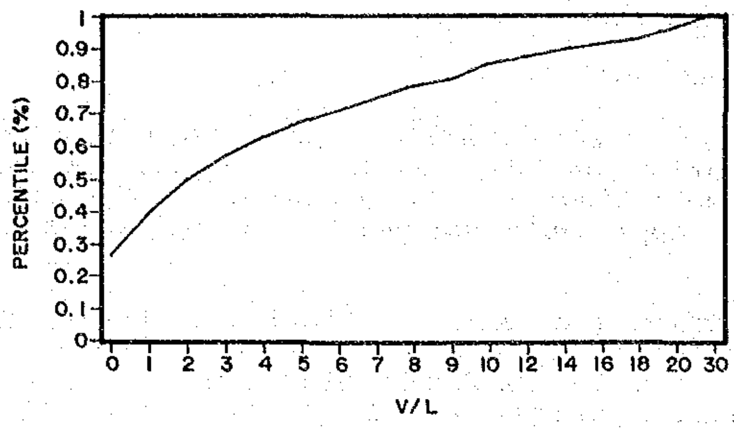


Fig. 3.3.1 V/L Percentile Value Distribution

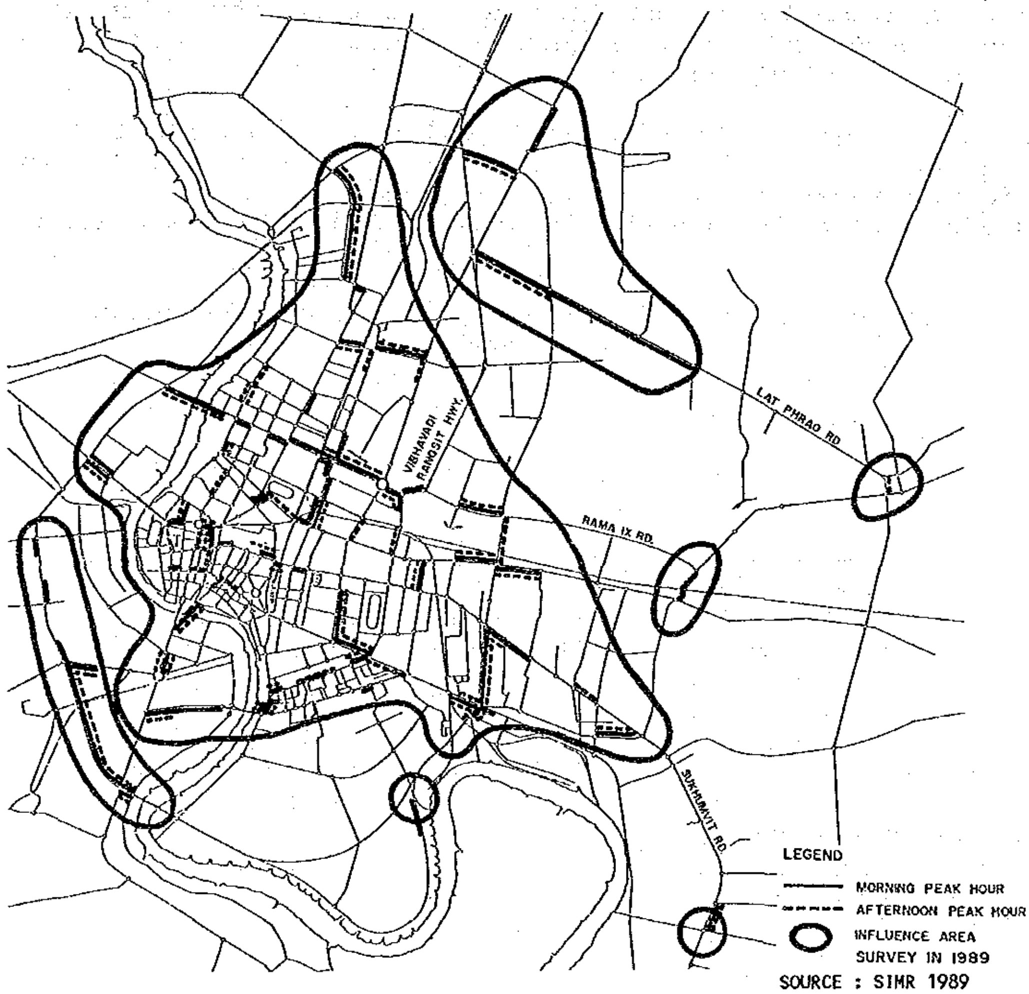


Fig. 3.3.2 Travel Speed Under 10 Km/H

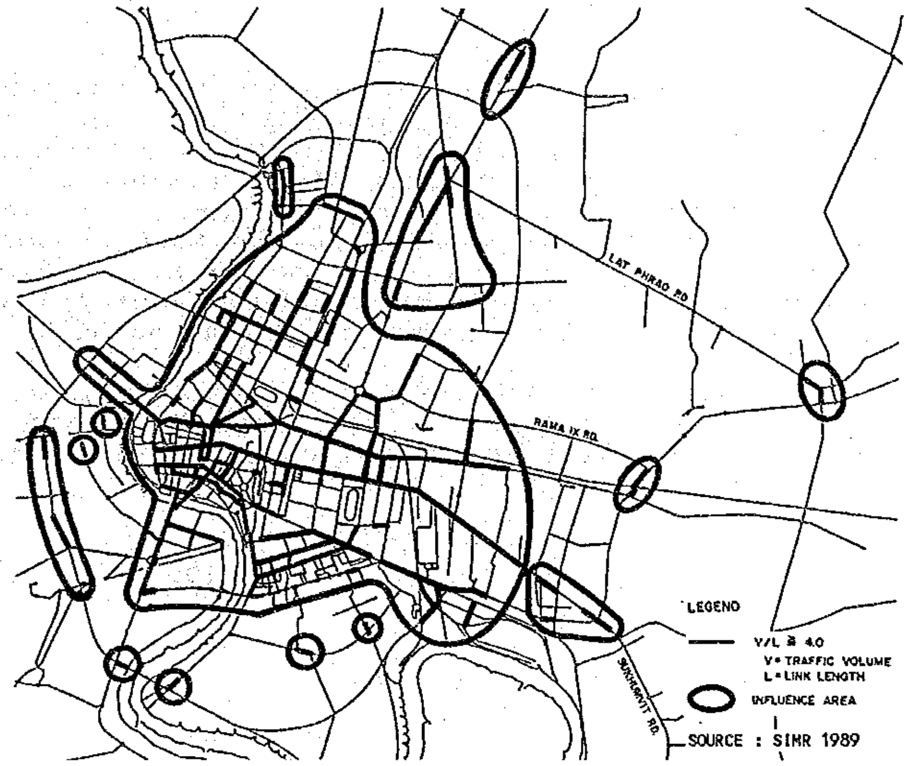


Fig. 3.3.3 Relation Ship Between Traffic Volume and Link Length

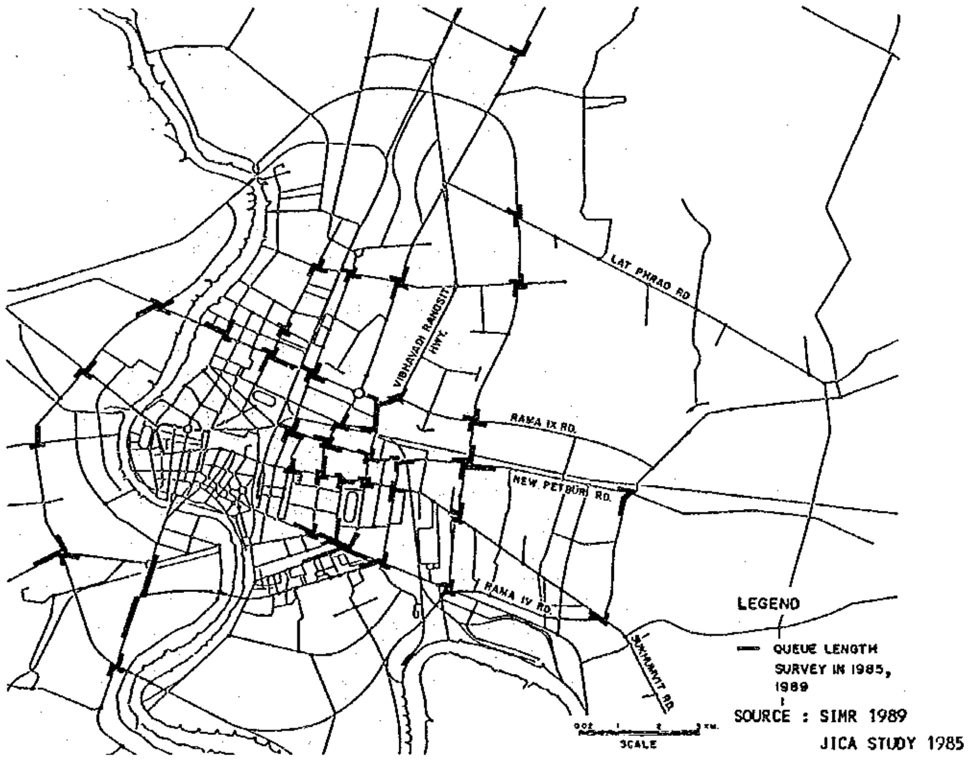


Fig. 3.3.4 Queue Length in Morning

3.3.2 Selection

Based on the criteria discussed above, the ATC Planning Area was selected as shown in Fig. 3.3.5 and Table 3.3.2. The Planning Area consists of several sections. The biggest section is bordered by the Middle Ring Rd, Petburi Rd, Phra Khanong Klongtan Rd, Rama IV Rd, Sathon Rd, Somdet Phra Chao Taksin Rd, and Chao Phraya River. This section is subject to the most concentrated level of improvements within the Planning Area. Other main sections are located on the Middle Ring Rd in the city's western and southern areas, on Lat Phrao Rd and on Ramkhamhaeng Rd.

In addition, the future road network was referred to in order to identify points where major roads intersect ETA Second Stage Expressway ramps, which will be completed by 1993, and these points were included in the Planning Area.

Table 3.3.2 ATC Planning Area in 1993

Area(Km2)	Main Area
101.0	* Middle Ring Rd - Petburi Rd - Phrakhanong Klongton Rd - Rama IV Rd - Sathon Rd - Somdet Phra Chao Taksin Rd - Chao Phraya River * Western and Eastern area on Middle Ring Rd * Lat Phrao Rd - Lat Phrao 053 Rd * Ramkhamhaeng Rd - Lat Phrao Rd

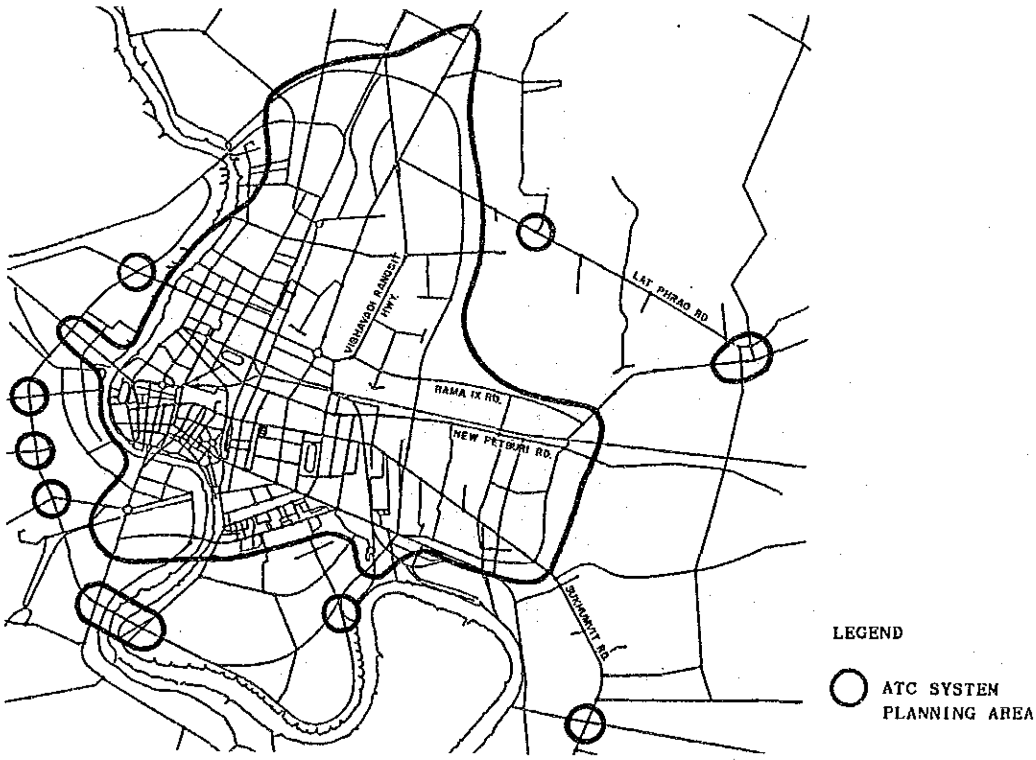


Fig. 3.3.5 ATC System Planning Area

4

TRAFFIC MANAGEMENT STUDY

CHAPTER 4 TRAFFIC MANAGEMENT STUDY

4.1 Study Objectives and Relation to ATC System Planning

Major flow control in force in Bangkok at present include one-way operation in the built-up area and one-way operation, unbalanced flow operation, contra-flow lanes and bus lanes on major arterials centering on Sukhumvit Rd and Petburi Rd In addition, other traffic management plans such as those related to public transportation projects and the area licensing system considered under STTR, are likely to be studied for the Medium- to Long-Term Road Transport Management/Improvement Plan.

As part of the Feasibility Study on the ATC System, which is targeted for the year 1993, a study of the one-way, unbalanced flow, and contra flow lane system currently implemented on major arterials centering on Sukhumvit Rd and Petburi Rd was conducted in advance of the Medium- to Long Term Road Transport Management / Improvement Plan. The system of controlling traffic flow on Sukhumvit Rd, Phetburi Rd, Phayatai Rd, Ratchawithi Rd and Ratchaprarop Rd is currently being reviewed for alteration, and the new system is to be implemented as soon as it has been finalized. Altering flow control on these roads, which comprise the core network of Bangkok's overall road network, will create traffic conditions that are considerably different from current conditions. For example, it is highly likely that bottlenecks at certain points will be eliminated, while new ones may be created at different locations. Hence, such a change will have a decisive effect on ATC planning.

Traffic circulation plans such as one-way schemes are indispensable to ATC planning. Since the existing traffic circulation plan is currently being reviewed for alteration, it is necessary, from the standpoint of formulating as effective an ATC plan as possible, to review the above-mentioned traffic circulation plans as part of the Feasibility Study.

4.2 Study Method

4.2.1 General

This study covers the area where current traffic circulation methods are being reviewed for alteration--in other words, the road network within the area bordered by the Middle Ring Rd to the east; the build-up area boundary to the west; Ratchawithi Rd and Asok-Din Daeng Rd to the north; and Sukhumvit Rd and Rama I Rd to the south. The study compares different flow control systems in terms of how they affect bottlenecks, travel speeds and road capacities in order to recommend the most suitable system for implementation. At the same time, it analyzes the changes that new methods of traffic circulation can be expected to produce in terms of the importance (saturation degree) of intersections. The results of this analysis will serve as an important reference point for ATC planning.

Since the results of this study were needed by the end of March 1989, O-D data to be obtained under the Medium- to Long-Term Master Plan study could not be used. Accordingly, the 1985 O-D data were used. In addition, since the new road network for 1993, the target year of the Feasibility Study, is undetermined at this stage, the study proposes traffic circulation improvements for the current road network (1988). A further study will be conducted for the 1993 road network after the configuration of said network has been determined and the method of turning Prohibition at new intersections has been determined.

The study was started by compiling peak-hour O-D tables based on the 1985 O-D data, for both the 1988 and 1993 road networks. This was followed by the formulation of traffic assignment and simulation models.

As indicated by the 1988 field survey, peak-hour traffic in the area subject to this study was more or less the same as in the previous survey (JICA Report in 1987). From this, we can judge that road capacities in the subject area have just about reached saturation degree. In other words, transport demand per peak hour in the subject area has not increased since the previous survey, despite the fact that car ownership has increased. In view of this factor, 1985 figures were applied without adjustment to peak-hour transport demand in 1988, rather than extrapolating the 1985 figures to 1988 based on car ownership growth.

A flow chart of the study is shown in Fig. 4.2.1 The study proceeded as follows:

a) Investigation of current traffic circulation
Revision of previous JICA survey results concerning number of lanes and link extension, and investigation of roads and grade-separated intersections completed subsequent to the JICA survey.

b) Tabulation of traffic circulation methods conducted during peak hours
Compilation and organization of data concerning number of lanes and link extension by direction by morning/afternoon peak hour, and data concerning bus lanes, bus network, contra-flow lanes, fixed unbalanced flow operation, reversible lane operation and traffic restrictions by direction.

c) Review of 1985 O-D data by time period

d) Preparation of O-D tables for morning and evening peak hours

e) Comparison of traffic circulaion systems and recommendation for current network

f) Determination of 1993 road network and turning prohibition at new intersections

g) Traffic circulation study for 1993 road network

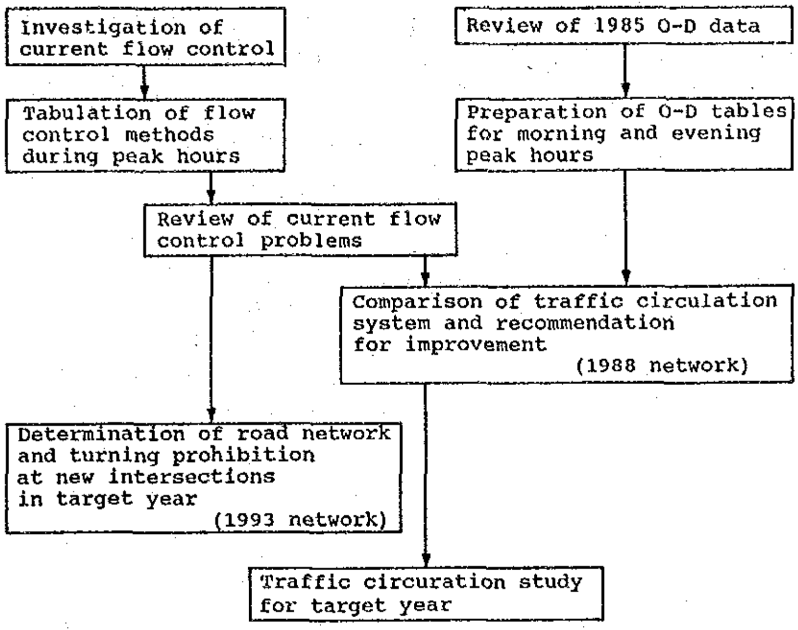


Fig. 4.2.1 Traffic Management Study Flow

4.2.2 Flow Analysis Model

1) Basic Conditions and Procedures

For the purpose of evaluating the effectiveness of traffic circulation methods, it is necessary to establish a method for expressing the delay time and queue length of a given intersection in order to simulate its saturation degree. Therefore, the use of a simulation model that can express delay time and queue length must be considered.

At the same time, the simulation model must fulfill the following conditions:

a) It can simulate conditions of oversaturation
b) It responds to changes in flow control
c) Its calculation time is relatively short

The procedure followed in arriving at the simulation model was as follows:

a) Preparation of O-D tables for the morning (7:00 - 8:00) and evening (17:00-18:00) peak hours

b) Establishment of link nodes for each traffic circulation alternative

c) Formulation of a peak-hour trip assignment model and calculation of data needed for the simulation model

d) Formulation of a simulation model

Passenger car unit (PCU) shown in Table 4.2.1 is used to convert various types of vehicles into passenger.

Table 4.2.1 Passenger Car Unit

Vehicle	Coefficient (pcu)
Car	1.0
Taxi	1.0
Mini Bus	1.5
Large Bus	2.1
Pick-up	1.0
Truck	2.5

2) Trip Assignment Model

A trip assignment model was formulated in order to obtain data required for the simulation model.

A flow chart of the trip assignment procedure is shown in Fig. 4.2.2.

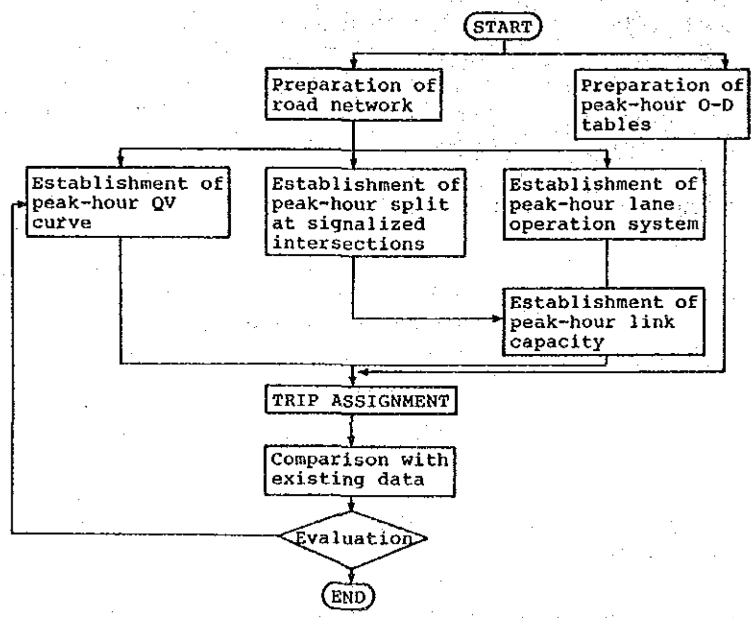


Fig. 4.2.2. Trip Assignment Procedure

The hourly capacity of a link is expressed in terms of its capacity at its bottleneck point. In the road network subject to this study, bottleneck points are usually the signalized intersections located at the link exit. Therefore, it is believed that hourly link capacity can be determined in accordance with the green interval ratio (gi) of the traffic signal at the link exit.

In view of the foregoing, the hourly (t) capacity of a given link (i) was obtained from the following equation:

$$Qoit = Sit \times git$$

Sit = capacity of road i during hour t
git = green interval ratio during hour t

3) Simulation Model

The simulation model, as shown in Fig. 4.2.3, covers the area bordered by the Victory Monument to the north, Sathon Rd to the south, the Middle Ring Rd to the east and the built-up area boundary to the west, and includes Sukhumvit Rd and other one-way roads that are being considered for two-way operation.

Although a traffic flow simulation model, as shown in Table 4.2.2, has already been developed, DESE-model developed by the Tokyo University is more suitable to the subject study, as it fulfills the conditions cited in the preceding section. The Tokyo University model (DESE) was developed for the purpose of evaluating different signal control systems, improving the efficiency of signal control through on-line optimization experiments and establishing a new signal control system for a road network that serves a wide area. A simplified version of this simulation model was used in the subject study in order to evaluate the effectiveness of the traffic circulation plans.

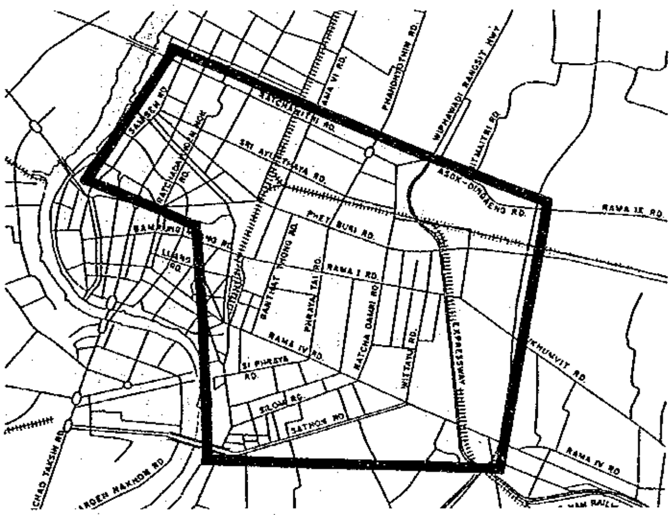


Fig. 4.2.3 Simulation Area

Table 4.2.2 Outline of Existing Simulation Models

Model	Main Use	Developed by (Year)	Basic Conditions: Simulates Road Network	Basic Conditions: Simulates Excess Saturation	Basic Conditions: Responds to Changes in Flow Control	Basic Conditions: Short Computing Time	Remark
TRANS	Signal control evaluation	U.S. (1966)	YES	NO	NO		
UTCS	Signal control evaluation	U.S. (1971)	YES	NO	NO		Based on TRANS; lane change, conflict between pedestrians and turning vehicles
NETSIM	Signal control evaluation	U.S. (1977)	YES	NO	NO		Improved version of UTCS; estimates fuel consumption and exhaust
MACSTRAN	Signal control evaluation	Japan (1975)	YES	YES	YES		Based on TRANS; improvement on turning and lane change movements; vehicles move at fixed speed or stand still
MICSTRAN	Signal control evaluation	Japan (1975)	YES	YES	YES		
SIGOP	Optimization of signal control parameters	U.S. (1974)	YES	NO	NO		
TRANSYT	Optimization of signal control parameters	U.K. TRRL (1974)	YES	NO	NO		
DESC	Signal control evaluation & optimization of signal control parameters	Japan TUSL (1986)	YES	YES	YES	YES	Includes macromodel (continuous volume) and micromodel (unit basis) for right-turning vehicles
Signal Forecast Control Model	Optimization of signal control parameters	Japan (1986)	YES	YES	NO		Forecasts traffic demand several minutes ahead and seeks best control parameter (split) for achieving target traffic condition (queue)
TRACSS	Signal control evaluation	Japan (1980)	YES	YES	NO		

Fig. 4.2.4 gives a configuration of the model used. Main sections of the model consist of the data input sector, signal control sector, traffic flow sector and data output sector. Simulation proceeds according to a periodic scanning method, with scanning conducted once every second.

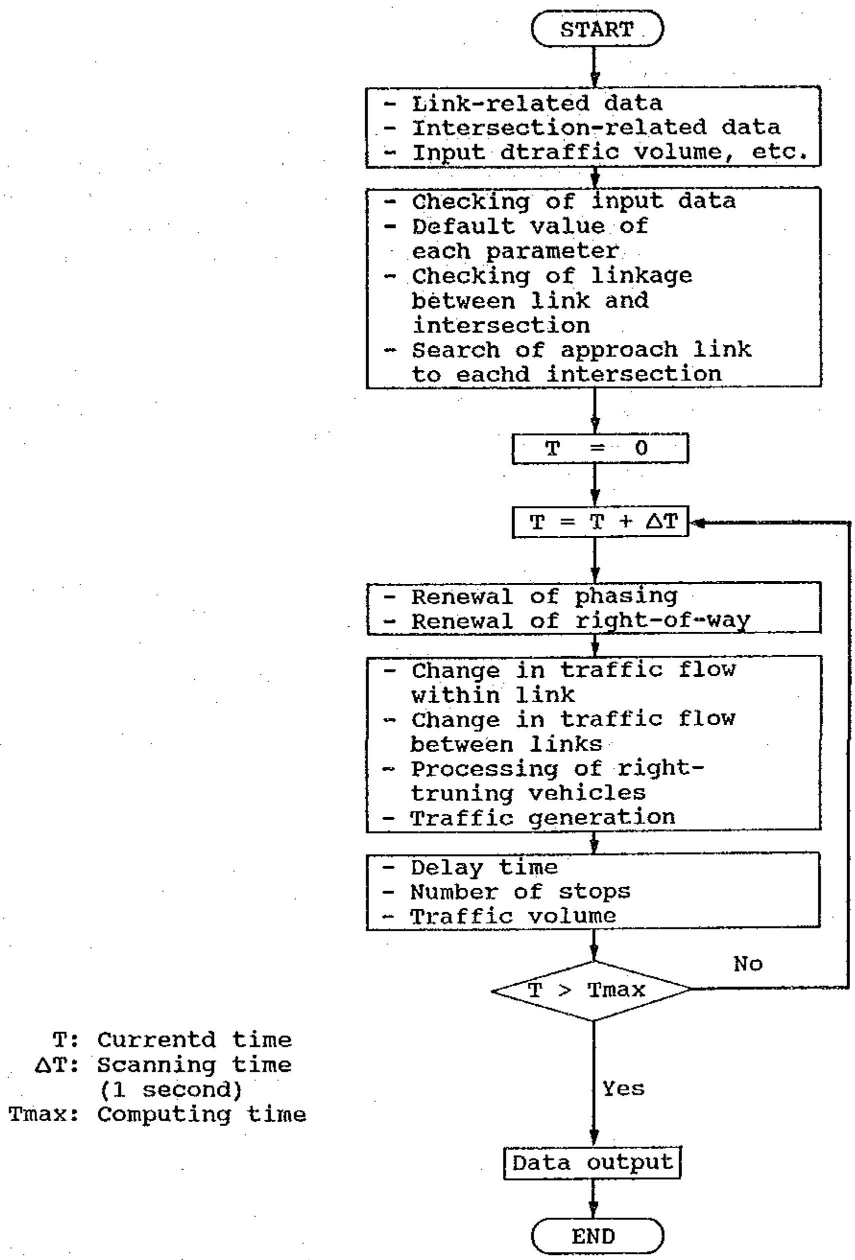


Fig. 4.2.4 Simulation Procedure

To run the simulation, such information as link data, signal control method, control parameters and incoming traffic volume are required. Link data consist of structural conditions such as geometric constraints and flow conditions such as saturation flow degree, intersection turning movement, etc. Inbound traffic volumes and turning movement were obtained from the results of the trip assignment conducted as a part of this study, and the saturation flow degree was obtained through actual observation. Further details are described below.

(1) Inbound Traffic

The volume of inbound traffic corresponds to the number of trips assigned to links located at the periphery of the simulation area. In addition, since the simulation area contains trip generation nodes, the number of trips generated from these nodes are also inputted by establishing a trip generation link.

(2) Saturation Flow Degree

The average saturation flow degree obtained from the results of the saturation flow survey is used uniformly. The value is 1900pcu per green hour per lane.

(3) Signal Control Parameters

a) Phasing: Two phases as a rule (four phases where there are right-turning lanes)

b) Cycle length: Standard 180 seconds

c) Split: Based on directional volumes as indicated by the trip assignment

d) Offset: None established

Since manual control by traffic policemen cannot be simulated and since it is necessary to have a uniform set of control in order to compare the effectiveness of different one-way systems, the same phasing, cycle length and offset were used in all simulations.

The simulation model does not take at-grade railroad crossings into account as their influence on traffic flow is considered to be minimal. In addition, bus movements are not taken into account, as the model is based on passenger car unit.

Trial simulations of current conditions at two intersections on the Middle Ring Rd and two on Rama IV Rd using the model gave results that were comparable to the results of OCMRT's 1988 survey of intersection traffic flow (20 survey points, of which four were in the simulation area).

4.3 Preliminary Considerations

4.3.1 Review of Current System

In order to realize the smooth flow of traffic in the Bangkok metropolitan area, one-way control was introduced on two separate occasions in the past. The earlier of the two covered the built-up area, where a large number of relatively narrow semi-arterials criss-cross each other. The more recent introduction was made in February 1984 and consisted of the establishment of two one-way loops on arterial roads.

Fig. 4.3.1 shows the one-way system introducted in 1984. Comments on the system given by the Evaluation Committee are summarized below:

a) Flow conditions within the one-way system
  - During peak hours, congestion was seen in certain sections, but travel speeds and volumes increased in other sections. The travel speeds of buses generally increased.
  - During off-peak hours, travel speeds increased.

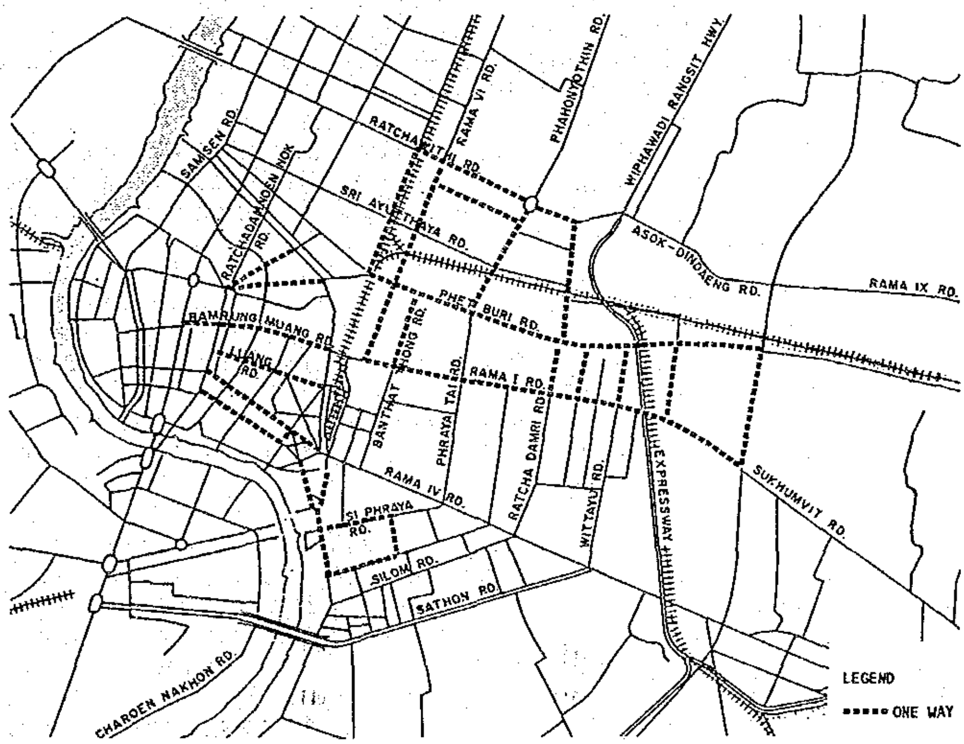


Fig. 4.3.1 One Way Traffic System in 1984

b) Flow conditions outside the one-way system
   - During peak hours, severe congestion was seen over a wide area.
   - During off-peak hours, there were no significant changes in traffic flow.

c) Changing from narrow streets to arterial roads became difficult and hazardous.

d) A greater number of traffic policemen were required to operate the one-way system.

e) Some bus users found it more convenient to change their routes.

f) Parking restrictions and bus lane regulations were adhered to more rigorously.

g) The use of privately-owned cars declined.

h) The safety of pedestrians declined.

Subsequent to the 1984 introduction, various changes in the initial one-way system were initiated, as follows:

a) In 1986, two-way operation was introduced on the following three roads in order to relieve bottlenecks created by right-turning vehicles: Rama VI Rd, Charoen Phon Rd and Ratchawithi Rd

b) In 1987, the Traffic Police took the initiative to introduce contra-flow lanes on the following three roads in order to relieve congestion: Petburi Rd, Ratchawithi Rd and Phaya Thai Rd

c) In 1988, contra-flow lanes were introduced on the following two routes:
   - Rama I Rd, from Pratum I intersection to Rajrasong intersection (whole day)
   - Petburi Rd, from Expressway off-ramp to Chitrom, and Ratchaprarop Rd, from Din Daeng to Soi Makkasan (whole day)

At present, contra-flow lanes, reversible lanes and fixed unbalanced flow are used in combination with the one-way system on arterial roads. However, the initial 1984 concept of clockwise operation of one-way loops has basically been maintained. Fig. 4.3.2 shows the number of lanes allocated to each direction during the morning peak hour, Fig. 4.3.3 shows the distribution of one-way and unbalanced flow streets, and Fig. 4.3.4 shows the distribution of bus lanes.

Under current conditions, the increase in detouring traffic caused by the one-way operation of arterials makes certain sections outside the one-way loops less convenient, while travel distances are generally longer, with motorists often required to pass through a number of congested intersection during their detours. In particular, long jams are created during peak hours at many intersections, and oversaturation at isolated intersections often affect traffic flow at other intersections owing to the overall congestion, creating oversaturation in some areas within the overall network and paralyzing the flow of traffic. Moreover, poor linkage between the ETA expressway and other roads causes severe congestion on expressway ramps and the expressway itself, lowering the advantages of using the expressway.

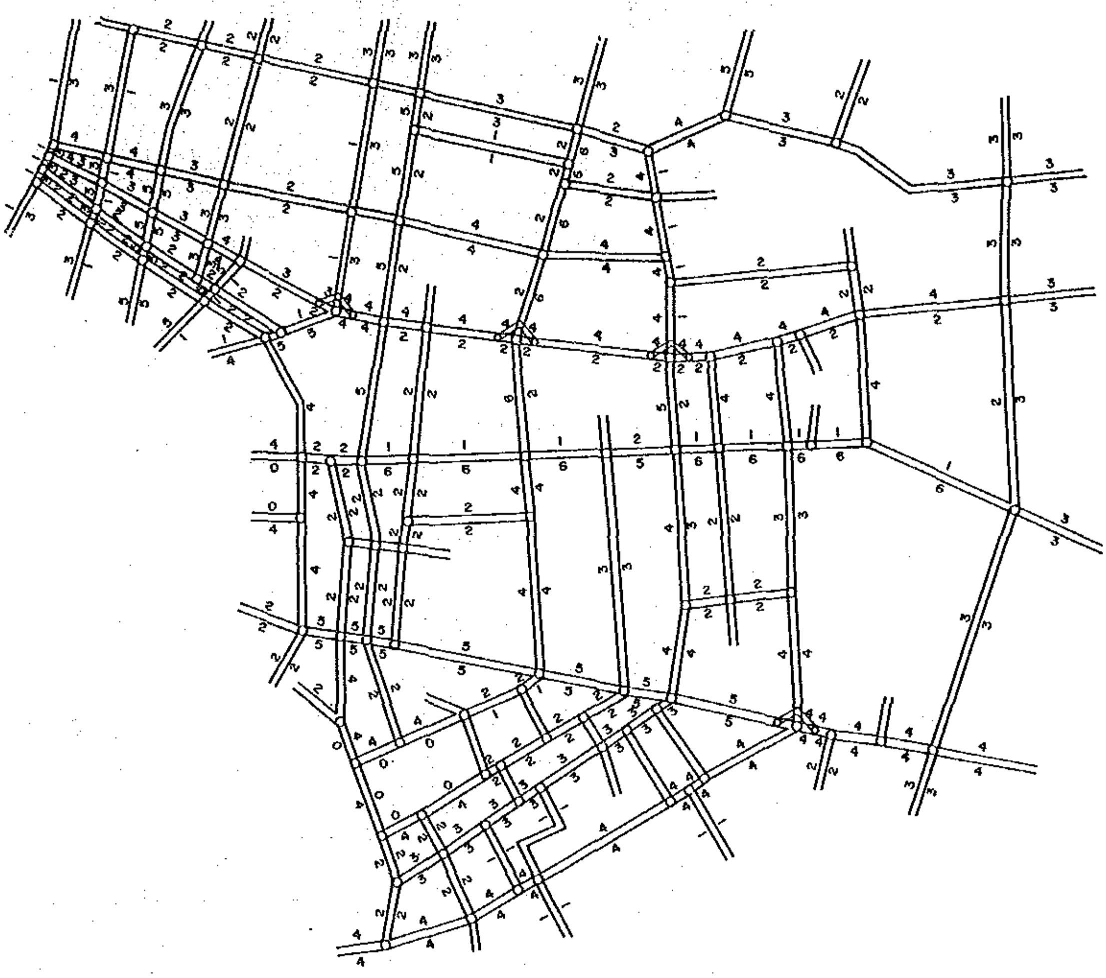


Fig. 4.3.2 Number of Lanes

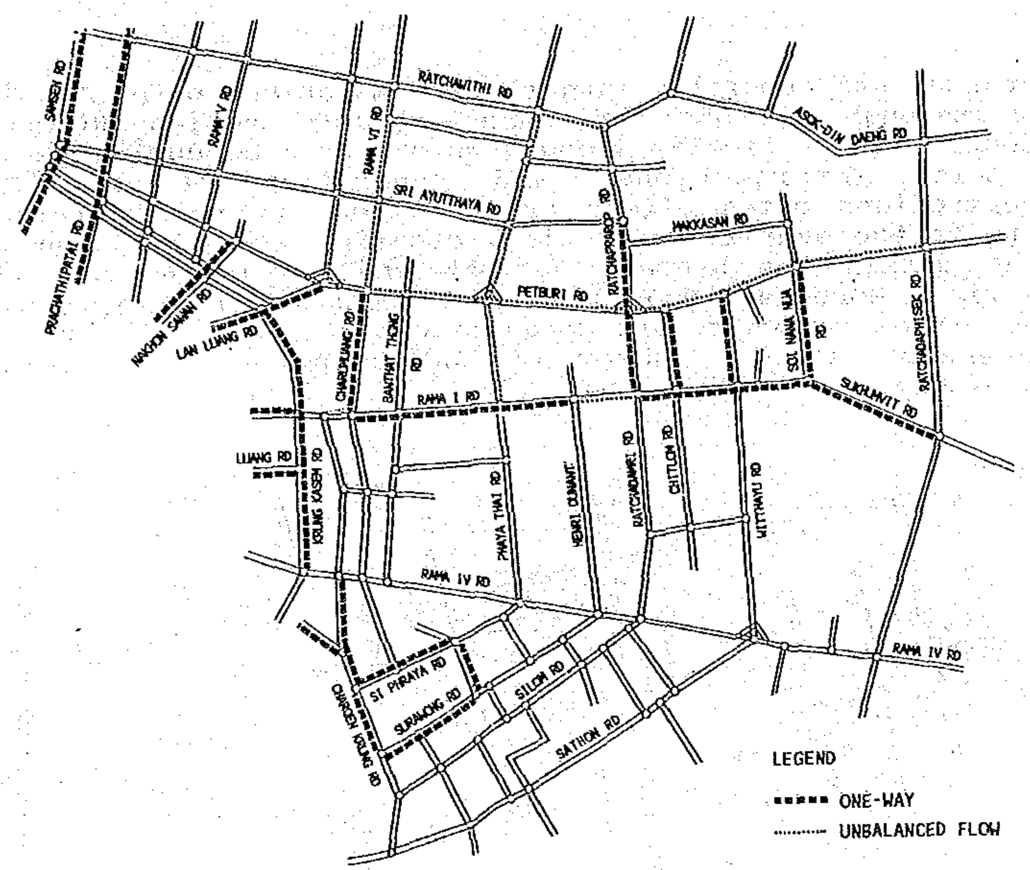


Fig. 4.3.3 Distribution of One-Way and Unbalanced Flow Street

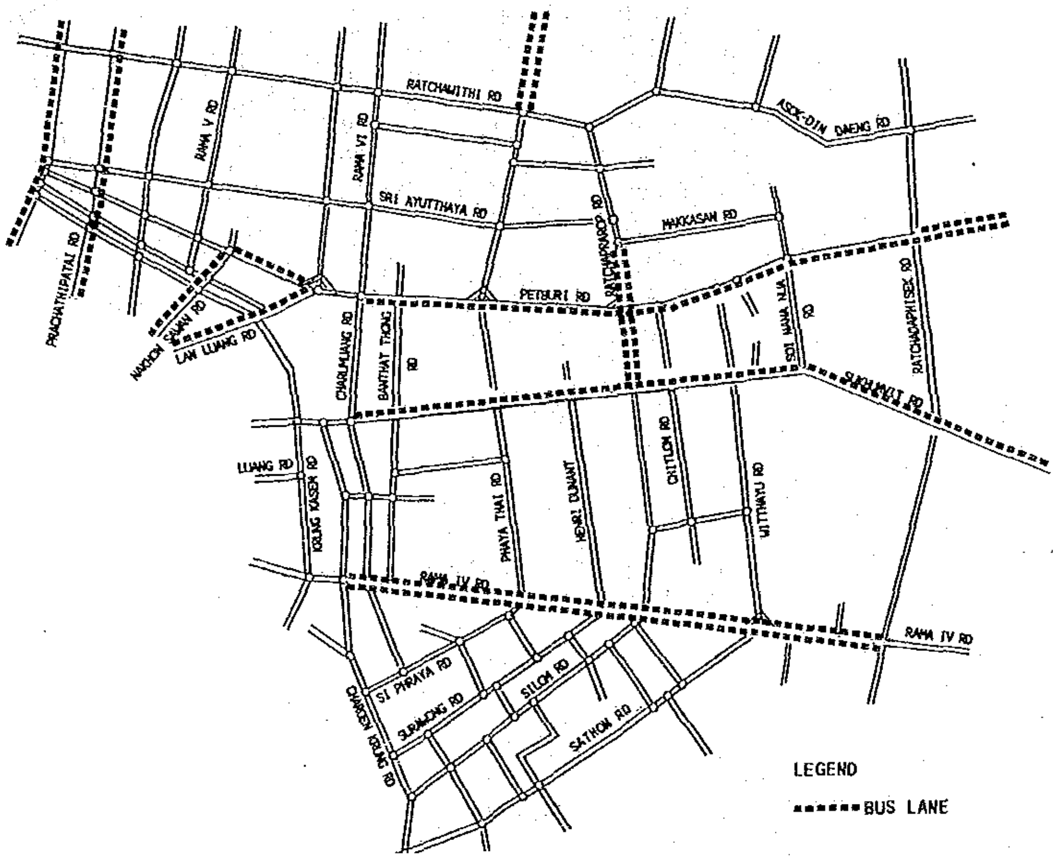


Fig. 4.3.4 Distribution of Bus Lane

4.3.2 Basic Concepts for Alternative Solutions

The selection of alternative flow control systems should take into account the need to ease the saturation levels of intersections, decrease delay time and queue length in the subject area and realize smooth flow to and from the expressway. It is necessary, therefore, to study the potential benefits of (a) a two-way unbalanced flow system (including reversible lanes), which can minimize the need for detours and ease congestion at intersections, and (b) a reversal of the current one-way system to a counter-clockwise operation as a way of processing the overwhelmingly heavy flow of traffic between the expressway and the city center in the morning and evening peak hours. A flow chart of the procedures for selecting alternative systems is shown in Fig. 4.3.5.

Prior to studying the two-way unbalanced flow system, the following study was made on two-way balanced flow, in which the same number of lanes are allotted to each direction, in order to establish a basis for determining the possible routes for unbalanced flow and the number of lanes to be allotted to each direction on these routes: Trips were assigned to road sections based on the minimum-route method, which does not take into account capacity limitations of individual road sections, in order to obtain the volume of demand in each section. Based on the results, those sections with high potential demand and those routes which were likely to benefit from unbalanced flow were identified. Lane distribution was determined by obtaining demand volumes based on the multi-step trip assignment method, which takes capacity limitations of individual road sections into account, and then reassigning the lanes in each section so as to achieve a balance in the degree of congestion in the two directions.

Based on the foregoing, the five systems listed below were selected for rough appraisal. Concerning the two-way reversible system given in 4) and 5) below, the two-way unbalanced flow study discussed above indicated that this system is the most effective, as it allows lanes to be allotted as required during the morning and evening peak hours.

1) Existing system
2) Fixed counter-clockwise one-way loop operation (reversal of current system; two counter-flow lanes to be provided on Sukhumvit Rd and Petburi Rd each)
3) Reversible counter-clockwise one-way loop operation (a proposal, discussed in 1989 Feb., consisting of a large number of sections with reversible lanes)
4) Two-way reversible flow combined with two-way unbalanced flow based on trip assignment studies
5) A simplified version of the above two-way reversible flow system

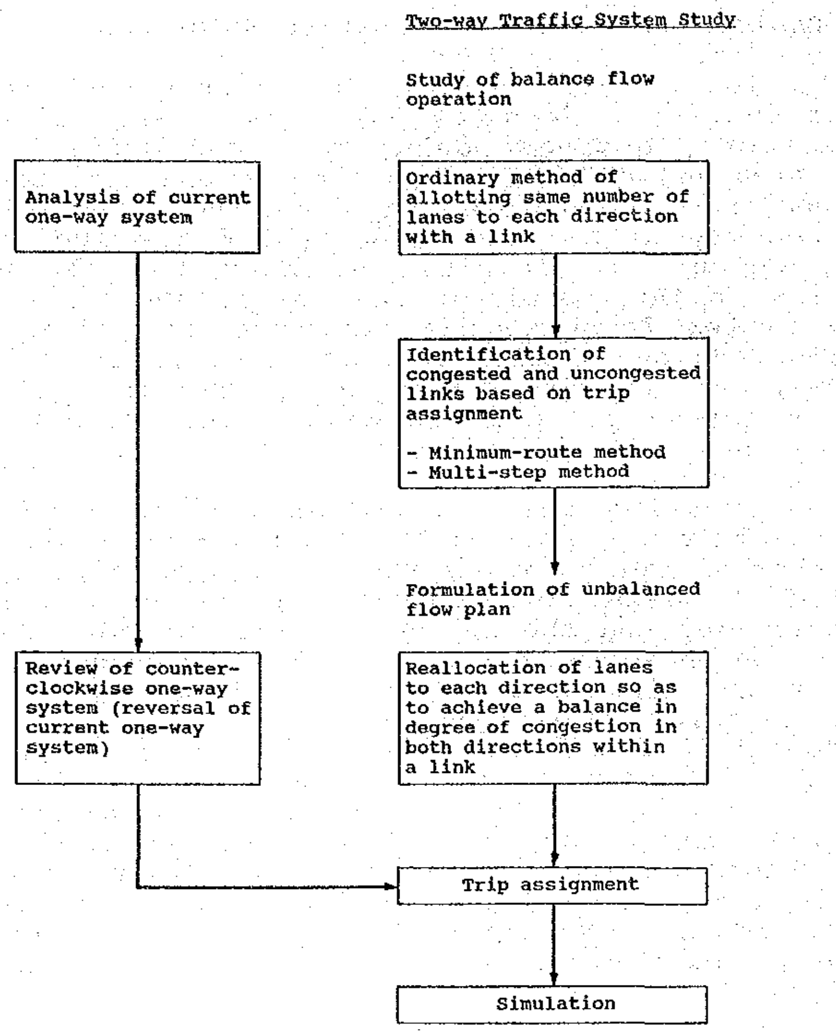


Fig. 4.3.5 Alternative Selection Procedure

The five systems above are compared in Tables 4.3.1 and 4.3.2. After conducting a rough appraisal of the five systems, the following three alternatives were selected for more detailed evaluation:

- Case 1: Existing system (same as 1 above)
- Case 3: Counter-clockwise circulation system (same as 3 above)
- Case 5: Two-way reversible system (same as 5 above)

Fig. 4.3.6 shows the three alternatives listed above. Cases 3 and 5 are illustrated in further detail in Fig. 4.3.7.

Table 4.3.1 Type of Alternatives

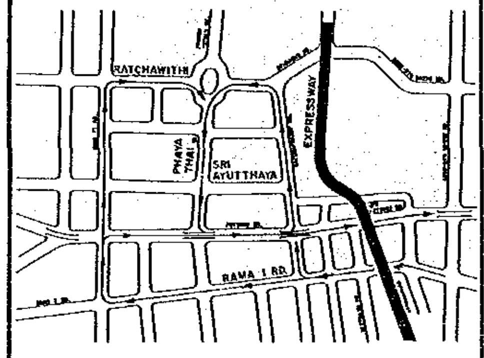
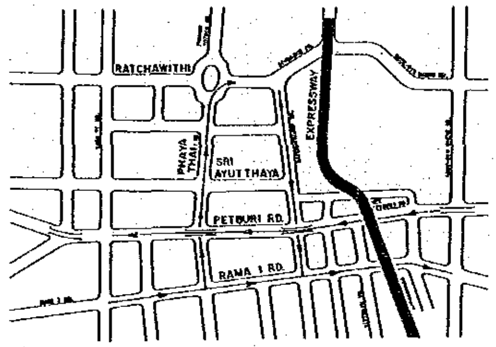
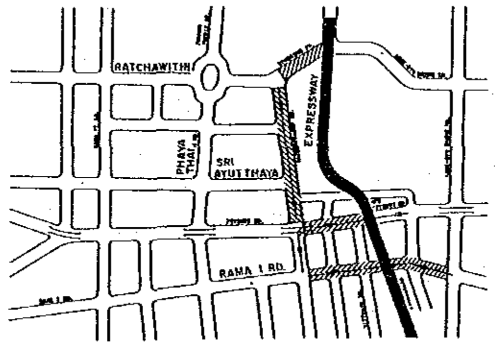
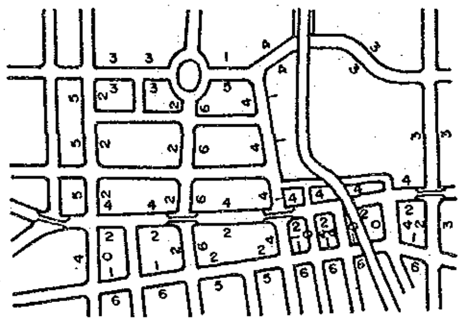
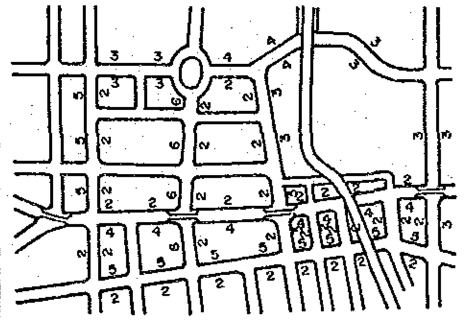
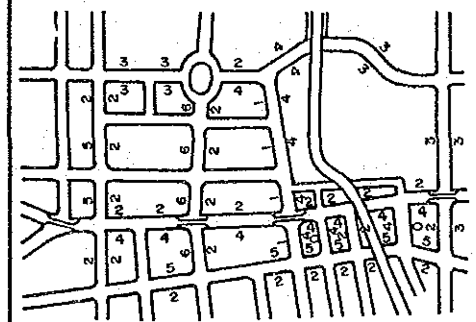
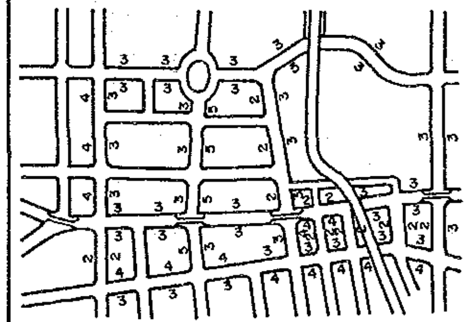
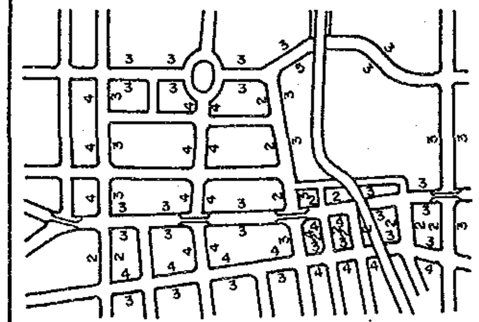
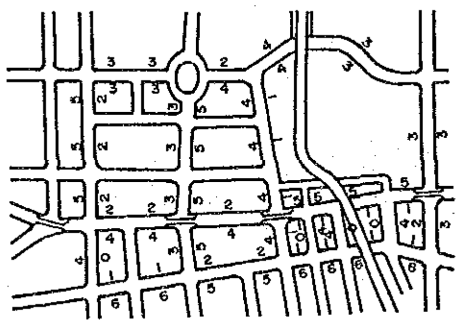
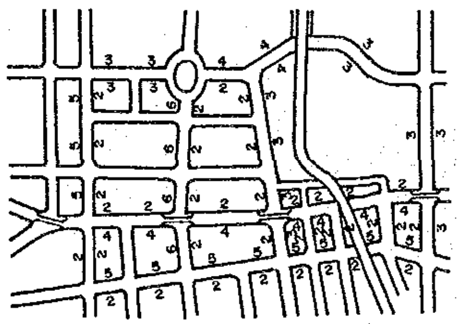
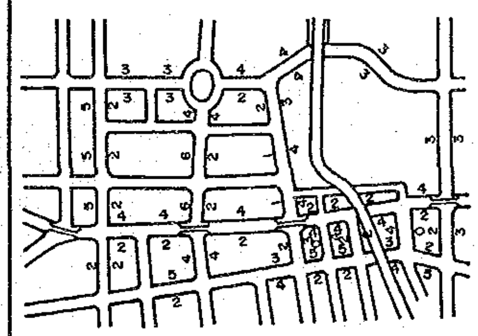
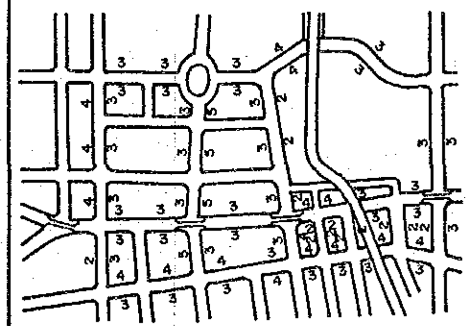
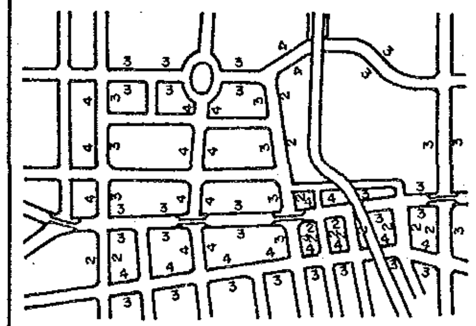
<table>
<tr><td colspan="2">CASE</td><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td></tr>
<tr><td colspan="2">TYPE OF DIRECTION</td><td>ONE-WAY</td><td>ONE-WAY</td><td>ONE-WAY</td><td>TWO-WAY</td><td>TWO-WAY</td></tr>
<tr><td colspan="2">REVERSIBLE</td><td>○ (MANUAL)</td><td>X</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td colspan="2">MAIN FLOW</td><td></td><td colspan="2"></td><td colspan="2">
Link with reversible lane</td></tr>
<tr><td rowspan="2">NO. OF LANE</td><td>MORNING PEAK HOUR</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>EVENING PEAK HOUR</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 4.3.2 Number of Lane by Alternatives (1)

SECTION		ALTERNATIVES	(1)		(2)		(3)		(4)		(5)	
			INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND
DIN DAENG-RATCHAWITHI (A)	①	M/P	3	3	3	3	3	3	3	3	3	3
		E/P	3	3	3	3	3	3	3	3	3	3
	②	M/P	5	1	2	4	4	2	3	3	3	3
		E/P	4	2	2	4	2	4	3	3	3	3
	③	M/P	4	4	4	4	4	4	5	3	5	3
		E/P	4	4	4	4	4	4	4	4	4	4
	④	M/P	3	3	3	3	3	3	3	3	3	3
		E/P	3	3	3	3	3	3	3	3	3	3
		M/P										
		E/P										
		M/P										
		E/P										
PETBURI (B)	①	M/P	2	4	4	2	4	2	3	3	3	3
		E/P	1	5	4	2	2	4	3	3	3	3
	②	M/P	2	4	4	2	4	2	3	3	3	3
		E/P	1	5	4	2	2	4	3	3	3	3
	③	M/P	2	4	4	2	4	2	4	2	4	2
		E/P	1	5	4	2	4	2	2	4	2	4
	④	M/P	2	4	4	2	4	2	4	2	4	2
		E/P	1	5	4	2	4	2	2	4	2	4
	⑤	M/P	2	4	4	2	4	2	3	3	3	3
		E/P	1	5	4	2	4	2	3	3	3	3
	⑥	M/P	2	4	4	2	4	2	3	3	3	3
		E/P	1	5	4	2	2	4	3	3	3	3

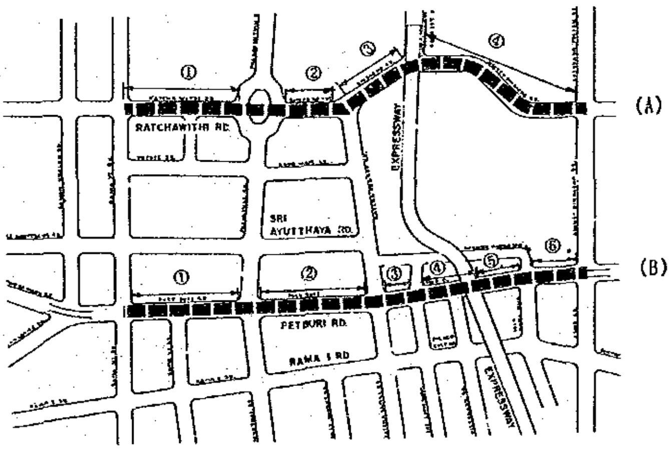


Table 4.3.2 Number of Lane by Alternatives (2)

SECTION \ ALTERNATIVES			(1)		(2)		(3)		(4)		(5)	
			INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND
RAMA I (C)	①	M/P	6	1	2	5	2	5	3	4	3	4
		E/P	6	1	2	5	2	5	3	4	3	4
	②	M/P	5	2	2	5	2	5	3	4	3	4
		E/P	5	2	2	5	4	3	3	4	3	4
	③	M/P	6	1	2	5	2	5	4	3	4	3
		E/P	6	1	2	5	2	5	3	4	3	4
	④	M/P	6	1	2	5	2	5	4	3	4	3
		E/P	6	1	2	5	2	5	3	4	3	4
	⑤	M/P	6	1	2	5	2	5	4	3	4	3
		E/P	6	1	2	5	4	3	3	4	3	4
	⑥	M/P	6	1	2	5	2	5	4	3	4	3
		E/P	6	1	2	5	5	2	3	4	3	4
		M/P										
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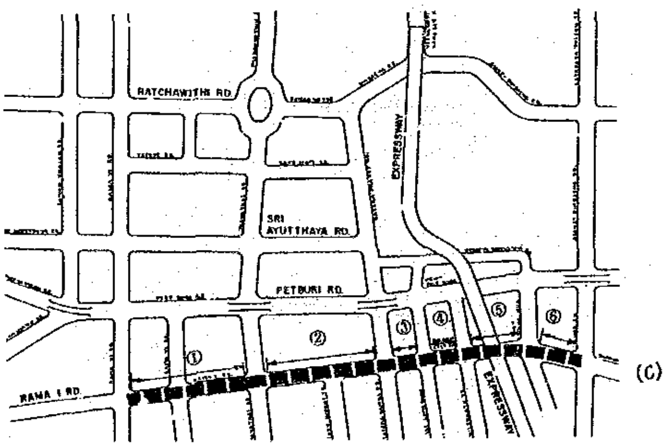

Table 4.3.2 Number of Lane by Alternatives (3)

SECTION \ ALTERNATIVES			(1)		(2)		(3)		(4)		(5)	
			SOUTHERN	NORTHERN	SOUTHERN	NORTHERN	SOUTHERN	NORTHERN	SOUTHERN	NORTHERN	SOUTHERN	NORTHERN
RAMA VI (D)	①	M/P	2	5	2	5	2	5	3	4	3	4
		E/P	2	5	2	5	2	5	3	4	3	4
	②	M/P	2	5	2	5	2	5	3	4	3	4
		E/P	2	5	2	5	2	5	3	4	3	4
	③	M/P	2	5	2	5	2	5	3	4	3	4
		E/P	2	5	2	5	2	5	3	4	3	4
	④	M/P	-	4	2	2	2	2	2	2	2	2
		E/P	-	4	2	2	2	2	2	2	2	2
PHAYA THAI (E)	①	M/P	6	2	2	6	2	6	5	3	4	4
		E/P	5	3	2	6	4	4	5	3	4	4
	②	M/P	6	2	2	6	2	6	5	3	4	4
		E/P	5	3	2	6	2	6	5	3	4	4
	③	M/P	6	2	2	6	2	6	5	3	4	4
		E/P	5	3	2	6	2	6	5	3	4	4
	④	M/P	6	2	2	6	2	6	3	5	4	4
		E/P	5	3	2	6	4	4	3	5	4	4
RATCHAPRAROP (F)	①	M/P	1	4	3	2	4	1	3	2	3	2
		E/P	1	4	3	2	3	2	2	3	2	3
	②	M/P	1	4	3	2	4	1	3	2	3	2
		E/P	1	4	3	2	4	1	2	3	2	3
	③	M/P	1	4	3	2	4	1	3	2	3	2
		E/P	1	4	3	2	4	1	2	3	2	3
	④	M/P	1	4	3	2	4	1	4	3	4	3
		E/P	1	4	3	2	3	2	4	3	4	3

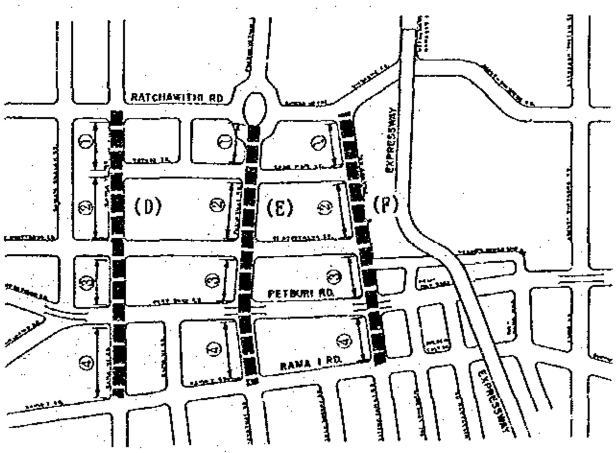

Table 4.3.2 Number of Lane by Alternatives (4)

SECTION \ ALTERNATIVES			(1)		(2)		(3)		(4)		(5)	
			SOUTHERN	NORTHERN	SOUTHERN	NORTHERN	SOUTHERN	NORTHERN	SOUTHERN	NORTHERN	SOUTHERN	NORTHERN
RATCHADAMRI (G)	①	M/P	4	-	2	2	4	-	2	2	2	2
		E/P	4	-	2	2	4	-	2	2	2	2
		M/P										
		E/P										
WIRELESS (H)	①	M/P	-	4	2	2	2	2	2	2	2	2
		E/P	-	4	2	2	2	2	2	2	2	2
		M/P										
		E/P										
SOI-NANA (I)	①	M/P	4	-	2	2	-	4	2	2	2	2
		E/P	4	-	2	2	-	4	2	2	2	2
		M/P										
		E/P										
ASOK (J)	①	M/P	3	3	3	3	3	3	3	3	3	3
		E/P	3	3	3	3	3	3	3	3	3	3
	②	M/P	3	2	3	2	3	2	3	2	3	2
		E/P	3	2	3	2	3	2	3	2	3	2
		M/P										
		E/P										
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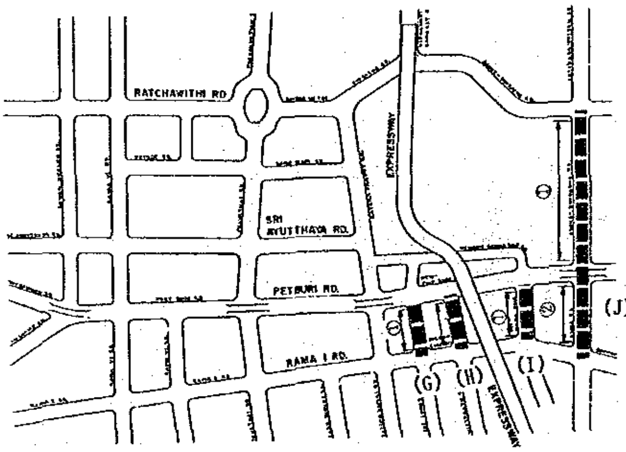
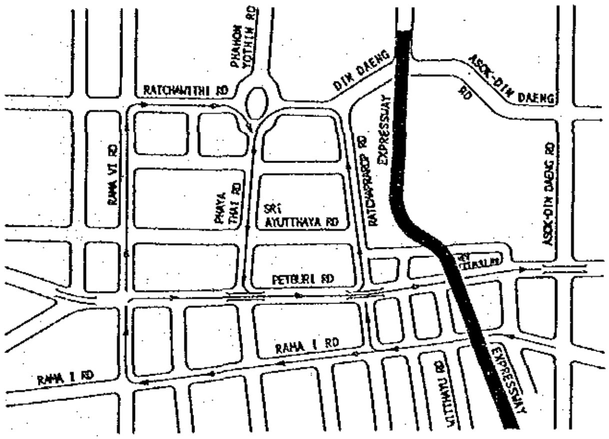
		M/P										
		E/P										



Existing System, Case (1)

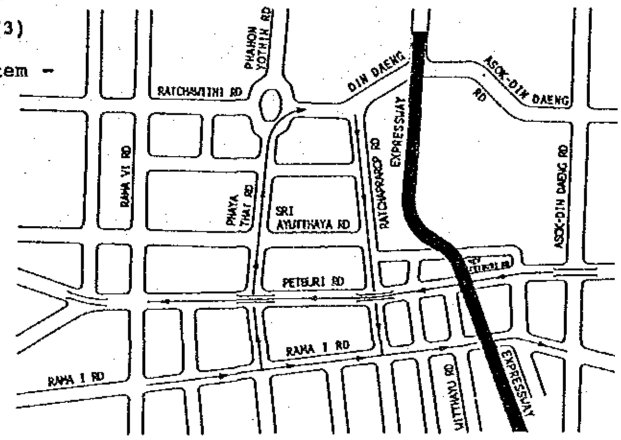


Legend

←—— main flow

Counter-clockwise System, Case (3)

- Reverse flow of existing system -

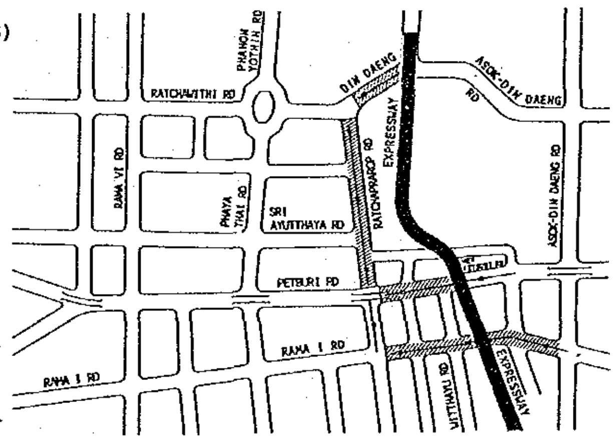


Legend

←—— main flow

Note: Two lane for opposite flow

Two-Way Reversible Flow, Case (5)



Legend

////////// Link with reversible lane

←—— main flow in morning peak hour

Fig. 4.3.6 Concept of Alternatives

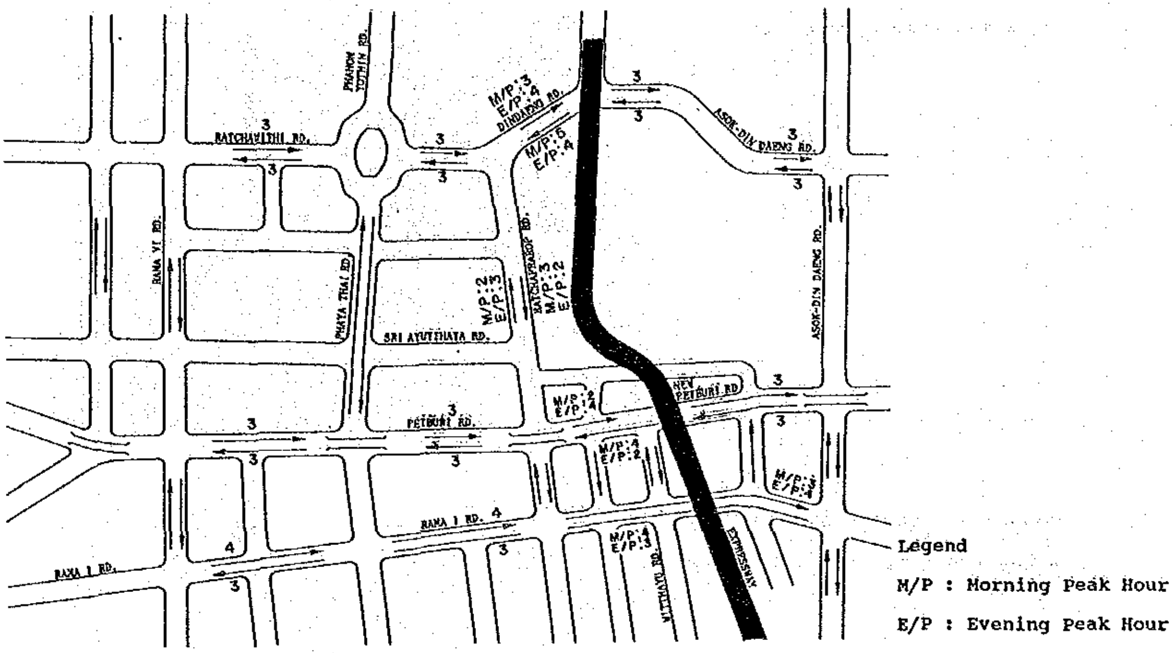


Fig. 4.3.7 Traffic Lane Allocation for Two-Way Reversible Plan Case-(5)

4.4 Traffic Management Plan

4.4.1 Evaluation Indices

To compare the overall effectiveness of the three alternatives listed above, indices applicable to the simulation area as a whole and indices applicable to individual intersections or road sections were selected. They are as follows:

1) Indices Applicable to Simulation Area as a whole

   a) Total Delay Time

      Total delay time in the simulation area is the sum total of delays that occur during a peak hour within the simulation area and in road sections approaching intersections that are located at the periphery of the simulation area (it does not refer to the sum total of delays that occur up to trip completion).

   b) Total Queue Length

      Total queue length in the simulation area is the sum total of queues that are created within the simulation area and at intersections along the borders of the simulation area.

2) Indices Applicable to Intersections/Road Sections

a) Saturation degrees of major intersections and their distribution
b) Average travel speeds on major roads
c) Queue lengths at major intersections and major road sections
d) Queue lengths on expressway ramps

4.4.2 Evaluation for Current Network

1) Delay Time and Queue Length

Table 4.4.1 compares the three alternatives listed in the preceding section in terms of total delay time, total queue length and maximum inbound traffic volume, as obtained from computer simulations. As the tables indicate, Cases 3 and 5 show better results than the current system (Case 1) during both peak hours.

Total delay time in Case 5 is 7% lower than the current level during the morning peak hour and 6% lower during the evening peak hour. Corresponding figures for Case 3 is 4% and 1%.

Total queue length shows a marked improvement in Case 5: 14% lower than the current level during the morning peak hour and 16% lower during the evening peak hour.

Table 4.4.1 Comparison of Each Alternative
(One-Way Traffic Study)

Case		Morning Peak Hour		Evening Peak Hour		Remarks
		Total Delay Time (Hours. Vehicles)	Total Queue Length (Km.)	Total Delay Time (Hours. Vehicles)	Total Queue Length (Km.)	
Existing System (Clockwise)	Case - (1)	9,648 (1.00)	92.8 (1.00)	9.058 (1.00)	76.1 (0.98)	Included new link of Rama IX
Couter-Clockwise System	Case - (3)	9,297 (0.96)	87.7 (0.95)	8.952 (0.99)	72.1 (0.95)	Included reversible lane
Two Way Reversible System	Case - (5)	8,978 (0.93)	79.7 (0.86)	8,476 (0.94)	64.0 (0.84)	Reversible link Din Daeng Road Ratchaprarop Road New Pheburi Road Sukhumvit Road

2) Distribution of Saturation Degree

Table 4.4.2 compares the three alternatives in terms of the saturation degrees of 32 major intersections located within the current one-way system area.

Of the 32 intersections, 16 have saturation degrees of more than 1.0 under the current system, 15 in Case 3, and 14 in Case 5.

Moreover, as many as 13 intersections have saturation degrees of 1.2 or higher under the current system, indicating that the system creates severe congestion and can easily lead to complications owing to the interaction of a number of oversaturated intersections. There are 8 intersections with rates of 1.2 or higher in Case 3 but only 5 in Case 5.

Case 5 has fewer intersections that are oversaturated than case 1 and 3, which means that it is less likely to cause the oversaturation of the entire network.

Table 4.4.2 Evaluation of Saturation Degree on Each Case (Morning Peak Hour)

Unit : No. of Intersection

Saturation Degree	Over Saturation			Near Saturation		Under Saturation		Total
Case	≧1.5	1.5>≧1.2	1.2>≧1.0	1.0>≧0.9	0.9>≧0.8	0.8>≧0.7	<0.7	
Case-(1)	7	6	3	4	1	5	6	(100) 32
Case-(3)	4	4	7	4	6	1	6	(100) 32
Case-(5)	1	4	9	4	4	2	8	(100) 32

3) Average Travel Speed

Table 4.4.3 compares the three alternatives in terms of average travel speeds on major roads during the morning and evening peak hours, as obtained from computer simulations.

The subject roads are as follows: the three east-west arterial routes running between the Middle Ring Rd and Phaya Thai Rd--Asok-Din Daeng, Din Daeng and Ratchawithi; New Petburi and Petburi; and Sukhumvit and Rama I--and the two north-south arterial routes running between Ratchawithi Rd and Rama IV Rd--Phaya Thai; and Ratchaprarop and Ratchadamri.

Table 4.4.3 Average Travel Speed by Simulation Analysis

Unit : Km/hour

Section	Case	Morning Peak Hour (1)	Morning Peak Hour (3)	Morning Peak Hour (5)	Evening Peak Hour (1)	Evening Peak Hour (3)	Evening Peak Hour (5)
1	A	10.4	11.4	12.4	10.3	21.5	24.1
	B	18.6	21.8	22.0	23.3	16.5	23.3
2	A	17.9	26.7	27.9	26.2	26.4	26.9
	B	9.8	23.4	25.0	14.8	23.8	24.5
3	A	9.0	12.3	17.2	15.9	23.5	25.1
	B	17.6	12.0	14.9	12.1	19.5	20.3
4	A	7.8	16.4	18.7	9.7	19.2	20.8
	B	20.6	20.4	21.2	19.8	20.7	21.1
5	A	14.0	19.4	17.5	14.7	21.3	22.7
	B	21.5	5.6	23.2	21.2	6.8	23.3

Between Middle Ring Rd and Phaya Thai Rd:
- 1. : Asok-Din Daeng Rd, Din Daeng Rd and Ratchawithi Road
- 2. : New Petburi Rd and Petburi Rd
- 3. : Sukhumvit Rd and Rama I Rd

Between Ratchawithi Rd and Rama IV Rd:
- 4. : Phaya Thai Rd
- 5. : Ratchaprarop Rd and Ratchadamri Rd

A : (1.3) Inbound Flow
B : (5) Southern Flow
C : (1.3) Outbound Flow
D : (5) Northern Flow

The results are summarized below.

a) Average speed of inbound vehicles during morning peak hour (east-west routes)

- Case 5: Significant increases compared to the current level on New Petburi Rd and Sukhumvit Rd but more or less the same on Asok-Din Daeng Rd.

- Case 3: Marked improvement on New Petburi Rd but more or less the same on the other two arterials.

b) Average speed of outbound vehicles during morning peak hour (east-west routes)

- Case 5: Marked improvement on New Petburi Rd, slight improvement on Asok-Din Daeng Rd and slight deterioration on Sukhumvit Rd

- Case 3: Large increase on New Petburi Rd but major decrease on Sukhumvit Rd

c) Average speed on east-west routes during evening peak hour

- Case 5: Significant increases on Asok-Din Daeng Rd and Sukhumvit Rd for outbound traffic and on New Petburi Rd and Sukhumvit Rd for inbound traffic.

- Case 3: Same conditions as in Case 5 for inbound traffic. For outbound traffic, an improvement on Sukhumvit Rd is offset by a decrease on Asok-Din Daeng Rd

d) Average speed on north-south routes

Both Cases 3 and 5 show major increases in the average travel speed of inbound traffic during the morning peak hour, with the exception of the Ratchaprarop-Ratchadamri route in Case 3, where speed declines significantly. Similar results were obtained for the evening peak hour.

4) Saturation Flow Degrees at Major Intersections

Of the 32 intersections discussed in Section 2) above, 14 were selected for further analysis concerning their saturation degrees during the morning peak hour. The results are shown in Table 4.4.4.

Saturation flow degrees are generally lower in Cases 3 and 5 than in Case 1, with the exception of the Ratchaprarop-Sukhumvit intersection in Case 3. Moreover, Case 5 has the effect of lowering saturation at intersections that are oversaturated under the current system and of raising saturation at intersections that are undersaturated under the current system. Thus, it creates a more balanced flow of traffic within the overall network than the other two alternatives.

Table 4.4.4 Evaluation of Saturation Degree at Each Intersection

(Morning Peak Hour)

Intersection	Case-(1)	Case-(3)	Case-(5)	Intersection	Case-(1)	Case-(3)	Case-(5)
Middle Ring & New Petburi Rd	1.47	2.02	1.38	Ratchprarop Rd & Sukhumvit Rd	0.97	1.25	1.10
Middle Ring & Sukhumvit Rd	1.28	1.19	1.09	Vibhavadi Rangsit Rd & Din Daeng Rd	2.07	1.15	1.12
Soi 3 & New Petburi Rd	1.57	1.67	1.12	Ratchawithi Rd & Din Daeng Rd	1.24	1.00	0.86
Soi 3 & Sukhumvit Rd	1.45	0.81	1.07	Victory Monument	1.59	1.26	1.41
Witthayu Rd & New Petburi Rd	1.26	0.62	1.10	Phaya Thai Rd & Sri Ayutthaya Rd	0.72	1.10	0.98
Witthayu Rd & Sukhumvit Rd	1.12	1.36	0.91	Phaya Thai Rd & Petburi Rd	0.80	0.95	0.72
Ratchadamri Rd & New Petburi Rd	0.97	1.00	1.08	Phaya Thai Rd & Rama I Rd	0.62	1.14	0.88

5) Queue Lengths at Major Intersections

Queue lengths (average length during one peak hour) at major intersections and in major sections are shown for each alternative in Table 4.4.5. Figs. 4.4.1-4.4.6 show where traffic jams of 100 meters or longer occur under each of the three alternatives during the morning and evening peak hours.

A comparison of Figs. 4.4.1, 4.4.3 and 4.4.5, which show bottleneck conditions during the morning peak hour, shows that congestion is generally lighter in Case 5. The same can be said for the evening peak hour.

A point to note is that Case 5 results in the significant reduction of congestion on the expressway off-ramp during both peak hours, thus raising the efficiency of expressway operation. Case 3 produces similar results, except that it is unable to improve conditions on the Sukhumvit ramp during the morning peak hour.

Table 4.4.5 Comparison of Each Alternative

Location	Queue Length (m)					
	Morning Peak Hour			Evening Peak Hour		
	Case-(1)	Case-(3)	Case-(5)	Case-(1)	Case-(3)	Case-(5)
New Petburi Rd ETA-off ramp	370	180	190	260	140	70
Sukhumvit Rd ETA-off ramp	340	350	210	310	100	120
New Petburi Rd						
outbound flow						
Witthayu Rd Intersection	340	210	220	small	430	100
Middle Ring Intersection	510	small	240	490	300	100
inbound flow						
Soi 3 Intersection	small	170	small	(contra)	small	small
Ratchaprarop Rd	small	360	small	(contra)	150	small
Sukhumvit Rd						
outbound flow						
between Soi 3 and Ratchadamri Rd	(contra)	860	small	150	200	180
inbound flow						
between Soi 3 and Witthayu Rd	480	240	310	small	550	100
between Soi 3 and Middle Ring Rd	430	560	450	460	330	280
Asok-Din Daeng Rd						
outbound flow						
Middle Ring Intersection	140	220	270	430	160	150
Din Daeng Rd						
inbound flow						
Ratchaprarop Rd	550	490	350	410	350	150
Ratchawithi Rd						
inbound flow						
Victory Monument	390	320	250	small	120	small
Ratchaprarop Rd						
inbound flow						
between Sri Ayutthaya Rd and Petburi Rd	(contra)	610	180	(contar)	200	100
Phaya Thai Rd						
inbound flow						
between Sri Ayutthaya Rd and Petburi Rd	250	530	120	70	500	small
Rama VI Rd						
inbound flow						
between Sri Ayutthaya Rd and Petburi Rd	180	110	130	small	small	130
Sawankhalok Rd						
inbound flow						
between Sri Ayutthaya Rd and Petburi Rd	230	330	280	210	250	150
Witthayu Rd						
north bound flow						
New Petburi Rd	360	150	100	small	110	small
South bound flow						
Sukhumvit Rd	(one-way)	190	230	(one-way)	small	150

(Note) small means "less than 100 m."

Morning Peak Hour (7:00-8:00) Unit : M

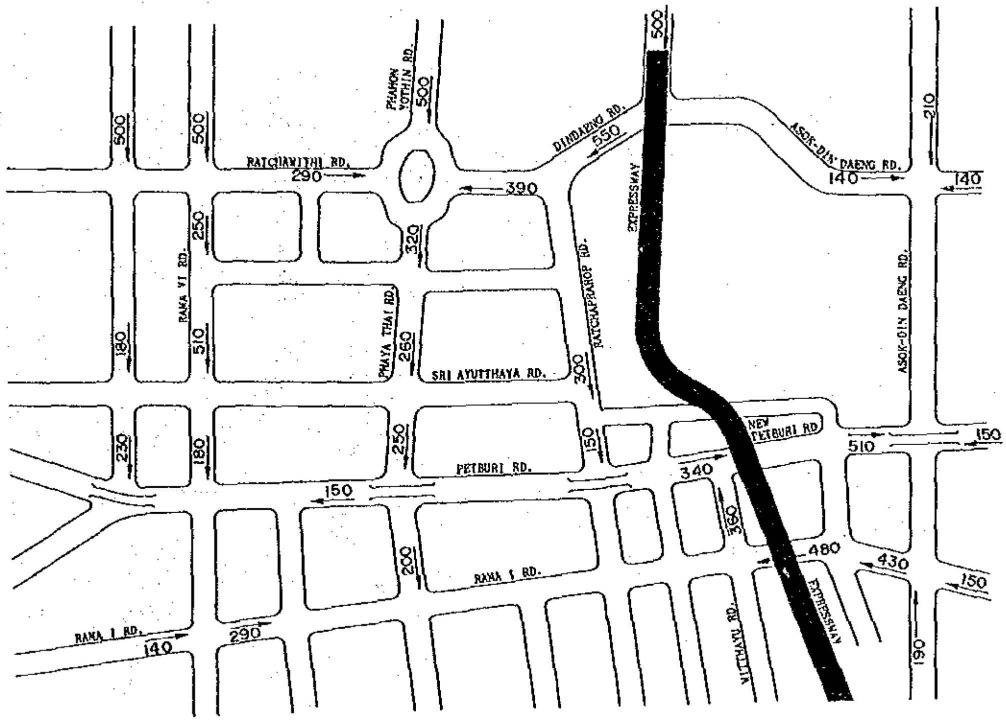


Fig. 4.4.1 Queue Length Case-(1)

Evening Peak Hour (17:00-18:00) Unit : M

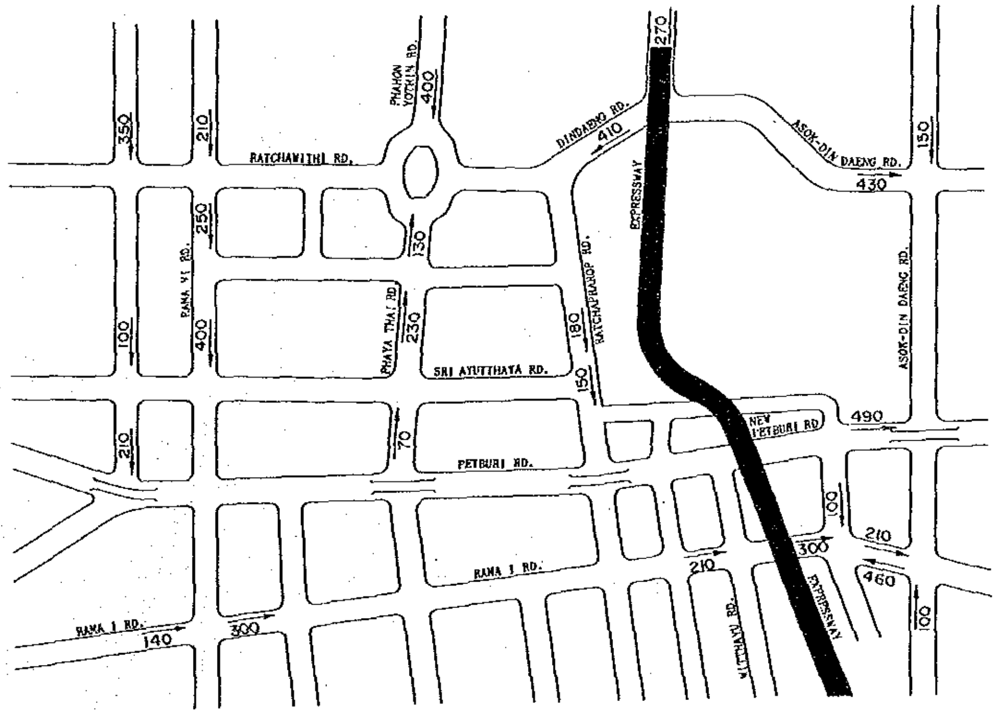


Fig. 4.4.2 Queue Length Case-(1)

Morning Peak Hour (7:00-8:00)   Unit : M

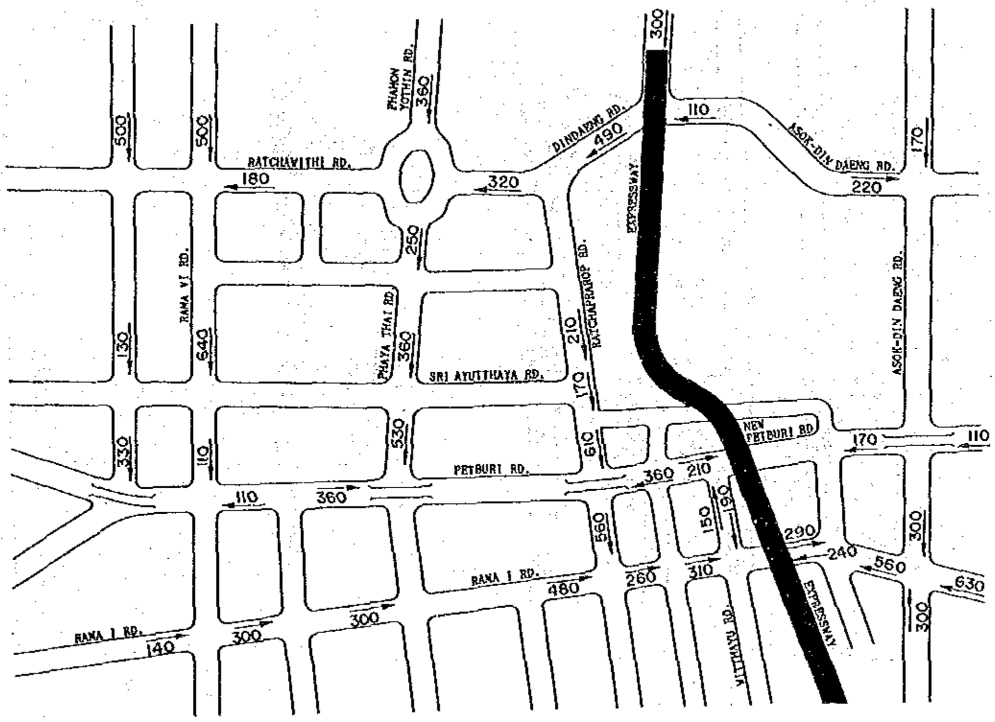


Fig. 4.4.3 Queue Length Case-(3)

Evening Peak Hour (17:00-18:00)   Unit : M

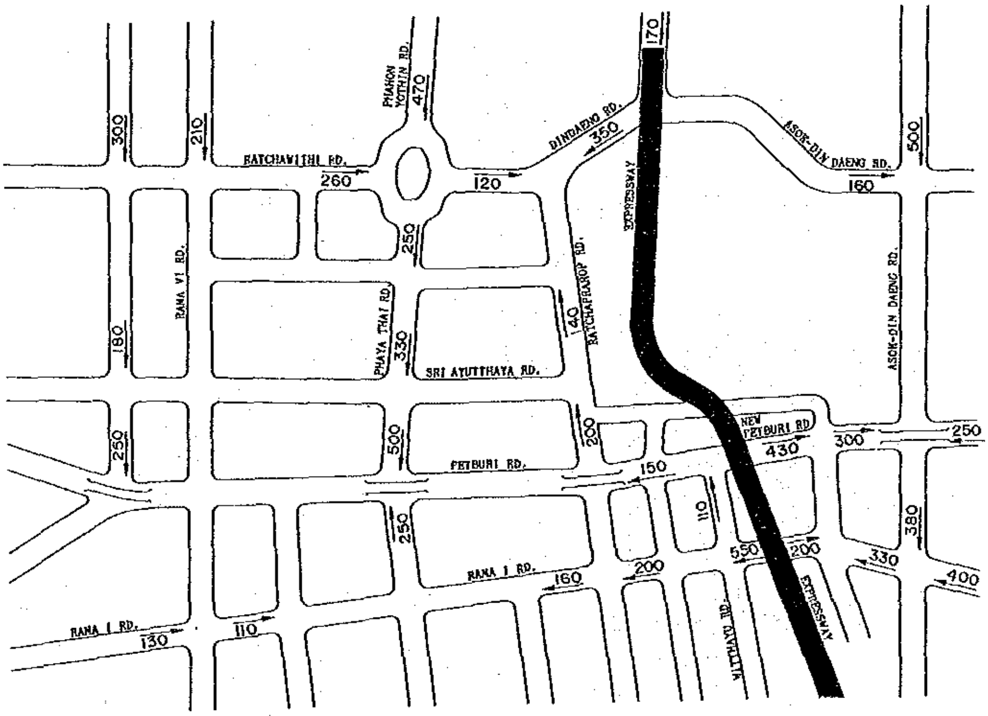


Fig. 4.4.4 Queue Length Case-(3)

Morning Peak Hour (7:00-8:00) Unit : M

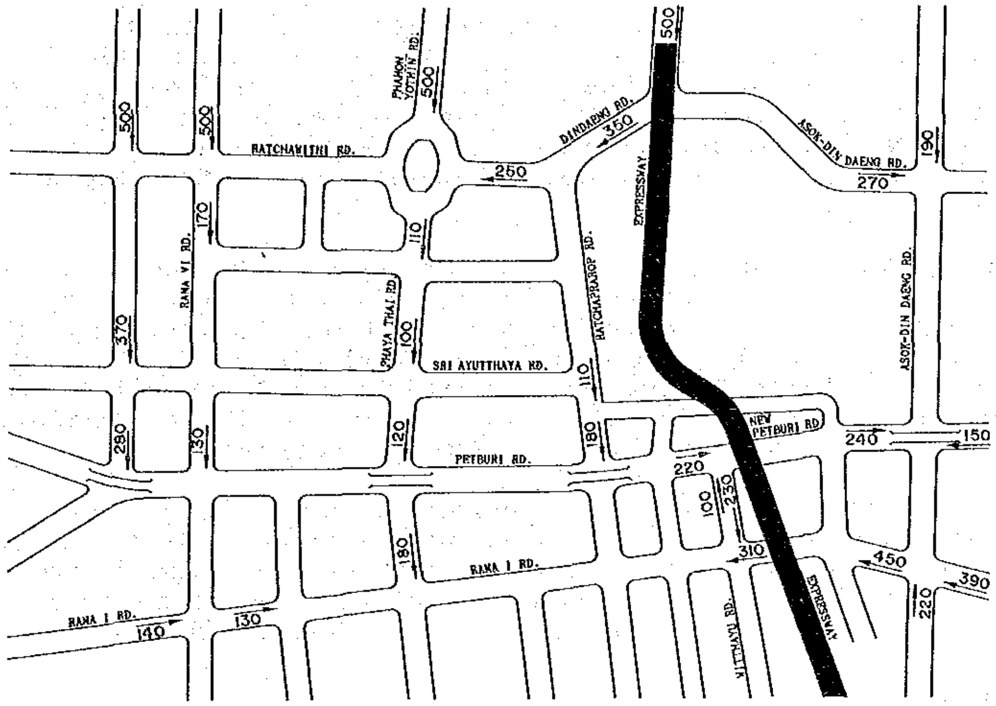


Fig. 4.4.5 Queue Length Case-(5)

Evening Peak Hour (17:00-18:00) Unit : M

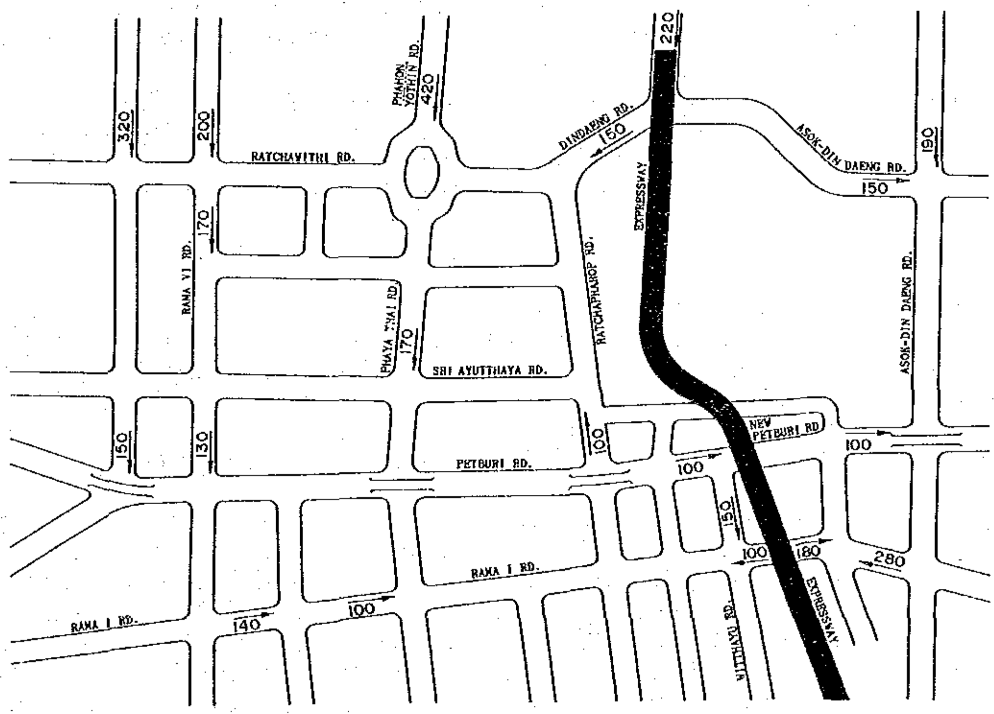


Fig. 4.4.6 Queue Length Case-(5)

6) Overall Evaluation

The current flow control system (Case 1) scored low in such factors as total queue length and total delay time which indicate overall conditions in the subject area. Moreover, the system results in a large number of oversaturated intersections, with oversaturation occurring along a series of intersections in some areas. It also creates heavy congestion on the expressway and its access ramps.

Case 3, by reversing the current system to counter-clockwise operation, results in the virtual elimination of congestion on the expressway off-ramp on New Petburi Rd and significantly increases travel speed on New Petburi Rd However, this alternative fails to improve conditions on Sukhumvit Rd including the expressway off-ramp, and even leads to deteriorated conditions on part of the north-south arterials.

Case 5, a two-way reversible system, scored higher than the other two alternatives on all the factors discussed above (total queue length, intersection saturatin degree, average travel speed, etc.). In addition, it has the effect of dramatically easing congestion on both the New Petburi and Sukhumvit off-ramps.

Conclusion

a) The current system is the least effective of the three alternatives evaluated.

b) The two-way reversible system (Case 5) is suitable for the current network. (It requires the installation of additional facilities for operating reversible lanes.)

c) The counter-clockwise one-way system (Case 3) improves flow conditions in certain sections but worsens conditions in other sections; thus, the overall effect is not necessarily favorable for the current network.

7) Further Study of Two-way Reversible System

Based on the foregoing, we recommend the two-way reversible system (Case 5) as the most effective traffic management method for the current network. However, since it may be difficult to effect reversible-lane operation in all four sections at once, a limited version -- where reversible lanes will be introduced in only two sections -- was reviewed as an alternative.

At present Din Daeng Rd is operated as a reversible lane street based on manual control by traffic policemen, and good results have been obtained. In addition to this section, reversible-lane operation may be effective on New Petburi Rd and Sukhumvit Rd Accordingly, based on BMA's request, the following system was reviewed as an additional alternative (Case 5'): reversible lanes on Din Daeng Rd and New Petburi Rd, and fixed unbalanced flow on Sukhumvit Rd and Ratchaprarop Rd (see Fig. 4.4.7).

Table 4.4.6 compares the four alternatives in terms of total delay time and total queue length during the evening peak hours, and Table 4.4.7 compares queue lengths at major locations during the evening peak hours. Comparison of saturation degrees between Case 5 and Case 5' in evening peak is shown in Fig. 4.4.8.

Table 4.4.6 Total Delay Time and Total Queue Length

	Morning Peak Hour		Evening Peak Hour	
	Total Delay (hours)	Total Queue (km)	Total Delay (hours)	Total Queue (km)
Case-(1)	9,648 (1.00)	92.8 (1.00)	9,058 (1.00)	76.1 (1.00)
Case-(3)	9,297 (0.96)	87.7 (0.95)	8,952 (0.99)	72.1 (0.95)
Case-(5)	8,978 (0.93)	79.7 (0.86)	8,476 (0.94)	64.0 (0.84)
Case-(5')	8,978 (0.93)	79.9 (0.86)	8,733 (0.96)	67.0 (0.88)

Notes :
1. Case-(1) : Existing System
2. Case-(3) : Counter-Clockwise System
3. Case-(5) : Two-way Reversible System with 4 reversible links
4. Case-(5') : Two-way Reversible System with 2 reversible links
5. ( ) : Index values : 1.00 = Case-(1)

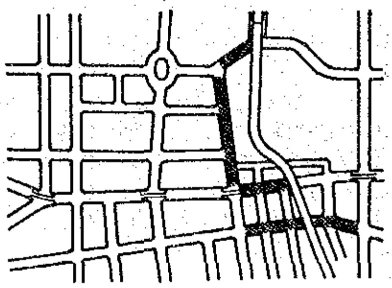
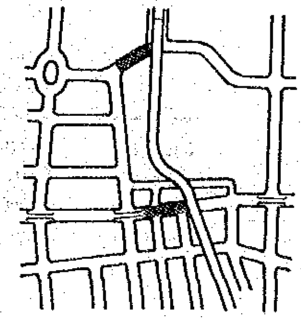
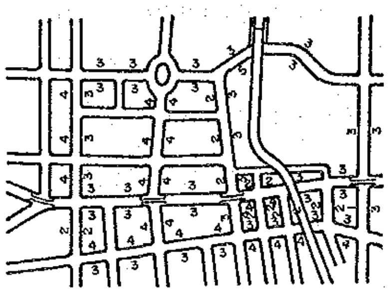
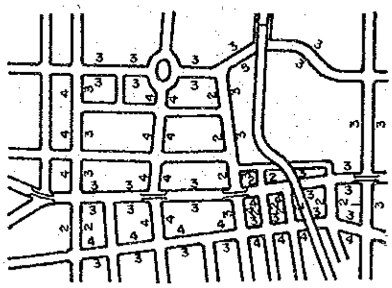
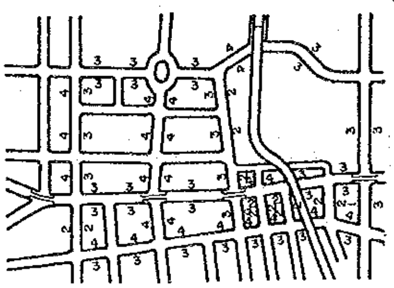
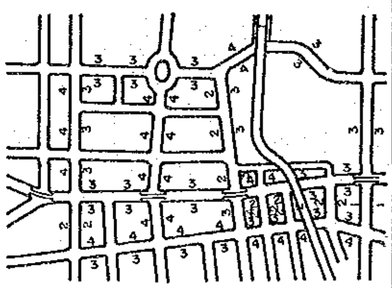
CASE		(5)	(5')
TYPE OF DIRECTION		TWO-WAY	TWO-WAY
REVERSIBLE		○	○
MAIN FLOW		 LINK WITH REVERSIBLE LANE	 LINK WITH REVERSIBLE LANE
NO. OF LANE	MORNING PEAK HOUR		
	EVENING PEAK HOUR		

Fig. 4.4.7 BMA Requested Plan Two-Way Reversible

Table 4.4.7 Comparison of Each Alternative

Evening Peak Hour (m)

Location	Queue Length (m)		
	Case-(1)	Case-(5)	Case-(5')
New Petburi Rd ETA-off ramp	260	small	small
Sukhumvit Rd ETA-off ramp	310	120	140
New Petburi Rd outbound flow			
Soi 3 Intersection	small	100	120
Middle Ring Intersection	490	100	110
inbound flow			
Soi 3 Intersection	(contra)	small	small
Ratchaprarop Rd	(contra)	small	small
Sukhumvit Rd outbound flow between Soi 3 and Ratchadamri Rd	150	180	290
inbound flow between Soi 3 and Witthayu Rd	small	100	small
between Soi 3 and Middle Ring Rd	460	280á	310
Din Daeng Rd inbound flow Ratchaprarop	410	150	150
Ratchawithi Rd inbound flow Victory Monument	small	small	small
outbound flow Ratchaprarop	small	small	110
Rama I Rd outbound flow	small	100	160
Ratchaprarop Rd outbound flow between Din Daeng Rd and Sri Ayutthaya Rd	small	small	190
Phaya Thai Rd inbound flow between Victory Monument and Sri Ayutthaya Rd	small	170	230

Note small : less than 100 m

Total delay time and total queue length in Case 5' are greater than in Case 5 but smaller than in Cases 1 and 3. In addition, queue lengths and saturation degrees at major locations in Case 5' are either the same or only slightly higher than in Case 5. In view of these results, Case 5' is believed to be effective as a temporary measure.

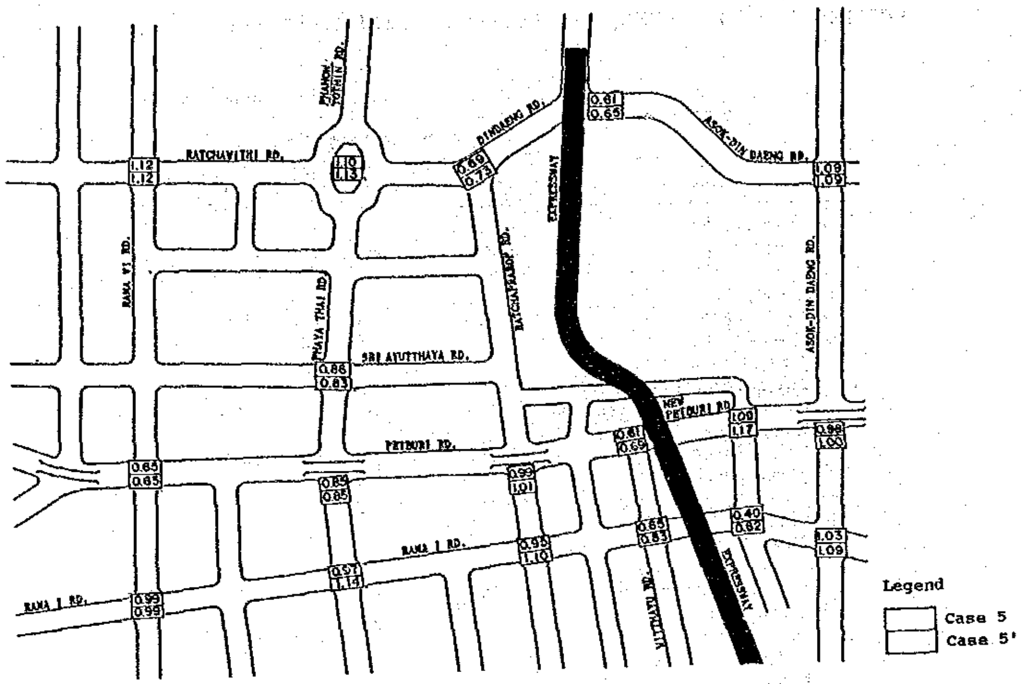


Fig. 4.4.8 Comparison of Saturation Degrees between Case-(5) and Case-(5') in Existing Netwrok

4.4.3 Traffic Management System for Future Network

The preceding section discussed the traffic management plans recommended for the current network: the two-way reversible plan (Case 5) and its limited version applicable to Din Daeng Rd and New Petburi Rd (Case 5').

The ETA's Second Stage Expressway and new flyovers to be completed in the future are expected to have a considerable impact on traffic conditions in the Study Area. Therefore, it is necessary to determine how the two plans mentioned above will be affected by the completion of these projects and whether it is necessary to adjust the plans to the new network.

The road network in 1993, when the new ATC system will be introduced, is described in Section 3.2 above. However, in accordance with BMA's suggestion, the 1993 network reviewed here does not include the Din Daeng - Ratchaprarop flyover.

1) Total Delay Time and Total Queue Length

Simulation results on the applications of Cases 5 and 5' to the 1993 road network--which includes the Second Stage Expressway and new flyovers--with respect to total delay time and total queue length are shown in Table 4.4.8.

Table 4.4.8 Total Delay Time and Total Queue Length (1993 Network)

Case	Morning Peak Hour		Evening Peak Hour	
	Total Delay (Vehicle-hrs)	Total Queue (km)	Total Delay (Vehicle-hrs)	Total Queue (km)
Case 5	8,031	72.7	7,652	59.0
	(0.83)	(0.78)	(0.84)	(0.77)
Case 5'	8.031	72.7	7,943	62.0
	(0.83)	(0.78)	(0.88)	(0.81)
Case 5	8,978	79.7	8,476	64.0
(1988 network)	(0.93)	(0.86)	(0.94)	(0.84)

Note: ( ) : Index value;
1.00 = Case 1 (existing system, 1988 network).

The results show that the new network serves to reduce both total delay time and total queue length in either of the two Cases. As far as these factors are concerned, the application of Case 5 or Case 5' to the 1993 road network entails no problems.

2) Saturation Degrees of Major Intersections

Table 4.4.9 compares the effectiveness of Case 5 when applied to the current and 1993 networks in terms of the saturation degrees of major intersections.

Table 4.4.9 Saturation Degree

Location	Morning Peak Hour	
	New Network Case-(5) (m)	Existing Network Case-(5) (m)
Middle Ring Rd & New Petburi Rd	1.38	1.38
Middle Ring Rd & Sukhumvit Rd	1.06	1.09
Ratchaprarop Rd & New Petburi Rd	0.74	1.08
Ratchaprarop Rd & Sukhumvit Rd	0.89	1.10
Phaya Thai Rd & Petburi Rd	0.71	0.72
Phaya Thai Rd & Rama I Rd	0.83	0.88
Rama VI Rd & Petburi Rd	0.90	0.86
Rama VI Rd & Rama I Rd	1.50	1.24
Ratchawithi Rd & Rama VI Rd	0.97	1.24
Victory Monument	0.98	1.41
Ratchawithi Rd & Din Daeng Rd	1.06	0.86
Vibhavadi Rangsit Rd & Din Daeng Rd	1.02	1.12
Witthayu Rd & New Petburi Rd	0.71	1.10
Soi 3 & New Petburi Rd	1.00	1.12
Soi 3 & Sukhumvit Rd	0.55	1.07
Witthayu Rd & Sukhumvit Rd	0.73	0.91

The saturation degrees of most intersections are the same or lower in the 1993 network, indicating that the Second Stage Expressway and new flyovers will help reduce congestion. An exception is the Rama IV Rd - Rama I Rd intersection. The deterioration here is thought to be due to the fact that the Second Stage Expressway will be only partially open in 1993; the full-scale opening of the Expressway is expected to lower the saturation degree of this intersection.

In view of the foregoing, there appears to be no need for adjusting the recommended plan for a two-way reversible system.

3) Queue Lengths at Major Intersections

Queue lengths on ETA Expressway off ramps and at major intersections are shown in Tables 4.4.10 (morning peak hour) and 4.4.11 (evening peak hour).

During the morning peak hours, traffic jams occur at the junction between Petburi Rd and the Second Stage Expressway's Petburi ramp. In addition, congestion on Rama VI Rd is slightly heavier. This is thought to be due to the congestion of a number of Second Stage Expressway ramps linked to the road.

Table 4.4.10 Queue Length

Location	Morning Peak Hour	
	New Network Case-(5) (m)	Existing Network Case-(5) (m)
ETA - off ramp		
New Petburi Rd	110	190
Sukhumvit Rd	190	210
Petburi Rd	150	-
(ETA - 2nd Stage)		
Din Daeng Rd		
(in bound) Ratchaprarop Rd	150	350
Ratchawithi Rd		
(in bound) Victory Monument	190	250
Ratchaprarop Rd		
(in bound) Sri Ayutthaya Rd	small	110
(in bound) Petburi Rd	240	180
Phaya Thai Rd		
(in bound) Sri Ayutthaya Rd	180	210
(in bound) - Victory Monument		
Rama VI Rd		
(in bound) Ratchawithi Rd ~ Sri Ayutthaya Rd	260	170
Sri Ayutthaya Rd ~ Petburi Rd	240	130
New Petburi Rd & Petburi Rd		
(out bound) Middle Ring Rd	160	240
(out bound) Witthayu Rd	160	220
(out bound) Banthat Thong Rd	180	-
Sukhumvit Rd & Rama I Rd		
(in bound) Soi 3 ~ Witthayu Rd	110	310
(in bound) Soi 3 - Middle Ring Rd	220	450

Table 4.4.11 Queue Length

Location	Evening Peak Hour		
	New Network Case-(5) (m)	New Network Case-(5') (m)	Existing Network Case-(5) (m)
ETA - off ramp			
New Petburi Rd	50	50	70
Sukhumvit Rd	50	50	120
Petburi Rd			
(ETA - 2nd Stage)			
Din Daeng Rd			
(in bound) Ratchaprarop Rd	130	130	150
Ratchaprarop Rd			
(out bound) Sri Ayutthaya Rd	110	120	100
Ratchawithi Rd		110	small
Rama VI Rd			
(in bound) Ratchawithi Rd			
~ Sri Ayutthaya Rd			170
Sri Ayutthaya Rd			
~ Petburi Rd	90	90	130
New Petburi Rd & Petburi Rd			
(out bound) Middle Ring Rd	100	100	100
(out bound) Soi 3	-	-	100
(out bound) Banthat Thong Rd	60	60	-
Sukhumvit Rd & Rama I Rd			
(out bound) Middle Ring Rd	-	100	small
(out bound) Soi 3 ~ Ratchadamri Rd	-	380	180
(in bound) Soi 3 ~ Witthayu Rd	160	60	100
(in bound) Soi 3	140	110	280

Queue lengths on roads subject to the recommended reversible lane system--New Petburi Rd, Sukhumvit Rd, Din Daeng Rd, etc.--are generally shorter, confirming the effectiveness of Case 5 applied to the new network.

4) Additional Study Concerning Din Daeng Rd Flyover Project

(1) Objective

The objective is to grasp the influence of traffic flow related to The Two Way Reversible System according to the construction of following flyover and/or underpass.

a) a flyover between Din Daeng Rd and Ratchawithi Rd to let inbound flow avoid crossing.

b) an underpass between Din Daeng Rd and Asok - Din Daeng Rd to let outbound flow avoid crossing.

(2) Study case

The study cases are below:

Case-(a).... without flyover, without underpass
Case-(b).... with flyover, without underpass
Case-(c).... without flyover, with underpass
Case-(d).... with flyover, with underpass

Note:

- These 4 cases are studied on the connection with case 5 which was estimated in former study as a two-way reversible system.
- Judging from the feasibility of construction, case-(a) and case-(c) are studied on the connection with case 5' except of other cases.

(3) Evaluation

Total Delay Time & Total Queue Length are as follows.

o These result show that case-(d) is obviously most effective to reduce queue length.

o According to the request from BMA, the comparison between case-(b) and case-c was carried out, Table 4.4.14 shows that the underpass between Din Daeng Rd and Asok - Din Daeng Rd seems to be prior to the flyover between Din Daeng Rd and Ratchawithi Rd in Morning Peak Hour.

Table 4.4.12 Total Delay Time & Total Queue Length (Morning Peak Hour)

Case	Flyover	Underpass	Total Delay Time (hours)	Total Queue Length (km)
Case 5 (a)	without	without	8,031 (0.83)	72.7 (0.78)
Case 5 (b)	with	without	7,896 (0.82)	72.5 (0.78)
Case 5 (c)	without	with	7,949 (0.82)	71.9 (0.77)
Case 5 (d)	with	with	7,784 (0.81)	69.2 (0.75)

Note : ( ) : Index values
1.00 = Case-(1) (Existing System, 1988 Network)

Table 4.4.13 Total Delay Time & Total Queue Length (Evening Peak Hour)

Case	Flyover	Underpass	Total Delay Time (hours)	Total Queue Length (km)
Case 5 (a)	without	without	7,652 (0.84)	59.0 (0.77)
Case 5 (b)	with	without	7,650 (0.84)	58.2 (0.76)
Case 5 (c)	without	with	7,614 (0.84)	58.1 (0.76)
Case 5 (d)	with	with	7,528 (0.83)	57.9 (0.74)
Case 5'(a)	without	without	7,943 (0.88)	62.0 (0.81)
Case 5'(c)	without	with	7,919 (0.87)	61.5 (0.81)

5) Case Study without Flyover on Din Daeng Road.

(1) Without the flyover project on Din Daeng Rd (Case-a)

Fig. 4.4.9 shows the saturation degrees of the main intersections in the simulation area to compare its condition in Case 5 and that in Case 5'.

In Case 5, the saturation degrees on Din Daeng Rd - Ratchawithi Rd intersection and Din Daeng Rd - Viphawadi Rangsit Rd show that both intersections are near saturated in evening peak.

But, in Case 5', Din Daeng Rd - Ratchawithi Rd intersection are more severely saturated than the Case 5.

In view of the foregoing, reversible lane operation may be effective to Ratchaprarop Rd in partially in order to reduce the saturation degrees of that intersection.

Evening Peak Hour

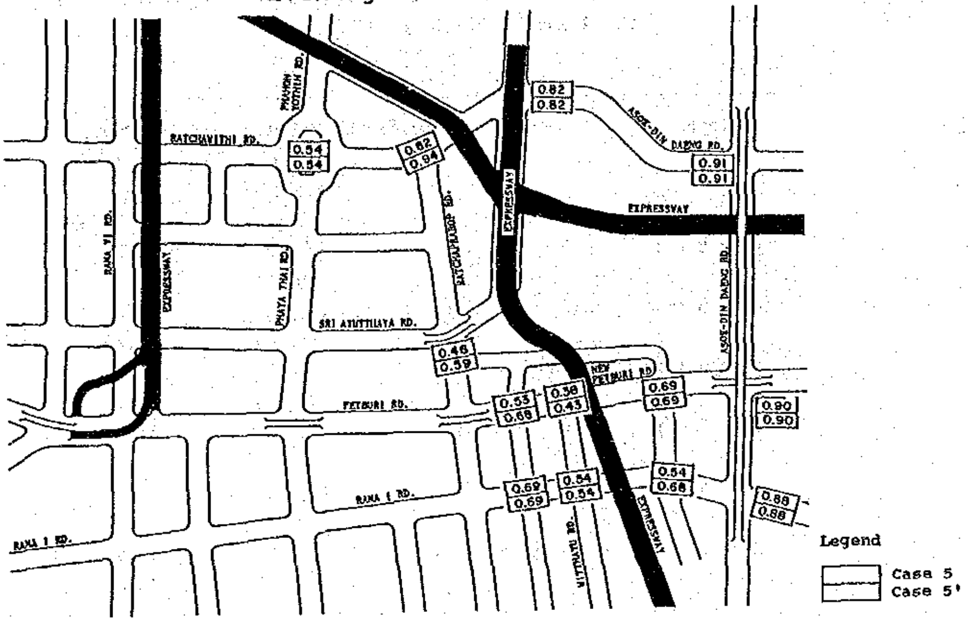


Fig. 4.4.9 Comparison of Saturation Degrees betweeen Case 5 and Case 5' in 1993 without the Flyover Project on Din Daeng Rd

(2) With an underpass between Din Daeng Rd and Asok - Din Daeng Rd, and without a flyover on Din Daeng Rd - Ratchawithi Rd, intersection.

Under the condition that there is an underpass and is not a flyover, the saturation degrees of Case 5' are shown in Fig. 4.4.10.

Obviously, Din Daeng Rd - Ratchawithi Rd intersection is fully saturated in spite of nearby intersections being in undersaturation. This result also shows reversible lane operation on Ratchaprarop Rd is effective to avoid traffic congestion.

According to these study (1) and (2), it would be desirable to introduce reversible lanes, at least partially, on Ratchaprarop Rd in future.

Evening Peak Hour

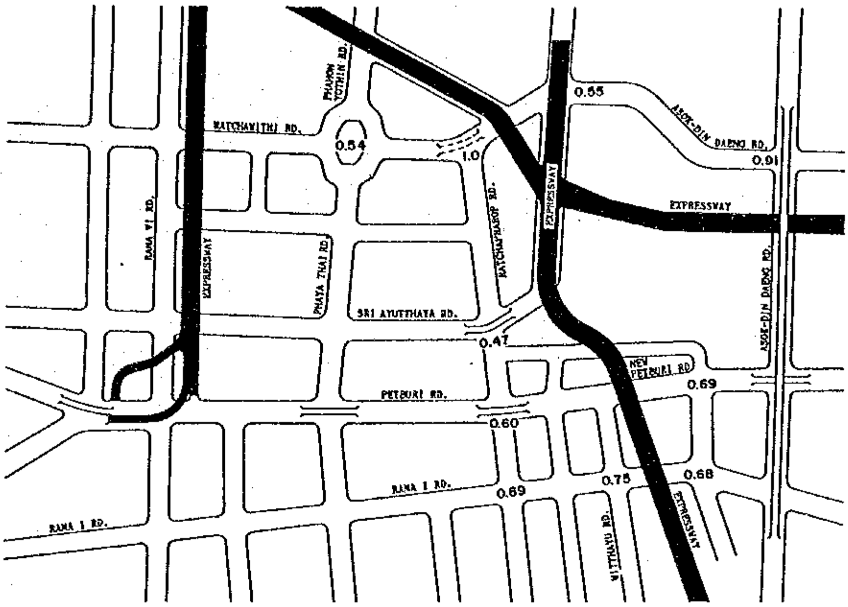


Fig. 4.4.10 Saturation Degrees without Flyover with Underpass in 1993

6) Overall Evaluation

Based on the foregoing, the two-way reversible plan (Cases 5 and 5')recommended for the current network is confirmed to be effective for the road network expected in 1993.

It may, however, be necessary to consider the improvement of traffic flow on Rama VI Rd as there are a few intersections with slightly increased saturation levels and queue lengths on this road. In addition, since Case 5' tends to create congestion on Din Daeng Rd - Ratchawithi Rd intersection during the evening peak hours in the case without a flyover on it's intersection, it would be desirable to introduce reversible lanes, at least partially, in this road in the future.