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THE DETAILED DESIGN STUDY ON AREA TRAFFIC CONTROL PROJECT IN BANGKOK IN THE KINGDOM OF THAILAND

MAIN VOLUME

FINAL REPORT

OCTOBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

THE DETAILED DESIGN STUDY ON AREA TRAFFIC CONTROL PROJECT IN BANGKOK IN THE KINGDOM OF THAILAND MAIN VOLUME FINAL REPORT OCTOBER 1990 JAPAN INTERNATIONAL C

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PREFACE

In response to the request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a detailed design study on Area Traffic Control Project in Bangkok and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Thailand a survey team headed by Dr.Juro Kodera, comprising of members from Yachiyo Engineering Co.Ltd. and Fukuyama Consultants International Co.Ltd. from March to June, 1990 and from July to September 1990.

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

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

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

October, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

1. OBJECTIVE OF THE STUDY

The objective of this Study is to carry out the detailed design study and prepare the necessary documents for the implementation of the first stage of the Area Traffic Control (ATC) system Project in Bangkok as proposed by JICA in August 1989.

2. STUDY AREA

The study covers the area as examined by the previous the JICA Feasibility Study, and particularly the area identified as the Stage I for the implementation of the proposed ATC System. This area is shown in Figure 1.

3. STUDY ORGANIZATION

This Study was carried out by Japan International Cooperation Agency in conjunction with the Bangkok Metropolitan Administration. The organization for the Study is as follows:

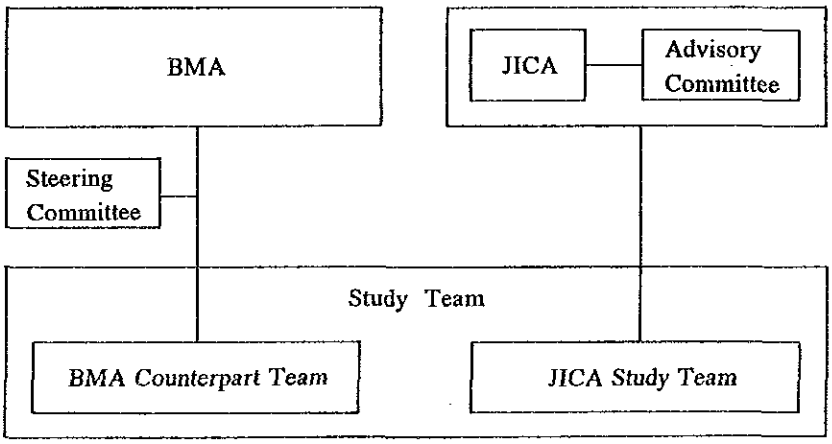

Figure 2 : Study Organization

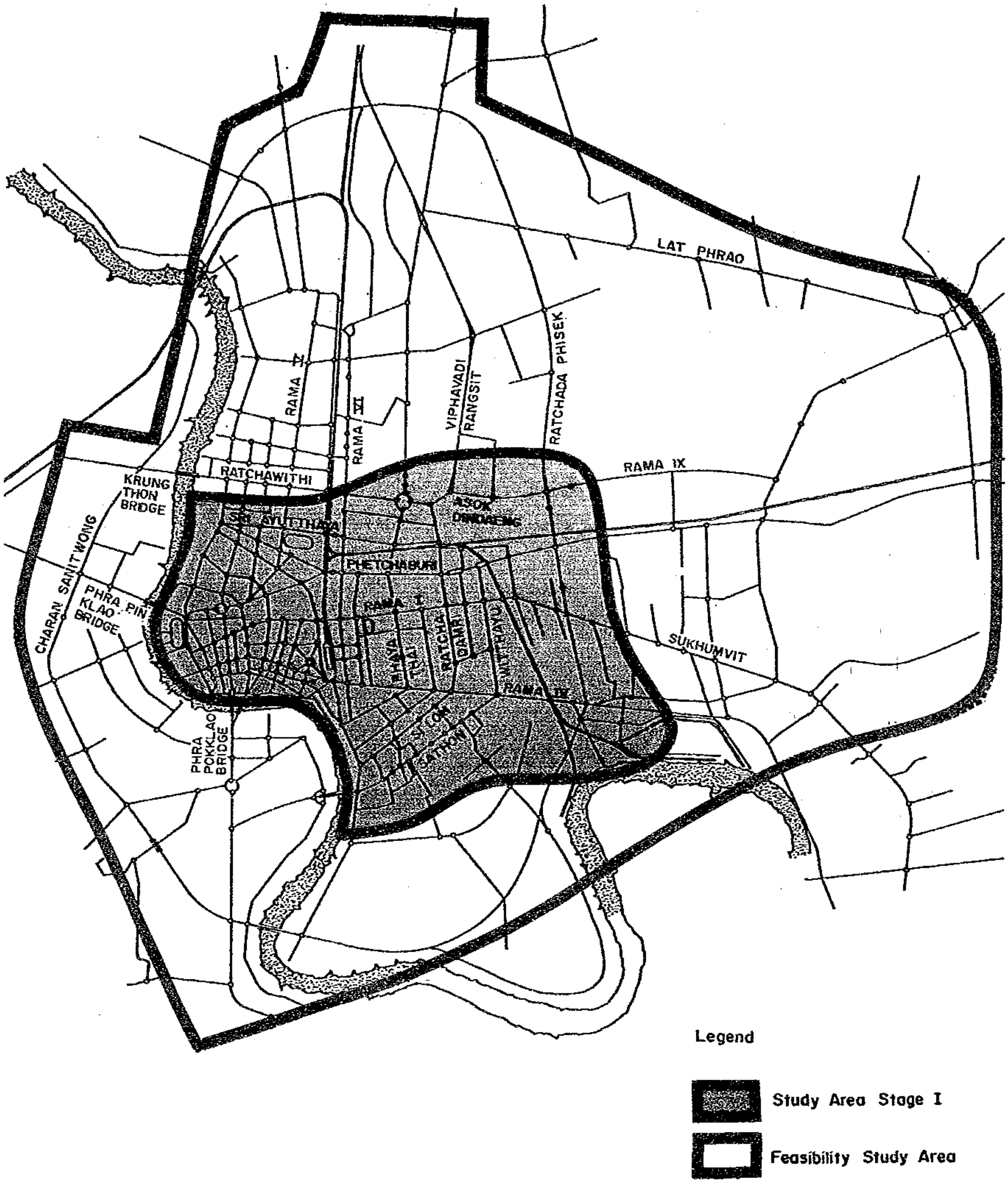

Figure 1 : The Study Area

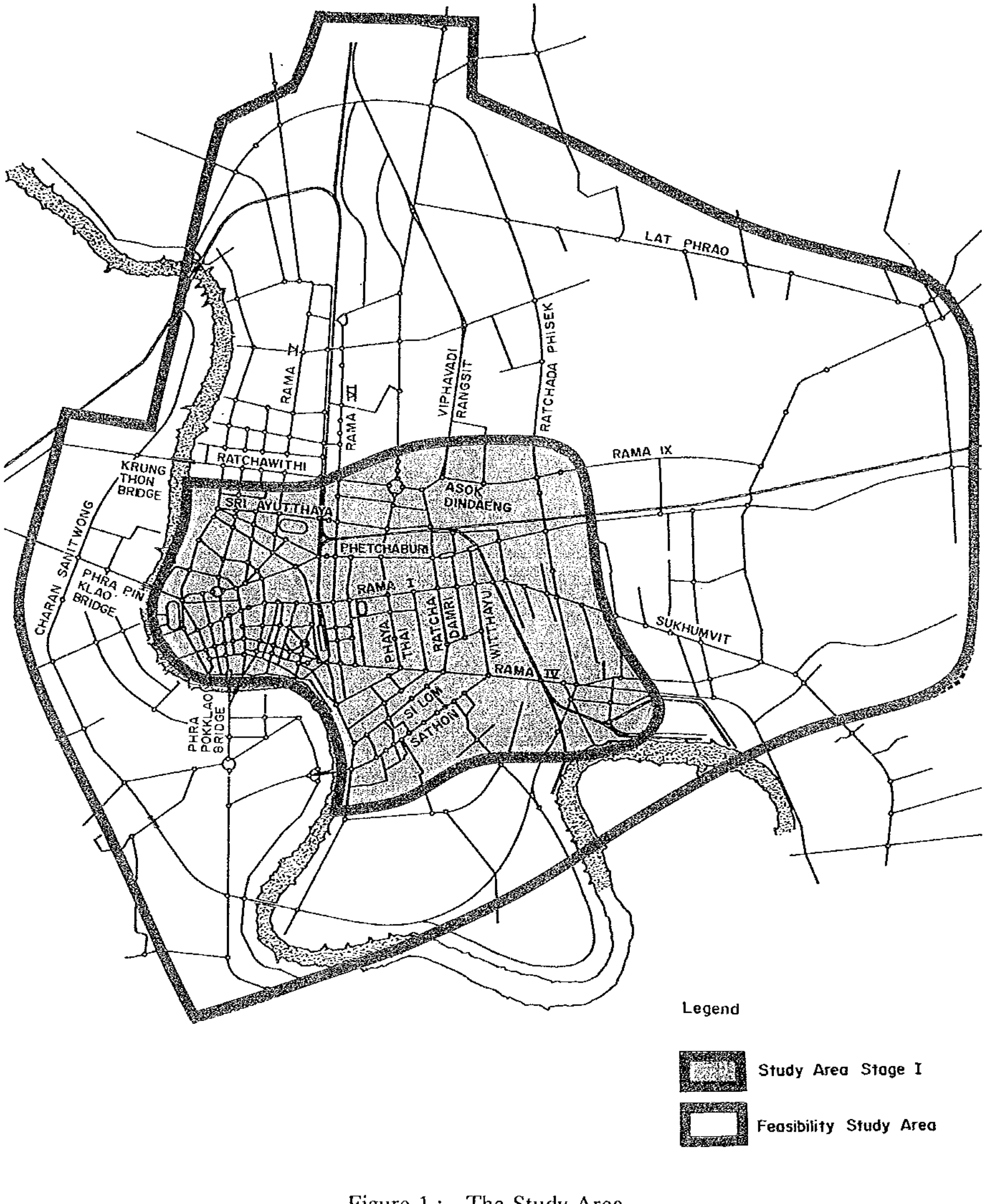

Figure 1 : The Study Area

4. LIST OF MEMBERS FOR THE STUDTY

STEERING COMMITTEE

1.	Mr.Boonyawat Tiptus (Chairman)	-	Director of Traffic Engineering Division, BMA
2.	Dr.Prapon Wongwichien	-	Director of Public and Integrated Planning Division ,BMA
3.	Col.Sanong Krittayabarn	-	Traffic Police Division, Police Department
4.	Mr.Rapw Charutula	-	Office of Committee for the Management of Road Traffic (OCMRT), OPP, MOI
5.	The Late Mr.Tanit Srichu	-	Public Work Department, BMA
6.	Mrs.Krittaya Satcharak	-	Policy and Planning Department
7.	Mr.Anek Chaowakasem	-	Chief of Traffic System, Sub-Division, Traffic Engineering Division, BMA
8.	Mr.Surapol Wattanavicharn	-	Chief of Traffic Sign & Marking Sub-Division, Traffic Engineering Division, BMA
9.	Mr.Suphachai Tangsriwong	-	Chief of Traffic Signal Sub-Division, Traffic Engineering Division, BMA
10.	Mr.Nikom Porntharakcharoen	-	Chief of Design & Planning Section, Traffic Engineering Division, BMA
11.	Mr.Somkid Wongthangswad	-	Chief of Traffic Signal Planning Section, Traffic Engineering Division, BMA
12.	Ms.Hansa Khamthong	-	Chief of Transport Study Section, Traffic Engineering Division, BMA
13.	Mr.Tripob Khantayaporn	-	Chief of Traffic Signal Control Section, Traffic Engineering Division, BMA

JICA ADVISORY COMMITTEE

1.	Prof.Masaki KOSHI	-	University of Tokyo
2.	Mr.Michimasa IKEDA	-	Ministry of Construction
3.	Mr.Akio MIYACHI	-	Ministry of Construction
4.	Mr.Keizo KAGAWA	-	JICA Headquarters

JICA STUDY TEAM

1.	Mr.Juro KODERA	-	Team Leader
2.	Mr.Kokuro HANAWA	-	Contracting/Implementation Planning
3.	Mr.Kimio KANEKO	-	Traffic Management
4.	Mr.Yasuo NABESHIMA	-	Contracting/Maintenance Planning
5.	Mr.Saburo SHIMAUCHI	-	Signal Design (hardware)
6.	Mr.Yoshio YOSHIDA	-	Signal Design (software)
7.	Mr.Yutaka TAKAHASHI	-	Building Facility
8.	Mr.Tetsuya TAHIRA	-	Facility Design I
9.	Mr.Tsukasa TOMOTANI	-	Facility Design II
10.	Mr.Koji HIRANO	-	Facility Design III
11.	Mr.Mok YOU CHUA	-	Bidding Documents
12.	Mr.Akio TATSUNO	-	System Analysis
13.	Mr.Kenjiro MATSUMOTO	-	Cost Estimate

LIST OF REPORT

Besides this Main Volume, there are another 10 volumes of reports, drawings and supporting information on the Bangkok ATC System Project. These are:

1. Summary Volume
2. Supplementary Volume Part 1: Draft Prequalification Document and Evaluation Table.
3. Supplementary Volume Part 2: Draft Tender and Contract Documents.
4. Supplementary Volume Part 3: Draft Technical Specifications.
5. Supplementary Volume Part 4: Draft General Design Plans.
6. Supplementary Volume Part 5: Draft Signal Installation Plans.
7. Supplementary Volume Part 6: Draft Design Volumes and Signal Phasing Plans.
8. Supplementary Volume Part 7: Draft Vehicle Detector Installation Plans.
9. Supplementary Volume Part 8: Intersection Existing Layout Plans.
10. Supplementary Volume Part 9: Existing Utility Lines Plans.

OCTOBER 1990

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BACKGROUND

CHAPTER 1 BACKGROUND

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, 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.

The signalized intersection were initially under the ATC or isolated control modes without updating the control parameter as years go by, and these signals were found to be incapable of coping the much increased traffic. Traffic police which was organized into 4 operational divisions in Bangkok, then started to control these signals manually and has been doing so up to today.

Meanwhile, since the existing road network is 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.

A feasibility study on improving and expanding Bangkok's Area Traffic Control System was carried out between November 1988 and March 1990 with the technical cooperation of the Japanese Government.

Pursuant to the feasibility study and in response to the request of the Thai Government, the Japanese Government agreed to extend technical assistance in the execution of The Detailed Design Study on Area Traffic Control Project in Bangkok in The Kingdom of Thailand (the Study). The Japan International Cooperation Agency (JICA), which is responsible for implementing technical cooperation programs of the Japanese Government, dispatched a preliminary survey mission to Bangkok in December 1989 to conduct a reconnaissance survey and to finalize the Scope of Works for the Study. After the Scope of Works was agreed upon by the Bangkok Metropolitan Administration (BMA), the JICA dispatched a study team to Bangkok in March 1990 to help carry out the Study.

The following problems concerning traffic flow were identified in Bangkok;

a) 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 Road, Middle Ring Road, Din Daeng Road, Ratchawithi Road, and Chao Phraya River, causing chronic congestion within the area.

b) Congestion in the above-mentioned 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.

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

d) 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.

e) 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 longer owing to the one way scheme in the sparse network of roads in the area, which results in longer detour trips.

f) There is a tendency toward high accident frequency on Rama IV Road, Sukhumvit Road, Phetchaburi Road, Phaya Thai Road, and Si Ayutthaya Road, where congestion is severe. The rate of rear-end collisions is high.

g) The frequency of traffic flow interruption caused by the official events is high.

The following problems concerning traffic signal facilities were identified in Bangkok;

a) The existing ATC System has several problems related to its operation. 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.

b) 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.

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

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

In the feasibility study the relationship between traffic volume and link length, current traffic congestion and the future road network were used for selecting the ATC Planning Area.

The planning area of the feasibility study is approximately 101 sq.km as shown in Figure 1.1. The major area is bordered by the Middle Ring Road, Rama IX Road, Phra Khanong-Klongtan Road, Rama IV Road, Sathon Road, Pracha Tipok Road, Taksin Road, and Chao Phraya River. This major area is subject to the most concentrated level of improvements within the Planning Area. Other intersection nodes are located on the Middle Ring Road in the city's western and southern areas, on Lat Phrao Road and on Ramkhamhaeng Road.

For the implementation of the ATC System in the subject area, construction will be carried out in two stages with the aim of commencing system operation in 1993. Figure 1.2 shows the area covered by each stage. Stage I covers 143 signalized intersections. Stage II covers 92 signalized intersections.

Target areas for Stages I and II were determined by evaluating the effects of the ATC System on vehicle delay time in various parts of the subject area.

The effect of the ATC System (With, Without) on total delay time in each zones was then calculated for the morning peak hour, using the following evaluation index obtained through simulations.

$$I_i = \Delta D_i / S_i$$

Where, I : Evaluation index

i : Zone Number

ΔD_i : Total delay time Without ATC minus total delay time With ATC in zone i

S_i : Total travel distance ATC (vehicle-kilometers) in zone i

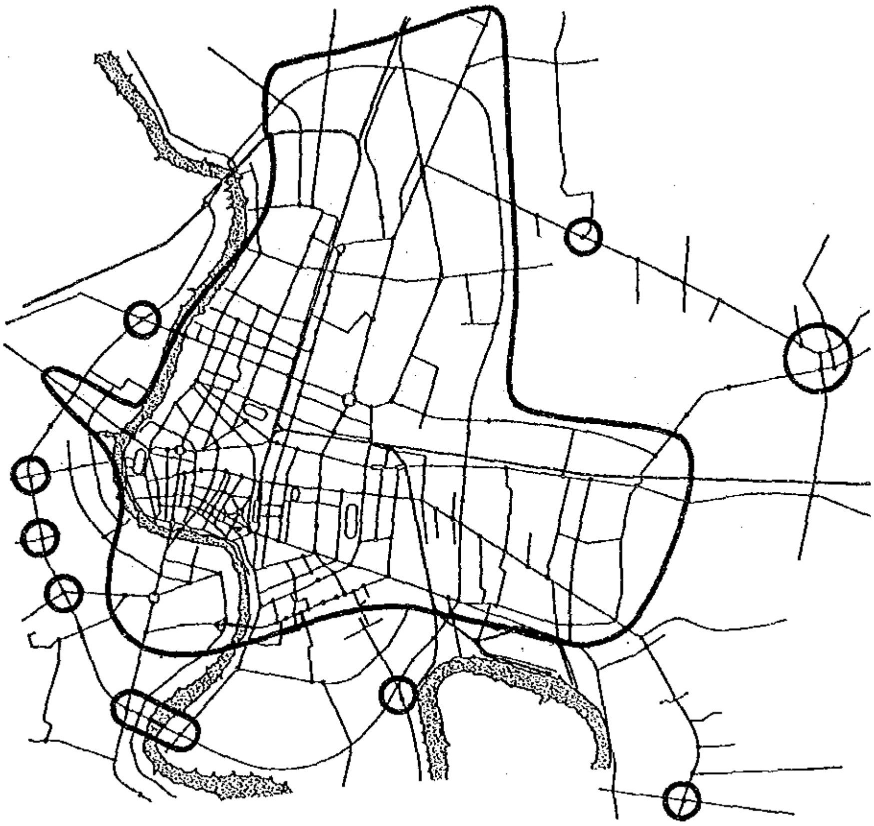


Figure 1.1 ATC System Planning Area

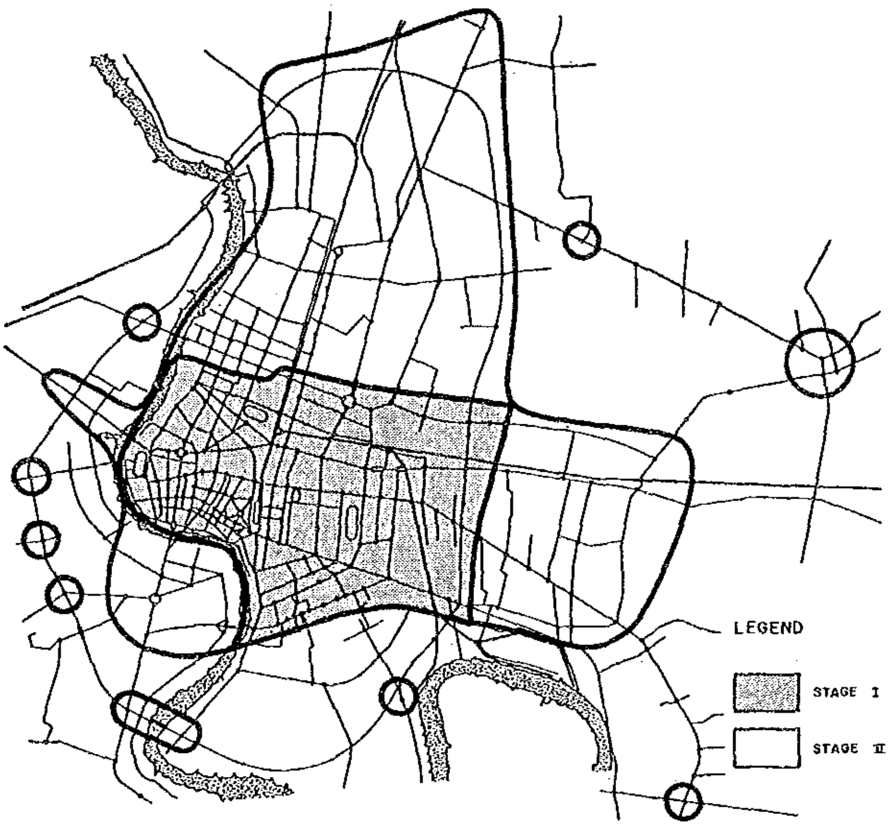


Figure 1.2 Zone Division for Stage Plan

CHAPTER 2

BASIC TRAFFIC CONDITIONS FOR ATC SYSTEM

CHAPTER 2 BASIC TRAFFIC CONDITIONS FOR ATC SYSTEM

2.1 ATC Planning Area and Current Traffic Conditions

2.1.1 ATC Planning Area

The target area for Stage I, is the area (31 sq.km) bordered by the Si Ayutthaya Road, Sawankhalok Road, Ratchawithi Road, Din Daeng Road, Asok Road, Rama IV Road, Sathon Road, Charoen Krung Road, Yaowarat Road, Phahurat Road, Rachini Road, Chakkraphong Road, and Samsen Road.

2.1.2 Existing Road Network to be Covered by ATC System

Figure 2.1 shows the existing road network to be covered by ATC and Figure 2.2 shows the distance between intersections. There are five east-west arterial roads and five north-south arterial roads that serve traffic within the ATC Planning Area. The east-west arterials are Si Ayutthaya Road, Ratchawithi Road-Din Daeng Road, Ratchadamnoen Klang Road-Lan Luang Road-Phetchaburi Road-New Phetchaburi Road, Bamrung Muang Road-Rama I Road-Phloen Chit Road- Sukhumvit Road and Charoen Krung Road-Rama IV Road. The north-south arterials are Chakkraphong Road-Samsen Road, Rama V Road, Charoen Krung Road-Rama IV Road, Phaya Thai Road-Phahon Yothin Road, and Ratchadamri Road-Ratchaprarop Road.

The name and the length of arterial roads in ATC Planning Area are shown as follows;

a)	Si Ayutthaya Road	(4.2 km)
b)	Ratchawithi Road	(1.8 km)
c)	Din Daeng Road	(0.6 km)
d)	Ratchadamnoen Klang Road	(1.2 km)
e)	Asok-Din Daeng Road	(2.3 km)
f)	Lan Luang Road	(1.7 km)
g)	Phetchaburi Road	(3.1 km)
h)	New Phetchaburi Road	(1.6 km)
i)	Bamrung Muang Road	(1.8 km)
j)	Rama I Road	(2.5 km)
k)	Phloen Chit Road	(1.1 km)
l)	Sukhumvit Road	(1.8 km)
m)	Charoen Krung Road	(4.6 km)
n)	Rama IV Road	(4.8 km)
o)	Chakkraphong Road	(2.0 km)
p)	Samsen Road	(1.2 km)
q)	Rama V Road	(0.7 km)

r) Rama VI Road (3.7 km)
s) Phaya Thai Road (3.5 km)
t) Ratchadamri Road (1.7 km)
u) Ratchaprarop Road (1.8 km)

Figure 2.3 shows the number of lanes on approaches to the signalized intersections located in the subject road network.

Major one-way arterial roads have the following total number of lanes: Phetchaburi Road-New Phetchaburi Road, 5-7 lanes; Rama I Road-Phloen Chit Road-Sukhumvit Road, 6-7 lanes; Rama VI Road 4-9 lanes; Phaya Thai Road, 8 lanes; Ratchaprarop Road, 7-8 lanes; Asok Road (Soi Sukhumvit 21 Road), 4-9 lanes.

Number of lanes on other arterial roads is as follows: Rama IV Road, 10-11 lanes; Ratchadamnoen Klang Road-Lan Luang Road 6-12 lanes; Ratchadamri Road, 6-8 lanes; Din Daeng Road, 6-8 lanes.

2.1.3 Current Traffic Circulation Method

The major circulation methods in Bangkok are as follows;

a) One-way Road Method
b) Unbalanced lane Method
c) Bus Lane Method

1) One-way Road Method

Figure 2.4 shows the one-way system. The major one-way trunk roads are Sukhumvit Road, Ratchaprarop Road, and Bamrung Muang Road. At present, contra-flow lane, reversible lanes and fixed unbalanced flow are used in combination with the one-way system on arterial roads. In principle, however, clockwise operation of one-way loops has basically been maintained.

2) Unbalanced Lane Method

The location of unbalanced lane roads are shown in Figure 2.4. The unbalanced lane roads are located in the traffic congestion area in the center of the city. The main unbalanced lane roads are Phetchaburi Road (4 lanes and 2 lanes), Phaya Thai Road (6 lanes and 2 lanes), Rama VI Road (5 lanes and 2 lanes), Ratchaprarop Road (4 lanes and 2 lanes), Sawankhalok Road (3 lanes and 1 lane), a part of Phloen Chit Road (5 lanes and 2 lanes), and Ratchawithi Road (3 lanes and 2 lanes).

3) Bus Lane Method

The location of the bus lane regulated roads are shown in Figure 2.4. In principle, a bus lane is designed as a contra-flow lane when it is combined with a one-way road or an unbalanced lane road. Although the regulation is strictly applied by policemen to every bus lane during the rush hours, however, many bus lanes except for a part of the Ratchaprarop Road, are used by other ordinary vehicle except the rush hours and bus lanes are stuffed with buses and cannot demonstrate the bus lane effect.

2.1.4 Vehicular Traffic Flow

1) Current Traffic Volume

Traffic flow in the subject area in 1989 is shown below. Figure 2.5 shows vehicular traffic volumes in the Study Area.

Table 2.1 Traffic Volume on Major Roads (1989)

PCU, both directions

Road	Range of Volume		
		Peak Hour	
	12 Hours	08:00 - 09:00	16:00 17:00
Rama IV	108,900-55,200	9,100-4,700	10,300-4,100
Phetchaburi	83,500-66,900	6,400-2,900	6,600-2,600
Sukhumvit	70,200-73,900	6,800-6,900	5,400-5,900
Phloen Chit	79,100-66,600	7,700-6,400	6,200-4,900
New Phetchaburi	78,600-56,200	6,800-2,300	7,900-2,300
Din Daeng	73,700-53,900	6,700-5,200	5,500-3,600
Phaya Thai	72,400-43,100	5,400-3,200	5,400-4,000
Sathon	71,300	6,100	6,300
Ratchadamnoen-Klang	70,300	5,900	6,900
Rama I	62,000-42,900	5,700-4,100	5,100-3,200
Ratchaprarop	50,200-42,400	3,700-3,600	4,400-3,700
Soi Asok (Sukhumvit 21)	43,500-48,200	3,800-4,600	3,400-3,700
Ratchadamri	36,800	3,100	3,200

(1) 12-Hours Volume

Table 2.1 gives two-way 12-hours traffic volumes on major roads. Two-way 12-hours traffic volumes (PCU) on major arterial roads in the Study Area range approximately between 36,800 and 108,900. The highest value of 108,900 was observed on Rama IV Road, which links the east and west sides of the city.

Figure 2.1 Existing Road Network on ATC System Planning Area

Figure 2.2 Distance between Intersections

Figure 2.3 Number of Lane at Intersection (1989)

Figure 2.4 One-Way Road, Unbalanced Lanes and Bus Lane

Traffic volumes on one-way arterial roads running from west to east are as follows: Phetchaburi Road, 66,900-83,500 and New Phetchaburi Road, 56,200-78,600. Traffic volumes on one-way arterials roads running in the other direction, in other words from east to west, are as follows: Rama I Road, 42,900-62,000; Phloen Chit Road, about 66,600-79,100; and Sukhumvit Road, about 70,200-73,900.

Traffic volume on Phaya Thai Road, a one-way arterial road running from north to south, is about 43,100-72,700. Traffic volumes on one-way arterial roads running in the opposite direction, in other words from south to north, are as follows: Ratchadamri Road, about 36,800 and Ratchaprarop Road, about 42,400-50,200.

(2) Peak-Hour Volume

Table 2.1 also gives two-way traffic volumes on major roads during the morning and afternoon peak hours. Two-way traffic volumes (PCU) on major arterial roads in the Study Area range approximately between 9,100 and 2,300 during the morning peak hour (8:00-9:00) and 10,300 and 2,200 during the afternoon peak hour (16:00-17:00). Further details are discussed below.

a) Morning Peak Hour
During the morning peak hour, Rama IV Road shows the heaviest traffic volume at about 4,700-9,100. Traffic volumes on one-way east-west arterials are as follows: Phetchaburi Road and New Phetchaburi Road, about 2,300-6,800; and Rama I Road, Phloen Chit Road and Sukhumvit Road, about 4,100-7,700. Traffic volumes on one-way north-south arterials are as follows; Phaya Thai Road, about 3,200-5,400; and Ratchadamri Road and Ratchaprarop Road, about 3,100. Traffic volumes on other roads are as follow: Din Daeng Road, about 5,200-6,700; Ratchadamnoen Klang Road, about 5,900; and Sathon Road, about 6,100.

b) Afternoon Peak Hour
Rama IV Road also shows the heaviest traffic volume during the afternoon peak hour at about 4,100-10,300. Traffic volumes on one-way east-west arterials are as follows: Phetchaburi Road and New Phetchaburi Road, about 2,300-7,900; and Rama I Road, Phloen Chit Road and Sukhumvit Road about 3,200-6,200. Traffic volumes on one-way north-south arterials are as follows: Phaya Thai Road, about 4,000-5,400; and Ratchadamri Road and Ratchaprarop Road, about 3,200-4,400. Traffic volumes on other roads are as follows: Din Daeng Road, about 3,600-5,500; Ratchadamnoen Klang Road, about 6,900; and Sathon Road, about 6,300.

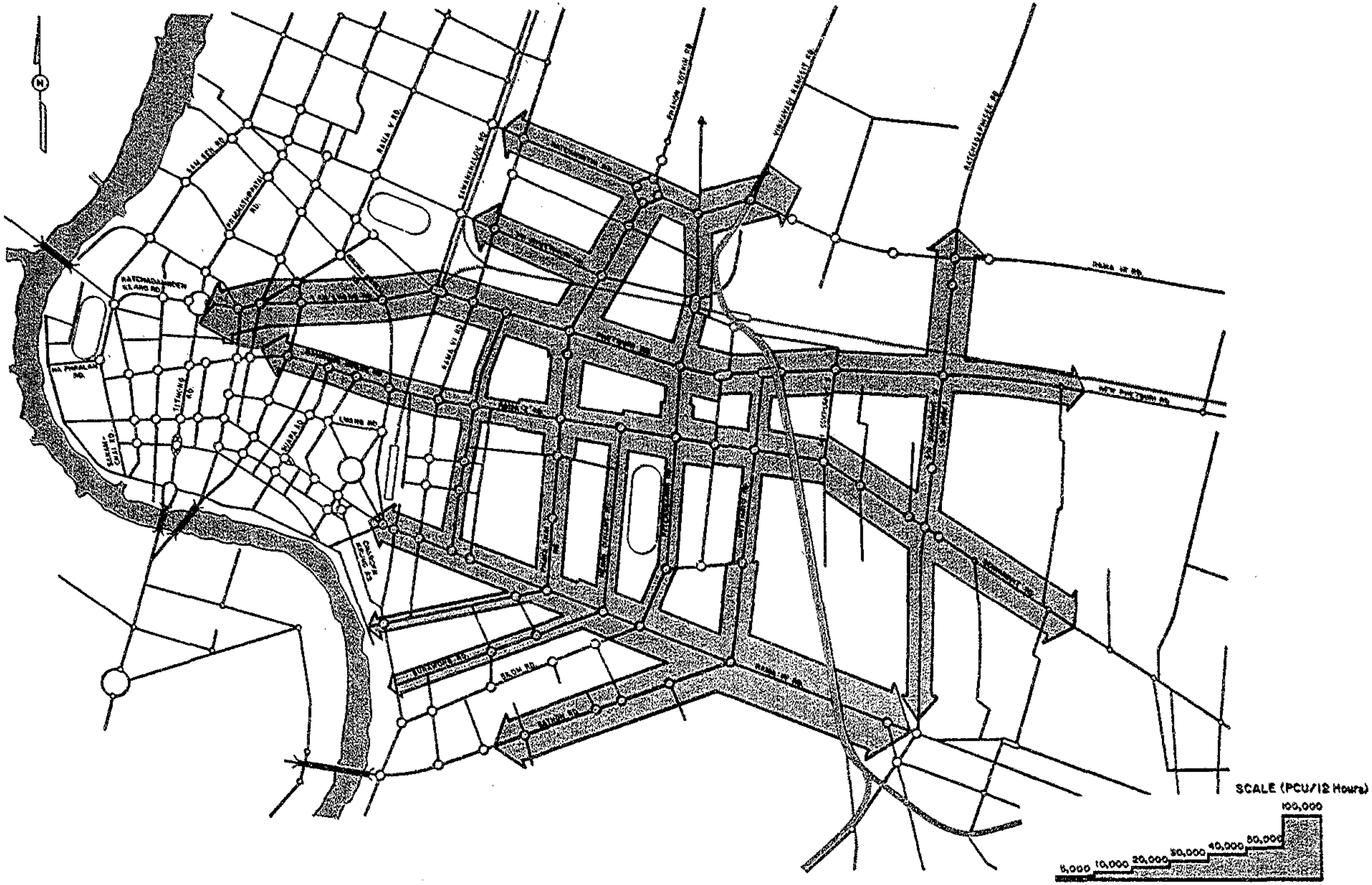


Figure 2.5 (1) Existing Traffic Volume in 1989 (12 Hours)

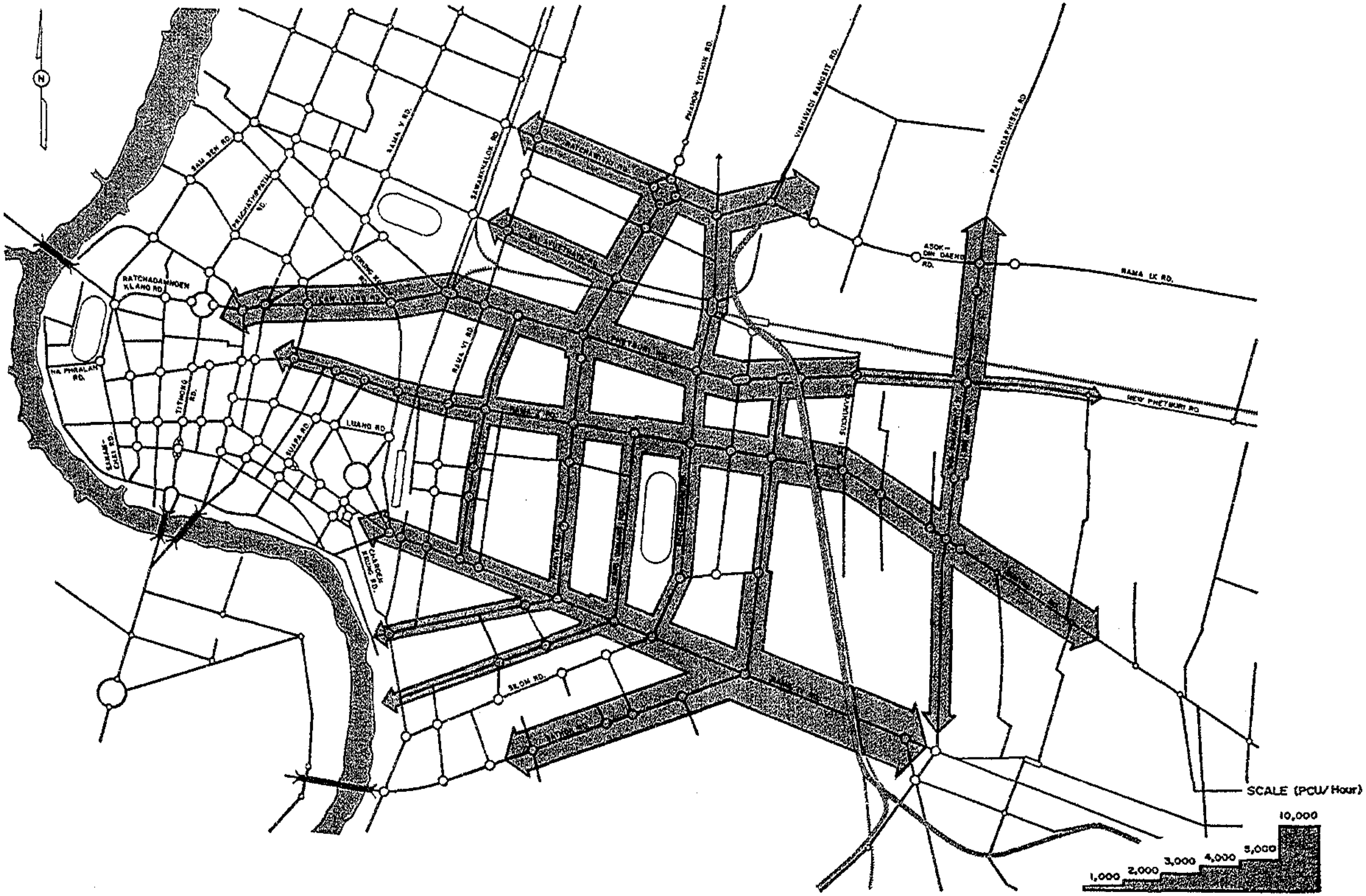


Figure 2.5 (2) Existing Traffic Volume in 1989 (Morning Peak Hour 08:00-09:00)

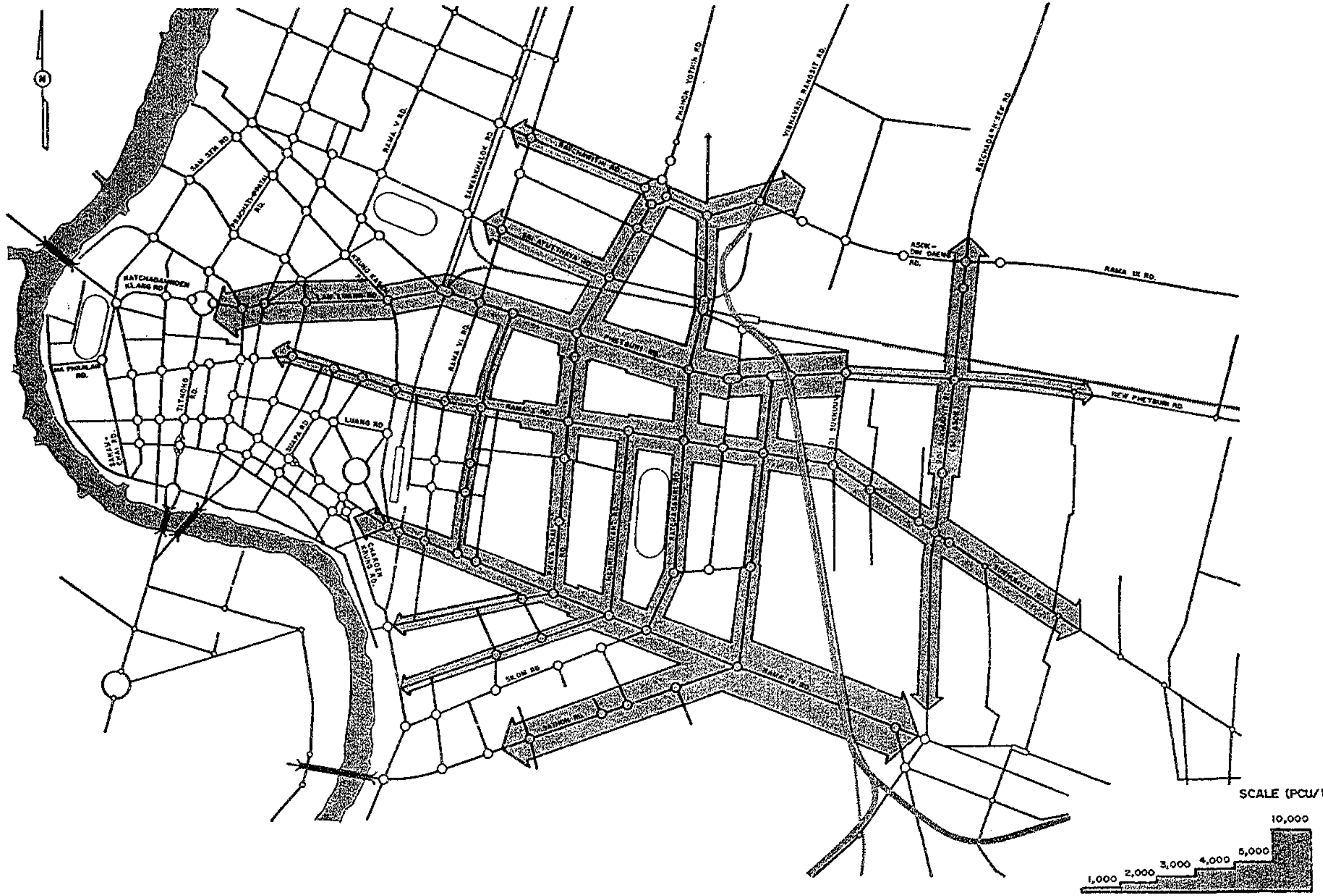


Figure 2.5 (3) Existing Traffic Volume in 1989 (Evening Peak Hour 17:00-18:00)

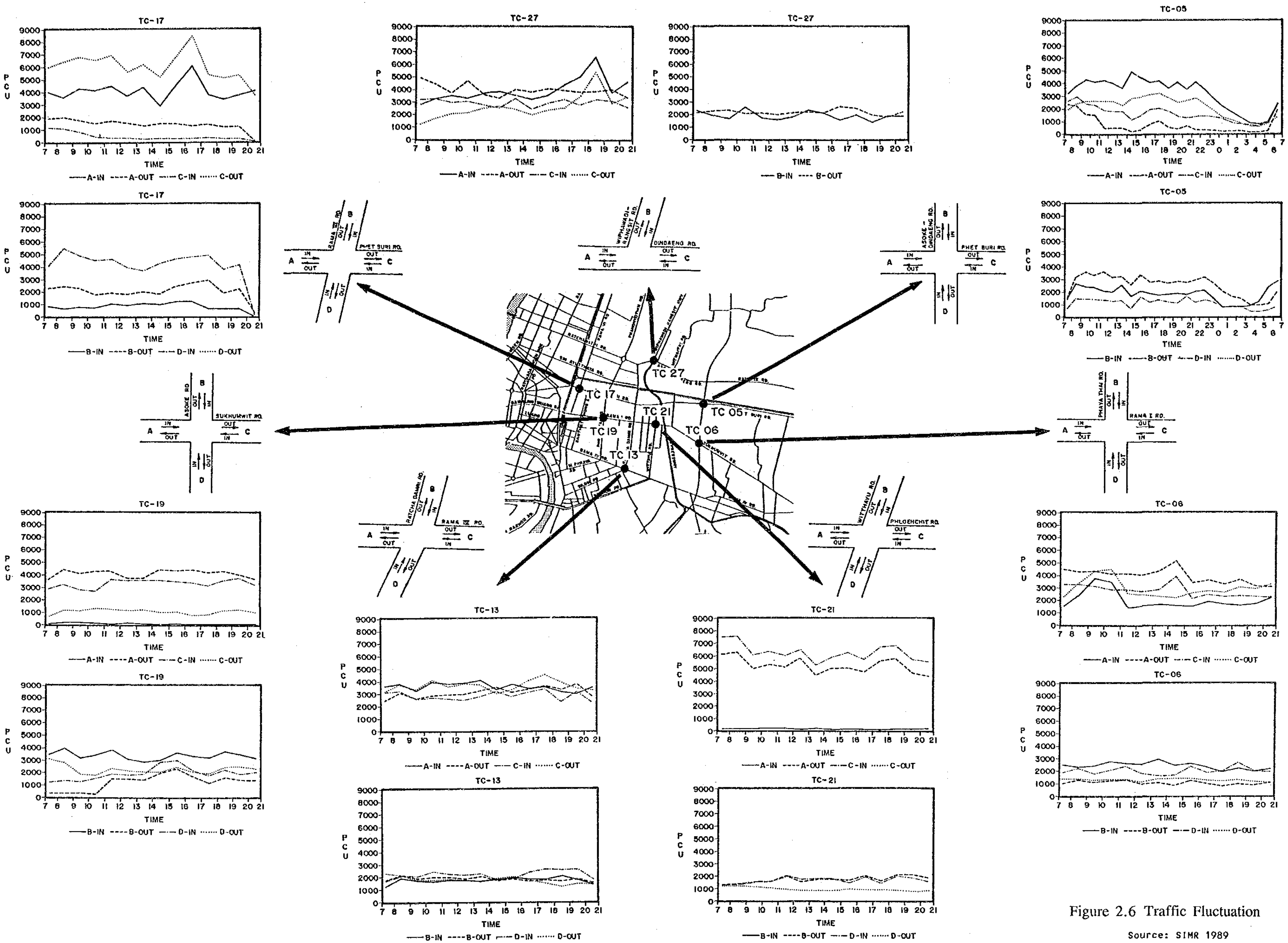


Figure 2.6 Traffic Fluctuation

Source: SIMR 1989

(3) Hourly Fluctuation

Figure 2.6 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 Road during the morning peak hours were charted for each day of the week as shown in Figure 2.7. 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.

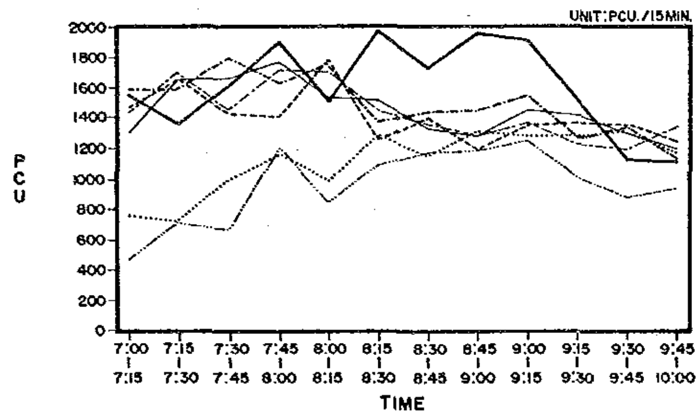


Figure 2.7 (1) Traffic Fluctuation During a Week
(Section ETA-Soi 3 Sukhumvit Road, Inbound)

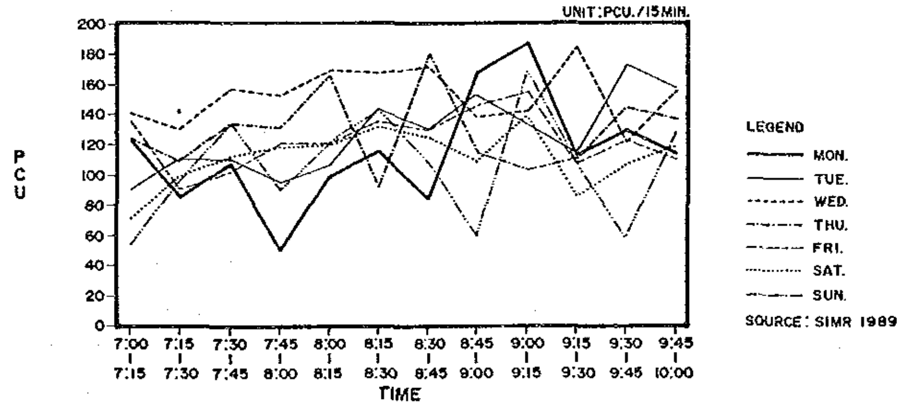


Figure 2.7 (2) Traffic Fluctuation During a Week
(Section ETA-Soi 3 Sukhumvit Road, Outbound)

2.2 Framework for ATC System Plan

2.2.1 Target Year

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.

2.2.2 Future Road Network to be Covered by ATC System

1) General

At present, road transport projects are being pursued by the BMA, ETA and other agencies. Of these, the projects shown in Figure 2.8 are slated for completion by 1993. When determining the road network to be covered by the ATC System, these projects were taken into account as preconditions. The projects are a part of the ETA's Second Stage Expressway and the flyover on Rama IV Road, Asok Road. and Din Daeng Road.

2) Two-way/Reversible Lane Road

The following one way trunk roads in ATC planning area are assumed to be operated by the method of Two-way/reversible lane system.

The subject road sections are the section between Ratchaprarop Road and Vibhavadi Rangsit Road on Din Daeng Road (roughly 0.6 km), the section between Din Daeng Road and Phetchaburi Road on Ratchaprarop Road (roughly 1.4 km), the section between Soi Som Prasong 3 Road and the ETA Expressway on Phetchaburi Road (roughly 0.9 km), and the section between Ratchaprarop Road and the Middle Ring Road on Sukhumvit Road (roughly 2.5 km). These sections are shown in Figure 2.9.

2.2.3 Intersection to be Covered by ATC System

1) Signalized Intersections

Figure 2.10 gives the locations of intersections to be covered by ATC System. Intersections to be signalized consist of those being planned by the BMA; those which will be created by the construction of the ETA Expressway (Second Stage) ramps and U-turn signalized intersections.

As shown in Table 2.2 a total of 143 intersections were identified, of which 128 are already signalized, 15 will be signalized, (15 intersections include 4 ETA Expressway ramp intersections and 5 U-turn signalized intersections).

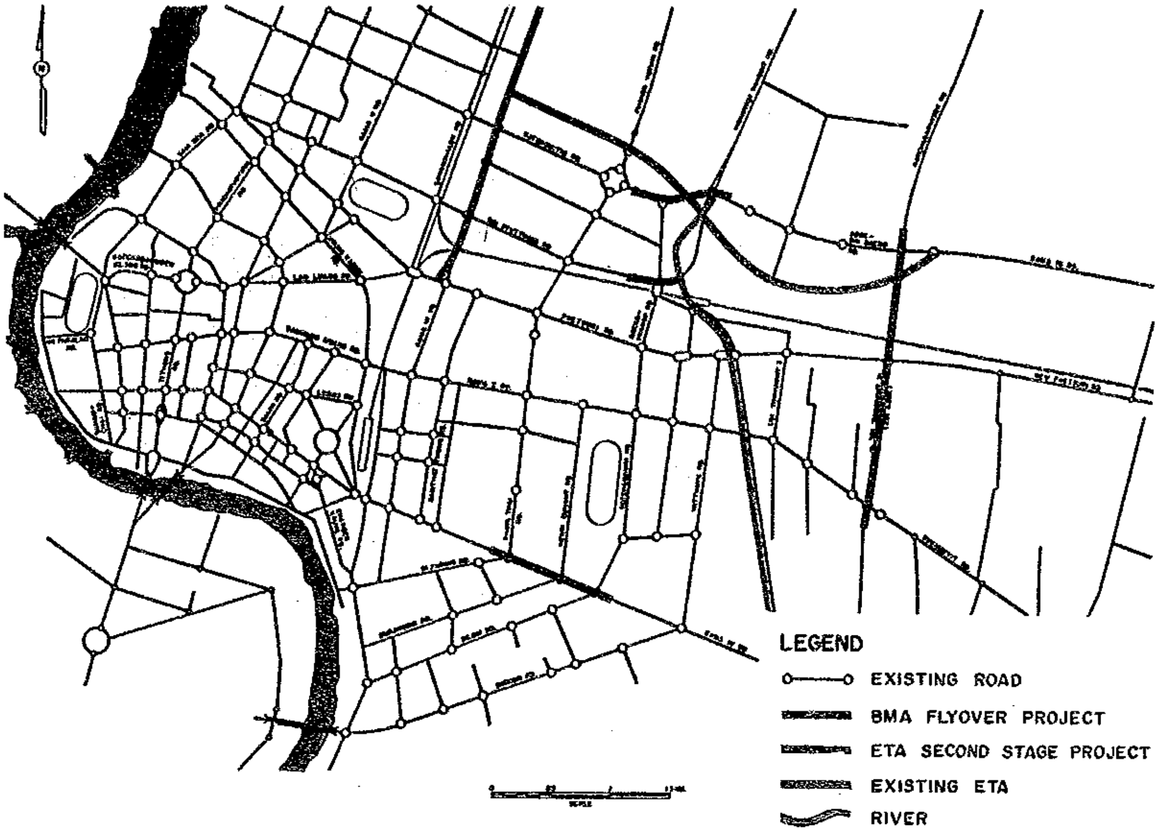


Figure 2.8 Future Road Network (1993) on ATC System Planning Area

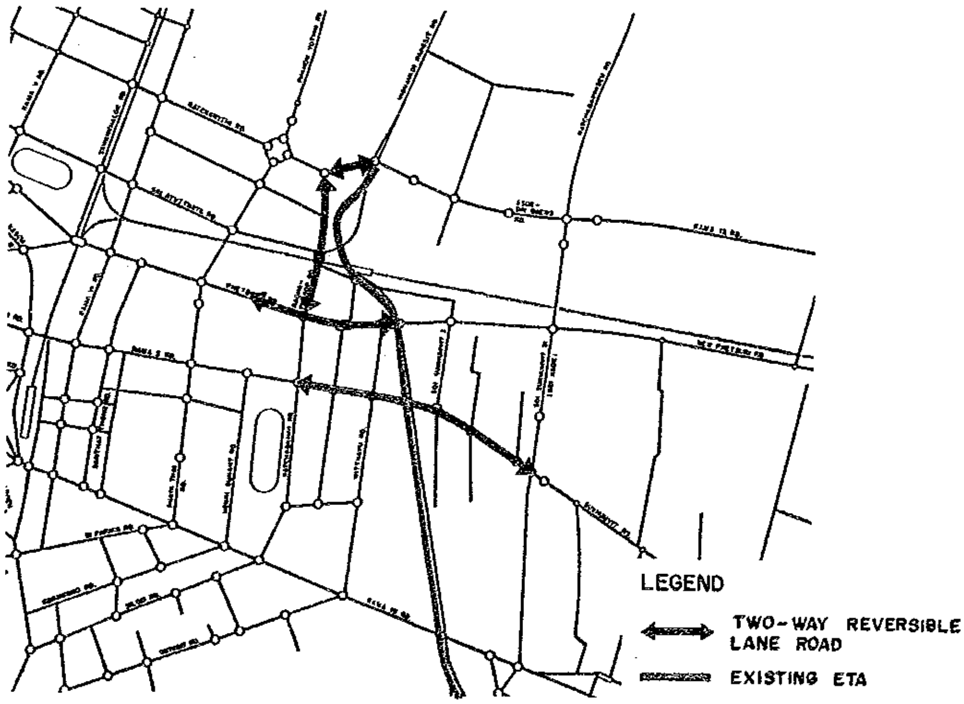


Figure 2.9 Two-Way/Reversible Lane Scheme Selected Road Sections

Table 2.2 Intersection to be Covered by ATC System

Year	Existing Signalized Intersection	Planned Signalized Intersection	U-turn Signalized Intersection	Total
1993	128	10	5	143

The above-mentioned 143 intersections subject to control by the ATC System were divided into 35 key intersections and 108 ordinary intersections. A key intersection serves as the base point for determining the ATC cycle, split and offset. In principal, the key intersection will be controlled based on responsive system. Figure 2.11 shows the locations of key intersections.

The following conditions and criteria were used to select key intersections; at least one of the approaches must be a major road (arterial or semi-arterial) in the ATC planning area. And if an intersection satisfying the above condition has a saturation degree of at least 0.7 from the consideration of processing traffic volume fluctuation and very low travel speed, it is categorized as a key intersection. Based on a study of the road network in the target year, ETA Expressway ramp intersections which are considered important from the standpoint of processing traffic are categorized as key intersections.

2.2.4 Future Traffic Conditions

The volume of future vehicular traffic was forecast and the method and results are discussed below. This volume is used as the design volume for ATC System.

1) Forecast Method

The volume of vehicular traffic in 1993, the target year for the operation start of the ATC System, was forecast in accordance with the following conditions. The traffic assignment procedure is given in Figure 2.12.

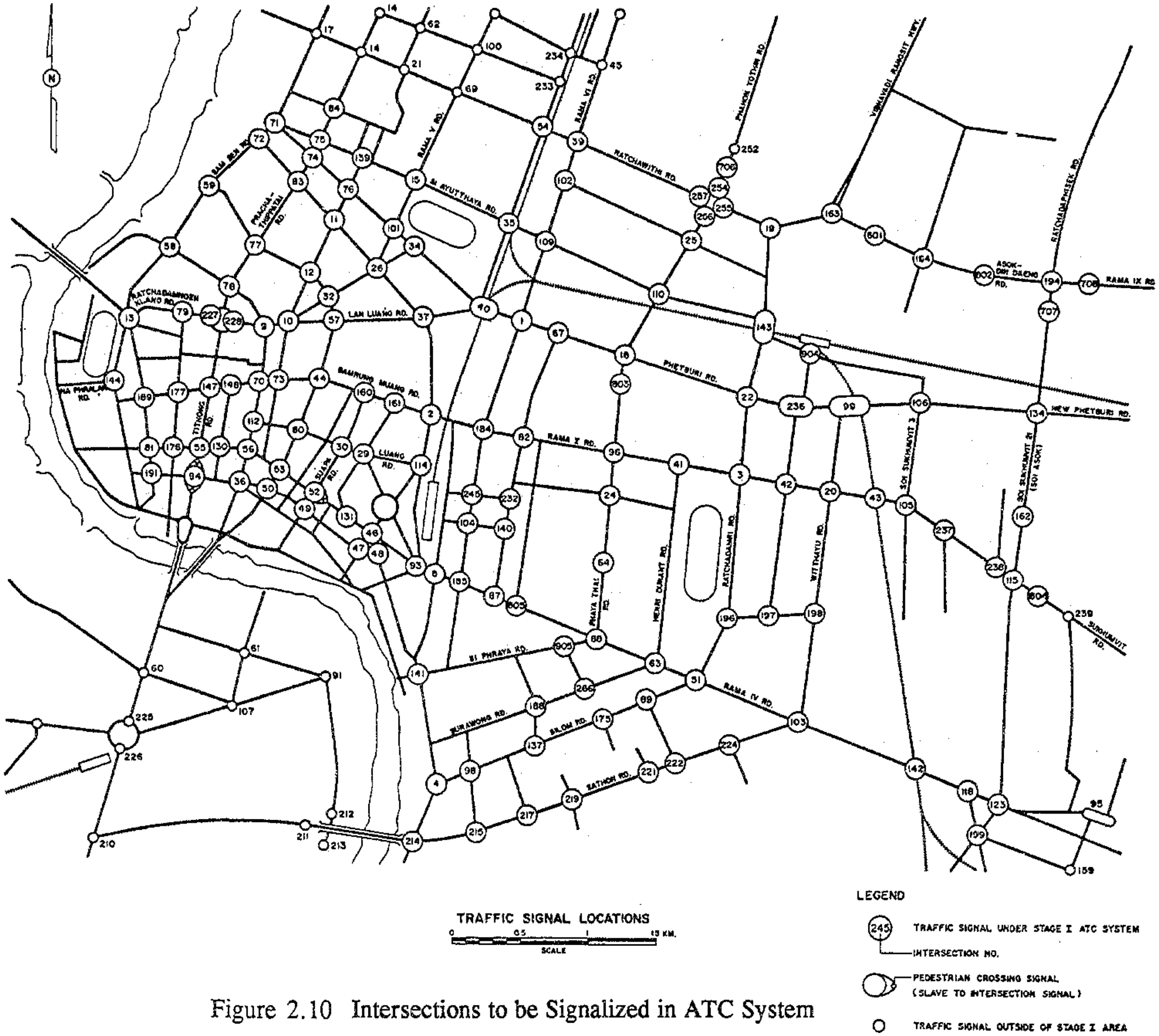


Figure 2.10 Intersections to be Signalized in ATC System

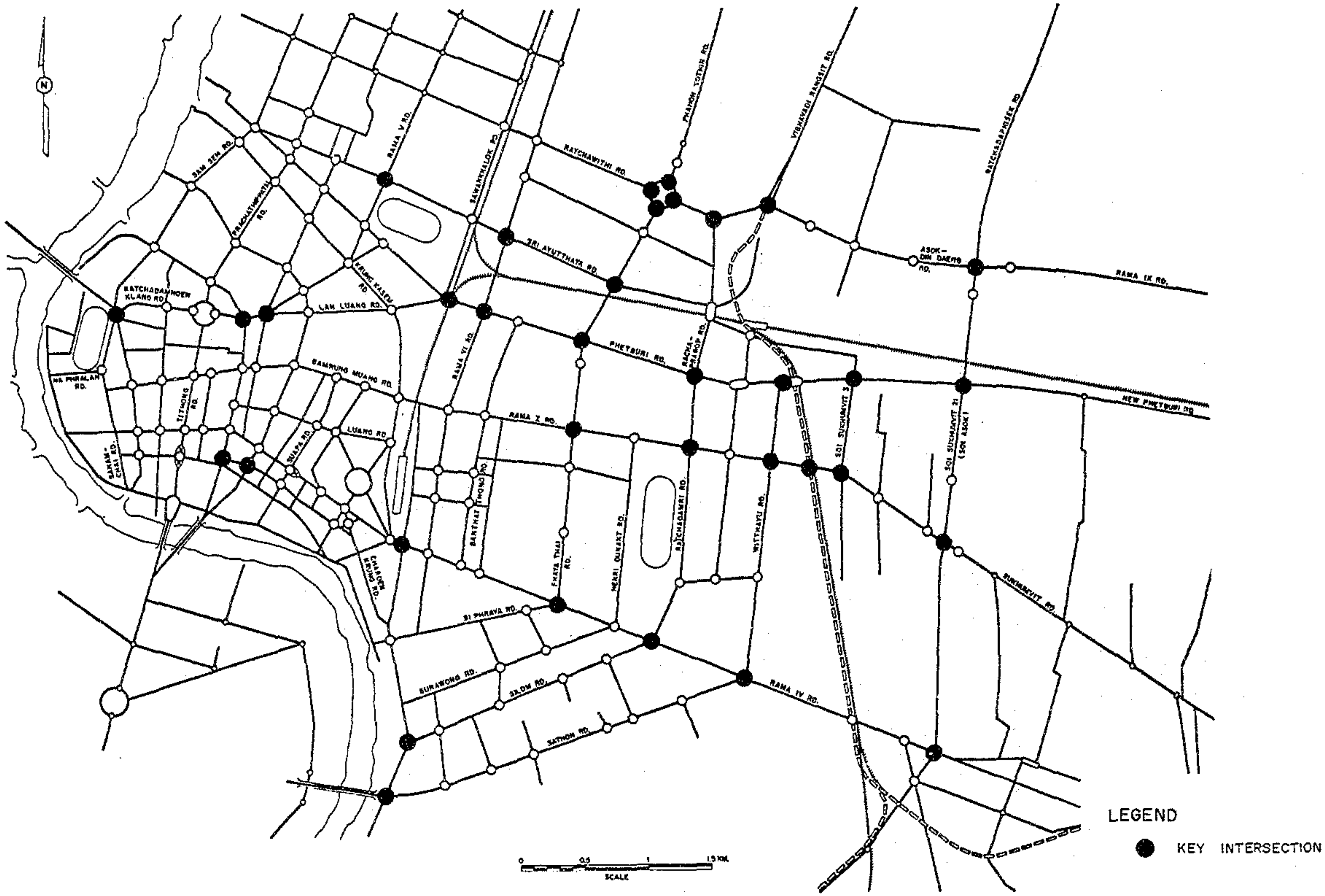


Figure 2.11 Location of Key Intersection

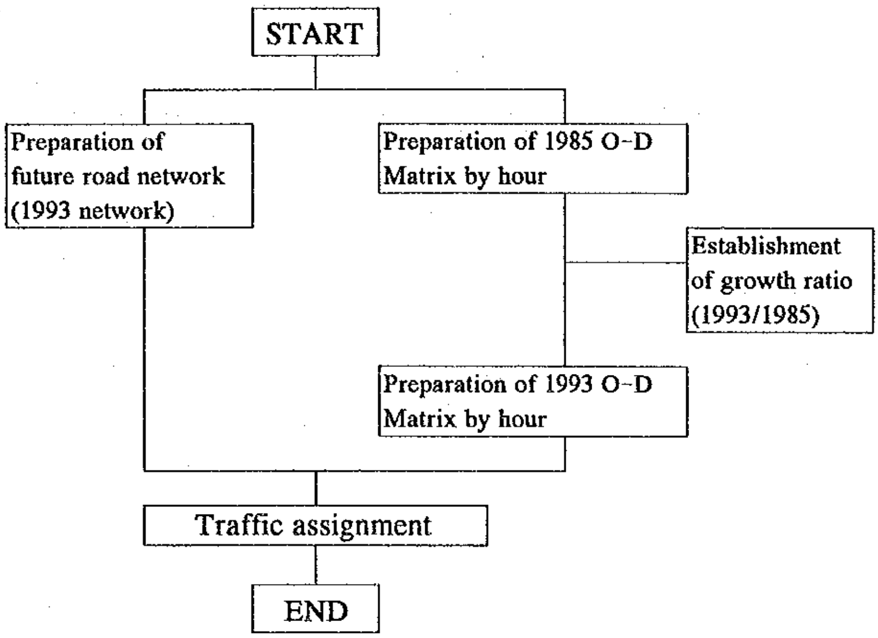


Figure 2.12 Work Flow

(1) Road Network

The road network subject to traffic assignment corresponds to the Future Road Network (1993) discussed in Section 2.2.2.

(2) Vehicles OD Distribution Matrix

The Vehicles OD Distribution Matrix in 1993 is obtained as follows. The Vehicles OD Distribution Matrix in 1985, which was based on the results of the car OD survey conducted in 1985 by the JICA Study, was adjusted in accordance with the growth rates established in the current study applicable to the volumes of traffic generation and attraction of 1993 in each zone.

2) Design Volume

The forecast volume of vehicular traffic in 1993 was assigned to the subject road network by time period and by direction based on the above-mentioned conditions. These hourly traffic volumes by time period and by direction were established as the design traffic volumes. Figure 2.13 shows the hourly traffic volume at key intersection. The design traffic volume of the 143 subject intersections are given in detail in Part 6 (Design Volume and Signal Phasing Plans). Traffic conditions at main key intersections during peak hours are described below.

(1) Ratchadamnoen Klang - Phra Sumen - Maha Chai Intersection (No.9)

Intersection No. 9 is located above the Klong Phadung Krung Kasem Canal and consists of east-west arterial Ratchadamnoen Klang Road and Phra Sumen Road-Maha Chai Road, which runs north-south. Two-way hourly volume on Ratchadamnoen Klang Road is about 3,500-6,700, while that on Phra Sumen Road-Maha Chai Road is about 180-3,000. During the morning peak hour, two-way volume on Ratchadamnoen Klang Road surges to 6,300-6,700.

(2) Lan Luang - Ratchadamnoen Nok - Nakhon Sawan Intersection (No.10)

Intersection No. 10, which is located next to Intersection No. 9, is a five-legged intersection consisting of east-west arterials Ratchadamnoen Klang Road, Lan Luang Road and Nakhon Sawan Road and north-south Ratchadamnoen Nok Road. Two-way hourly volume on east-west Ratchadamnoen Klang Road is 3,500-6,600, that on Lan Luang Road is 1,500-2,000 and that on Nakhon Sawan Road is 1,000-2,100. Corresponding volume for north-south Ratchadamnoen Nok is 1,400-3,800. Traffic flow is heavy during the morning peak hour.

(3) Ratchadamnoen Klang - Ratchadamnoen Nai Intersection (No. 13)

Intersection No. 13, which is located at the northern boundary of the Old City, is a five-legged intersection consisting of east-west arterial Ratchadamnoen Klang Road (Phra Pinklao Bridge) and Ratchadamnoen Nai Road and Chakkraphong Road, which run north-south. Two-way hourly volume on Ratchadamnoen Klang Road is about 3,000-9,700, while that on Ratchadamnoen Nai Road and Chakkraphong Road is about 300-2,300. Two-way hourly volume on the side of the Phra Pinklao Bridge is especially heavy at 5,600-9,700, reaching about 9,700 during the morning peak hour.

(4) Witthayu - Phloen Chit Intersection (No. 20)

Intersection No. 20 consists of Phloen Chit Road-Sukhumvit Road which runs east-west, and Witthayu Road, which runs north-south. Traffic exiting from the ETA Expressway ramp that connects with Phloen Chit Road passes through this intersection. Two-way hourly volume on Phloen Chit Road is about 3,600-6,700, while that on Witthayu Road is about 1,700-3,700.

(5) Si Lom - Ratchadamri - Rama IV Intersection (No. 51)

Intersection No. 51 is located at an entrance to the Si Lom Road shopping area. A continuous overpass is to be constructed above Rama IV Road. The intersection consists of Rama IV Road, which runs east-west, and Ratchadamri Road and Si Lom Road, which run north-south. Two-way hourly volume on Rama IV Road is about 2,400-3,900, while that on Ratchadamri Road and Si Lom Road is about 3,000-4,900.

(6) Phaya Thai - Rama IV - Si Phraya Intersection (No. 88)

Intersection No. 88 is located in the central business district of Bangkok city, at the eastern end of the continuous overpass which is to be constructed above Rama IV Road. The intersection consists of Rama IV Road, which runs east-west, and Phaya Thai Road and Si Phraya Road, which runs north-south. Two-way hourly volume on Rama IV Road is about 1,800-3,700, that on Phaya Thai Road is about 2,400-4,200, and that on Si Phraya Road is about 1,400-2,400.

(7) Witthayu - Phetchaburi - Din Daeng Port Expressway Intersection (No. 99)

Intersection No. 99 consists of Phetchaburi Road, which runs east-west, and Witthayu Road, which runs north-south. Traffic exiting from ETA Expressway ramp that connects with Phetchaburi Road passes through this intersection. Two-way hourly volume on Phetchaburi Road is about 3,000-5,200, while that on Witthayu Road is about 100-2,500. The intersection is virtually a T intersection since volume on the northward approach is only about 100-200.

(8) Sukhumvit - Soi Sukhumvit 21 (Asok) - Ratchadaphisek Intersection (No. 115)

Intersection No. 115 is the easternmost intersection along Phloen Chit Road-Sukhumvit Road, which are operated as reversible-lane roads. It consists of Sukhumvit Road, which runs east-west, and Soi Sukhumvit 21 Road, which is a north-south arterial comprising part of the Middle Ring Road. Two-way hourly volume on Sukhumvit Road is about 3,500-4,200, while that on Soi Sukhumvit 21 Road is about 1,100-1,800.

(9) New Phetchaburi - Asok Din Daeng Intersection (No. 134)

Intersection No. 134 is located at the eastern boundary of the Study Area and consists of New Phetchaburi Road, which runs east-west, and Asok Din Daeng Road, which runs north-south. There is a flyover above New Phetchaburi Road at present, and a continuous overpass is to be constructed above Asok Din Daeng Road. Two-way hourly volume on New Phetchaburi Road is about 1,500-3,600, while that on Asok Din Daeng Road is about 2,000-3,900.

(10) Vibhavadi Rangsit - Din Daeng Intersection (No. 163)

Intersection 163 consists of Din Daeng Road, which run east-west, and Vibhavadi Rangsit Road, which runs north-south. Vibhavadi Rangsit Road, which connects with the ETA Expressway, which passes through this intersection as a flyover, while an underpass is to be constructed on Din Daeng Road. Two-way hourly volume on Din Daeng Road is about 2,500-4,600, while that on Vibhavadi Rangsit Road is about 600-4,300.

(11) Victory Monument Intersection (No. 254-257)

Intersection No. 254-257 is a major roundabout located at the northern boundary of the Study Area. It consists of Ratchawithi Road, which runs east-west, and Phahon Yothin Road and Phaya Thai Road, which run north-south. An intersection connecting with an ETA Expressway ramp will be constructed on Phahon Yothin Road. Two-way hourly volume on Ratchawithi Road is about 1,900-4,400, while that on Phahon Yothin Road and Phaya Thai Road is about 1,300-4,400.

Figure 2.13 (1) Design Volume (Morning Peak Hour 08:00-09:00)

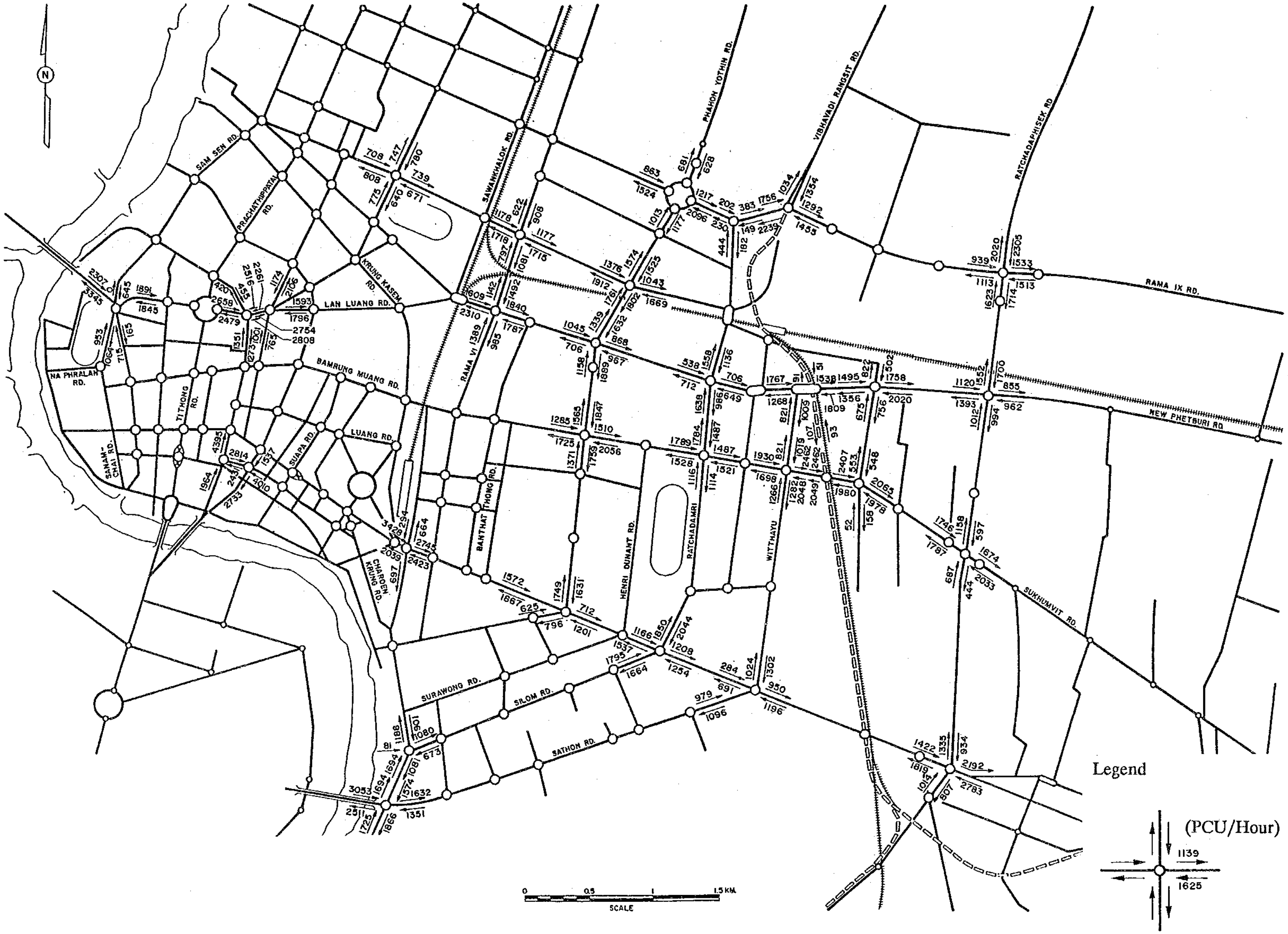


Figure 2.13 (2) Design Volume (Daytime 13:00-14:00)

Figure 2.13 (3) Design Volume (Evening Peak Hour 17:00-18:00)

2.3 Traffic Engineering Improvement

2.3.1 Traffic Circulation Method

Figure 2.14 shows the location of planned Two-way/Reversible Lane System. It is assumed that before implementation of ATC System the traffic facilities for Two-way/Reversible Lane System will be constructed by BMA.

1) Operating Method

(1) Time Periods for Reversible Lane

As a general rule, time periods for reversible lanes were established so that priority is given to inbound traffic during the morning hours when commuter traffic is heavy and to outbound traffic during the afternoon hours. Accordingly, priority is given to inbound traffic between 6:00 and 11:00, and priority is given to outbound traffic after 11:00.

(2) Traffic Operation Method

Reversible lanes will be operated by the traffic police. Reversible lane usage will be notified to drivers by overhead lane direction signals and signs attached to gantry or pedestrian bridge, variations in lane line color, and lane-use designators (the temporary sign used currently by the Police). As a general rule, overhead lane direction signals will be provided at the starting and ending points of reversible lanes, and, between these points, overhead lane direction signs will be attached to existing pedestrian bridges. The use of pedestrian bridges will reduce the cost of overhead lane direction signals. At intersections, reversible lane usage will notified by variations in lane line color and by lane-user designators. In areas outside the reversible lane section, guide signs will be installed 150-200 meters upstream from the starting point in order to warn drivers.

In reversible lane sections, parking and diverging right-turning movement onto side roads will be restricted.

Standard traffic operation methods to be applied to intersections and other road sections are shown in Figure 2.15.

2) Traffic Facilities Plan

The Planned locations of traffic facilities are shown by subject route in Figure 2.14.

Standard designs of traffic facilities required for reversible lane operation are shown in Figure 2.16.

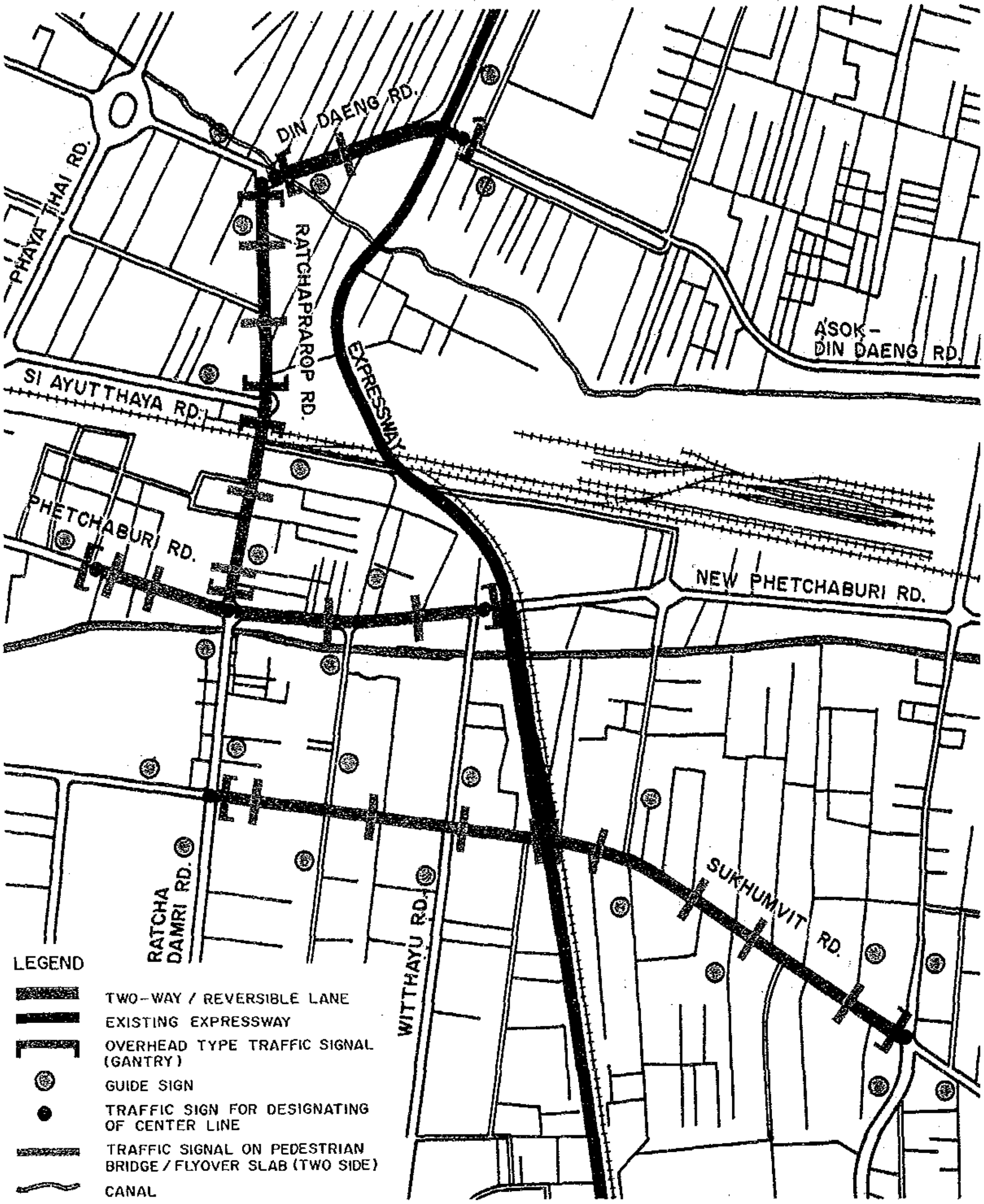


Figure 2.14 Locations of Two-Way / Reversible Lane and Traffic Facilities

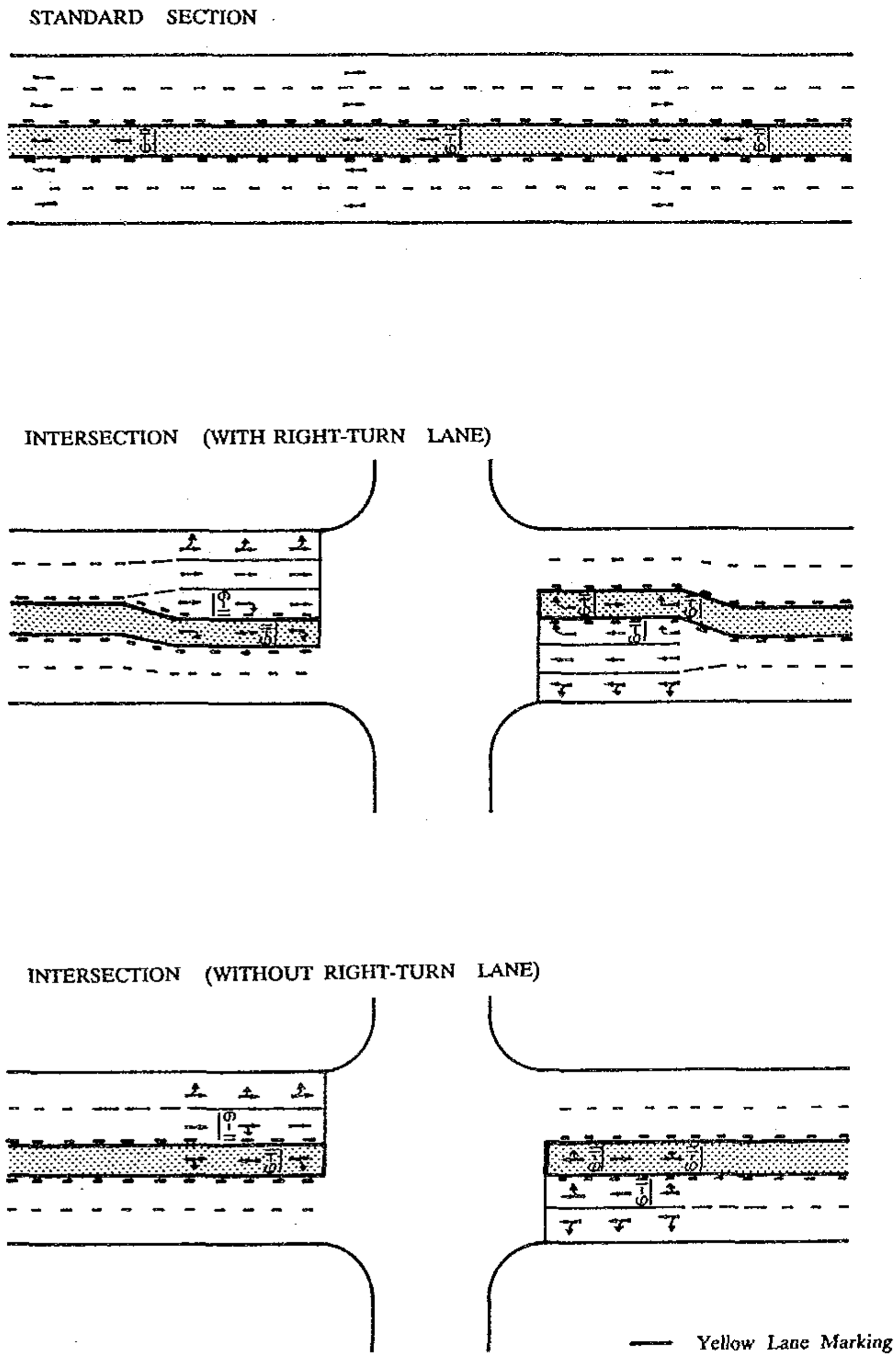
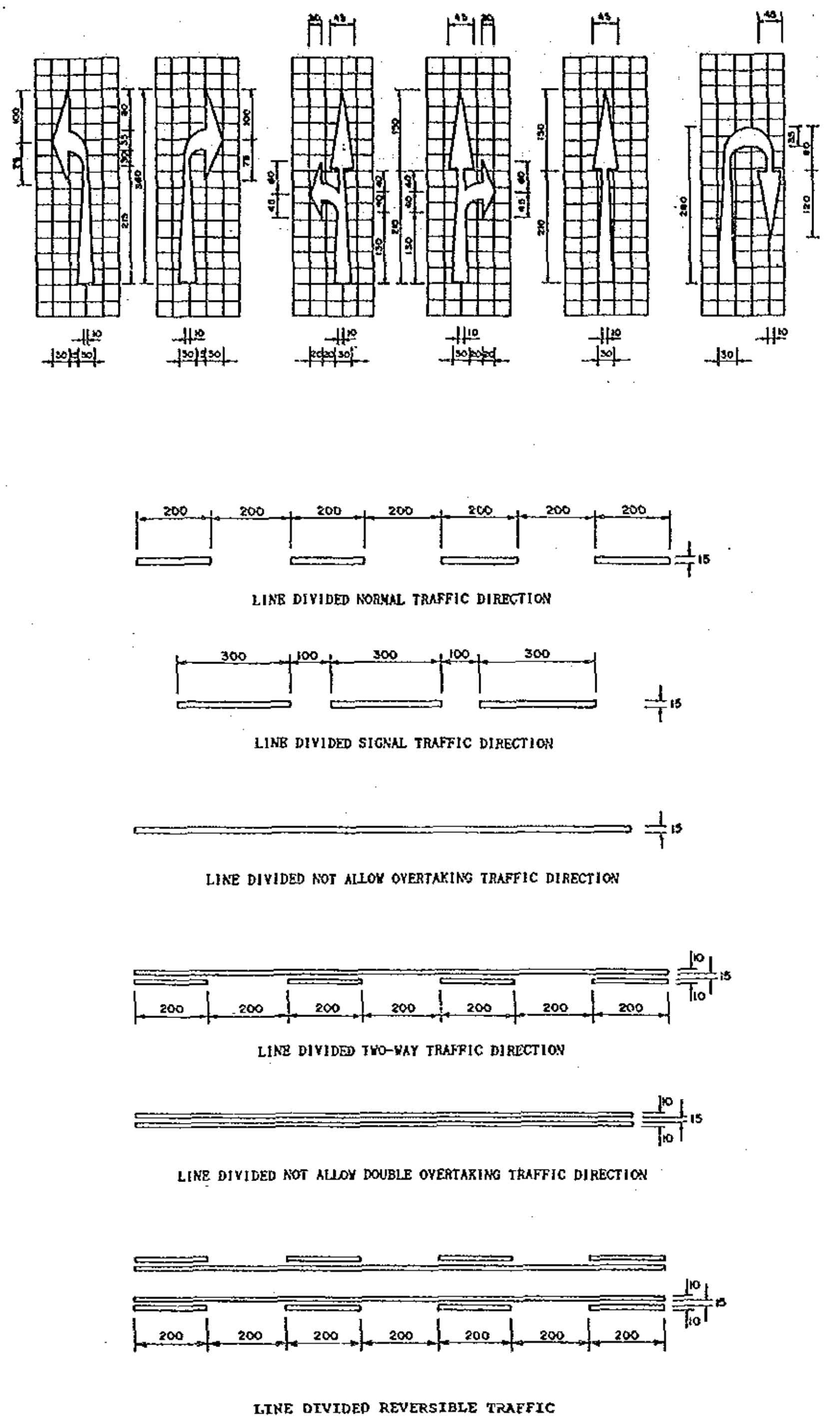


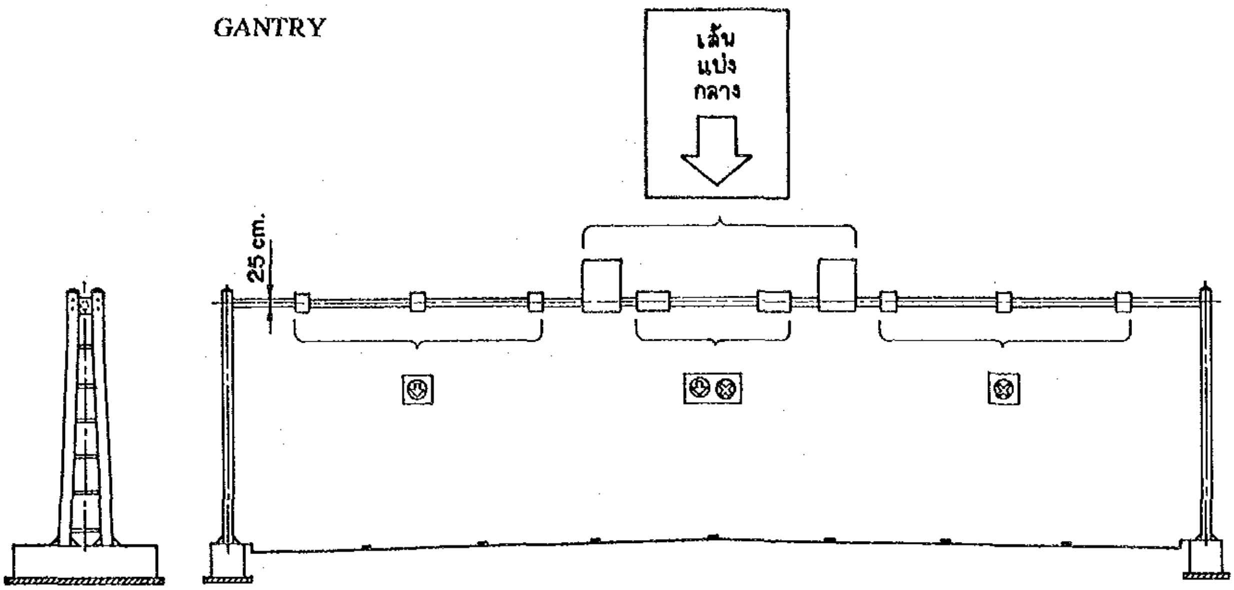
Figure 2.15 Standard Traffic Operation Method



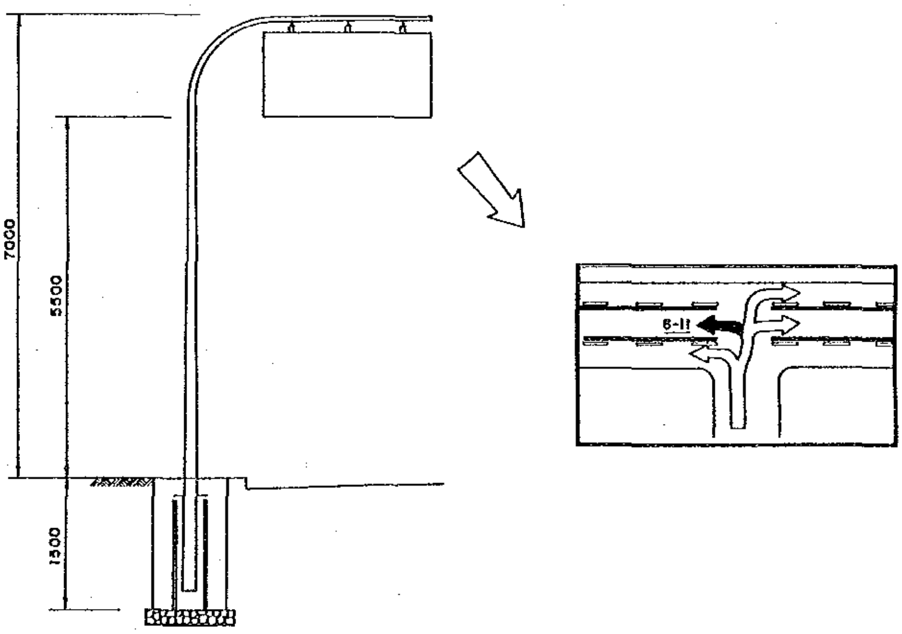
ROAD MARKING SOURCE : BMA

Figure 2.16 (1) Standard Traffic Facilities

GANTRY



GUIDE SIGN (SIGNALIZED INTERSECTION)



DIRECTION SIGN

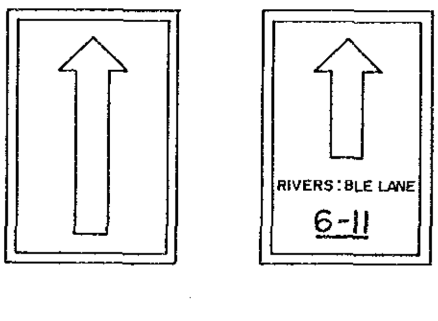


Figure 2.16(2) Standard Traffic Facilities

2.3.2 Intersection Improvement

Along with the introduction of the ATC System, it is necessary to implement traffic engineering improvement that can enhance the beneficial effects of the System. This section discusses some of the traffic management facilities that should become necessary in conjunction with the installation of ATC System signal facilities.

The intersection improvements were based on the following factors:

(1) Traffic Circulation Plan (including the reversible lane plan)
   a) Reversible lanes
   b) Changes in traffic regulations

(2) Lane operation improvement for handling future traffic flow
   a) Addition of exclusive right-turn lanes
   b) Improvement of channelizing islands

(3) Installation of planned traffic signals
   a) Planned-signalized intersections
   b) U-turn signal intersections

These reviews were conducted by taking into consideration the 1993 traffic volume, the existing shapes of the subject intersections, and existing plans.

1) Improvement Plan

In conjunction with the reversion of the lane at existing signalized intersections, as called for in the Traffic Circulation Plan, a pavement marking plan for the intersections was prepared in order to achieve the smooth flow of traffic. In addition, in conjunction with the installation of traffic signals at non-signalized intersections, a channelization plan for these intersections was prepared in order to control traffic flow on major and minor approaches and to ensure the safety of pedestrians.

These improvements are listed in Table 2.3, and salient points of the improvements are discussed below.

Table 2.3 Improvement Measures

Improvement Measures	Traffic Circulation Plan	Lane Operation for Future Traffic Flow	Planned Signalized Intersection
1. Improvement of pavement markings where lane operation is to be altered	o	o	o
2. Addition of exclusive right-turn lane	o	o	o
3. Improvement of channelizing island	o	o	o
4. Improvement of median	o		o
5. Installation of pedestrian crossing	o		o
6. Plan in conjunction with introduction of reversible lanes	o		o

(1) Improvement of Pavement Markings where Lane Operation is to be Altered

Pavement markings such as arrows, stop lines, and center lines will be improved at intersections where the one-way regulation is to be altered or where the system of lane operation is to be altered due to changes in traffic demand.

(2) Addition of Exclusive Right-Turn Lanes

Exclusive right-turn lanes will be established at intersections with a high volume of right-turning traffic, in order to ensure the smooth flow of straight-through traffic and to process right-turning traffic more efficiently.

a) Exclusive right-turn lanes will be provided with right-turn pockets.

b) Right-turn pockets will be constructed either by cutting off the median and allotting the resulting space to the pocket or, where there is no median, by shifting the center line to the lane in the opposite direction.

(3) Improvement of Channelizing Islands

Improvements with respect to the locations and shapes of channelizing islands were reviewed for intersections which have a high volume of left-turning traffic and which require more than the current number of exclusive left-turn lanes, and for intersections where the line of movement of vehicles will be altered by a change in traffic regulations.

(4) Improvement of Medians

In conjunction with changes in traffic regulation and the opening of new roads, medians that are located where traffic is to pass straight through will be cut away.

(5) Installation of Pedestrian Crossings

In conjunction with changes in traffic regulations, pedestrian crossings will be provided at intersections where the current one-way operation is to be altered to a two-way operation and where there is no pedestrian bridge nearby.

(6) Plan in Conjunction with Introduction of Reversible Lanes

Pavement markings and signs will be improved as necessary for reversible lane operation.

Of the 143 intersections subject to control by the ATC System, 67 require one or more of the improvements described above. These intersections are shown in Fig. 2.17. The improvements required at each intersection are listed in Table 2.4.

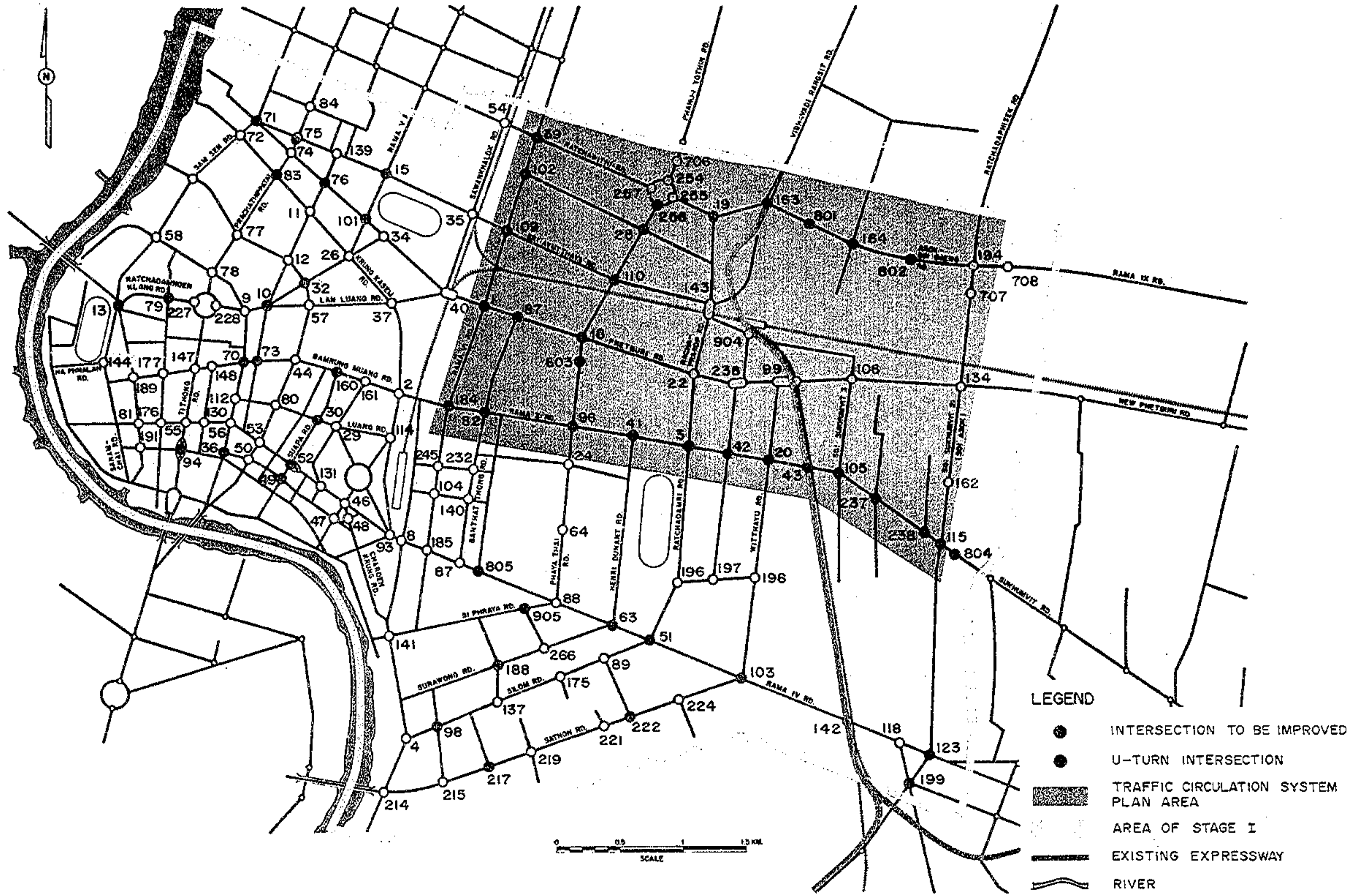


Figure 2.17 Intersection to be Improved

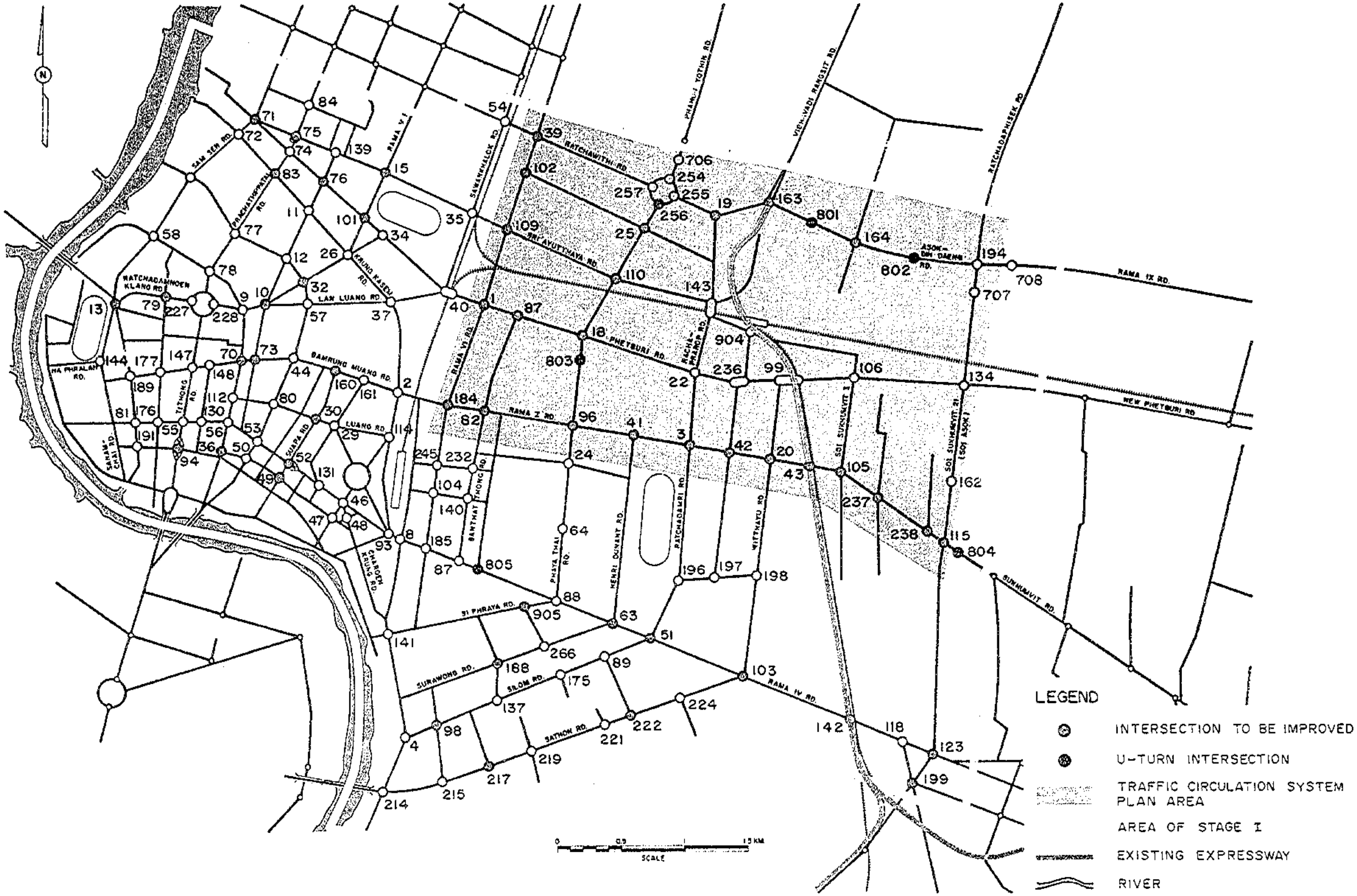


Figure 2.17 Intersection to be Improved

Table 2.4 (1) Improvement Measures by Intersection

(1) Int.No.	(2) Type	App-roach	(3) Main Projects I	II	III	(4) Improvement Measures 1	2	3	4	5	6	Remark
1	K	4	*			o		o		o		Change to Two-Way
3	K	4	*		*	o		o			o	Reversible Lane
10	K	6							o			
12	A	4							o			
13	K	5			*		o		o			
15	K	4				o						
18	K	4	*		*	o						Change to Two-Way, Flyover
19	K	3	*		*		o		o		o	Reversible Lane, Flyover(Plan)
20	K	4	*		*	o	o	o			o	Reversible lane
22	K	4	*		*	o	o		o		o	Reversible lane, Flyover
25	B	4	*			o	o			o		
30	C	4				o						One-Way
32	B	4				o						
36	K	4				o						One-Way
39	A	4	*		*	o	o					Change to Two-Way
40	K	4				o	o		o			Ramp(Plan), Flyover
41	A	3	*			o						Change to Two-Way
42	B	4	*			o		o			o	
43	K	4	*			o					o	Reversible lane, Ramp
49	B	4				o						One-Way
51	K	4			*	o	o					Elevated Road(Plan)
52	B	4					o					
54	B	4				o						One-Way
63	A	4			*		o					Elevated Road(Plan)
67	B	3	*			o		o				Change to Two-Way
70	B	4				o						One-Way
71	B	5				o						One-Way
73	B	4				o	o					One-Way
75	B	4				o						One-Way
76	A	4				o						
79	B	4				o						
80	B	4				o						
82	B	4	*			o	o	o				Change to Two-Way
83	C	6				o						One-Way
94	A	4				o						One-Way
96	K	4	*		*	o		o				Change to Two-Way
98	B	4				o						
99	K	5	*		*	o		o				Reversible Lane
101	B	6					o					
102	B	3	*			o	o	o				Change to Two-Way
103	K	4			*	o		o			o	Flyover
105	K	4	*			o						Reversible Lane
106	K	4	*			o	o	o				Change to Two-Way
109	K	4	*		*	o						Change to Two-Way
110	K	4	*		*	o						Change to Two-Way

Table 2.4 (2) Improvement Measures by Intersection

(1) Int.No.	(2) Type	App-roach	(3) Main Projects I	II	III	(4) Improvement Measures 1	2	3	4	5	6	Remark
115	K	4	*		*	o	o	o			o	Reversible Lane, Elevated Road(Plan)
123	K	4			*	o			o			Flyover(Plan)
134	K	4	*		*	o	o					Flyover, Elevated Road(Plan)
143	K	5	*			o	o	o	o		o	Reversible Lane
160	C	3				o						One-Way
163	K	4	*						o	o	o	Reversible Lane, Underpass(Plan)
164	B	4	*			o						Change to Two-Way
184	C	4	*			o	o	o				One-Way
188	C	4				o						
199	A	5				o	o	o				
217	B	3				o						
218	B	4				o						
221	B	3				o						
236	B	4	*			o		o	o	o	o	Reversible Lane
237	B	4	*			o		o			o	Reversible Lane
238	B	3	*			o		o			o	Reversible Lane
254-257	K	4	*			o			o			Ramp(Plan)
801	U	3			*					o		
802	U	3			*	o	o	o				
803	U	2	*		*	o	o	o				
804	U	2			*	o	o	o				
905	C	3			*	o						

Note :
1) Int No. : Intersection No. is specified by Traffic Police

2) Type Major Approach Minor Approach

	Major Approach	Minor Approach
K :	Key Intersection	
A :	5 Lanes or more	5 Lanes or more
B :	4 Lanes or more	4 Lanes or more
C :	3 Lanes or more	3 Lanes or more
U :	U-turn Signal	

3) Main Projects
- I : Traffic Ciculation System Plan
- II : Planned Signalized Intersection
- III : Right-turn Traffic-actuated Control

4) Improvement Measures
- 1 : Road Marking
- 2 : Exclusive Right-turn Lane
- 3 : Installation of Pedestrian Crossing
- 4 : Improvement of Channelizing Island
- 5 : Improvement of Median
- 6 : Improvement in Conjunction with Introduction of Reversible Lanes

2.4 Evaluation of ATC System

2.4.1 Effect of ATC System on Reduction of Delay Time and Stopping

In order to estimate the benefits by applying the ATC System, traffic flow is simulated using a main frame computer. The simulation was made for 1993.

For both cases of "with-" and "without ATC control" total delay time and total number of stopping are obtained as the simulation results, based on which savings in VOC and TTC are quantified. Prior to the simulation OD traffic volumes in 1993 are forecast, using the vehicle OD table surveyed in 1985 and future demographic framework developed in the study of SIMR/JICA.

Future traffic flow is simulated under the condition of two way reversible lane system. "With-" and "Without ATC control" are specified by the different control conditions concerning to traffic responsive control, saturation flow rate and signal coordination.

Simulation is conducted for one hour each of morning peak time, daytime and evening peak time. Total delay time and number of stopping are shown in Table 2.5.

Table 2.5 Reduction of Total Delay Time and Stopping by ATC System

	Without ATC			With ATC		
	Morning 07-08:00	Daytime 13-14:00	Evening 17-18:00	Morning 07-08:00	Daytime 13-14:00	Evening 17-18:00
Total Delay Time (hours)	12,371 (1.00)	6,632 (1.00)	10,199 (1.00)	8,654 (0.70)	5,078 (0.77)	7,360 (0.72)
Total Number of stopping (1000 times)	1,012 (1.00)	518 (1.00)	870 (1.00)	664 (0.66)	415 (0.80)	616 (0.71)

Note: Figure in ( ) shows the rate to "without ATC" case

In addition, Table 2.6 gives the effects of the ATC System on traffic flow at the main key intersections shown in Figure 2.18. The table applies to the morning peak hour (7:00-8:00), when congestion is the severest. Although disparities exist between locations, the table indicates that total delay time is reduced by about 15-35% and total stoppage time by about 20-35%.

Table 2.6 Reduction of Delay Time and Stopping at Key Intersection (Morning Peak Hour)

No.of Key Intersection	Case	Delay Time (Hours/H.Vehicle)	Number of Stopping (Times/H.Vehicle)
1	Without ATC	62.3	4592
	With ATC	*51.7 (0.83)*	*3720 (0.81)*
2	Without ATC	34.4	2113
	With ATC	*23.4 (0.68)*	*1458 (0.69)*
3	Without ATC	164.7	4709
	With ATC	*133.4 (0.81)*	*3673 (0.78)*
4	Without ATC	208.9	6394
	With ATC	*154.6 (0.74)*	*5051 (0.79)*
5	Without ATC	47.7	2271
	With ATC	*31.5 (0.66)*	*1476 (0.65)*
6	Without ATC	53.9	2854
	With ATC	*39.3 (0.73)*	*2055 (0.72)*
7	Without ATC	47.5	4337
	With ATC	*39.0 (0.82)*	*3817 (0.88)*
8	Without ATC	46.3	6068
	With ATC	*28.7 (0.62)*	*3884 (0.64)*
9	Without ATC	62.9	2885
	With ATC	*48.4 (0.77)*	*2135 (0.74)*
10	Without ATC	52.0	2933
	With ATC	*37.4 (0.72)*	*2170 (0.74)*
11	Without ATC	48.6	4836
	With ATC	*39.4 (0.81)*	*3627 (0.75)*
12	Without ATC	58.7	6105
	With ATC	*48.1 (0.82)*	*4884 (0.80)*
13	Without ATC	94.0	6830
	With ATC	*67.7 (0.72)*	*4918 (0.72)*
14	Without ATC	85.0	3706
	With ATC	*59.5 (0.70)*	*2557 (0.69)*
15	Without ATC	75.5	3382
	With ATC	*57.4 (0.76)*	*2604 (0.77)*
16	Without ATC	44.4	2550
	With ATC	*30.6 (0.69)*	*1658 (0.65)*
17	Without ATC	39.2	1742
	With ATC	*26.7 (0.68)*	*1202 (0.69)*
18	Without ATC	111.6	4677
	With ATC	*89.3 (0.80)*	*3555 (0.76)*
19	Without ATC	297.7	7825
	With ATC	*220.3 (0.74)*	*5791 (0.74)*
20	Without ATC	8.9	608
	With ATC	*5.7 (0.64)*	*407 (0.67)*
21	Without ATC	55.4	3111
	With ATC	*41.0 (0.74)*	*2209 (0.71)*
22	Without ATC	204.8	4622
	With ATC	*161.8 (0.79)*	*3467 (0.75)*
23	Without ATC	31.4	1856
	With ATC	*24.2 (0.77)*	*1336 (0.72)*
24	Without ATC	481.9	5647
	With ATC	*327.7 (0.68)*	*3671 (0.65)*

Note: ( ) = Ratio to Without ATC Case

2.4.2 Economic Benefit of ATC System

Road Network used for simulation consists of 447 links in total. The sum of products of traffic volume and unit VOC plus TTC of each link will give the total hourly traffic costs. The difference of the above-mentioned sum between "with" and "without" ATC case is regarded as the benefit of the ATC System. Above-mentioned calculation is conducted using such data as unit VOC/TTC and the vehicle type composition, hourly fluctuation of traffic volume. Table 2.7 shows the estimated annual benefits in 1993 to 2007.

Table 2.7 Economic Benefits in 1993 to 2007

(Million Baht)

Year	VOC Saving	TTC Saving	Total
1993	181	540	722
1994	185	570	755
1995	189	599	788
1996	192	629	821
1997	195	654	848
1998	198	678	876
1999	200	703	903
2000	203	727	931
2001	206	752	958
2002	209	777	985
2003	212	805	1,017
2004	215	835	1,049
2005	218	866	1,082
2006	221	898	1,116
2007	224	931	1,151

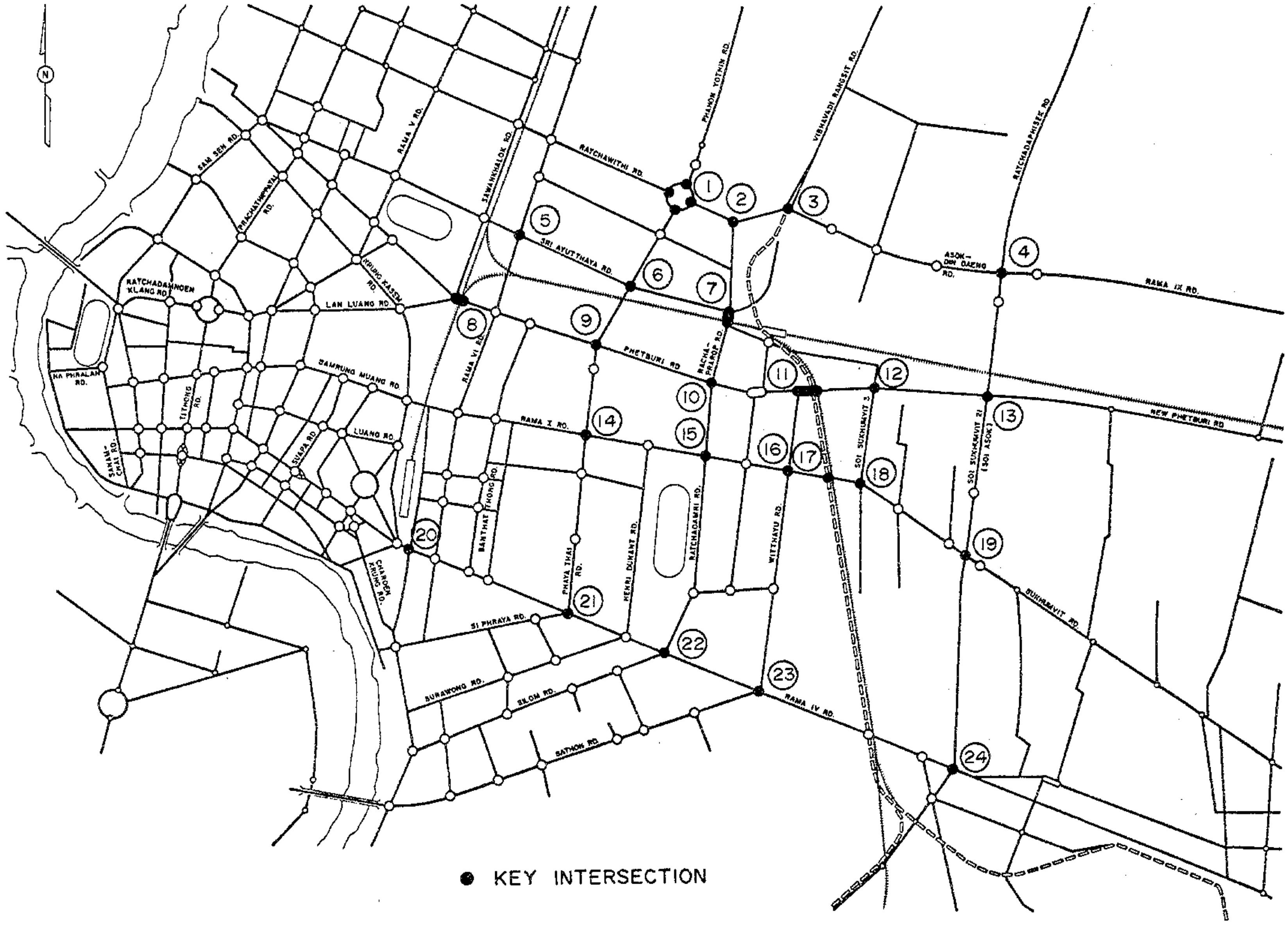


Figure 2.18 Main Key Intersection Selected for Evaluation

CHAPTER 3

ATC SYSTEM DESIGN

CHAPTER 3 ATC SYSTEM DESIGN

3.1 ATC System Plan

3.1.1 General

The Bangkok Area Traffic Control (ATC) System-Stage I will comprise of a signal system controlling 143 major intersections, and other traffic surveillance and control related systems in the central part of Bangkok.

The whole ATC System will be controlled on-line with real time operation for 24 hours a day and 7 days a week, by the central computer located at the Traffic Control Center (TCC) in the BMA building, Dinso Road, Bangkok. Traffic signals at intersections will be linked with the TCC by the existing cable network which is installed and managed by the Telephone Organization of Thailand (TOT).

Under the Stage I Project, the BMA will implement two independent system, namely:

- Traffic signal system
- CCTV system

The work involved in this project includes:

- installation of central facilities
- installation of local equipment
- installation of cable
- establishment of traffic control center

As for future expansion, the system is designed with a capability of controlling up to 400 signals and 1,600 detectors. Other than expanding the data base, bringing future signals on line will not require additional hardware or software modification of the central computer system.

3.1.2 Signal System Functions

1) Functions

The ATC System will provide the following functions:

(1) Area Wide Coordinated Signal Control Function

The system is capable of coordinated as well as isolated control of all of the signals in the project. It will be capable of coordinated control on a real-time basis from the traffic control center based on current traffic flow data obtained from vehicle detectors (traffic responsive control). This traffic responsive control can be adopted to all traffic flow conditions ranging from under-saturation to over-saturation.

The system will provide signal control on a time-of-day basis as a backup for the traffic responsive control. It will also be possible to operate the signals manually on site in case of emergency.

(2) Data Gathering and Processing Function

The system will be capable of gathering traffic related information by means of vehicle detectors, public telephones, fax devices and wireless radio system managed by the BMA and the police department.

Detector data including vehicle volume and occupancy will be transmitted to the central computer system for control, monitoring, and statistical data compilation purposes.

(3) Equipment Monitoring Function

The system will be capable of monitoring the conditions of all major center and field equipment at all times, detecting and reporting their failure immediately and automatically.

(4) Man-Machine Interface Function

The system will be possible to confirm traffic information gathered by the system via such visual devices as a control room wall map and CRT displays of work stations. The system will also allow the input of case-by-case control parameters determined on the basis of information obtained by the system, under circumstances where it is necessary to carry out non automatic control strategies.

(5) Data-Recording Function

The system will keep permanent records of detector data, operation status, manual intervention activities, and equipment failure history in daily and monthly report formats for future references and analysis.

2) Basic Signal Control Method

The intersections to be signalized in the ATC system are categorized into two groups namely key intersections and ordinary intersections. Key intersections are those which have higher degree of saturation and need more careful and precise control. They are usually crossings of major streets. Ordinary intersections are those other than key intersections. Key and ordinary intersections are designated in the course of system design. Control of key intersections will correspond to their saturation levels at any given point in time, as indicated by on-line data obtained from vehicle detectors. Control of ordinary intersections will be subordinated to that of the neighboring or nearest key intersections.

Traffic conditions at the key intersection will be divided into the three levels of under-saturation, near-saturation, and over-saturation. Splits, cycle lengths and offsets will be determined separately for each level. Table 3.1 outlines the traffic conditions and control parameters applicable to each level.

(1) Cycle

Cycle is determined based on plan selection method depending on the detector data.

(2) Offset

Offset is determined based on time-of-day plan selection method. The reasons of using a time-of-day method for offset decision are:

a) Transition period between one offset pattern to another tends to cause undue congestion to traffic because of the meaningless offsets during transition. Too frequent change of offset should therefore be avoided.

b) Benefit obtainable from traffic-responsive finer adjustment of offsets is not expected to be large enough to overcome the cost and the disbenefit mentioned in a).

(3) Split

Split is decided in the traffic responsive manner. The method is having an adjustment value which is a constant in seconds or percent of cycle time added to the phase for the most congested approach while subtracting such value from the phase for the least congested one at each cycle.

Table 3.1 Control Method Principles

	Under-saturation[1]	Near-saturation[2]	Over-saturation[3]
CYCLE			
Each Sub-area		Selection (depending on the Occupancy and Volume)	
SPLIT			
Key Intersection		Adjustment[4]	
Ordinary Intersection		Adjustment (depending on given key intersection)	
OFFSET		Time-of-day Selection [5]	

Notes:

(1) Under-saturation - Vehicles arriving in the last cycle time are all cleared in the current cycle with appropriate split control.

(2) Near-saturation - Vehicles arriving in the last cycle time are not at times cleared in the current cycle depending on the cycle, even with appropriate split control. However, the number of uncleared vehicles are not large to form a long queue.

(3) Over-saturation - Traffic demand which is the sum of the vehicles arriving at the intersection in the last cycle and the vehicles already existed in the queue exceeds the service volume of the current cycle. When the arrival rate exceeds the service rate, the queue grows.

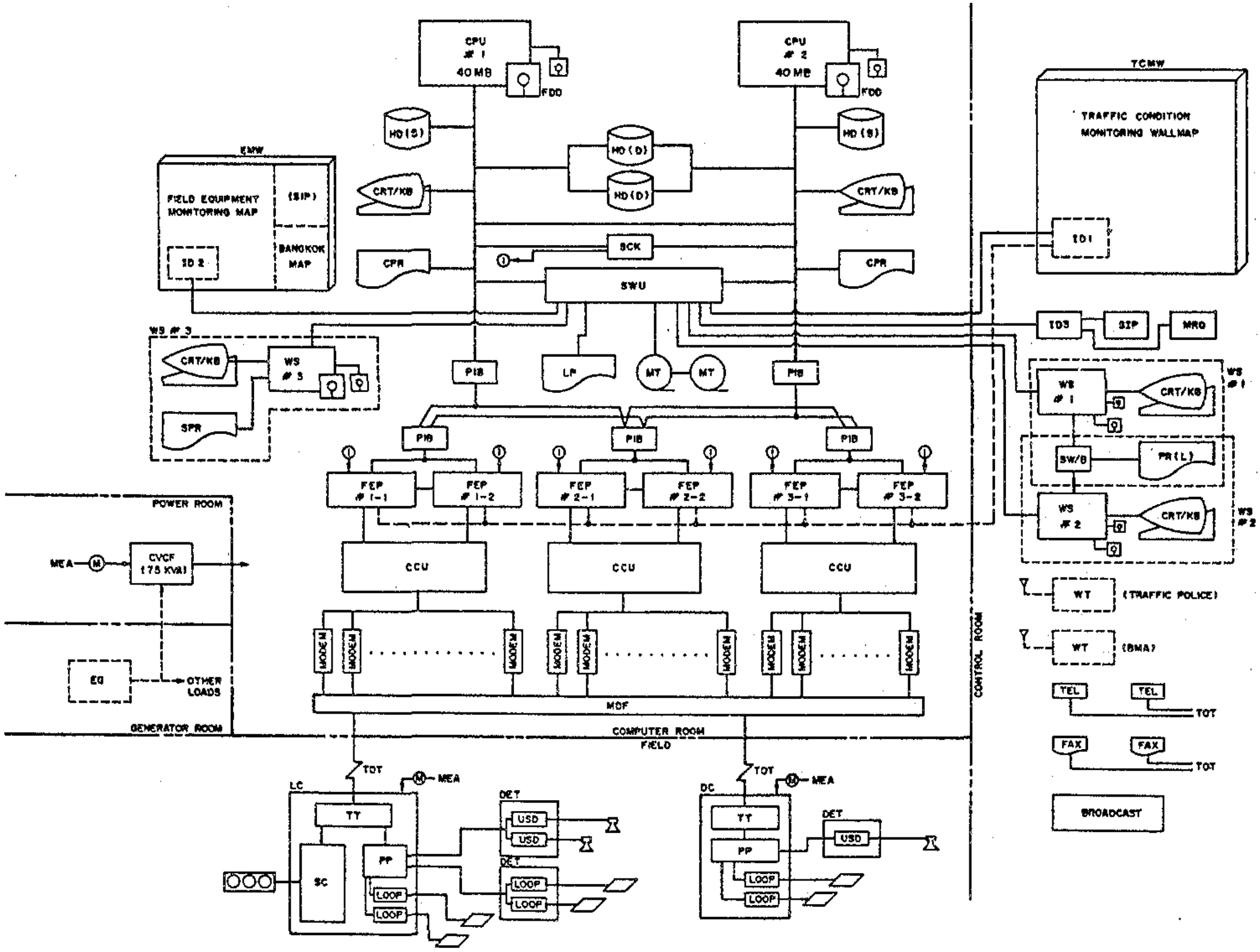
(4) The split adjustment at key intersections will be executed cycle by cycle. When queues have simultaneously exceeded the furthest detector points on two or more approaches where signal phases are different, it is impossible to adjust the split according to detector data. In such a case, some constraints such as limit of queue length or limit of occupancy will be given for each approach to the intersection.

(5) Offsets for use in over-saturation should be determined in such a way that the numbers of vehicles which can be stored in the approach links to the over-saturated intersection are maximized. The purpose of this is to minimize the area affected by the over-saturation.

3) System Composition

The hardware configuration of the ATC System is shown in Figure 3.1.

A traffic condition indication wallmap, two work stations, a control desk for performing man-machine interface function etc.will be provided in the control room. Two sets of identical central processor units with peripherals, a work station, central transmitting equipment, a equipment monitoring indication wallmap etc. will be installed in the computer room.



ABBREVIATION	NAME IN FULL
CPU	CENTRAL PROCESSING UNIT
FDD	FLOPPY DISK DRIVE
HD (S)	HARDDISK UNIT FOR STORING PROGRAMS
HD (D)	HARDDISK UNIT FOR STORING WORK DATA
CRT/KB	CRT DISPLAY / KEYBROAD
CPR	CONSOLE PRINTER
SCK	SYSTEM CLOCK
SWU	SWITCHING UNIT
LP	LINE PRINTER
MT	MAGNETIC TAPE UNIT
TCMW	TRAFFIC CONDITION MONITORING WALLMAP
EMW	EQUIPMENT MONITORING WALLMAP
ID 1-3	INDICATION DRIVER
SIP	SYSTEM INDICATION PANEL
MRQ	LOCAL MANUAL REQUEST PANEL
WS	WORK STATION
PR (L)	LASER PRINTER
SW/B	PRINTER SWITCHING BUFFER
PIB	PARALLEL INTERFACE BUS
FEP	FRONTED PROCESSOR
CCU	CENTRAL COMMUNICATION UNIT INCLUDING PROCESSOR
MODEM	MODULATOR / DEMODULATOR
MDF	MAIN DISTRIBUTION FRAME
TOT	LEASED LINE FROM THE TELEPHONE ORGANIZATION OF THAILAND
MEA	POWER SUPPLY FROM THE METROPOLITAN ELECTIC AUTHORITY
M	WATT-HOUR METER
LC	LOCAL CONTROLLER
TT	TERMINAL TELEMETRY
SC	SIGNAL CONTROLLER
DC	DETECTOR CONTROLLER
PP	PRE-PROCESSOR FOR DETECTOR
DET	DETECTOR CABINET
VSD	ULTRASONIC DETECTOR
LOOP	LOOP INDUCTIVE DETECTOR
SPR	SERIAL PRINTER
CVCF	CONSTANT VOLTAGE / CONSTANT FREQUENCY SUPPLY
EG	ENGINE GENERATOR
WT	WIRELESS
IEL	TELEPHONE SET
FAX	FACSIMILE

Figure 3.1 Traffic Signal System Configuration Diagram

On the field, local controllers, terminal transmitter-receiver, vehicle detector etc. will be installed.

3.1.3 Software Configuration

Figure 3.2 shows the software configuration. In the figure, the flow of real time data-processing is shown by bold lines representing the most critical flow from the standpoint of loading.

The software will consist of several system programs and application programs.

The System Programs include:

a) Operating system
b) Language support system
c) Dualization system
d) Other options (Data Base Management System etc.)

The Application Programs for signal control are categorized according to each function as follows:

a) Program for area wide signal control
b) Program for collecting and processing data from vehicle detectors
c) Program for monitoring the system equipment
d) Program for input-output via man-machine interfaces
e) Program for data storage and reporting

All the application programs will be assigned to either the CPU (upper-tier computer) or the FEP (lower-tier computer). The programs for area wide signal control must be developed, taking into consideration Bangkok's traffic conditions and road network.

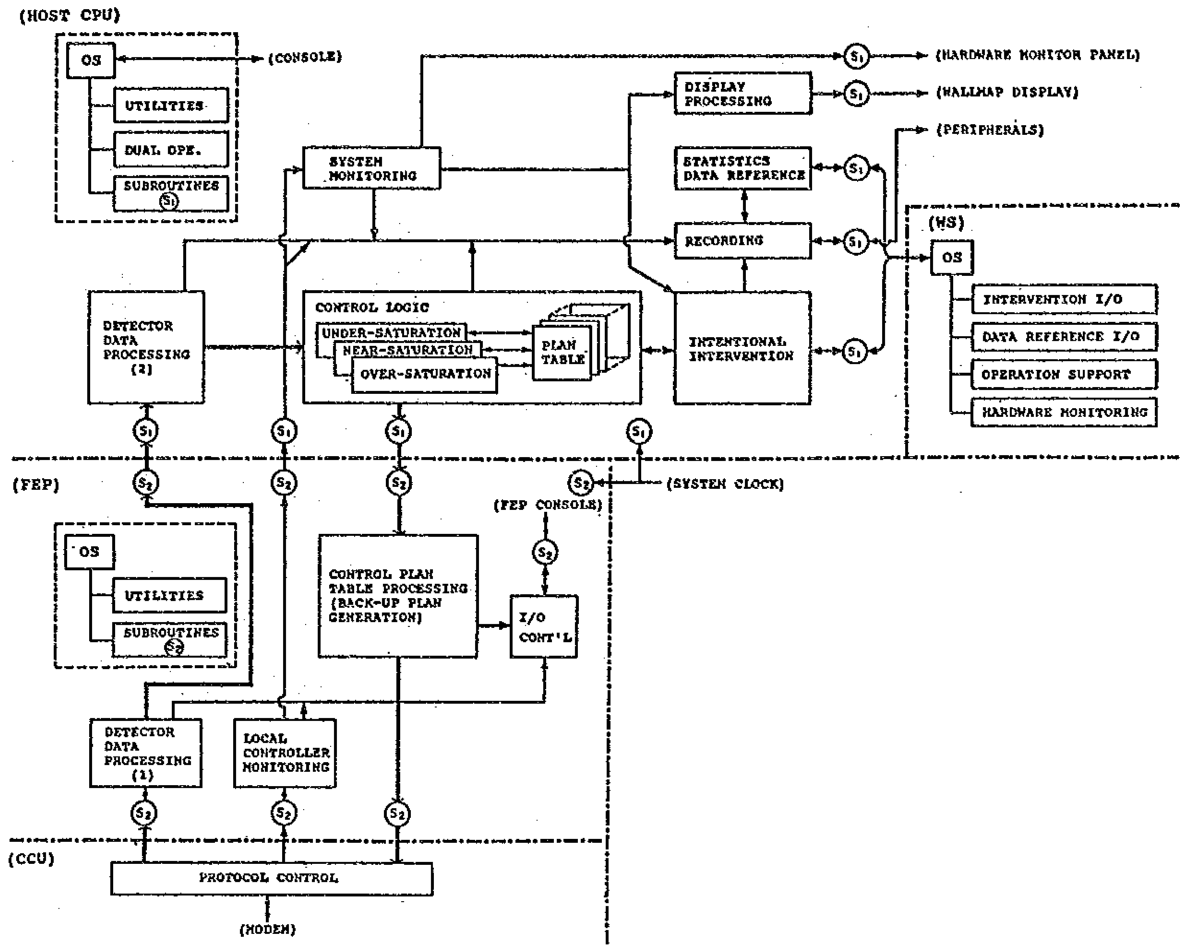


Figure 3.2 Software Configuration

3.2 Facilities Plan

3.2.1 Central Facilities

1) Control Center

(1) Location

The Traffic Control Center will be located on the first floor of the BMA 1 building.

(2) Layout

The layout of the Control Center will be as shown in Figure 3.3. The following points must be taken into account when planning facilities in the Control Center.

a) A power supply room will be located next to the kiosk at the basement of the BMA building. A power supply terminal panel and uninterrupted power supply devices will be provided in the room. A power generator with an engine will be installed in the yard space on the same floor. A fuel tank to be provided will have enough capacity to operate continuously the power generator for 24 hours without refueling.

b) The Control Center will be divided into a Control Room and a Computer Room. Both rooms will have a free-access floor (raised floor). Each room will be equipped with a separate air conditioning system and ducts for the cooled air will be placed below the surface of the free-access floor.

c) In the Control Room, a wallmap (size 6m x 6m) for displaying traffic conditions will be mounted on the wall. A CCTV panel of comparable size will be placed on the left side of the wallmap.
A control desk will be placed on a stage at a distance of about eight meters from the wallmap in order to retain the full visibility of the wallmap and CCTV monitors.

In addition, anterooms for the traffic engineer and traffic officer, radio broadcasting booth, small lounge, resting room, and wet area (lavatory, washroom, etc.) will be provided.

d) The Computer Room will mainly house the computers and their related equipment, data transmission equipment, an equipment monitoring indication wallmap and air conditioners. A software storage room and an anteroom for the maintenance crew will also be provided.

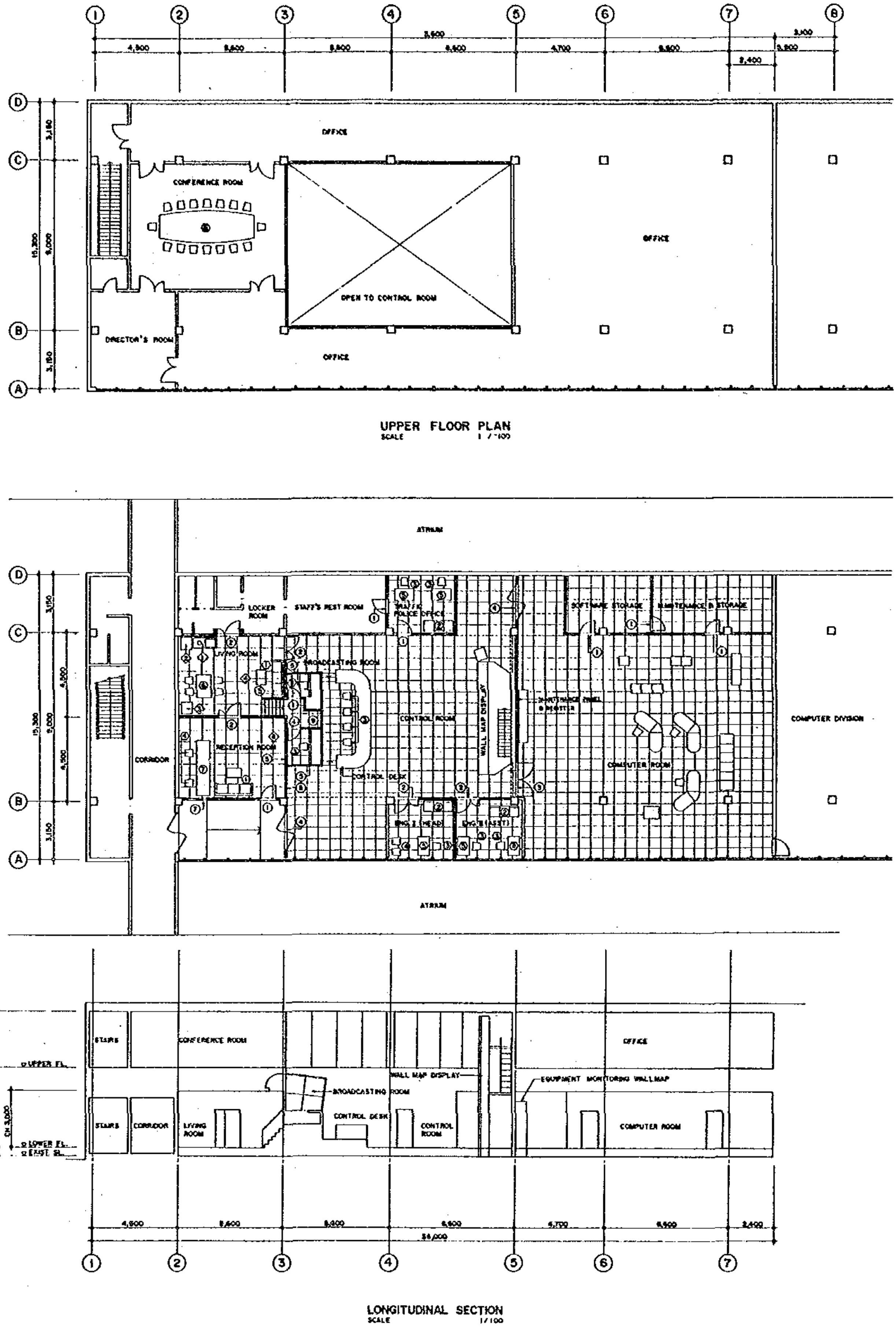


Figure 3.3 Lay-out of Control Center

2) Central Computer System

(1) Hierarchy Architecture and Dual System

The System will have a hierarchy architecture and a dual system. With a hierarchy architecture, work load is shared by the upper-tier computer (central processing unit; CPU) and the lower-tier computer (front-end processor; FEP). To allow the CPU to operate without wasting its capacity, the FEP will handle on-line input/output.

The dual system will be applied to the following hardware:

a) CPU
b) Data-storage hard disk shared by the two sets of CPU's
c) FEP

General-purpose high-speed parallel bus (commonly known as general-purpose interface bus: GPIB) will be adopted for the communication system linking the CPU and FEP's.

(2) Peripheral Devices

Peripheral devices will all be linked to the upper-tier computer for ease of operation. The following peripheral devices will be provided for each of the two sets of CPU's:

a) Console CRT display keyboard
b) Console printer
c) Hard disk for system storage
d) Floppy disk drive
e) Magnetic tape device
f) Work station

In addition, a system clock that can supply standard time data for the whole system will be provided.

(3) CPU Capacity

From the standpoint of processing capacity and speed, the CPU will be a minicomputer-class machine of 1 MPIS level with a 32-bit, 25-MHz core processor.

The processing capacity will correspond up to 400 local controllers in the future. A sum of 235 local controllers is expected to be in operation after the completion of Stage 2. The processing speed is considered on the basis of data-processing frequency and total throughput time, under the condition that the system will be primarily under traffic-responsive control. Data-processing frequency is established by the signal cycle, and total throughput time is established as 5 minutes maximum.

3) Central Equipment

The components of central equipment are as follows.

(1) CPU (Including Floppy Disk Drive,Interfaces for Peripherals)
(2) Console CRT/Keyboard
(3) Console Printer
(4) Hard disk Unit (for System Storage)
(5) Hard disk Unit (for Data Storage)
(6) Magnetic Tape Unit
(7) System Clock
(8) Switching Unit for Dual Operation
(9) Line Printer
(10) Work Station
(11) Traffic Monitoring Wallmap
(12) CCTV Monitoring Panel
(13) Equipment Monitoring Wallmap
(14) System Indication Panel
(15) Local Manual Display
(16) Camera Operation Console and TV Monitor
(17) Central CCTV Controller
(18) Time Lapse VTR and TV Monitor
(19) BMA Wireless Talky
(20) Traffic Police Talky
(21) Telephone with Extension
(22) Facsimile
(23) Front-end Processor
(24) Communication Control Unit
(25) MODEM
(26) MDF (Main Distribution Frame)
(27) Power Switching Panel
(28) Air Conditioner
(29) Cooling Tower
(30) Uninterrupted Power Supply
(31) Engine and Generator (including Battery, Fuel Tank)
(32) Exclusive Furniture
(33) Maintenance Parts

3.2.2 Transmission System and Communication Lines

1) Transmission System and Equipment

Transmission equipment will compose of a communication control unit (CCU), gathered modems, main distribution frames (MDF) at the TCC, and terminal transmitter-receivers (TTR) in the field.

The System will adopt a decentralized back-up system with traffic responsiveness as a precondition. The back-up signal control plans and timetables will be stored in terminals and updated periodically (about once a day) from the center. The numerical data transmission method may be used to transmit data in this system.

For the transmission protocol in this method, a standardized High-Level Data Link Control (HDLC) will be made available. This will be applied to the Communication Control Unit.

2) Communication Lines

Communication Lines will consist of lines leased from the TOT. In the TOT line network, stations are linked to each other by pulse code modulation, while subscriber terminals are linked to stations by metallic line. A single two-wire cable system will be used.

3.2.3 Field Equipment

These are local controller and vehicle detector as the main field equipment:

1) Local Controller

Local controller will execute signal control according to the control modes, shown in Table 3.2. Local controller will be installed at all the intersections and linked to the control center to afford on-line control. Their functions are to control traffic signals in an appropriate manner and to transmit data obtained from nearby detectors.

Manual control by police will be possible on request to the TCC. The pre-emption control will be considered for intersections near railway crossing.

Table 3.2 Priority of Modes and Fail-Safe System

Operation Mode	No.	Control Mode	Equipment Controlling	Status of Equipment Condition	Operator Override (Operation)	Operator Override (Table Change)
Central Computer Operation Mode (On-Line)	(1)	Traffic responsive control	CPU	Normal Operation	Yes	Yes
	(2)	Time-of-Day control	FEP	CPU Off-Line		
Standby Operation Mode	(3)	Isolated Time-of-Day control	Local Controller	CPU & FEP or Cable Line Off-Line	Yes	Yes
	(4)	Fixed time control by RAM store	Local Controller	(1),(2),(3) mode Off-Line	Yes	Yes
	(5)	Fixed time control by ROM store	Local Controller	(1),(2),(3),(4) Off-Line	Yes	No
	(6)	Flashing control	Local Controller	(1),(2),(3),(4), (5) Off-Line	Yes	No
Manual Operation Mode	(7)	Manual control	Local Controller Policemen Control	Permit/Reject	No	-
Local Operation Mode	(8)	Extension Actuated Control	Local Controller	No activity under (5),(6),(7)	No	Yes
	(9)	Railway Pre-emption	Local Controller	No activity under (5),(6),(7)	No	Yes
Portable Local Controller Operation Mode	(10)	Portable Local Controller	Portable Local Controller	Existing Local Controller is down	No	No

2) Vehicle Detectors

(1) Functions

Vehicle detectors are to detect the presence of motor vehicles for the collection of traffic data related to traffic-responsive control, collection of congestion status, and compilation of traffic statistics.

(2) Standard Placement

The standard placement of vehicle detectors will depend on the intersection classification:

a) Key Intersection
Detectors will be placed at 150, 300 and 600 meter locations from the stop line on each approach to a key intersection. The detector positioned at 600 meters away will be omitted if it is beyond the next intersection belonging to a different sub-area.

b) Ordinary Intersection
Detectors will be placed at 150 meters from the stop lines for the purpose of determining cycle and split length in a sub-area. However, detectors will be provided only at the following ordinary intersections:

- Intersection in a sub-area that contains no key intersection

- Intersection that requires split control in the same manner as the key intersection

(3) Type of Detector and Selection

Two types of detectors are available, namely induction loopcoil and ultrasonic. This project proposes the installation of the less expensive induction loopcoil detector. The loopcoil detector also has the advantage over the ultrasonic detectors of being embedded under the road pavement and thus unobtrusive. The ultrasonic detectors are used in special cases only such as at locations where there are frequent excavation works which may damaged the loopcoil detectors, or where a pedestrian overpass or some similar structure can be used for mounting the detector heads. Table 3.3 gives the number of vehicle detectors by type while their installation location are shown in Figure 3.4.

Table 3.3 Number of Detector by type

	Functions	Loop	Ultra-sonic
(1)	Coordinated Area Control & Split Control	277	50
(2)	Vehicle Actuated Control (13 Intersections)	17	0
(3)	Congestion Indication	(277)	(50)
(4)	Traffic Statistics (21 Check Points)	93+(20)	21+(4)
	Sub Total	387	71
	Total	458	

Note : ( ) Detectors as installed for Function (1)

(4) Concentration of Detector Pulses

To reduce the number of transmitting lines that must be leased from the TOT, local controllers are equipped with transmitters to collect the pulses emitted by the nearby detectors. Detectors located within 300 meters from an intersection are basically connected by cables to the local controller at the same intersection.

For detectors located over 300 meters from an intersection, one of these detectors will be equipped with a transmitter that is connected to a nearby detector.

Figure 3.5 shows a typical plan for concentrating detector pulses.

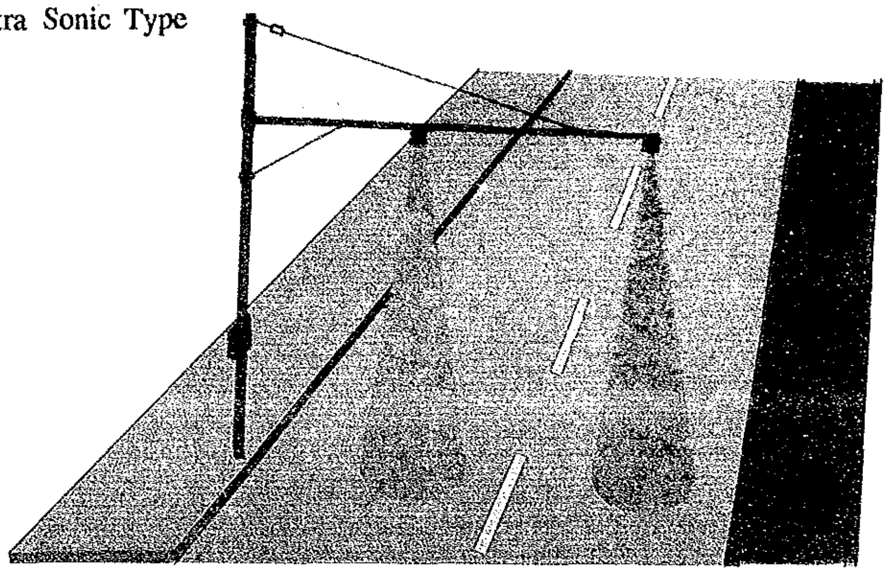
(5) Standard Installation Plan

The standard installation plan for detectors is shown in Figure 3.6.

3) Standard Installation Plan Near Intersections

To reduce the cost of field equipment, the existing facilities will be used wherever possible. The existing signal poles, handholes, conduits and also cables will be retained if possible. Local controllers are replaced with those for on-line control. Where the existing traffic lights have low visibility, lights mounted on tall poles are added (some of the old traffic lights are to be replaced). Junction boxes are also added.

Ultra Sonic Type



Loop Type

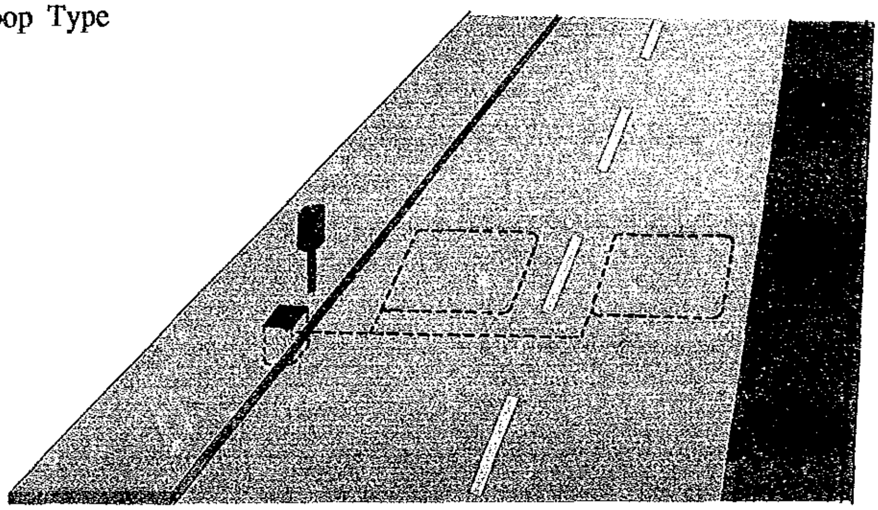


Figure 3.4 Type of Vehicle Detector

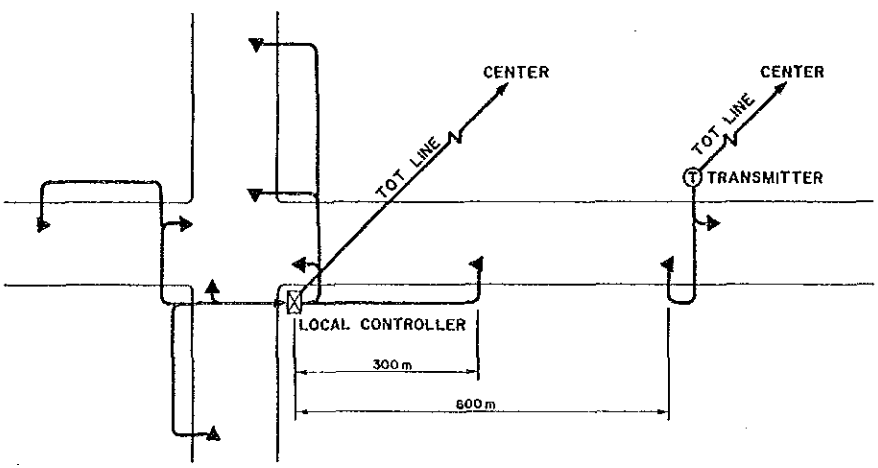
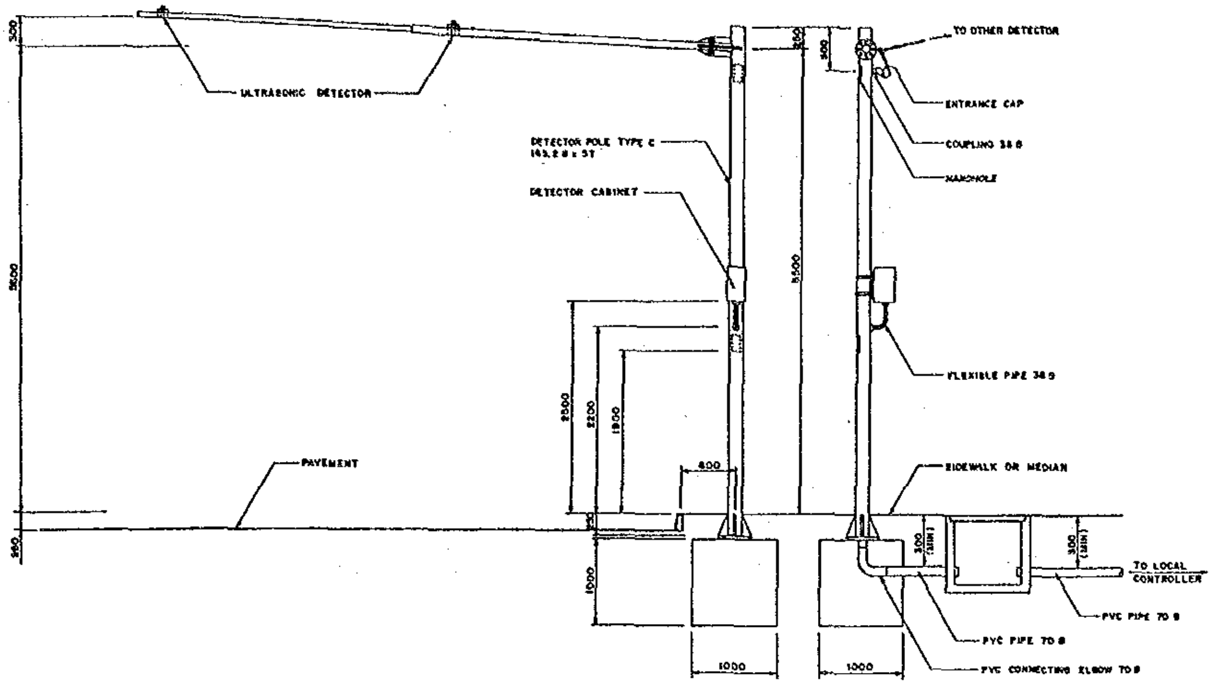


Figure 3.5 Detector Pulses Concentrating Plan

(1) Ultrasonic Type



(2) Loop Type

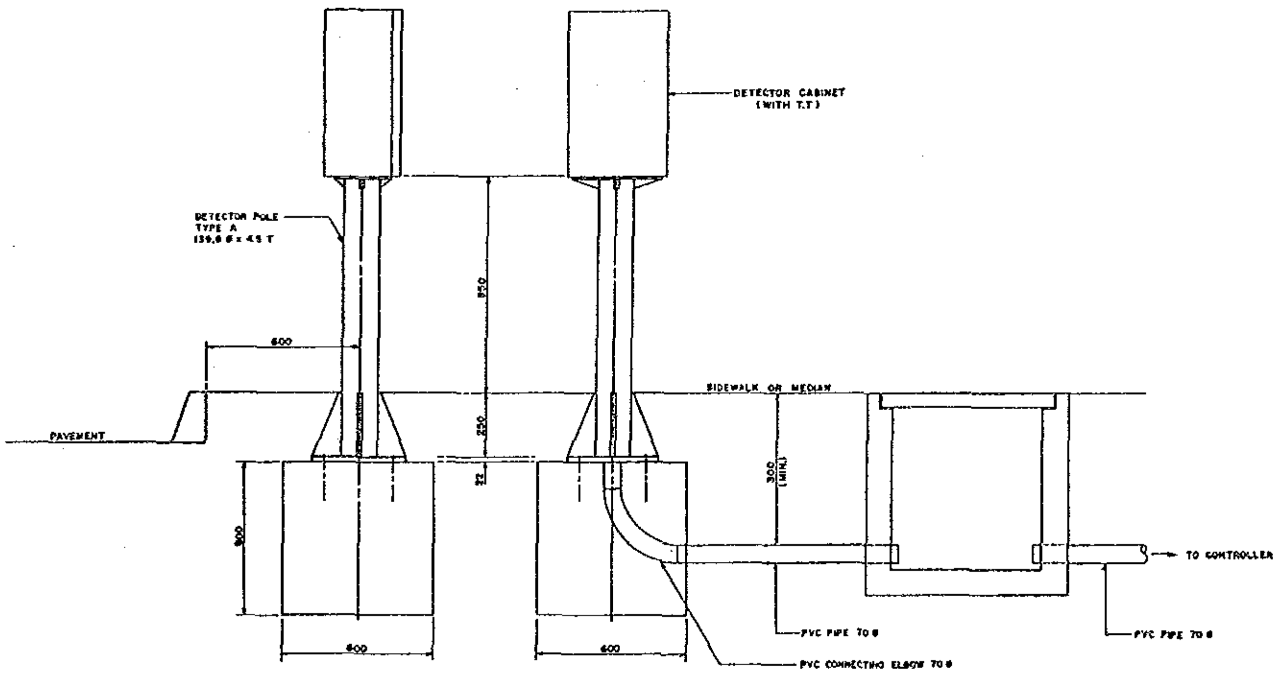


Figure 3.6 Standard Installation Plan for Detector

3.2.4 CCTV System

1) Camera Site

The five (5) intersections listed below will be provided with CCTV cameras. Figure 3.7 shows the locations where the cameras will be mounted:

a) Ratchadamnoen Klang - Ratchadamnoen Nai Intersection (No. 13)
b) Phaya Thai - Phetchaburi Intersection (No. 18)
c) Sukhumvit - Soi Sukhumvit 21 - Ratchadapisek Intersection (No. 115)
d) Sathon - Witthayu - Rama IV Intersection (No. 103)
e) Ratchadapisek - Asok Din Daeng Intersection (No. 194)

2) Transmission System

The optical fiber network that the TOT is planning to construct will be used for the video signal transmission from the field to the control center. The existing TOT telephone network will be used for the camera control signals from the control center to the field.

3) Monitor Unit

The ratio of monitor units to cameras will be 1:1, and twenty-one inch TV monitor will be used. The CCTV cameras will conform to the PAL color television system.

4) Camera Operation Console

Through a camera operation console installed on the control desk, it will be possible to control the camera lens to pan, tilt, zoom or focus by means of switches. A nine-inch or more TV monitor will be provided for this purpose.

5) Time-Lapse VTR

Single-frame video recording will be possible upon manually selecting the camera required. A nine-inch or more TV monitor will be provided for this purpose.

6) Central CCTV Controller

The central CCTV controller will be equipped with a camera position control switching circuit, time-lapse VTR switching circuit, camera position signal multiplexing circuit, and optical modem.

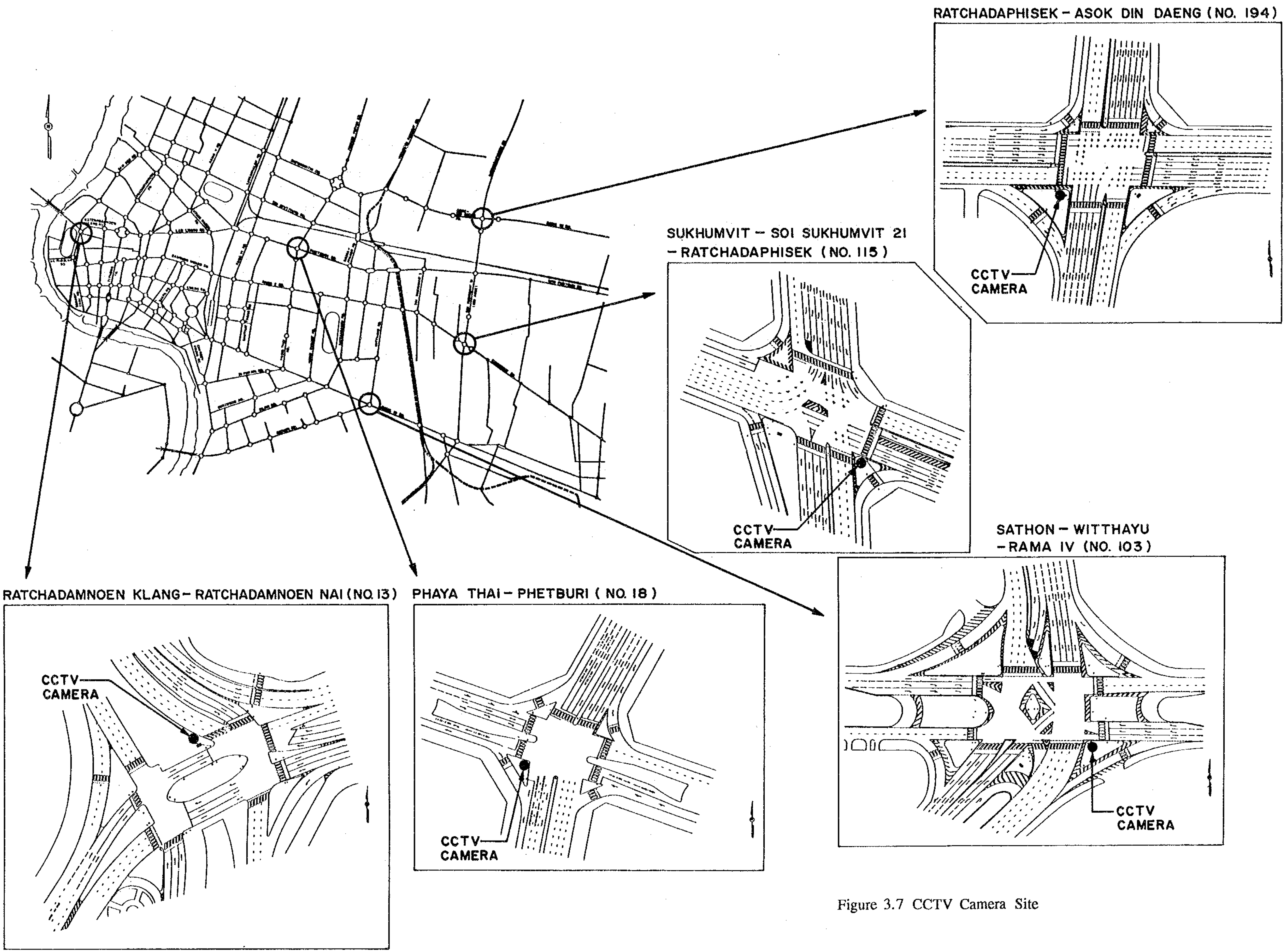


Figure 3.7 CCTV Camera Site

CHAPTER 4

MAINTENANCE AND OPERATION PLAN

CHAPTER 4 MAINTENANCE AND OPERATION PLAN

4.1 Operational Management

Operational management is the process by which the intentions of the traffic controller are conveyed to the road users, and is to be directly implemented by the Traffic Engineering Division of the BMA. Therefore, the contractor should take care to design the system equipment in such a way that special skills are not required to operate the control center.

Requirements to be fulfilled by the contractor when designing the operational management plan are as follows:

(1) Establishment of action patterns necessary for operating the control center, and preparation of center and equipment operation manuals.

(2) Indication of the space and equipment needed for operational management.

(3) Indication of the costs required for operational management.

(4) Indication of the skills in which the candidate staff must undergo training, as indicated by the staff plan of the Traffic Engineering Division, and of the costs and time frame involved.

The outline of purpose center/equipment operation manuals will be shown in Table 4.1, and the respective response between the control center to the traffic police will be shown in Table 4.2.

Table 4.1 Purpose Center/Equipment Operation Manuals

	Purpose	Content
Equipment Operation Manual	Upon equipment delivery, the contractor shall explain how to operate the equipment delivered	(1) Method of operating the central processing unit (2) Method of regulating traffic during emergencies (3) Method of gathering and recording management data (4) Method of preparing and storing management documents
Center Operation Manual	During the term of guarantee, the contractor shall dispatch a traffic engineer to explain how to operate the control center	(1) Method of conducting periodic checks on traffic conditions (2) Method of updating signal control parameters (3) Method of expanding and/or relocating signal facilities (4) Plan for upgrading signal control methods

Table 4.2 Respective Response

	Control Center	Traffic Police
Normal Flow	Carries out daily tasks in accordance with the center/ equipment operation manuals	- Directs traffic by hand signals in order to prevent intersections from jamming and vehicles from stopping on railroad tracks - Provides guidance on traffic manners
Heavy Flow	Identifies excessive congestion spots based on data from vehicle detectors, and notifies the traffic police center	Upon instructions from the traffic police center, directs traffic in order to alleviate congestion
Special Events	Based on information from the organization concerned,reviews the need for local manual control. If necessary, instructs a traffic officer, via the traffic police center, to effect manual control	In accordance with instructions from the control center via the traffic police center, effects local manual control
Emergency	Collects related data from the traffic police center by telefax	Sends traffic management related information to the control center via the traffic police center by telefax

4.2 Maintenance

1) General

(1) General Requirements

The purpose of this maintenance contract is to keep the signal system and related equipment in operation in the manner originally intended, that is to guide, regulated, warn, and facilitate the orderly movement of traffic with due regard for the safety of life, limb, and property of motorists and pedestrians and to prolong the useful life of the equipment. Repair must be done in a timely manner.

The requirements described herein shall be considered the minimum standards to be followed for the maintenance and repair of all equipment covered under this Contract. Unless otherwise specified, the standards for equipment and equipment performance shall be in accordance with the installation contract documents.

(2) Scope of Work

The contractor shall furnish all labor, tools, shop facilities, equipment, spare parts, and material and perform all work necessary to maintain in good working manner all traffic signal system and associated equipment.

Maintenance services are required to cover all signal and CCTV systems equipment installed in the Bangkok ATC System Project - Stage I.

The various classifications of maintenance and repair work and related services to be performed by the contractor include the following:

a) Preventive Maintenance
The work to be done consists of monthly inspection/cleaning and quarterly or bi-annual checking, cleaning, routine replacement or overhaul of parts as recommended by the manufacturer, and servicing of various system components and related equipment. Minor deficiencies uncovered during the performance of preventive maintenance shall be corrected immediately and all adjustment, tuning, and calibration necessary to keep the equipment in the best operating condition shall be performed. Any problems which require further attention or use of spare part(s) shall be recorded on the TED/BMA Fault Report Form and they shall be corrected according to the provisions for corrective maintenance or accident repair as appropriate.

b) Corrective Maintenance
The work to be done consists of correcting malfunctions resulting from equipment deterioration and failure under normal operating conditions. However, replacement or servicing of equipment parts which, according to manufacturer's recommendations, should be replaced or serviced at regular intervals, shall be considered as within the scope of the preventive maintenance.

c) Accident Repair
The work to be done consists of repairing damages to the equipment due to accidents, vandalism, act of God, pavement failures, and construction activities of other contractors and includes clean up of debris, erecting necessary warning and safety devices, and hook-up of temporary equipment if required to insure the safety of the public.

d) System Modifications
The work to be done consists of modifying the system to improve the operation or to conform to new operational requirements. The work shall be done as directed by the engineer.

e) Consultation
The contractor shall designate representatives in his organization whom shall be available to TED staff for consultation at no added expenses to TED/BMA. The scope of consultation shall include cost estimates and explanation of functional and operational characteristics of equipment.

f) Maintenance and Repair Records
The contractor shall maintain a comprehensive records of all maintenance and repair activities and spare parts consumptions. The records shall include, as a minimum, maintenance check lists, fault reports, spare parts receiving and consumption records, and work orders.

(3) Signal Turn-off and Signal on Flash

The contractor shall notify the TED office in advance of any signal turn-offs or signal on flash necessitated by his operation.

(4) Liquidated Damages

The contractor shall be assessed liquidated damages for failure to effect permanent repair within the specified time limit. Liquidated damages shall be deducted from payment due to the contractor.

2) Preventive Maintenance of Control Center Equipment

(1) Scope

Preventive maintenance of the Control Center shall cover all equipment necessary for the operation of the traffic signal and CCTV systems and shall include all associated power supply and air conditioning equipment.

(2) Monthly Inspection/Servicing

All Control Center equipment shall be inspected, cleaned, and adjusted as required, and checked for functional deficiencies either through test operation, use of test programs, inspection of indicator lamps, or other manufacturer recommended procedures.

(3) Quarterly and Bi-annual Inspection/Servicing

Various equipment and/or components and their operations shall be checked and serviced every three(3) or six(6) months. As a minimum, the items identified in the Preventive Maintenance Check Lists. Routine replacement or overhaul of equipment or equipment components as recommended by the manufacturer shall be done as part of the quarterly and bi-annual inspection/servicing work.

3) Preventive Maintenance of Field Equipment

(1) Monthly Inspection/Servicing of Signal

Each intersection and pedestrian signal shall be inspected monthly. As a minimum, the following shall be performed:

a) Walk the intersection or crosswalk and visually inspect all signal heads and pedestrian push buttons for proper operation, alignment, and damages.

b) Observe and check for proper operation of the signal.

c) Observe and check for proper operation of local detectors if any. For each loop coil, check for pavement or sealant failure. Any damage or pending failure shall be reported immediately to TED.

d) Check all handhole covers and poles for damages.

(2) Monthly Inspection of Vehicle Detectors

For the purpose of this maintenance contract, vehicle detectors shall include all loop-coil and ultrasonic vehicle detectors. Each loop-coil detector shall be inspected monthly for pavement or sealant failure. Any damage or pending failure shall be reported immediately to TED.

(3) Monthly Inspection of CCTV Cameras

Each CCTV camera shall be visually inspected and checked each month for proper operation and mounting. Any damage or pending failure shall be reported immediately to TED.

(4) Quarterly and Bi-annual Inspection/Servicing of Field Equipment

All cabinets, controllers, lanterns, poles, footings, handholes, detectors, CCTVs, and communication equipment shall be inspected every 3 or 6 months. As a minimum, the items identified in the Preventive Maintenance Check Lists. Routine replacement and overhaul of equipment or equipment components shall be done as part of the quarterly and bi-annual inspection/servicing work.

4) Schedule and Check Lists

(1) Schedule for Preventive Maintenance

The contractor is required to submit to the engineer a complete schedule for all preventive maintenance work two (2) weeks of receiving the Notice to Proceed. The schedule shall be in sufficient detail to indicate which part of the monthly inspections is to be performed in each week and which part of the quarterly and bi-annual inspections is to be performed in each month and the number of maintenance technicians and inspectors to be assigned.

The contractor will be required to revise the schedule if the work load and the man-power assignment are unbalanced or unrealistic. Failure to submit an acceptable schedule within six (6) weeks of receiving the Notice to Proceed shall be sufficient cause for suspension of the Contract and/or withholding of payments due to the contractor.

(2) Check Lists

The dates of inspection shall be recorded in the Preventive Maintenance Check Lists. The contractor is required to submit a copy of all check lists every three months and as requested by the engineer at any time. The contractor is also required to keep an up-to-date check list in each controller and detector cabinet, and in the control center.

Failure to maintain or submit the check lists shall be sufficient cause for suspension of the Contract and/or withholding of payments due to the contractor.

5) Corrective Maintenance and Accident Repair

(1) Response and Service Times

Corrective maintenance and accident repair shall be provided on a 24-hour a day, 7-day a week basis. Immediate action shall be taken to safeguard the public at any time a signal installation becomes partly or totally inoperative from any cause whatsoever.

The contractor shall provide TED a telephone number for receiving service calls. The telephone shall be manned 24 hours a day and 7 days a week. All fault reports must be recorded on the TED Fault Report Form immediately upon receiving the call.

The maximum response times, i.e. the elapsed time from receiving notification to arriving at the job site, shall be as follows:

a) Emergency Signal Repairs:
   - day (6:00 to 20:00) -- 2 hours
   - night (20:00 to 6:00) -- 4 hours

b) Other Repairs -- 24 hours
   Emergency Signal Repairs -- The following shall be classified as Emergency Signal Repairs:
   - Signal on flash
   - Signal blackout not caused by power outage
   - Any faults other than power outage which has or will cause two or more local controllers to be dropped off-line
   - Failure of the uninterrupted power supply system in the Control Center
   - Failure of any equipment which has or will cause the central traffic control system to shut down or rendered inoperative
   - Any failure which is determined by the engineer or the Police to pose immediate hazard to the public.

If the fault can not be permanently repaired immediately, a temporary repair or remedial measure sufficient to safeguard the safety of the public shall be effected by the contractor and the engineer shall be so notified. Permanent repairs shall be completed as soon as possible, and in all cases within 72 hours of notification unless extended in unusual circumstances, such as lack of a particular foreign spare part which the contractor is not required to keep inventory by the engineer.
Failure to meet the response time requirements by the contractor shall be sufficient cause for TED/BMA to authorize repairs to be completed by others and deduct the costs of such repair from payments due to the contractor. Repetitive failure shall be sufficient cause for TED/BMA to

cancel the Contract. Failure to effect permanent repairs within the specified time period by the contractor may also result in being assessed liquidated damages as described in Section 4.2,1),(4) "Liquidated Damages".

(2) Fault Report and Work Order

Each and every corrective maintenance and accident repair work must be documented on the TED Fault Report Form and TED Work Order Form by the contractor. A copy of completed work order forms must be submitted with the monthly invoice. No payment will be made without submitting the completed work order forms. The Fault Reports shall be kept in a log book and shall be made available to TED/BMA upon request at any time.

6) Training

As part of TED's continuous training program for its staff, The TED office intends to assign staff members to observe the contractor's operation from time to time. At no added cost to the TED/BMA, the contractor is required to:

a) Notify TED's maintenance section, at least 48 hours in advance, all preventive maintenance work to be carried out;

b) Notify TED's maintenance section just before a field crew is dispatched to perform corrective maintenance or accident repair work; and

c) Answer all technical questions from TED staff regarding maintenance and repair operations.

CHAPTER 5

FUTURE EXPANSION PLAN

CHAPTER 5 FUTURE EXPANSION PLAN

5.1 Introduction

The Stage I ATC system and its associated works are expected to enhance significantly traffic conditions within the project boundary of Bangkok. The Stage I project area, however, does not cover the entire Bangkok city, and even within the project boundary there will be still much room for improvements in traffic conditions after the completion of the Stage I project. Thus, the expansion of the traffic control system and its associated works both within and outside the stage I project area is deemed essential.

The basic approach to be taken in the future project will be on the concept of building on the Stage I system with additional equipment identical or similar to those installed in the Stage I project. The 1989 feasibility study has indicated the field and observed traffic conditions at those potentially problematic sites covered in the Stage I as well as future projects.

The main categories of works to be included in the immediate future project are:

(1) expansion of the traffic signal system
(2) improvement of traffic control devices for reversible lane control
(3) introduction of fire lane control function
(4) introduction of graphic CRT for TCC operators
(5) improvement of the BMA radio system
(6) traffic engineering improvements

For each category of work, a brief description of requirements is given below. Tentatively, the future expansion work is called Bangkok ATC System Project-Stage II for convenience.

5.2 Traffic Signals

The intersections which are warranted for signalization are shown in Figure 5.1.

A total of 92 intersections are to be signalized in Stage II, of which 7 are within the Stage I project boundary, and the rest are outside the Stage I project area. Among the latter, 20 are identified as key intersections. A total of 235 intersections will be centrally controlled after the completation of the Stage II.

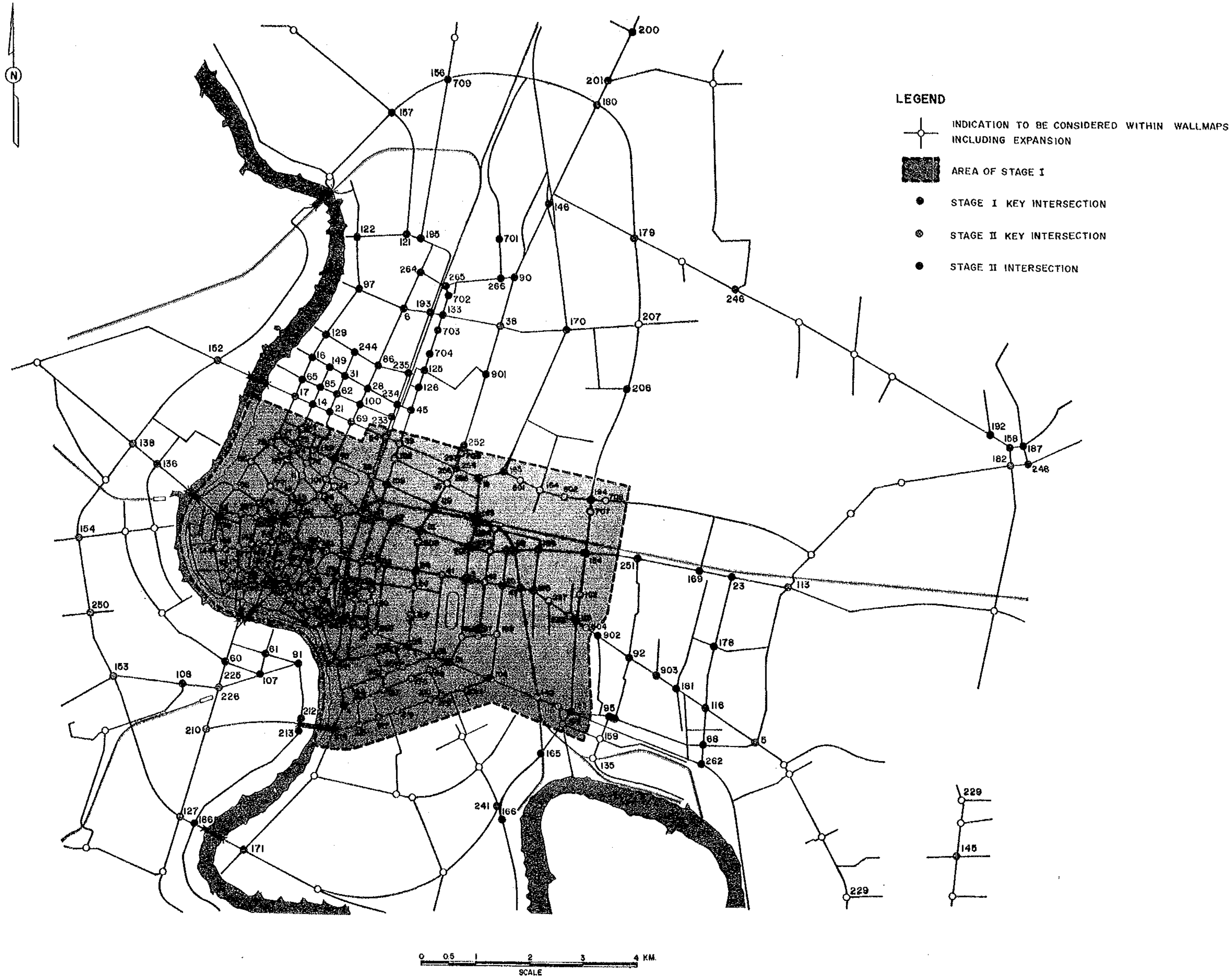


Figure 5.1 Intersection to be Signalized in Stage II

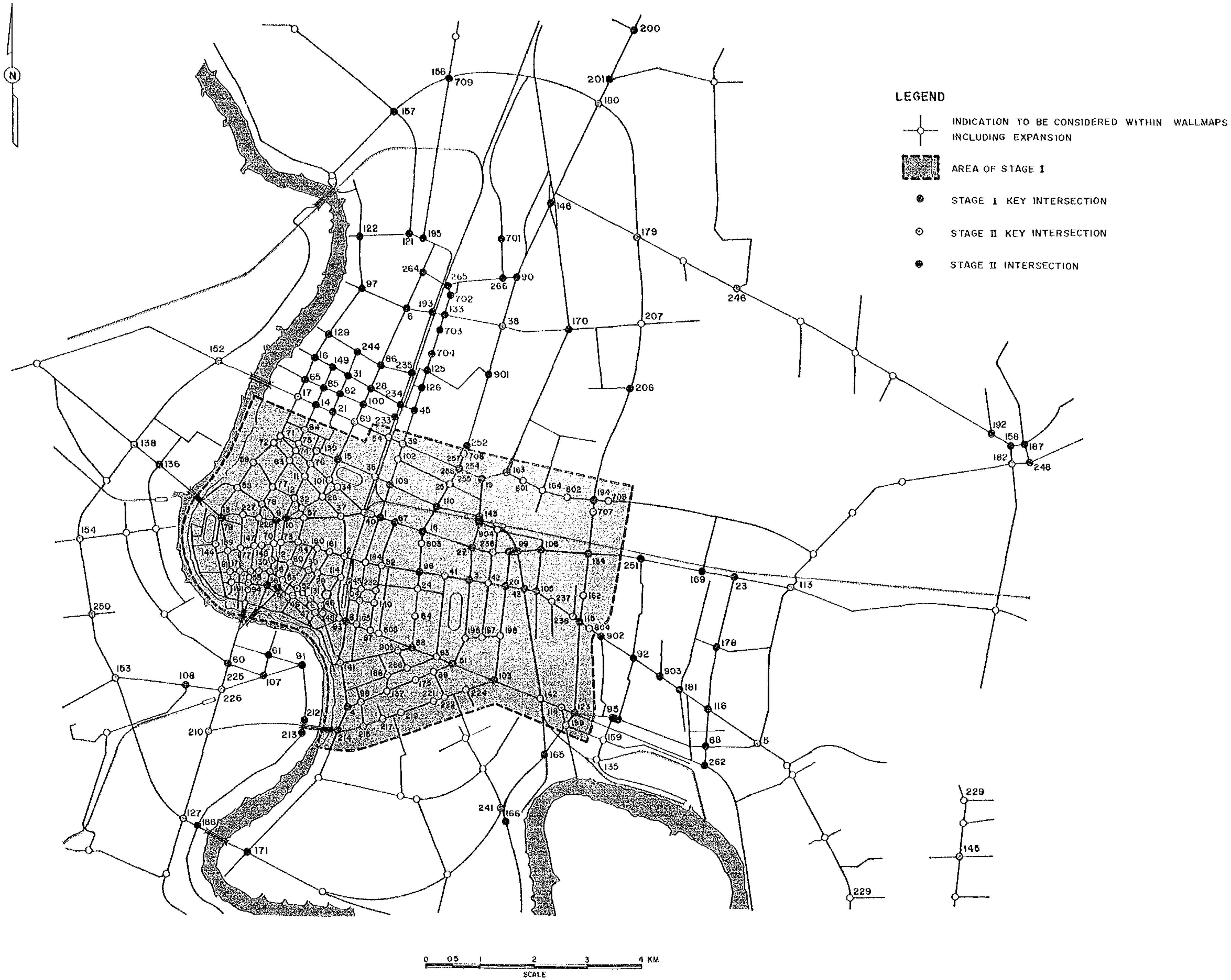


Figure 5.1 Intersection to be Signalized in Stage II

In Stage I of the ATC project, the central facility including the main computer, the front-end processors and signal system software can accommodate up to 400 signals without any subsequent modification. The Stage II expansion of the signal system will therefore bring the above proposed intersections under the control of the central computer system installed in the Stage I project through the TOT communication lines.

It is envisaged that the facility modifications in Stage II will be minimal except for furnishing additional FEP and communication equipment at the control center and additional local equipment identical or similar to those of the stage I signal system.

It is felt that additional mid-block pedestrian signals may have to be installed so that pedestrian can cross streets with less apprehension in doing so. Pedestrian signals will be installed at locations where large volume of pedestrians are expected such as in the vicinity of market places and schools.

5.3 Traffic Control Devices for Reversible Lane

The stage I project has included the installation of traffic control devices for reversible lane control, consisting of overhead flashing light indicators with a green arrow and red cross above each reversible lane. The locations of poles or gantries for overhead flashing light indicators is shown in Figure 2.14.

These signals are to indicate either allowable or prohibitive direction of traffic flow respectively. Markings for reversible lane control such as lane markings, arrow markings with designated time period are also included in the works to be carried out in Stage I.

In Stage I, the indicators will be locally and manually controlled. Each of these indications, however, may not be coordinated or synchronized along a route.

It is felt that this Stage I reversible lane control system should be modified and up-graded to allow central control of the flashing light indicators from the Traffic Control Center, thus coordinating them along each route. Simultaneous red cross flashing lights in both directions should also be incorporated to prohibit the usage of the reversible lane(s) for safety reason during the direction transition.

5.4 Fire-Lane Control

The future expansion project will introduce a fire-lane control function. The fire-lane control allows the quick passage of emergency vehicles and V.I.P cars by holding the green display for designated directions of signalized intersections along the route.

It is envisioned that the related software in the computer and the work station will be added or modified, and also a new work station with a graphic CRT display for input/output data will be introduced in the future project (see the next section of 5.5 " graphic CRT display").

The operational procedure is as follows:

a) The operator will input through the work station commands to activate fire-lane control corresponding to a group of signals,
b) The computer will then send the fire-lane control command to the front-end processor,
c) The front-end processor will finally issue the step-holding command signal to the local controller.

The command signal, after being received by the local controller would cause the controller to hold the green display of a designated phase when the display has advanced to that phase. To cancel the fire-lane control after the passage of the emergency vehicles or V.I.P cars, the operator is required to turn off on the keyboard of the work station to deactivate the fire-lane control.

Grouping of the intersections, the green holding phases and also scheduled time are pre-defined in the system via work-station input.

During the execution of the fire-lane control, the computer monitors the signal operation and the graphics CRT displays confirmation status. The operator can monitor the green holding situation of each intersection from the display. The work-station printer will also print out messages consisting of start time and end time of control and intersection group number for record keeping purposes.

The computer will also have a function of canceling the fire-lane control operation automatically after the lapse of a set time period to avoid holding the green display for an unacceptable length of time.

5.5 Graphic CRT Display

It is envisaged that a graphic CRT display showing all traffic and control conditions related to a selected signal intersection or a group of signalized intersections would be useful and efficient for operator and/or traffic engineers in evaluating the traffic control operation.

The system needs to provide a new work station capable of operating a graphic CRT display, in addition to the work stations installed in Stage I.

The system may have the following graphic pictures for man-machine communication:

a) Illustrating graphically the current traffic conditions in the entire controlled area, in a selected group of signalized intersections or at a single selected signal intersection,
b) Illustrating and showing the operating status including signal aspects on-off, and preset parameters,
c) Altering the resettable control parameters while watching the current traffic and operating status,
d) Simulating and illustrating traffic conditions under the various possible traffic control parameters,
e) Showing the failure information,
f) Interventing signal control.

5.6 Improvement of The BMA Radio System

The existing BMA radio system is a small-scale system with only 18 number of independent handy-transceivers in use by the TED. The Central Police Department was provided with approximately 2000 number of independent handy-transceiver units using two transmission channels both for crime and traffic control. In stage I, two small base stations will be installed on the control disk of the Traffic Control Center to transmit traffic conditions information and control to/from the fields. However, each base station will cover only a part of Metro Bangkok and furthermore, these systems may be operated independently by each authority.

These systems will eventually be inadequate for the exchange of sufficient information for Traffic surveillance and control in the near future as the ATC System area coverage is expanded.

In Stage II, it is essential and important to introduce a new radio system to enable the frequent communications of traffic conditions and control related information between the Traffic Control Center and fields, between the BMA and the Central Police Department. These useful information may be then given as traffic information to drivers through commercial radio broadcasting from the Traffic Control Center.

The following describes a rough idea of the new radio system for ATC system Stage II:

a) The new radio system is to be provided as one system for the BMA and Police Department,
b) The covered area of the system is Metro Bangkok,
c) The base station will be established at the Traffic Control Center,
d) Sub-base stations will be established at district police departments,
e) Terminal devices will be provided in police boxes, patrol cars, and for policemen, maintenance men etc,
f) The information to be sent through the system should be restricted to only traffic related information and emergency information,
g) All the massages of communication will be recorded and kept in computer disk or magnetic tape at the Traffic Control Center.

5.7 Traffic Engineering Improvements

a) Geometric improvements
Geometric improvements of major intersections will be further required in Stage II in order to maximize the efficiency of signals and to improve the safety of road users. Channelization of intersections, median shifting, pavement improvements and minor widening of roadways will be included in this work category.

b) Pavement markings
Markings including center lines, lane markings, pedestrian crossings etc. are needed at the intersections and road sections. In relation to signalization, the material to be used for the markings will preferably be thermoplastic type paint instead of conventional paint. The thermoplastic type paint will last for 2-3 years, whereas the conventional point may fade away in a couple of months.

c) Traffic signs
Regulatory signs such as STOP signs, NO TURN signs and Bus Lane signs are essential for operation of traffic circulation system. Other types of signs such as warning signs and guide signs are also desirable. Works for installing adequate signing will also be included in Stage II.

CHAPTER 6

IMPLEMENTATION PLAN

CHAPTER 6 IMPLEMENTATION PLAN

6.1 General

The implementation of the Bangkok ATC Project - Stage I as described below is taken to start from the issuance of the "Letter of Invitation To Tender" (tender call) to the pre-qualified tenderers up to the completion of the project marked by the issuance of the Certificate of Final Acceptance. The whole implementation would likely to take 42 to 46 calendar months.

This whole implementation period, however can be sub-divided into three sub-periods by the nature of activities involved:

(1) The first sub-period begins from tender call to the signing of contract with the selected contractor. This period will probably takes about 8-10 months depending on the time taken to appraise the tender proposals from perspective tenderers and the speed the final decision is made.

(2) The second sub-period starts from the issuance of Notice To Proceed to System Design Approval. This period involves the issuance of Notice to Proceed to the contractor and such activities as system briefing and finally the approval of the system proposed. It will probably takes about 4-6 months depending on how fast the proposed system can be approved.

(3) The third sub-period covers the 18 month installation period of the proposed system and the 12 month guarantee maintenance period.

Table 6.1 Implementation Plan

Sub-period 1			Sub-period 2			Sub-period 3		
Tender Call	to	Contract Signing	Notice to Proceed	to	System Design Approval	Installation	to	End of Guarantee Maintenance
8 to 10 months			4 to 6 months			30 months		
			42 to 46 months					

6.2 Sub-Period 1: From Tender Call to Signing of Contract

The first sub-period from tender call to the signing of contract involves the following steps or activities:

(1) Issuance of "Letter of Invitation To Tender" to Pre-qualified Tenderers.

The BMA is to issue an official "Invitation to Tender" letter to the shortlisted pre-qualified prospective tenderers, inviting them to tender for the project. The letter shall have to state the dead line and venue for submitting the tender proposals, the date, time and venue for a pre-tender conference and the date the tender documents are available for purchase.

(2) Preparation of Tender Proposals

Upon purchase of the tender documents, the prospective tenderers are given a reasonable time period to prepare their respective tender proposals in accordance to the various requirements as stipulated in the tender documents. A minimum of 75 days should be set aside for this task. Within this period, the beginning 30 days are set aside for enquiries. Prospective tenderers may enquire about any provisions or requirements in the tender documents which they are in doubt in writing to the BMA. During this period, the BMA has the rights to issue any changes, additions or deletion to the tender documents as addendum to the prospective tenderers.

(3) Opening of Tenders

The submitted tenders are opened immediately upon the lapse of deadline. The first task is to check whether each tender contains a technical proposal, a financial proposal and a tender deposit, all of which are contained and sealed in separate envelopes.

(4) Tender Evaluation

For the Bangkok ATC Project-Stage I, the tender evaluation is to be carried out in two steps.

The technical proposals will be opened first for an evaluation of the technical aspects of the proposals. The evaluation process involves the scrutiny on the compliance of tenderers' proposals to the technical specifications and the comparability of any alternative systems proposed by the tenderers. Depending on the variation of systems proposed by prospective tenderers, the evaluation process may take 2-4 months. During this period, clarifications and supplementary information from tenderers proposing alternative systems may be required.

Table 6.2 Sub-period 1 - Tender Call to Contract Signing

A Total of 8 - 10 months							
	3.0 - 3.5 months	2.5 - 3 months		2.5 - 3.5 months			
Tender Call	Tender Proposals	Evaluation of Tenders		Decision	Tender Negotiation	Contract Signing
	30 days for enquiries	Technical Evaluation	Cost Evaluation			

All tender proposals whose technical proposals have met the requirements of the technical specifications shall be subjected to the second round of evaluation, ie. financial evaluation. Those technical proposals which do not meet the basic requirements of the technical specifications shall be rejected and returned together with the unopened financial proposals to their tenderers. A cost evaluation is be carried out by appraising the Contract Price tendered against the quality of the system proposed.

(5) Decision

A summary table of the evaluation results shall be prepared and the final selection made by the decision maker, ranking at least the three best tenders.

(6) Notice of Award

A notice of award shall be issued to the successful tenderer. The successful tenderer shall be given a specific time to accept the award, failing which shall mean his rejection. In case the successful tenderer rejects the offer, the BMA shall have to offer the project to the next best tenderer.

(7) Tender Negotiation

Depending on the contents of the system proposed by the selected contractor and BMA's requirements, a tender negotiation may become necessary and carried out at this stage whereby amendments to the tender documents can be made to the mutual agreement of both parties before a contract is signed.

(8) Contract Signing

Both parties shall be readied to enter into a legal contract. But before doing so, the contractor shall have to produce a performance bond to the satisfaction of the BMA.

6.3 Sub-Period 2: From Notice to Proceed to System Design Approval

(1) Notice to Proceed

After the signing of the Contract, the BMA shall dispatch a "Notice to Proceed" to the contractor. This date marks the beginning where the contractor may take steps to prepare for work in connection with the Project.

(2) System Briefing

The contractor is required to give a system briefing to BMA within 30 days from the date of Notice to Proceed.

(3) Program of Work and CPM

The contractor has to submit to BMA for approval his proposed programming of work using a CPM within 45 days from the date of Notice to Proceed.

Table 6.3 Sub-period 2-Notice To Proceed to System Design Approval

4 to 6 months			
3 months			1 to 3 months
Notice to Proceed	System Briefing	Approval of Work Program	System Design Approval

(4) Submit Proposed System Design for Approval

The contractor has to submit to the BMA in detail the proposed system design for approval.

(5) System Design Approval

The BMA shall review the system design submitted by the contractor and seek clarifications or further information if necessary. A final approval shall have to be given before any actual manufacturing of equipment, software can start.

6.4 Sub-Period 3: From Installation to end of Guarantee Maintenance

(1) Installation Period

Once the system design has been approved by the BMA, the contractor shall proceed to manufacture all central and terminal equipment, software and all other equipment required under the Contract.

a) Factory Tests
When the equipment are ready, factory tests shall be carried out at the place of manufacture. The designated Engineer shall attend these tests and give approval for the test results.

While these are on-going, the contractor may proceed with the necessary background work such as civil work on site, installation of poles and other work with locally supplied parts. When the foreign manufactured parts have been shipped and arrived on site, their installation shall begin.

b) Issue the Certificate of Completion of Portion of Work
As the installation work progresses, various portions of the work completed shall undergo testing and trial operation for a period of 30 days. Certificates of Completion of Portion of Work shall be issued for portion of the works that have undergone successful trial operations. This allows the BMA to Take Over and operate those portion of the works.

Table 6.4 Sub-period 3-Installation to Guarantee Period Maintenance

30 months			
	18 months Installation Period		12 months Guarantee Maintenance Period
Factory Test	Test and Trial Operation of Portion of Work	Test and Trial Operation of Whole Work	Preventive and Corrective Maintenance
	Classroom Training		On-the-job Training

c) Training
As the installation work is on-going, the contractor is required to carry out training of BMA staff as required under the Contract. Training materials shall be first submitted for approval and two classroom training sessions shall be conducted.

d) Issue the Certificate of Completion of Whole Work
When all installation work are completed, the whole system shall undergo testing and a trial operation period of 60 days. The Certificate of Completion of Whole Work shall be issued upon the successful trial operation of the whole system.

(2) Guarantee Period Maintenance

The issue of the Certificate of Completion of the Whole Work marks the beginning of the 12 month Guarantee Period Maintenance. The contractor shall carry out all necessary corrective and preventive maintenance of the system and conduct on-the-job training for BMA staff.

At the end of this guarantee maintenance period, a Final Acceptance Certificate shall be issued upon the satisfactory acceptance by BMA of all works under this Contract.

6.5 Extended Maintenance

Before the end of the Guarantee Maintenance Period, the BMA has the option to sign a separate Annual Contract with the contractor for maintaining the system based on the proposal submitted by the contractor on "Extended Maintenance". This extended maintenance shall be subjected to annual renewal between BMA and the contractor.

Table 6.5 The Extended Maintenance Contract

This Contract	New Contract	Future Expansion Plan
Bangkok ATC Project Stage I	Annual Renewable Extended Maintenance Contract	Bangkok ATC Project Stage II
42 to 46 months	Every 12 months	

6.6 Future Expansion

The System shall be expanded in future when the need arises to widen the coverage of the ATC System or up-grade the existing system functions.

6.7 Project Monitoring Team to the BMA

Throughout the Implementation Period, the BMA shall have to engage a project monitoring team to provide advice and assist the BMA, particularly on technical matters and in monitoring the implementation of the entire project.

During the first sub-period, the project monitoring team shall assist the BMA in answering enquiries on technical matters from the tenderers, appraising the tender proposals on their compliance to the technical specifications or alternative systems which the tenderers may have proposed and finally tender negotiation with the contractor.

In the second sub-period, the project monitoring team shall assist the BMA in appraising the work program and examining/approving the detail system design submitted by the contractor.

For the final sub-period, the project monitoring team shall monitor the installation and maintenance work throughout the entire 30 months. These would include assisting the BMA in verification of actual work done on site for progress payment, trouble shooting, among other things.

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