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THE KINGDOM OF THAILAND

BANGKOK METROPOLITAN ADMINISTRATION

STUDY ON ROAD IMPROVEMENT, REHABILITATION AND TRAFFIC SAFETY IN BANGKOK

FINAL REPORT

VOLUME II ROAD IMPROVEMENT

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF ABBREVIATIONS

BMA	Bangkok Metropolitan Administration
CPD	City Planning Division, BMA
CMD	Construction and Maintenance Division, BMA
DD	Design Division, BMA
PPD	Policy and Planning Division, BMA
PPSd	Public Works Planning Sub-division, BMA
DPW	Department of Public Works, BMA
DDS	Department of Drainage and Sewerage, BMA
TED	Traffic Engineering Division, BMA
MOI	Ministry of Interior
OARD	Office of Accelerated Rural Development, MOI
OCMRT	Office of the Committee for the Management Road Traffic, MOI
OPP	Office of Policy and Planning, MOI
PWD	Public Works Department, MOI
TCPD	Town and Country Planning Department, MOI
TPD	Traffic Police Division, MOI
LDPD	License Division of Police Department, MOI
MOC	Ministry of Communications
DOH	Department of Highways, MOC
DLT	Department of Land Transport, MOC
ETA	Expressway and Rapid Transit Authority of Thailand
NESDB	National Economic and Social Development Board
SRT	State Railway of Thailand
MEA	Metropolitan Electricity Authority
AIT	Asia Institute of Technology
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
BS	British Standards
CAB	Cable Box
CBD	Central Business District
HCM	Highway Capacity Manual
MCI	Maintenance Control Index
MSL	Mean Sea Level
MTS	Mass Transit System
NECO	National Executive Council Order
PCU	Passenger Car Unit
PSI	Present Serviceablility Index
RAL	Richtlinien für die Anlage von Landstraßen
SSES	Second Stage Expressway System
STTR	Short Term Urban Transport Review

ROAD IMPROVEMENT

1. INTRODUCTION

While various proposal have been made to solve the traffic problem in Bangkok from viewpoint of long-term and regional traffic strategy, it is in urgent need to fully utilize the existing road network and reduce the traffic congestion on it. As stated in the first volume this report, the function of the existing road network can be expected to be strengthened to certain extent by implementing relatively small scale improvements.

From this standpoint, it is of substantial significance to find out default of the network, or traffic bottleneck to be more concrete.

This volume deals with the road improvement plan to the existing roads in Bangkok, comprising 1) development and application of a traffic rating method to identify traffic bottlenecks and 2) preparation of improvement plans for eleven (11) locations selected for demonstration purpose. The schematic study flow of road improvement plan is shown in Fig. 1.1.1, and the detailed study process is presented in each section.

Traffic rating method using the difference of speed before and after passing an intersection or suspected bottleneck was developed in this study, as illustrated in the later sections. Since there is no similar studies published in the past, the development of the method had to start from null, with limit of time and data. The developed method may have many rooms yet to be improved.

Identified bottlenecks were then examined and eleven (11) locations were selected for preparation of road improvement plans. The improvement plans were aimed at the optimum effect in terms of elimination of traffic bottlenecks or congestions fully utilizing the existing road facilities and of economic return on investment.

Formulation of the improvement plans was closely coordinated with the current policies and strategies of BMA together with the basic theories of road improvement which would be applied to the similar planning at other road locations in the future.

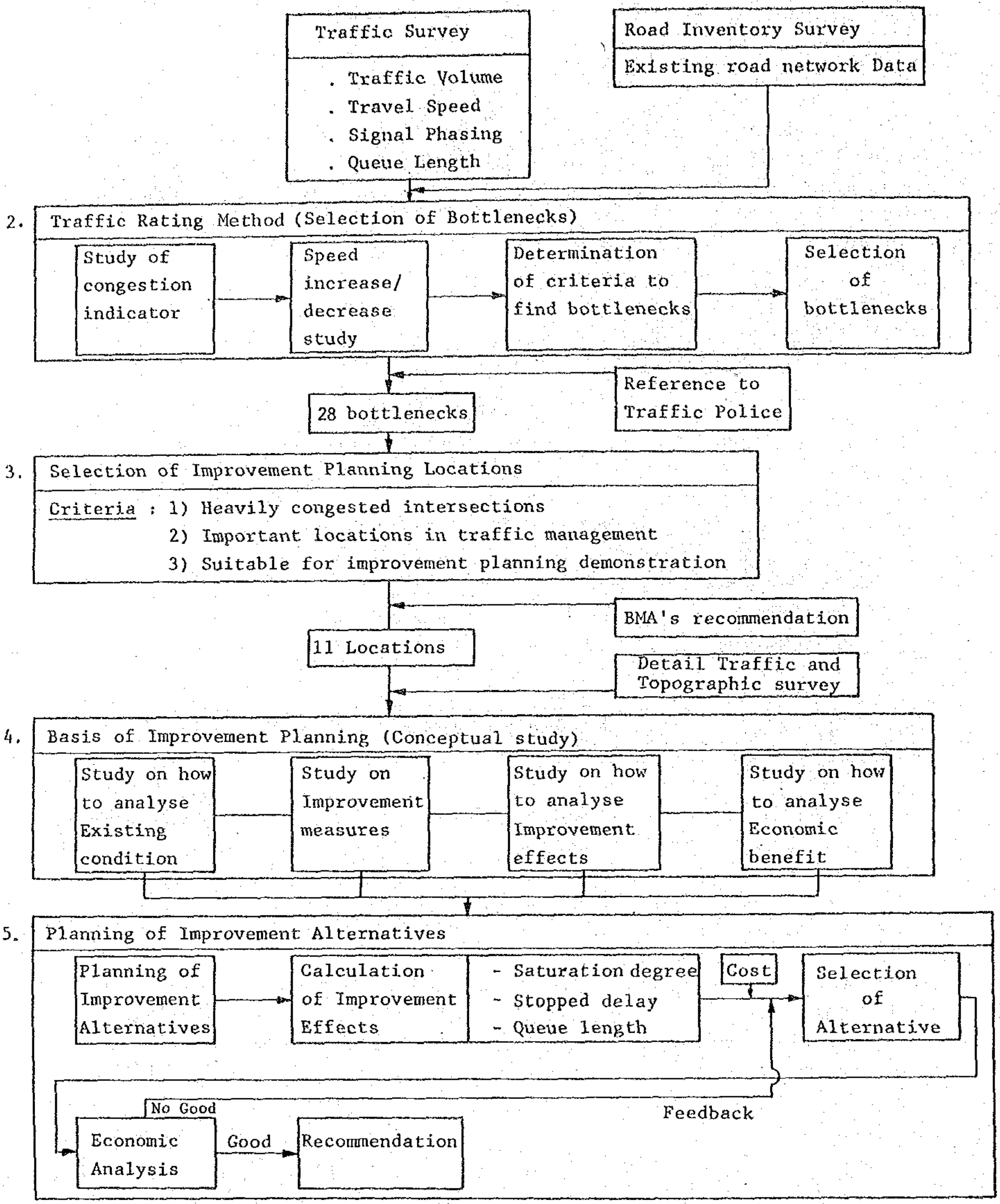


Figure 1.1.1 Flow Chart of Improvement Planning

2. TRAFFIC RATING METHOD

2.1 Objective of Traffic Rating Method

As stated in the previous section, it is essential for the efficient improvement of the road network to find out critical traffic bottleneck.

Since traffic congestions are visible and prima facie perceptible to road users, there are sometimes arguments to the effect that no rating methods are required for identifying bottlenecks of roadways, but only observation or judgment by traffic engineers. This may be true to some extent, particularly when number of bottlenecks are few and/or a road network is relatively small in size.

However, when it is necessary to identify a number of priority bottlenecks of roadways from a large road network, a proper traffic rating method based on analyses of valuable data related to roads and traffic , as well as judgments by experienced engineers could be useful for road administrators. Nevertheless, there is no established nor widely-used method available for this purpose.

Thus, development of appropriate traffic rating method for identifying traffic bottlenecks is desired. The method should be designed to identify traffic bottlenecks, or the critical locations which cause traffic congestion, in an objective manner or quantitatively.

It is also desired that the method should be done based on the data which can be obtained by simple and economical measurement.

2.2 Concept and Definition of Bottleneck

When there is some deficiency on a road and traffic flow is hindered, traffic congestion occurs and a section where vehicles are forced to slow down or even to stop is created. This deficiency can be such as insufficient width of road, saturation of intersection, inadequate geometry etc. The location of deficiency on road, or the cause of traffic jams is called "traffic bottleneck".

The word "traffic bottleneck" is sometimes used to refer the entire section of road where traffic jam exists. There seems to be no widely used definition of "traffic bottleneck". In this study, however, "traffic bottleneck" is defined as "location on road where some deficiency which causes traffic congestion exists". This definition is used because the purpose of this study is to identify bottlenecks in order to solve traffic congestions.

2.3 Concept and Applicability of Criteria

In general, any criteria to be applied in the traffic rating method for identifying bottlenecks shall not be of absolute nature, but can be variable or relative according to the function of roads and the road administration policy.

It can also be said that even with the objective aiming at improvement of efficiency on the existing road network in urban area where so much diversified zones and activities exist, the criteria can be variable depending on the road improvement policy as to what zone or activity shall be placed priority.

Therefore, it is to be mentioned that the criteria and the rating method developed and proposed in this study are similarly not of absolute nature applicable to any situations and conditions, but of the nature which is generally applicable to urban roads accommodating normal traffic.

2.4 Indicators of Traffic Conditions

The first step in developing rating method is to determine an indicator(s) by which traffic conditions can numerically and objectively evaluated. Traffic congestion problems can be measured and indicated in various forms of traffic features like travel speed (or travel time), congestion degree, queue length of waiting vehicles, number (or frequency) of forced stops due to traffic jam.

(1) Travel speed

An average travel speed over a given road stretch is calculated by "travel distance/travel time" where the travel time includes both running time and waiting time due to traffic congestion and/or traffic signals.

A rating method employing travel speed is simple and agreeable to road users' perceptive assessments on traffic conditions. However, since a travel speed in urban areas is largely governed by traffic signal operations at intersections, due attentions should be paid to collection and analysis of data regarding travel speed.

(2) Congestion degree/saturation degree

A congestion degree is defined by quotient of traffic volume over traffic capacity on a given road section. The traffic capacity can be generally determined by a highway design standard in a country where there are provisions with regard to traffic capacity by type of roads. Meanwhile the traffic volume can be obtained through traffic countings at roadsides. Same concept and procedure (traffic volume/capacity) is applied to measure a degree of congestion in an intersection. In this case, traffic volume/capacity ratio is usually called "saturation degree".

When a congestion degree is 1.0 or less, the road section could be assumed to meet traffic needs satisfactorily in terms of traffic engineering. On the other hand, a signalized intersection is considered to be "saturated" when saturation degree is around 0.9, due to the loss time involved in changing of signal phase.

The method adopting "congestion degree" in road traffic evaluation is a widely accepted approach to highway planning practices. Traffic capacity estimations for uninterrupted roadway (generally a road section between two adjacent major intersections) is relatively easily worked out, thanks to finding past experiences and researches in traffic and highway engineering, while saturation degree for intersections are difficult tasks due to the fact that traffic movements in intersections are complicated. In addition, traffic capacities at intersections are largely dominated by traffic management such as signal operation rather than road's structural functions. Thus, it seems that road traffic rating method by congestion degree/saturation degree is more practically applicable to uninterrupted roadways than intersections.

(3) Queue length & forced stop

A queue length of waiting vehicles on a road is to measure distance between the frontmost vehicle and the rearmost on in a platoon of packedup vehicles stemmed from such obstacles existing on a road as traffic signals or structural deficiencies. Most traffic queues start at intersections and extend backward on their approaches.

When this queue on an approach to an intersection is extraordinarily long, provided that an adequate traffic signal operation is maintained, the intersection is assumed to be potentially a bottleneck of traffic flow.

The number of forced stops of vehicles on a road indicates also traffic flow conditions. This leads to a general evaluation that the more the number of stops are, the more congested the road is.

Queue Length of vehicles and number of forced stops on roads are simple indicators of traffic conditions, and data of them are easily obtained. As the occurrence of vehicles queues and forced stops, however, are incidental phenomena which are less reliable to assess traffic conditions conclusively, they could be used as an auxiliary means to identify bottlenecks of road traffic.

2.5 Traffic Rating Method for Identifying Bottleneck

In this section, traffic rating method to identify traffic bottlenecks is discussed.

(1) Increase of speed as identifier of bottleneck

It would be reasonable to assume that vehicles increase their speed when they pass a bottleneck, unless there is another bottleneck ahead and hinders the traffic. (Figure 2.5.1)

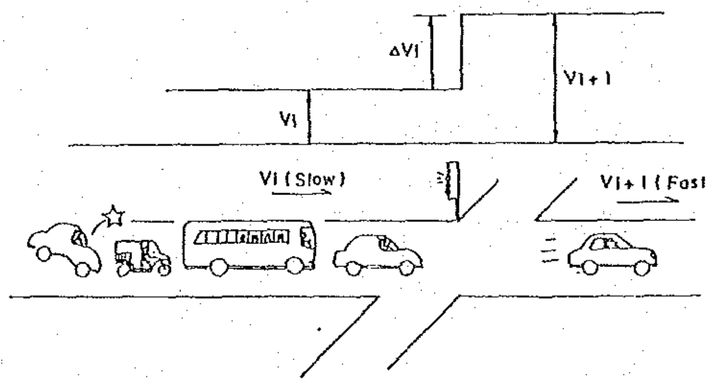


Figure 2.5.1 Schematic Illustration of Increase of Travel Speed after Bottleneck

Sometimes, bottleneck can be a section of road with certain length, such as a road section with insufficient width. Also in this case, speed of vehicles increases when vehicles get out of this section.

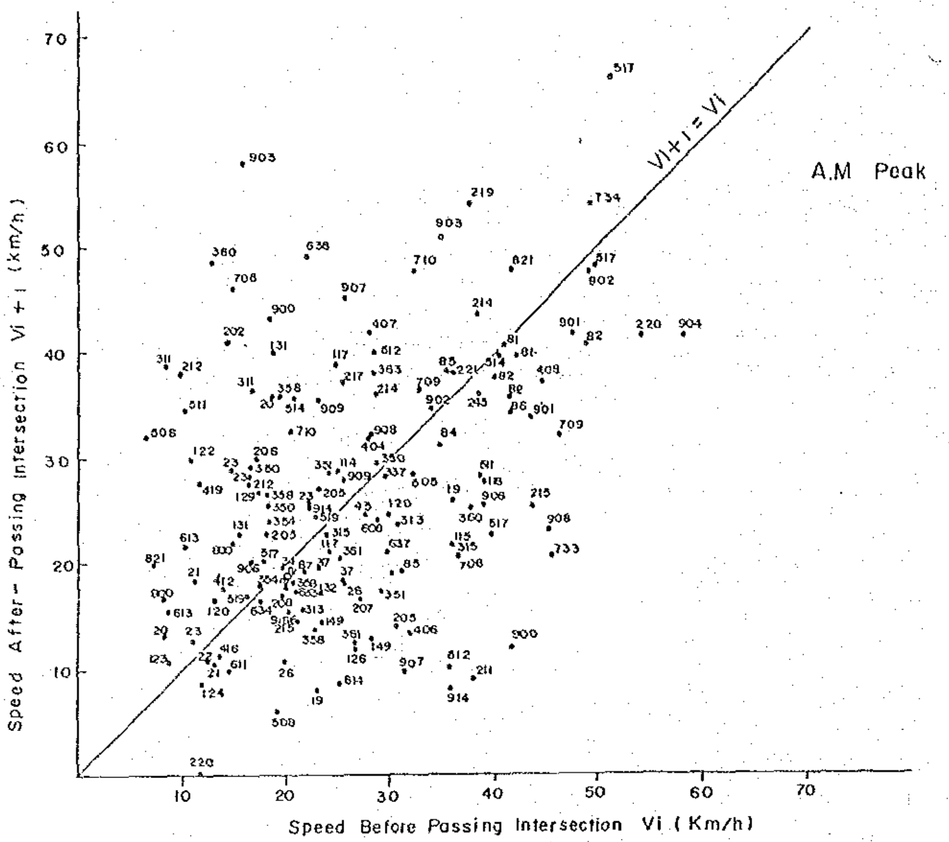
It also would be reasonable to assume that the more severe the traffic congestion is, the slower the travel speed of vehicles before passing the bottleneck becomes and, as a result, the larger the increment of speed at the bottleneck becomes. Hence, this increment of speed of vehicles that occurs when vehicles pass a certain location on a road can be an identifier of bottlenecks.

As described in the section of Traffic Survey, traffic congestion in Bangkok seems to be caused by crowded intersections, rather than by mid-block sections between them. For this reason, travel speed before and after passing intersections were compared (Figure 2.5.2). In the figure, speeds after passing intersection, V_{i+1} were plotted against speeds before passing intersections, Vi. Straight lines drawn in the figure indicate V_{i+1} = Vi. As can be seen in the figure, at roughly half of the intersections where travel speeds were measured, speed increased when vehicle passes them, while at another half of intersections, they decreased. The numbers beside each plotted point in the figure denote the Node Numbers assigned in the Inventory System. Routes of travel speed survey are shown in Appendix 2.5.1.

Travel speed of vehicles before and after passing the suspected traffic bottleneck is measured. The procedure for measuring travel speed used in this study is described in Appendix 2.5.2. Measurement of travel speed should be done as many times as possible to obtain reliable avarage data. From practical viewpoint, however, reasonable number of measurement seems to be five (5) to ten (10). In this study measurement was done for six times (six days) for each measurement section, and the result seems to be practically acceptable. The fluctuation of travel speed is shown in Appendix 2.5.3.

Furthermore only the positive increments of speed ($\Delta Vi = V_{i+1} - Vi$) at intersections were plotted against the speed before passing the intersection in Figure 2.5.3. Implication of Figure 2.5.3. is schematically illustrated in Figure 2.5.4.

Those intersections with large speed increment, ΔVi are prominent bottlenecks because speed of vehicles increases drastically when vehicles pass them. If these intersections are improved, travel speed will greatly increase.



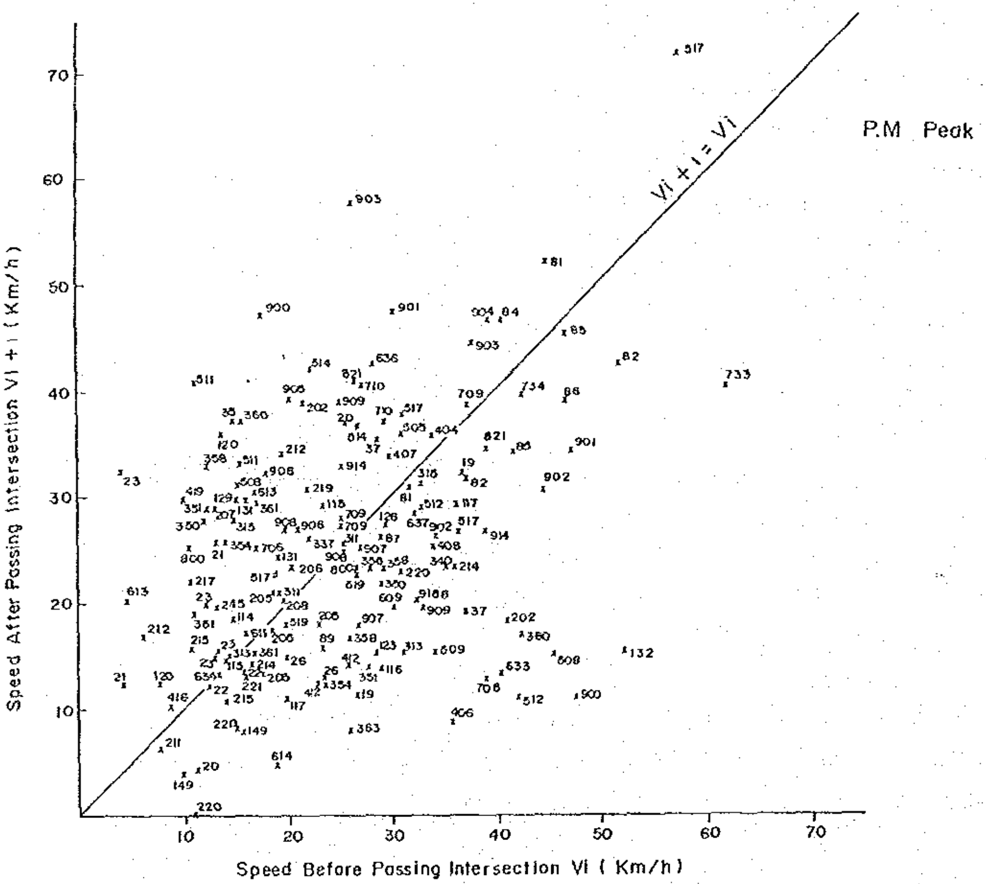


Figure 2.5.2 Comparison of Speeds Before and After Passing Intersections
(Number beside each plotted points denote Node Numbers)

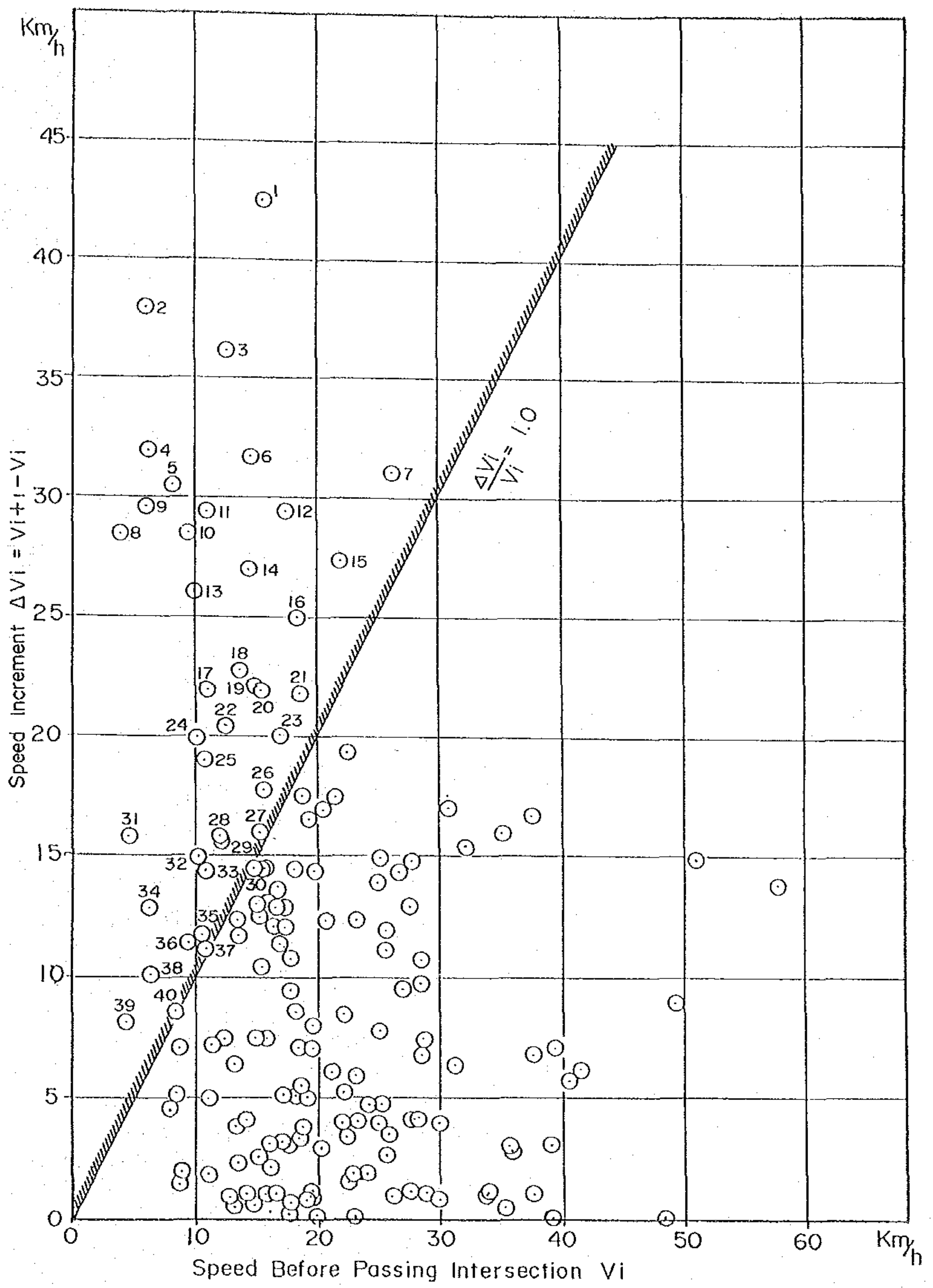


Figure 2.5.3 Speed Increment and Speed Before Passing Intersection

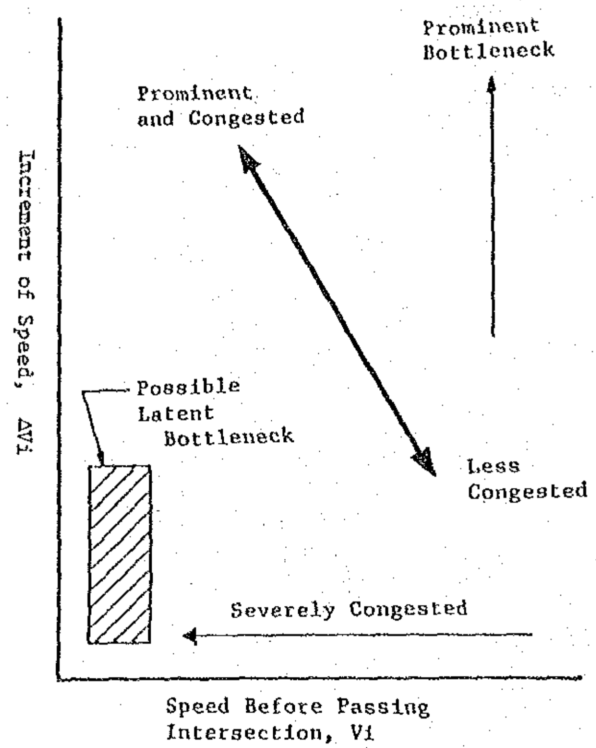


Figure 2.5.4 Schematic Illustration of Implication of Figure 2.5.3

Those intersections plotted in the lower left-hand corner are severely congested intersections because travel speed is low. Little increase of speed is considered to indicate the existence of bottleneck in the down-stream. These intersections have possibility of being "latent" bottlenecks. Once the bottleneck which is located in the down-stream is eliminated by improvement, these intersections may become a new bottleneck depending on the capacity and traffic volume.

Thus, intersections plotted in the upper, left-hand corner are prominent bottlenecks with severe congestion because travel speed is low before passing the intersections and increase drastically after passing them, and vice versa for the intersections plotted in judging from above findings, the study decided to adopt the travel speed before passing intersection (Vi) and its speed increment after passing intersection ($\Delta V = V_{i+1} - Vi$) as the indicators to identify the traffic bottleneck among intersections in Bangkok, because these two (2) indicators can express fairly well the nature of bottlenecks.

Here, the travel speeds Vi and Vi+1 stand for the ratios of measured distances to travel times which included running and waiting times on road sections.

When the travel distance on the surveyed road section varies to be relatively long or short, determination of the travel times, Vi and Vi+1 requires some adjustment . However, the main stream of this study proceeds on further without taking into account this adjustment, and as a supplemental study the method of such adjustment is discussed and related case study were conducted, which are described in Appendix 2.5.4.

(2) Process for determination of criteria

As discussed on in the previous chapter dealing with traffic survey application of a standard to determine the level of service of road that every road in the study area was assumed to have nearly same speed function, it was assumed that same sort of standard or criteria could be applied for identification of the bottleneck by these two (2) indicators represented by travel speed and its increment. In this context, the following concepts were induced;

a. The smaller the travel speed (Vi) on a road section i is, the greater the degrees of congestion and deterioration in level of service are.
b. The greater the speed increment (ΔVi) between the road section i and section $_{i+1}$ is, the greater speed recovery on section i can be expected by greater improvement effect.

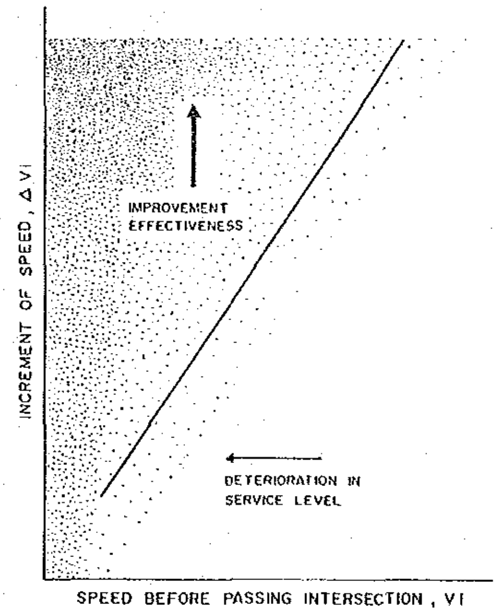


Figure 2.5.5 Concept of Improvement Identification

With these two (2) concepts as the basis of traffic rating method, the criteria which can contribute to the utmost utilization of the existing roads should be sougth for. This idea is conceptually shown in Fig. 2.5.4, which is indicating the strategy for seeking the criteria to identify bottlenecks where the intersections specified in "Prominent and Congested" area can be better improved to "Less Congested" area shown in Fig. 2.5.3.

Based on above idea or strategy, the zone to be identified as the bottleneck could basically be regarded as the area indicated by dot shade in Fig. 2.5.5.

This is further extended to be considered as the zone represented by the following equation.

$k = \Delta Vi / Vi$ .....equation (1)

where; k = a certain value by which the bottlenecks having great needs and large improvement effect can be screened to be on the candidate list of improvement plan.

It can be said that in above equation (1) Vi stands for the degree of traffic deterioration in terms of level of service at the bottleneck located on section i, and ΔVi stands for the degree of improvement effect after improvement of bottleneck. Therefore, this equation can be considered to incorporate these two factors, and can put the bottlenecks on the long list as the candidates of improvement plan.

Based on this equation (1), all the data at the surveyed spots or intersections were plotted on the rectanguler coordinates with Vi as X axis and ΔVi and Y axis. At the same time, a liner line was drawn on this coordinates assuming "k" = 1.

For cross-examination of applicability of this equation, two parameters were provisionally applied on the coordinates, the one as Vi = 10 Km/h, representing severe degress of deterioration in level of service and the other as ΔVi = 20 Km/h representing great improvement effect expected. With these two parameters, reviews and analysis were attempted, which revealed the following identifications.

1) Those spots (No.2, 4, 9, and 13 - Petburi/Phatthanakan, No.5 - Ratchavithi/Samsen intersection, No.8 - Witthayu/Rama IV intersection and No.10 - Petburi/Rama VI intersection) where the value of "k" is equal or greater than 1, and Vi = 10 Km/h as well as Vi = 20 Km/h simultaneously meet, will yield greater improvement effects.

2) On the other hand, those surveyed spots on some approaches to intersections on either of the peak hours where the value of "k" is smaller than 1 and Vi = 10 Km/h, seem to suggest the existence of possible bottlenecks spreading over considerable distance of sections including several adjacent intersections. These spots are showing great degree of deterioration in the level of service but can not be expected great effect of improvement by elimination of a single bottleneck. Therefore, it might require comprehensive measures along the sections by large scale improvement with substantial amount of investment for these spots including new route, etc.

3) At the same time, those spots situated in the zone where "k" < 1 as well as $\Delta Vi = 20$ Km/h, if such spots exist, can be said that the degree of deterioration is not severe.

Based on above concepts, review and analyses, the basic criteria of identification of traffic bottleneck was adopted as equation (1) in this study.

(3) Determination of criteria

As discussed above, "k" is a policy parameter for bottleneck identification, and therefore, determination of the value of "k" shall be based on the requirements to fully utilize the existing road network which is the main objective of this study. The rating of bottleneck by application of this "k" or equation (1) is the first step selection of the road sections or intersections where necessity and urgency of road improvement are to be recognized. Then, the second step is the comparison and determination of priorities of these bottlenecks taking other factors into consideration to be that final selection of the bottleneck for which the implementation plans are to be prepared and programmed. In order to comply with these general administrative procedures, and for the final selection of 10 improvement locations, the study adopted the first step criteria for rating the traffic bottleneck to be the value of "k" as 1, by which about 30 locations were chosen as the first selection.

However, it might be proper to note that the criteria for idetification of the traffic bottleneck is a variable factor which shall be modified according to the policy of road administrator whether he will take economic benefit oriented policy, service level intensive policy, etc.

(4) Identification of bottleneck

Figure 2.5.6. shows the locations of intersections where k is equal to or larger than 1.0. In the figure, numbers in circles correspond to the numbers in Figure2.5.3.

Figure 2.5.7 and 2.5.8 show locations of intersections superimposed on the figure showing level of service on the major roads. In these figures it is seen that the arrow marks indicating the intersections with equal to or larger than 1.0 are located at changing point of level of service or point of speed change along congested road sections.

The location and name of the bottlenecks identified by the developed rating method are shown in Table 2.5.1 and Fig. 2.5.9.

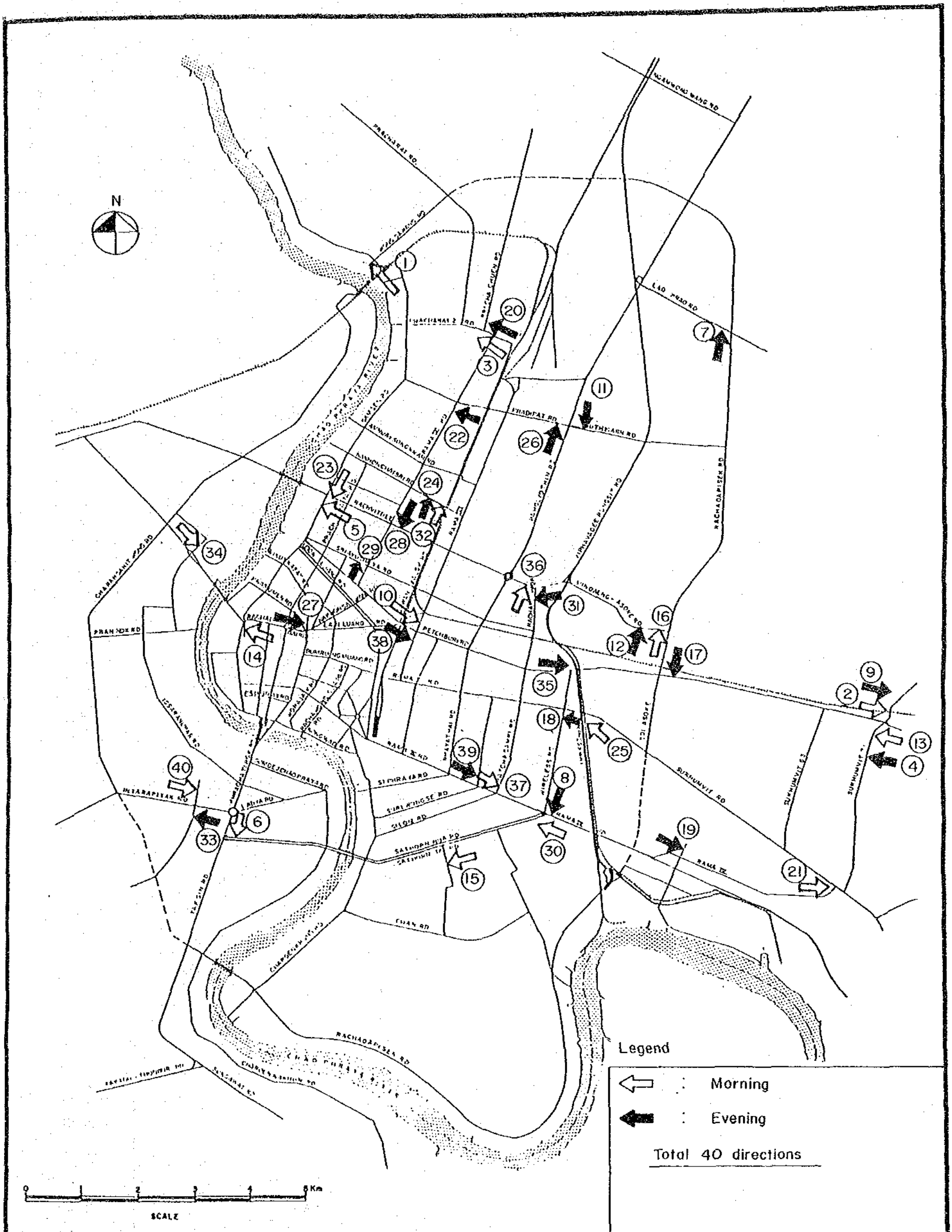


Figure 2.5.6 Bottleneck Intersections

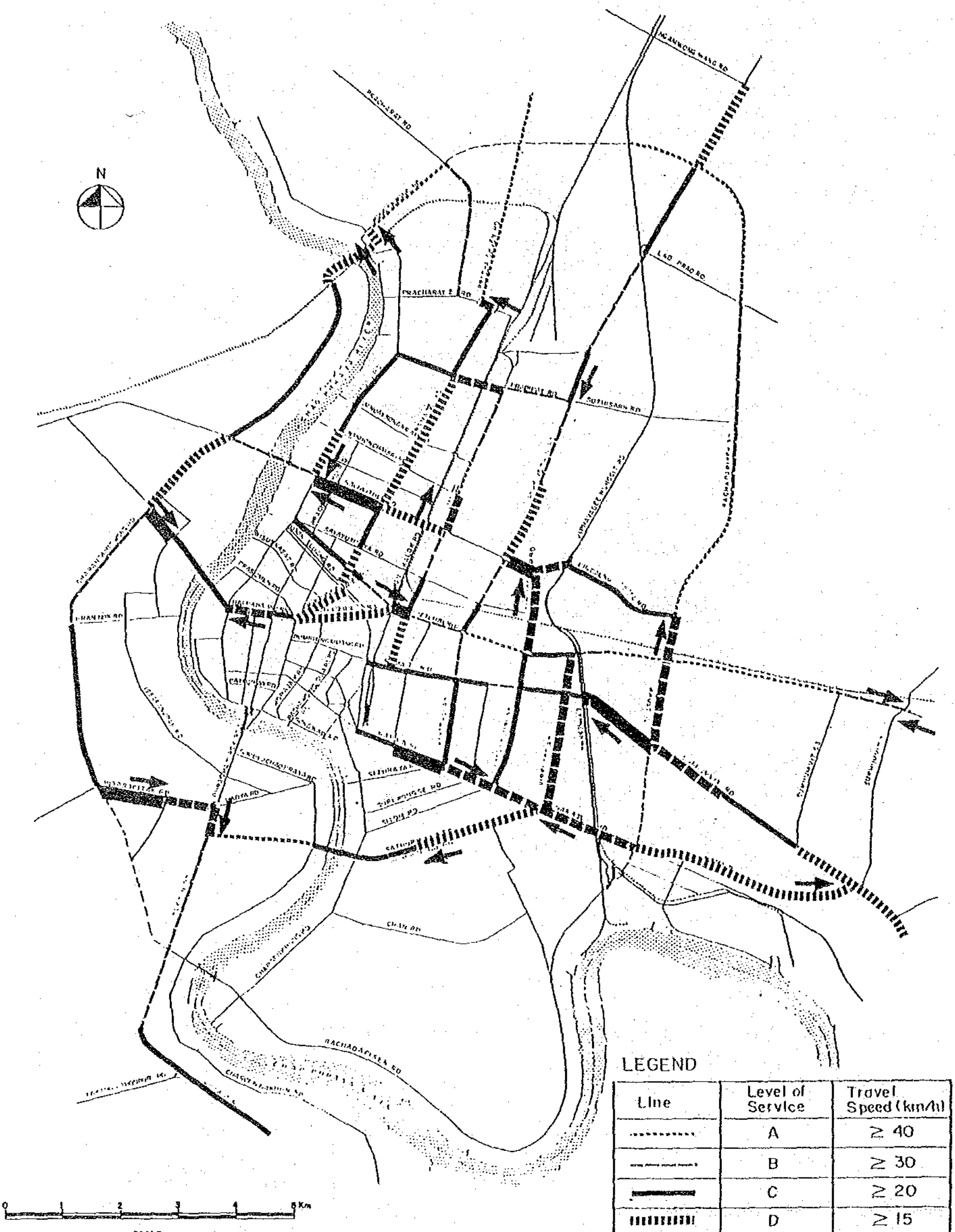
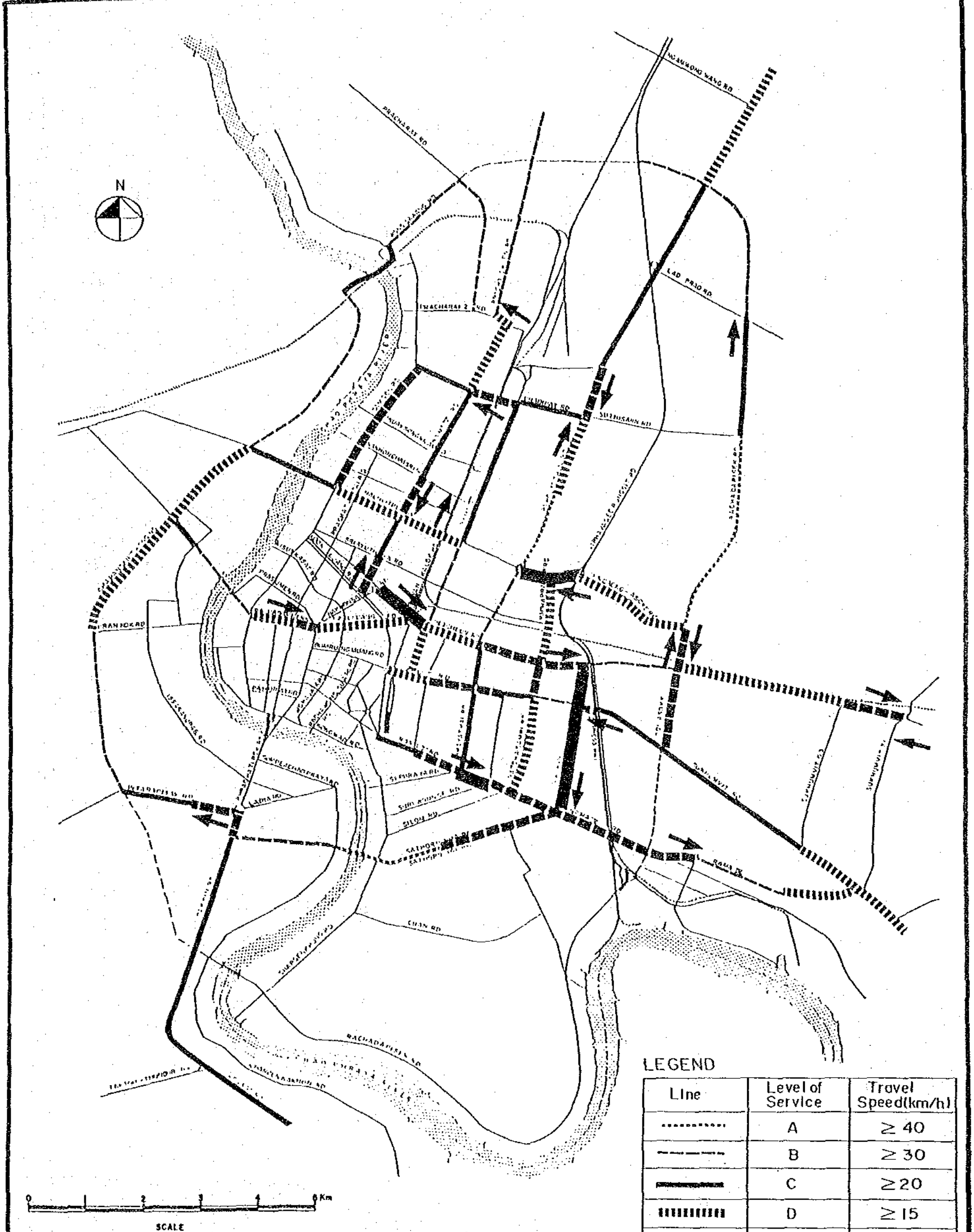


Figure 2.5.7 Identified Bottleneck and Level of Service (AM)



Line	Level of Service	Travel Speed(km/h)
....	A	≥ 40
-------	B	≥ 30
━━━━	C	≥ 20
IIIIIIIII	D	≥ 15
▬ ▬ ▬	E	≥ 10
████	F	< 10

Figure 2.5.8 Identified Bottleneck and Level of Service (PM)

Table 2.5.1 Bottleneck Intersections (Each Direction)

No.	Intersection Name of Road/Crossing Road	Node No.	In/Out Bound	Survey Time
1	Charan Sanitwong-Wong Sawan/Pibul Song Kharm	905	Out	AM
2	Petburi/Phatthanakan	245	Out	AM
3	Techawanit/Pracharat II	360	Out	AM
4	Petburi/Phatthanakan	245	In	PM
5	Ratchawithi/Samsen	311	Out	AM
6	Taksin/Sathon	706	Out	AM
7	Middle Ring/Latphao	903	Out (North)	PM
8	Witthayu/Rama IV	023	In (South)	PM
9	Petburi/Phatthanakan	245	Out	PM
10	Petburi/Rama VI	212	Out	AM
11	Phahon Yothin/Pradiphat	511	In	PM
12	Asok-Din Daeng	900	Out (North)	PM
13	Petburi/Phatthanakan	245	In	AM
14	Ratchadamnoen/Chakra Bongse	202	Out	AM
15	Sathon/Soi Saint Louis	636	Out (North)	AM
16	Asok-Din Daeng	900	Out (North)	AM
17	Middle Ring (Asok-Din Daeng)/Petburi	220	Out	PM
18	Sukhumvit/Witthayu	120	In	PM
19	Rama IV/Kasem Rat	035	Out	PM
20	Pracha Rat II/Pracha Chuen	360	Out	PM
21	Rama IV/Sukhumvit	131	Out	AM
22	Pradiphat/Rama V	358	In (West)	PM
23	Samsen/Ratchawithi	311	In	AM
24	Sawankhalok/Nakhon Chaisri	419	Out	PM
25	Sukhumvit/Exp. Ramp	122	In	AM
26	Pradiphat/Phahon Yothin	511	Out	PM
27	Ratchadamnoen Klang/Ratchadamnoen Nok	207	Out	PM
28	Ratchawithi/Rama V	351	In	PM
29	Si Ayutthaya/Rama V	350	Out	PM
30	Witthayu/Sathon	023	In	AM
31	Din Daeng/Ratchaprarop	613	In	PM
32	Sawankhalok/Nakhon Chaisri	419	Out	AM
33	Phetchakasem/Thoet Thai	800	Out	PM
34	New Arun Amarin/Arun Amarin	821	In	AM
35	Petburi/Witthayu	217	Out	PM
36	Ratchaprarop/Din Daeng	613	Out	AM
37	Rama IV/Silom	022	Out	AM
38	Petburi/Rama VI	212	Out	PM
39	Rama IV/Surawong	021	Out	PM
40	Phetchakasem/Thoet Thai	800	In	AM

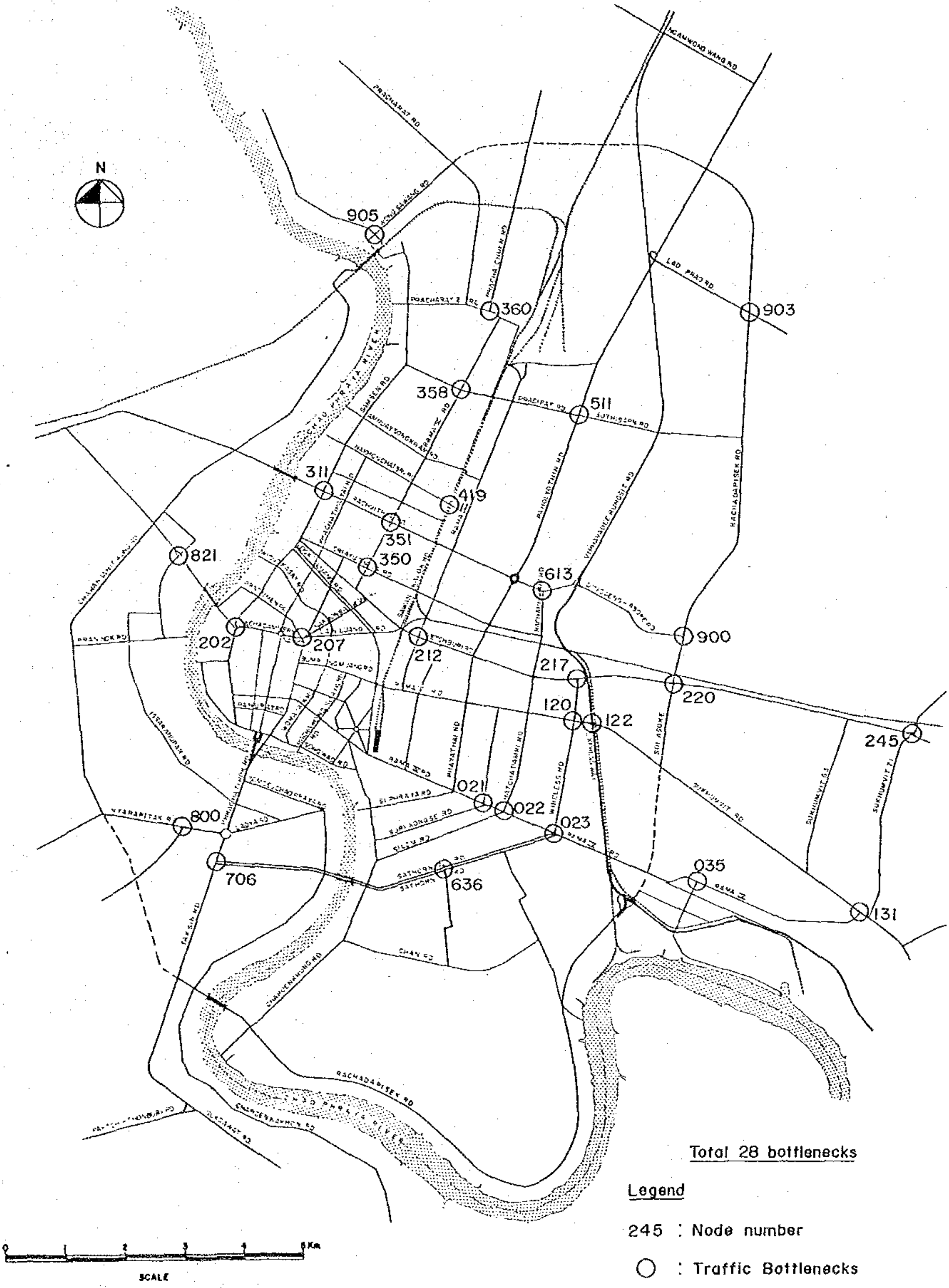


Figure 2.5.9 Location of Traffic Bottlenecks

2.6 Comprehensive Consideration on Identified Bottleneck

The proposed rating method is rather simple and rough screening of bottlenecks. Therefore, more detailed consideration should be given to the bottlenecks identified by this rating method, and importance (or priority for improvement) should be determined. This determination is left to the engineer's (or road-policy-marker's) judgment. The engineer in charge, or road policy maker, may take into consideration such factors as;

a) Traffic volume
b) Severeness of congestion which can be quantitatively expressed in terms of queue length, stoped delay, etc.
c) Importance of the bottleneck location relative to the road network of the area.
d) Cost and benefit of the improvement.
e) Right of way and other constraint.

There is no established method to combine these factors and lead to quantified priority.

3. SELECTION OF IMPROVEMENT PLANNING LOCATIONS

The locations of twenty eight (28) bottlenecks are shown in the former chapter of Traffic Rating Method The existing condition of bottleneck, such as number of lanes, traffic speed in peak hours, inflow traffic volumes and traffic queue lengths are shown in Table 3.1.1.

From the 28 intersections, 11 intersections are selected for improvement planning. The selected intersections are indicated in the Table 3.1.1 with asterisk (*) from the beginning to the eleventh. The locations are shown in Figure 3.1.1.

The selection of 11 intersections from 28 is carried out according to the following criteria.

(1) Criteria for the selection

The intersections are selected for the improvement planning according to the following criteria.

1) Heavily congested intersections
2) Important locations in traffic management
3) Suitable locations for improvement planning demonstration.

(2) Reasons of "Selected" 11 Intersections

Group A

Characteristics: Heavy traffic volume, long waiting time and important location in terms of traffic management (7 locations).

1) Pradiphat/Phahon Yothin Rd. (No.511)
   A flyover is proposed as one of the alternatives to solve the existing traffic congestion.
2) Dindaeng/Ratchaprarop Rd. (No.613)
   - ditto -
3) Petburi/Rama IV Rd. (No.212)
   - ditto -
4) Rama IV/Sathon Rd. (No.023)
   - ditto -
5) Ratchadamnoen Klang/Ratchadamnoen Nai Rd. (No.202)
   An underpass is proposed as one of the alternatives to avoid the interruption of the view.
6) Rama IV/Kasemrat Rd. (No.035)
   Traffic congestion is caused by two closely located intersections.

Table 3.1.1 Summary of Traffic Bottlenecks

Traffic data as of Sep.-Dec., 1985
* : Selected 11 intersections

Node No.	Name of Intersection	No. of Lanes and Traffic Direction	Traffic Speed (km/h) at peak hour			Inflow Traffic Volume(veh./h)		Max Queue Length(m)		Land Use
			Vi	Vi+1	Direction	a.m.peak	p.m.peak	a.m.peak	p.m.peak	
511*	Pradiphat/ Phahon Yothin	6 4 4 6	15.3 10.2 11.1	33.0 34.3 40.6	↑ p.m ↓ a.m ↓ p.m	6,304	-	443	-	Commercial Area
613 *	Dindaeng/ Ratchaprarop	6 8 5	10.2 4.6	21.8 20.3	↑ a.m ← p.m	8,747	9,700	-	-	Residential/ Commercial Area
212 *	Petburi/Rama VI	6 6 6 4	9.4 6.2	38.0 16.4	→ a.m → p.m	9,477	-	430	-	Commercial Area
023 *	Rama IV/Sathon	8 8 8 8	3.8	32.3	↓ p.m	13,819	14,874	730	745	Government Institution/Park/ Commercial Area
131*	Sukhumvit/Rama IV	6 6 6	18.5	40.4	→ a.m	7,137	7,746	83	275	Commercial Area
202 *	Ratchadamnoen Klang/ Ratchadamnoen Nai	2 6 12 6 4	14.2	41.3	← a.m	-	-	-	-	Park, Open Space/ Government Institution Area
900 *	Dindaeng-Asok	8 6 6 6	18.3 17.5	43.4 47.0	↑ a.m ↓ p.m	-	9,010	-	310	Commercial/Open Space Area

Table 3.1.1 Continued (1)

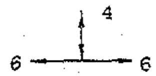
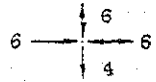
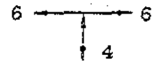
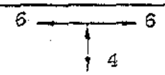
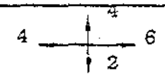
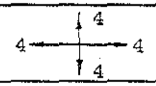
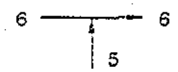
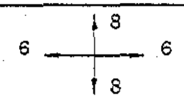
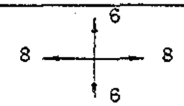
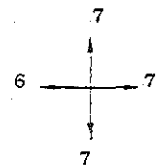
Node No.	Name of Intersection	No. of Lanes and Traffic Direction	Traffic Speed (km/h) at peak hour			Inflow Traffic Volume(veh./h)		Max Queue Length(m)		Land Use
			Vi	Vi+1	Direction	a.m.peak	p.m.peak	a.m.peak	p.m.peak	
360*	Pracharat II/ Pracha Chuen		12.6 15.2	48.9 37.0	← a.m ← p.m	-	-	-	-	Residential/ Commercial Area
220*	Petburi/Soi Asok		12.0 10.9	28.3 32.8	↓ a.m ↓ p.m	9,942	9,499	798	708	Commercial/ Residential Area
800	Phetchakasem/ Thoet Thai		8.2 10.4	16.8	← a.m ← p.m	(4,856)	(5,406)	-	-	- do -
035*	Rama IV/Kasemrat		14.5	37.0	← p.m	-	-	-	-	Residential Area
905	Wongsawang/Phibuls		15.6	58.2	↑ a.m	-	4,459	-	250	- do -
358	Thahan/Rama V		12.3	32.8	← p.m	4,413	-	118	-	Government Institution Area
351	Ratchawithi/Rama V		12.2	28.8	↓ p.m	-	4,724	-	375	- do -
350	Siayuthaya/Rama V		11.9	27.7	↑ p.m	-	-	-	-	- do -
311	Ratchawithi/Samsen		16.2 8.2	36.6 38.8	↓ a.m ← a.m	5,288	-	400	-	- do -

Table 3.1.1 Continued (2)

Node No.	Name of Intersection	No. of Lanes and Traffic Direction	Traffic Speed (km/h) at peak hour			Inflow Traffic Volume(veh./h)		Max Queue Length(m)		Land Use
			Vi	Vi+1	Direction	a.m.peak	p.m.peak	a.m.peak	p.m.peak	
419	Nakhonchaisi/ Swankhalok	6, 4, 4, 6	11.5 10.0	27.8 29.9	a.m p.m	-	-	-	-	- do -
207	Ratchadamnoen Klang/ Ratchadamnoen Nok	9, 10, 4, 4, 3	13.1	28.9	p.m	-	-	-	-	- do -
706	Sathon/Taksin	8, 6, 8	14.6	46.3	a.m	10,557	-	285	-	Commercial Area
636	Sathon/Soi St. Louis	8, 8, 2	21.9	49.3	a.m	-	-	-	-	Residential Area
021	Rama IV/Surawong	6, 8, 8, 4	4.3	12.5	p.m	(5,810)	(7,538)	-	-	Government Institution/ Commercial Area
022	Rama IV/Silom	6, 8, 8, 6	10.5	22.2	a.m	8,698	-	798	-	Park/Government Institution/ Commercial Area
120	Sukhumvit/Witthayu	5, 6, 6, 8	13.4	36.1	p.m	9,222	9,041	1,000	1,475	Commercial Area
122	Sukhumvit/Exp. Ramp	6, Ramp 6, 2, 2	10.7	29.8	a.m	(13,096)	(11,234)	-	-	- do -

Table 3.1.1 Continued (3)

Node No.	Name of Intersection	No. of Lanes and Traffic Direction	Traffic Speed (km/h) at peak hour			Inflow Traffic Volume(veh./h)		Max Queue Length(m)		Land Use
			Vi	Vi+1	Direction	a.m.peak	p.m.peak	a.m.peak	p.m.peak	
217	Petburi/Witthayu		10.7	21.9	p.m	5,794	8,529	135	748	Commercial Area
903	Latphao/Middle Ring		26.3	57.5	p.m	6,995	-	120	-	Low Density Residential Area
821	New Arun Amarin/ Arun Amarin		7.2	20.1	a.m	-	-	-	-	- do -
245*	Petburi/Ramkhamhaeng		10.0 7.3 7.7 7.7	36.6 45.5 40.1 37.4	a.m a.m p.m p.m	7,598	-	813	-	Commercial Area

Notes : 1. Vi : speed before passing intersection.
2. Vi+1 : speed after passing intersection.
3. Traffic volume excluding motorcycles.
4. Traffic volume in ( ) from OCMRT.

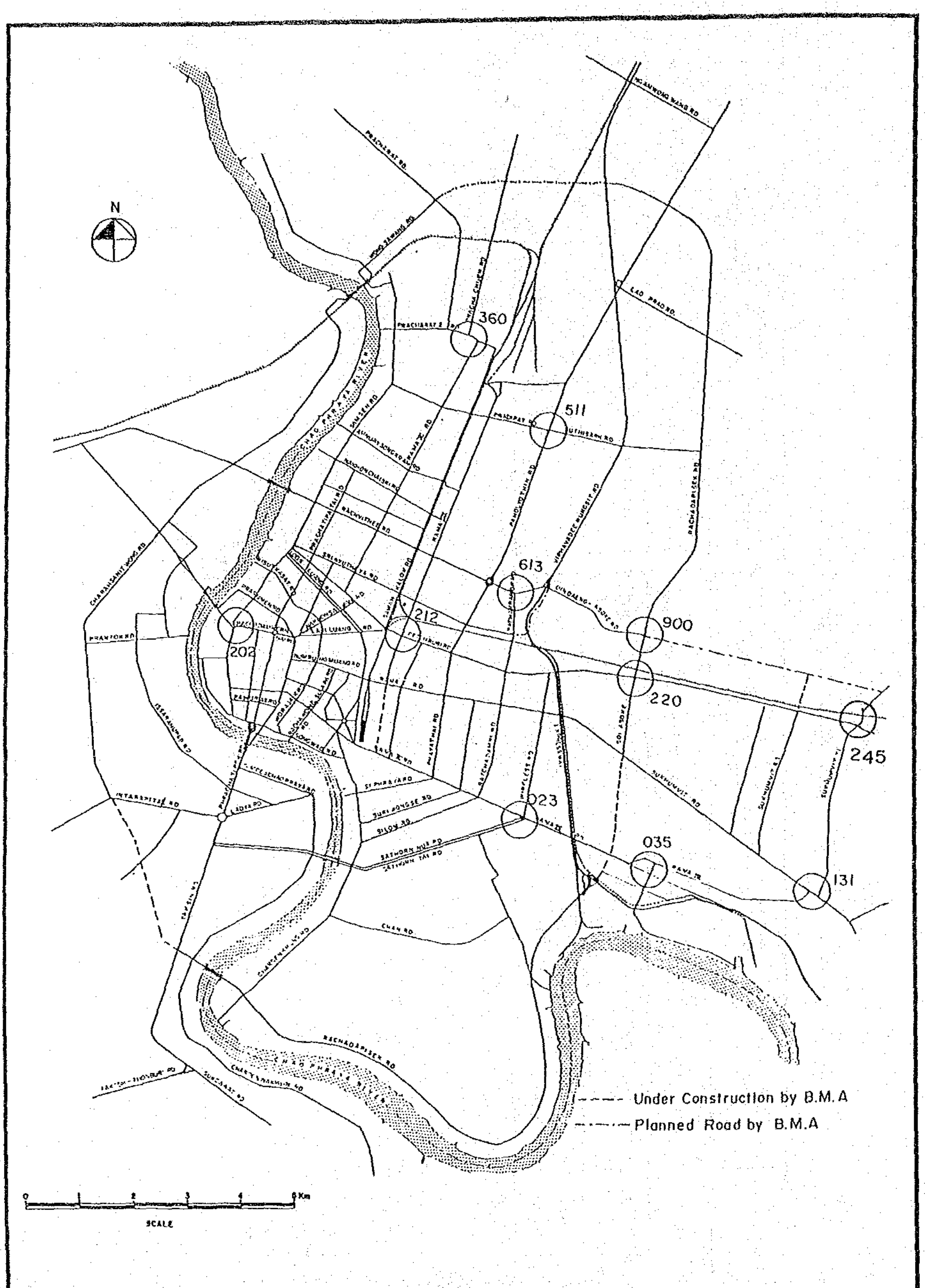


Figure 3.1.1 Location of Eleven Intersections

7) Petburi/Ramkhamhaeng (No.245)
Long queues and long waiting time are observed in peak hours.

Group B

Characteristics: Existing traffic volume is relatively low but the location is important (1 location).

8) Sukhumvit/Rama IV Rd. (No.131)
Realignment or a new road for neighboring Soi 71 is proposed as alternatives.

9) Pracharat II/Pracha Chuen Rd. (No.360)
Widening of south road (Rim Khlong Prapa Fang Sai) is proposed as one of alternatives.

10) Petburi Rd./Soi Asok (No.220)
Road widening of Soi Asok and bypasses are considered.

Group C

Characteristics: Existing traffic volume is not so heavy but the location is important (1 location).

11) Dindaeng - Asok Rd. (No.900)
After the completion of Samsen Khlong-side Rd., a large increase of traffic volume is expected. It is located on Middle Ring Rd.

There are other 17 locations screened by the traffic rating method but not selected for improvement planning, because of the reasons that improvement works or plans have already been underway at these locations. (Detail in Appendix 3.1)

4. BASIS OF IMPROVEMENT PLANNING

4.1 Road Policy and Improvement Planning

When an improvement of road is planned, many factors are taken into consideration, i.e. available fund, importance of the improvement relative to the whole road network, land use of the area, traffic volume, degree of congestion, constraint of right of way etc.

Although the examples of how these factors are taken into account are shown in each improvement planning, a few fundamental considerations are described here.

(1) Importance of the location/route relative to the road network

The first thing to be considered is the importance of the location. This is closely related to the importance of the route, on which the congestion is existing. It is common practice that improvements on major arterials are given high priority so that motorists are guided to use these major routes, thus, reducing the unnecessary congestion in minor roads. Hence, this matter is closely related to the road policy.

(2) Balanced improvement

Balanced improvement is required along the route. If only a few number of intersections have large capacities while other intersections remain to have small capacities, those intersections with large capacities cannot be fully utilized because the traffics are blocked at the intersections with smaller capacities.

If the improvement intersection has several adjacent intersections located nearby, which may influence the improvement effects integrated imptovement plan including these adjacent intersections shall be worked out, judging from engineering aspect.

(3) Extent of improvement

Another question is the extent of improvement, in other words, the degree which the congestion should be decreased to. For example, when a saturated intersection is to be improved, what value of saturation degree should be sought?

The answer to this question depends on various factors such as, importance of the intersection/road, traffic volume at present and/or in the future.

In this study, target of saturation degree after the improvement is proposed as follows.

Saturation degree 0.8 : For one hour peak traffic volume
Saturation degree 0.9 : For 15 minutes peak traffic volume

Saturation degree of each intersection was calculated using the above two peak traffic volumes. All the proposed improvement plans achieved the target and were justified as affective plans. The results are shown using one hour peak traffic volume in the report.

4.2 Process of Improvement Planning

The process of the road improvement planning is shown in Figure 1.1.1 of Introduction. In the planning, the followings are the major planning items carried out for each intersection.

(1) Traffic Survey

As the basis for formulation of the road improvement plans and for estimation of improvement effects, five (5) types of traffic surveys were planned and carried out at twenty two (22) intersections. The number of intersections surveyed is more than eleven (11) which was selected by traffic rating method, because the neighboring intersections were included in the survey.

Five (5) types of surveys carried out for this study were;

a) Intersection traffic volume survey
b) Queue length survey
c) Saturation flow rate survey
d) Traffic signal survey
e) Pedestrian crossing survey

Intersection traffic volume survey aimed at identification of the directional flows and their volumes at intersections. Queue length survey was intended for measuring the number of stopped vehicles by their queue length at the intersection. The survey on saturation flow rate is to find the maximum capacity of the intersection. The traffic signal survey was carried out to know how the signals affect the intersection capacity because many signal systems in Bangkok are controlled by traffic police at peak hours. Pedestrian crossing counts were made at two (2) intersections and the data was used for improvement planning.

The methods adopted for these surveys were the same as those described in Volume I, Traffic Survey.

(2) Analysis of Existing Conditions

Before actually formulating the road improvement plan, it is prerequisite to grasp the existing conditions at selected intersection in order to device the most effective plan coping with these conditions. The analyses of the existing conditions, such as geometric conditions and traffic flow, were carried out based on topographic and traffic surveys, the details of which are shown below.

1) General Description
   - Location, shape, lane number and function
2) Traffic flow
   - Volume, direction, peak and congestion
3) Constraints
   - Right of way, buildings, utilities and pedestrian bridge(s)
4) Degree of Congestion
   - Saturation degree, queue length and stopped delay
5) Cycle time analysis
   - Green time allocation and cycle length

(3) Planning of Improvement Alternatives

There are five main steps in formulation of the road improvement plan, starting from working out the possible improvement alternatives to the final recommendation of the proposed plan at each intersection. The plan formulation process in this study is shown as follows.

1) Making possible improvement alternatives
   - Signal timing, at-grade and grade-separation
2) Calculation of Improvement Effect
   - Change in traffic flow
   - Change in saturation degree, queue length and stopped delay
3) Comparison and selection of an alternative(1st step)
   - Advantage, disadvantage and their costs
4) Economic Analysis (2nd step)
   - Cost, Net benefit, B/C
5) Recommendation

(4) Other considerations

1) Coordination with urban facility planning:

It is to be mentioned that at time of implementation of the improvement plans worked out in this study, it is prerequisite and vital to closely coordinate with other urban facility plans such as ETA's mass transit system expected to pass through Rama IV Road and 2nd Stage Expressway running over Petburi/Rama VI Intersection. The coordination should be made on such aspects as the alignment, structure and construction method in line with the implementation schedule of relevant plans.

It is further to be mentioned that this study does not fall in the time to make such coordination, and therefore, road improvement plans were independently worked out from the standpoint that the physical plans of both the road improvement and other urban facility can be mutually feasible by coordination of the implementing agencies when such time comes.

2) Method of construction

This study aims at demonstrating to seek what sort of road improvement plan is adequate and appropriate at respective intersection selected.

There are two aspects to be taken into consideration for construction method; the one for traffic control to minimize deterioration of the existing traffic condition during construction, and the other for structural construction's method including temporary works. The first aspect can be managed by the similar traffic control methods which were experienced in the past road improvements. For the second aspect, it is considered to be possible to adopt the technically feasible construction method for the improvement plans from an engineering point of view. However, the practical construction method to be applied at time of implementation of the plan should be determined at time of detailed design with close coordination with other plans.

3) One way regulation as a prior condition

One way regulation being executed in Bangkok is a prior condition in this study, because the issue of traffic management is out of scope of this study.

4.3 Various Measures and Effects in Improvement Planning

The measure to attain the improvement target or effect at the selected intersection shall be as simple and economic as possible. The measures selected to be reviewed in this study fell into the following three categories ranked from the most economical to less economical one in improvement work.

1) Improvement of signal timing
2) At-grade improvement
3) Grade-separation improvement

The general features of each measure and effects are summarized as follows.

(1) Improvement of signal timing

It is the easiest improvement plan of the three to carry out. Ideally, a green time should be allocated in proportion to each traffic volume. But many of traffic signals in Bangkok are operated manually and the cycle lengths are generally longer than those of other countries.

Average green time of each direction is approximately in proportion to traffic volumes, even if the signal phasing is controlled irregularly by manual.

The study of signal timing is the first step of planning. Although, there are a few intersections where saturation degrees are decreased by adjustment of signal timing, it is not sufficient enougth to reach the improvement target. Therefore, it is necessary to combine the improvement of signal timing with other measures.

As for the traffic signal measures, significant improvement effects will not be expected by the improvement of signal timing at one intersection, when there are continuous group of over saturated intersections. For the improvement of over all signal timing, the introduction of A.T.C system (Area Trarric Control System) should be studied and realized as soon as possible.

(2) At-Grade improvement

There are several alternatives in at-grade improvement planning.
1) Road widening to increase the intersection capacity.
2) Provision of right or left-turn lanes

3) Provision of channelization
4) Improvement of road marking to make smooth traffic flow
5) Road realignment or construction of a new road

Items from 2) to 4) are rather small improvement, while items 1) and 5) normally require land acquisition, land clearance and new construction which cost more. In this study, at least one alternative of at-grade improvement plan was prepared for each intersection.

(3) Grade-separation improvement

Grade-separation improvement means the provision of a Flyover or underpass, which cost is most expensive as one unit. Both of them will improve the traffic condition much better than at-grade improvements normally.

(4) Calculation of improvement effects

The improvement effects are calculated for the critical approach and the total of the intersection. Calculated items are as follows.

1) Saturation degree of intersection
2) Queue length
3) Stopped delay

Estimation of saturation degree at an intersection was sought by the method explained in the section of Traffic survey, volume I. Queue length on each approach of the selected intersections before improvement was measured in this study as described in the traffic survey. The estimation of queue length after improvement was made by using the formula quoted from H.C.M, 1985.

The detailed discussion on the stopped delay time is shown in Section 4.4 (2).

The improvement planning was practised in accordance with the basic policy and the process of inprovement planning as discussed in this chapter. The out come of the study on road improvement plan is presented in this chapter.

4.4 Economic Evaluation

(1) Introduction

The economic evaluation in road improvement is commonly practiced by comparative assessment of such economic factors as the savings of travel time and vehicle operating costs being the benefits and the improvement investment costs comprising construction and operation/ maintenance costs.

The evaluation in this study was attempted identifying the net benefits mainly with the benefit elements as the travel time saving and reduction in vehicle operating cost to be yielded by road improvement, because they are the most sensitive factors in the evaluation. However, it can be said that more detailed evaluation might be exercised taking all the other benefit factors into account, including intangible benefits like impacts to environment, land use, beautification, etc.

(2) Estimation of benefit

1) Basis and assumptions

The basic policies of evaluation adopted in this road improvement plan are as follows;

a) The evaluation method shall be simple and practical in use,

b) The unit benefit of time saving to be yielded by implementation of the improvement plan is defined and measured by the difference of daily vehicle-delay times at an intersection before and after improvement which are based on the average stopped delay time per vehicle on each approach of the intersection.

c) The unit benefit of saving in vehicle operating cost(VOC) is defined and measured by the defference of the VOCs on the approaches of intersection before and after improvement which vary correspondent to the travel speed.

It is to be mentioned that the effects of the nearby intersections were reviewed from engineering aspects as described in section. 4.1.(2). Furthermore an accurate estimation of the traffic movement patterns at an improved intersection requires very complicated simulations, and projection of the benefits under such movement patterns can not be possible without identification of the traffic movements on all the road network, and therefore, they seem not practical.

Therefore, based on above evaluation policies, the following assumptions were adopted to estimate the effect or benefits of improvement plan.

a) Estimation of the benefits was made independently for each intersection where improvement was implemented.

b) The existing traffic volume was used the estimate of the benefits. First, the traffic flow pattern is estimated according to the improvement plan. Second, using the estimated traffic volume, the reductions of the stoped delay and VOC were calculated.

2) Estimation method for delay time saving

There are two (2) types of methods for estimation of the average delay time per vehicle at a certain intersection as the following;

a) Estimation method based on oversaturated condition

This method is based on the concept that the delay time can be estimated by the accumulative number of vehicles at the intersection obtained from the intersection traffic volume survey, and the number of stopped-vehicles estimated from the queue length survey. Figure 4.4.1 shows the relationship between the two factors.

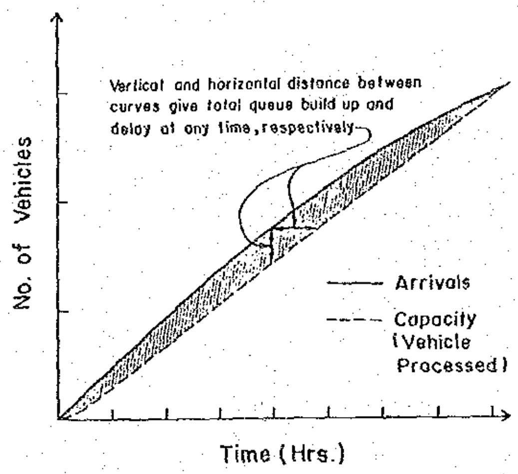


Figure 4.4.1 Relationship between Arrivals and Capacity

The average delay time per vehicle adopting accumulative number of stopped-vehicles (ΣVs) and capacity (vehicle processed; V) is obtained by the following equation, which was quoted from H.C.M.1985.

$$D = (\Sigma Vs \times I) / V \quad .....(1)$$

where;

D = average delay per vehicle

ΣVs = sum of stopped-vehicle counts

I = interval between stopped-vehicle counts

V = total volume observed during survey period
(source : H.C.M. 1985)

Vehicle - delay time corresponds with the area marked by the slashed line, plotting stopped-vehicles by curved line and the capacity by dotted line, as shown in Figure 4.4.1. It can be obtained by multiplying the total number of vehicles processed at the intersection (V) observed during the survey, referring from Equation (1), and is described by the following equation;

Vehicle - Delay Time $=\Sigma Vs \times I$ .....(2)

b) Estimation method for undersaturated conditions

This method is for calculating the delay time of randomly arriving vehicles at the approaches of signalized intersection. There is an equation for this estimation method in H.C.M. 1985, which is presented as follows.

$$d = 0.38\,C\,\frac{[1 - g/C]^2}{[1 - (g/C)(X)]} + 173\,X^2\left[(X-1) + \sqrt{(X-1)^2 + (16X/c)}\right] \quad .....(3)$$

where:

d = average stopped delay per vehicle for the lane group, in sec/veh;
C = cycle length, in sec;
g/C = green ratio for the lane group; the ratio of effective green time to cycle length;
X = v/c ratio for the lane group, and
c = capacity of the lane group

It is understood that this equation gives fairly reliable estimation of the delay time, but has some reservation where there is oversaturation because spillbacks may extend to adjacent intersections.

Estimation of the delay times before and after improvement was practiced in this study by application of above two equations depending upon the situations whether oversaturation occurs or not for long periods (> 15 min.)

c) Estimation procedure for delay time before improvement

For estimation of the average delay time per second per vehicle before improvement, Equation (1) was applied for the peak hours. For the off-peak hours, Equation (3) was adopted.

Since the intersection where road improvement is implemented to eliminate the existing bottleneck or oversaturation during peak hours, the delay time

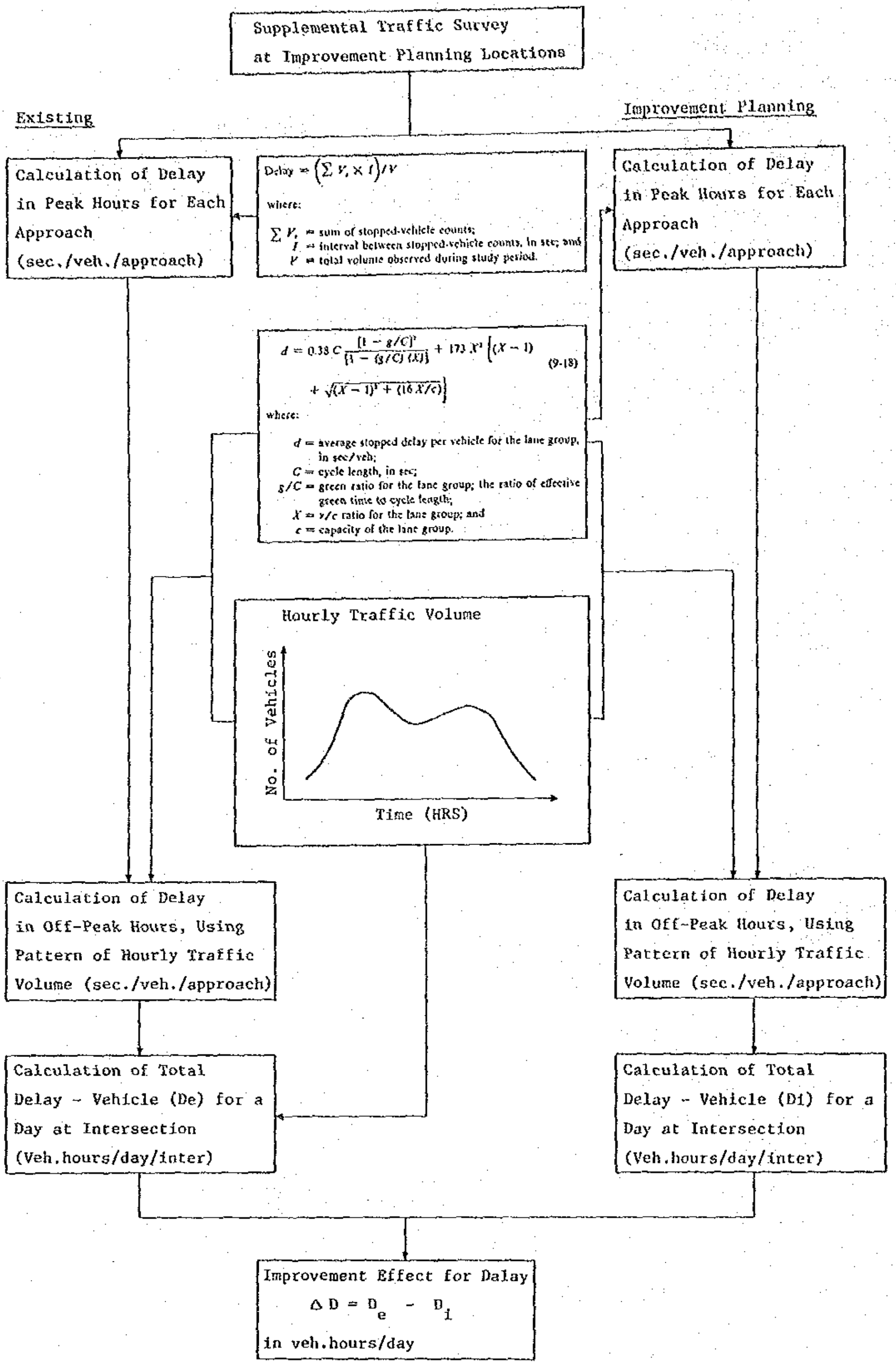


Figure 4.4.2 Estimation Procedure

for peak hours was estimated by Equation (1) applicable to oversturated condition. For estimation of the delay time during off-peak hours for which there was no traffic survey data available, Equation (3) was adopted assuming that oversaturation does not occur at these hours.

d) Estimation procedure for delay time after improvement

For estimation of the average delay time per second per vehicle after improvement, Equation (3) was employed regardless of the time zone of the day, since it can be assumed that there would be no oversaturation at each approach of the intersection after improvement is implemented.

Estimation of the difference of the total daily vehicle-delay times in vehicle-hour before and after improvement was made by the following process; i) estimation of each total daily vehicle-delay time before and after improvement by multiplying the attained average delay time in second per vehicle with the traffic volume observed and estimated at each improvement location, ii) comparison of two daily vehicle-delay times before and after improvement to attain the difference. This procedure is shown in Figure 4.4.2.

3) Estimation method of saving in vehicle operating cost(VOC)

Vehicle Operating Cost (VOC) varies depending on the type of vehicle and travel speed. The unit value of VOC by vehicle type is to be descussed in the paragraphs to follow, and here the discussion is focussed to identify the difference of travel speed before and after improvement.

As the theoretical estimation of accurate travel speed after improvement requires very complicated simulation with all the traffic data, the following assumptions were adopted to estimate it practically.

a) The travel speed of the road section before passing the bottleneck will increase correspondent to decrease of waiting time. This increased speed will be limited to the maximum equivalent to the travel speed after passing the bottleneck.

b) Estimation of difference of the total daily VOCs before and after improvement was made by the following process;
   - estimate total daily VOCs before and after improvement respectively by accumulating the hourly VOCs under applicable travel speeds to be those per day.
   - compare the two different total daily VOCs before and after

improvement, and attain the difference.

It is to be mentioned that the benefit element by decrease in VOC or difference of VOCs before and after improvement, estimated in this study may be rough compared to the benefit element by time saving, because of the following reason.

VOC correspondent to travel speed on a road section stretched to some extent of distance has been measured and published in many coutries. However, there is no reliable data on the VOCs on the approaches to the congested intersection where the vehicles show very complicated travel patterns by acceleration, deceleration, idling before passing through the traffic bottleneck.

Vehicle operating costs on such conditions are not obtained at present.

(3) Cost estimation

1) Criteria

The cost estimation for road improvement plan was carried out with the following criteria. The total cost comprises the project cost and maintenance/operation cost. The project cost consists of construction cost, OPT (overhead, profit and tax), land acquisition and compensation costs, contingencies and engineering fees.

- The unit cost was based on work item and was computed under the market conditions prevailing in November, 1986. There were approximately 20 different unit costs applied in cost estimation.

- The unit cost by work item was obtained by accumulating the labor cost, equipment cost, material cost, etc.

- Overhead, profit and tax (hereinafter abbreviated to as OPT) were included in the project cost based on the data given by BMA (referred to Appendix 4.4.1).

- Land acquisition and compensation cost were estimated based on the data obtained from BMA.

- Contingency allowance is included by 10% of the total of construction cost, OPT, land acquisition and compensation cost.

- Engineering fee was calculated based on the data of FIDIC according to complexity of the engineering work.

2) Unit construction cost by work item

The unit construction cost by work item was calculated from the material cost, labor cost, equipment cost, etc. Some items which BMA has cost estimation standard, are based on it. The result shown in Appendix 4.4.2 was verified against prevailing actual cost for construction work in Bangkok.

3) Land acquisition and compensation cost

Unit rate for land acquisition at each improvement site and compensation were obtained from BMA shown in Appendix 4.4.3.

Required land acquisition and compensation cost for each alternative of the improvement plans are shown in Appendix 4.4.4, 4.4.5.

4) Project cost

The project cost comprises the costs for construction, OPT., Land acquisition, compensation, contingencies and engineering. The construction cost for each alternative was computed based on the quantities (shown in Appendix 4.4.6 (1) - (3)) calculated in the preliminary design and on the unit cost for each work item.

The summary of project cost for each alternatives of the improvement plan is shown in Table 4.4.1 and the breakdown of the construction cost is shown in Appendix 4.4.7 (1) - (3).

5) Maintenance and operation expenditure

To ensure the original function of the improvement plan at each location, proper maintenance and adequate operation shall be carried out and related expenses shall be included in the expenditure budget.

The flyover is mainly to be of concrete structure and should be basically maintenance free. Routine maintenance is therefore confined to the costs of electricity for lighting, cleaning and minor repairs. As for underpass, the operation cost is needed to operate the road facilities such as water pumps, ventilation boosters, illumination, etc.

Table 4.4.1 Summary of Project Cost (1)

Unit : Million Baht

		Alt 1	Alt 2	Alt 3
Rama IV/Siphraya - Sathon	Construction	-	227.8	272.3
	Overhead, Profit and Tax	-	33.0	39.5
	Land Acquisition	-	-	-
	Compensation	-	-	-
	Sub-Total	-	260.6	311.8
	Contingencies	-	26.1	31.2
	Engineering	-	15.6	18.7
	TOTAL	-	302.5	361.7
Ratchadamnoen Klang Ratchadamnoen Nai	Construction	3.3	7.9	95.3
	Overhead, Profit and Tax	0.7	1.5	15.1
	Land Acquisition	-	-	4.8
	Compensation	-	-	-
	Sub-Total	4.0	9.4	115.2
	Contingencies	0.4	0.9	11.5
	Engineering	0.3	0.7	7.7
	TOTAL	4.7	11.0	134.4
Dindaeng/ Ratchaprarop	Construction	62.8	70.7	-
	Overhead, Profit and Tax	9.9	11.2	-
	Land Acquisition	2.5	2.5	-
	Compensation	-	-	-
	Sub-Total	72.2	84.4	-
	Contingencies	7.5	8.4	-
	Engineering	4.0	5.7	-
	TOTAL	86.7	98.5	-
Pradipat/ Phahon Yothin	Construction	18.6	45.6	56.8
	Overhead, Profit and Tax	3.4	7.4	9.3
	Land Acquisition	17.8	-	-
	Compensation	129.0	-	-
	Sub-Total	168.8	53.0	66.1
	Contingencies	16.9	5.3	6.6
	Engineering	1.4	3.2	4.0
	TOTAL	187.1	61.5	76.7
Petburi/Rama VI	Construction	4.7	33.8	-
	Overhead, Profit and Tax	0.9	5.8	-
	Land Acquisition	21.8	-	-
	Compensation	25.5	-	-
	Sub-Total	52.1	39.6	-
	Contingencies	5.2	4.0	-
	Engineering	0.4	2.0	-
	TOTAL	58.2	45.6	-

Table 4.4.1 Summary of Project Cost (2)

Unit : Million Baht

		Alt 1	Alt 2	Alt 3
Pracharat II/ Prachachuen	Construction	7.6	17.4	-
	Overhead, Profit and Tax	1.5	3.2	-
	Land Acquisition	5.6	23.8	-
	Compensation	6.6	9.9	-
	Sub-Total	21.3	54.3	-
	Contingencies	2.1	5.4	-
	Engineering	0.7	1.3	-
	TOTAL	24.1	61.0	-
Sukhumvit/ Rama IV	Construction	8.9	8.0	52.2
	Overhead, Profit and Tax	1.7	1.5	8.5
	Land Acquisition	54.5	51.9	-
	Compensation	27.4	54.4	-
	Sub-Total	92.5	115.8	60.7
	Contingencies	9.3	11.6	6.1
	Engineering	0.8	0.7	3.6
	TOTAL	102.6	128.1	70.4
Petburi/ Ramkhamheng	Construction	19.2	32.1	-
	Overhead, Profit and Tax	3.5	5.5	-
	Land Acquisition	3.7	4.1	-
	Compensation	-	-	-
	Sub-Total	26.4	41.7	-
	Contingencies	2.6	4.2	-
	Engineering	1.5	2.3	-
	TOTAL	30.5	48.2	-
Rama IV/ Kasemrat	Construction	4.5	-	-
	Overhead, Profit and Tax	0.9	-	-
	Land Acquisition	21.8	-	-
	Compensation	5.6	-	-
	Sub-Total	32.8	-	-
	Contingencies	3.3	-	-
	Engineering	0.4	-	-
	TOTAL	36.5	-	-
Petburi/ Soi Asok	Construction	0.086	-	-
	Overhead, Profit and Tax	0.026	-	-
	Land Acquisition	-	-	-
	Compensation	-	-	-
	Sub-Total	0.112	-	-
	Contingencies	0.011	-	-
	Engineering	0.010	-	-
	TOTAL	0.13	-	-

Maintenance and operation expenditure to each alternative is tabulated in Table 4.4.2.

(4) Economic analysis

1) Application of evaluation

For evaluation of the economic effectiveness of the proposed improvement plan, calculation of economic benefits in terms of monetary value of the difference of delay times and vehicle operating cost before and after implementation of the plan, and the costs comprising construction and maintenance costs were attempted for nine out of eleven selected improvement locations in this study after enough discussion with BMA's counterparts.

Out of eleven locations selected for improvement plans, the plans for two intersections, namely Dindaeng/Asok Roads and Petburi/Soi Asok Roads were considered to be worked out after completion of Samsen Khlong Road construction being done at present for the former, and of comprehensive study on Middle Ring Road to be expected in the near future for the latter. For the Petburi / Soi Asok intersection, the improvement plan on channelization was carried out. For these reasons, economic evaluations for these intersections were not attempted.

Also, among the improvement plans, there are two (2) plans, Plan No. P-1 on Rama IV/Si Phraya - Sathon Intersections and P-5 on Petburi/Rama VI Intersection, for which economic evaluations were made for two (2) alternatives for each improvement plan, as one of the factors for alternative comparison, because the costs of these alternatives are somewhat similar.

2) Evaluation period

A review has been made on the project life or evaluation period of the planned road improvement from the viewpoints of project nature, its scale in work volume and cost, and the time required for construction. The improvement plan to be implemented to the existing road assumes a nature of a sort of temporary arrangement requiring urgent remedial measures in comparatively small scale in work volume and related cost. Therefore, in spite of setting a evaluation period to be 20 years as is the case of new road development project, it was determined to be 10 year period. As a supplement, evaluation in 20 years was also attempted for comparative purpose.

Table 4.4.2 Maintenance and Operation Expenditure

Unit : Million Baht per annum

		Maintenance	Operation	Total
Rama IV/Siphraya-Sathon	Alt 1	-	-	-
	Alt 2	3.7	-	3.7
	Alt 3	3.9	-	3.9
Ratchadamnoen Klang/ Ratchadamnoen Nai	Alt 1	1.6	-	1.6
	Alt 2	1.6	-	1.6
	Alt 3	1.8	2.4	4.2
Dindaeng/ Ratchaprarop	Alt 1	2.7	1.0	3.7
	Alt 2	2.7	1.0	3.7
Pradipat/Phahon Yothin	Alt 1	1.0	-	1.0
	Alt 2	1.0	-	1.0
	Alt 3	1.1	-	1.1
Petburi/Rama VI	Alt 1	0.9	-	0.9
	Alt 2	1.2	-	1.2
Pracharat II/ Pracha Chuen	Alt 1	0.5	-	0.5
	Alt 2	1.1	-	1.1
Sukhumvit/Rama IV	Alt 1	2.1	-	2.1
	Alt 2	2.0	-	2.0
	Alt 3	1.5	-	1.5
Petburi/Ramkhamheng	Alt 1	1.0	-	1.0
	Alt 2	1.2	-	1.2
Rama VI/Kasemrat		0.6	-	0.6
Petburi/Soi Asok		0.1	-	0.1

3) Traffic volume for evaluation

As discussed in the preceeding section, 4.4 (2), Estimation of benefits, benefit estimation was made independently for each improvement intersection. The traffic volume at each intersection was assumed to remain unchanged before and after improvement, because the capacity ceilings of the adjacent intersections would limit the increase of traffic volume of the subject intersection. For those intersections where great increase in traffic volume is expected, their improvements shall be of large scale projects and their related plans shall be studied separately in detail.

4) Unit value of benefit

a) Unit value of time saving

Following the discussions on estimation of the difference in daily vehicle-delay time in terms of vehicle-hour in the preceeding section, estimation of the weighted averagevalue of time saving in monetary terms per vehicle-hour at 1986 price level was attempted. This estimation referred to the study on SSES of ETA, 1986 on unit time cost by type of vehicle, and also was based on the motor vehicle O-D survey of this study on vehicular compostion. As the motor vehicle O-D survey excluded the trips by motorcycle, the vehicular composition of motorcycle was assumed as 25% based on the traffic volume count surveys at road sides near the improvement locations. Since this survey revealed similar vehicular composition at various survey stations in the study area, the composition at each improvement location was assumed to be same in economic evaluation.

Subsequently, the weighted average value of time saving was calculated by application of the following Table 4.4.3, and arrived at 22.1 Baht per vehicle-hour.

b) Unit value of vehicle operaing cost(VOC)

Vehicle operating cost (VOC) is generally composed of the costs for fuel, oil, tyres, depreciation in use, maintenance for parts and labour, interest and age depreciation. The VOC by type of vehicle in Bangkok was referred to the study on SSES by ETA in the same way as the time saving for the vehicles travelling on the approaches to the improvement intersections. The detailed data on the VOCs are shown in Appendix 4.4.8. The vehicular composition was assumed the same as the case for time saving.

5) Calculation conditions and equation

The calculation to identify the net benefit or B - C, benefit/cost ratio (B/C) and IRR of each improvement plan was carried out with the following conditions and assumptions.

Table 4.4.3 Time Cost and Vehicular Composition in the Study Area

Type of Vehicle	Unit Value of Time Cost (Baht/veh.hr)	Vehicular Composition
1. Motorcycle	7.6	0.250
2. Car	18.6	0.341
3. Taxi	35.5	0.218
4. Pick-up	34.4	0.133
5. Truck	27.3	0.024
6. Bus	25.9	0.034
Weighted Average	22.1	1.000

1) Period of Evaluation : 10 years (20 years as supplement)
2) Price : current market price in 1986
3) Weighted Average Value of Time : 22.1 Baht per vehicle-hour
4) Unit Value of V.O.C. : See Appendix 4.4.8.
5) Vehicle Composition : 6 types whose composition is incorporated into the unit value of time and V.O.C as a weighted average.
6) Rate of Discount : 5 percent per year
7) Effective Days per Year : 260 days

The equations adopted in this calculation are shown below;

$$\sum_{t=1}^{T} \frac{Bt}{(1+r)t} - K - \sum_{t=1}^{T} \frac{Ot}{(1+r)t} = B - C$$

$$\sum_{t=1}^{T} \frac{Bt}{(1+r)t} \Big/ \left(K + \sum_{t=1}^{T} \frac{Ot}{(1+r)t}\right) = B/C$$

$$\sum_{t=1}^{T} (Bt - K - Ot) / (1+i)t = 0$$

where;

- K = road improvement construction cost
- Ot = operation/maintenance cost at "t"th year
- Bt = economic benefit at "t"th year
- r = rate of discount
- T = evaluation period in number of year
- i = economic internal rate of return

The economic evaluation for nine (9) improvement plans is summarized in Table 5.1.3 in the next chapter, and the details of economic analysis together with each benefit/cost calculation of the plan including comparison of improvement alternatives is shown in Appendix 4.4.9.

5. PLANNING OF IMPROVEMENT ALTERNATIVES

5.1 Summary of Road Improvement

(1) Proposed improvement plan

In accordance with the basis of intersection improvement planning discussed in the preceeding section, preparation of improvement alternatives at eleven (11) selected intersections was carried out.

The summary of the proposed improvement plans is presented in Table 5.1.1.

The improvement plans were made for ten (10) intersections because one (Dindaeng-Asok) needs plan coordination with Middle Ring Road improvement.

The typical measures applied for improvement planning are intended for elimination of traffic bottleneck at peak hours, mainly by provision of flyover or underpass and by widening of the existing road or construction of a new road at the selected intersection.

It is to be mentioned that determination for implementation of the proposed improvement plans shall be based on the comprehensive judgement comprising administrative policy on road network taking into account the present and future traffic demands, environmental aspects, availability of fund in addition to engineering and economic evaluation.

(2) Evaluation of improvement effects

Effectiveness of proposed improvement plans was analysed mainly by such evaluation factors as the engineering effects of decreases in saturation degree queue length and stopped delay, and the economic factors in terms of net benefit, benefit cost ratio, and economic internal rate of return (IRR).

For Petburi/soi Asok intersection improvement planning was minimized considering future larger scale improvement of Middle Ring Road. Therefore, the engineering effects and the economic factors were calculated for nine (9) locations excluding the above.

It is to be mentioned that this evaluation does not include such factors as the improvement policy and strategy of concerned authority and availability of funds needed for implementation of the plans, which will be dealt with by the road administrators.

Table 5.1.1 Summary of Improvement Plan

Location	Recommended Improvement	Direction	Length
1. Rama IV/ Si Phraya-Sathon	Sathon : Two-way, 4-lane flyover Si Phraya-Silom : Two-way, 4-lane (partly 2-lane) continuous flyover	Rama IV direction	Sathon: unknown Si Phraya-Silom: 1,470 m
2. Ratchadamnoen Klang/Nai	One-way, 3-lane underpass	Ratchadamnoen - Phrapinklao	520 m
3. Dindaeng/ Ratchaprarop	At Ratchaprarop : One-way, 2-lane flyover (including 1 reversible) At Expressway : One-way, 2-lane underpass	Dindaeng-Ratchawithi. Dindaeng Rd. direction	420 m 390 m
4. Pradiphat/ Phahon Yothin	Two-way, 3-lane (including 1 reversible) flyover	Pahon Yothin Rd.	520 m
5. Petburi/ Rama VI	One-way, 2-lane flyover	Petburi Rd.	520 m
6. Pracharat II/ Pracha Chuen	At-Grade (new road)	Along Khlong Prapa	730 m
7. Sukhumvit/ Rama IV	Two-way, 2-lane flyover	Rama IV Rd.	770 m
8. Petburi/ Ramkhamheang	At-Grade (Road widening)	All directions	-
9. Rama IV/ Kasemrat	At-Grade (new road)	Beside Soi Ari	250 m
10. Dindaeng-Asok	(Plan coordination with Middle Ring road required)		-
11. Petburi/Soi Asok	At-Grade (increase of lane numbers)	Two direction	-

The summary of evaluation by engineering factors is presented in Table 5.1.2, and that by economic factors in Table 5.1.3, and the combined evaluation of each improvement plan is summarized as follows:

i) Rama IV/Si Phraya - Sathon Intersection

The proposed improvement plan at these intersections to provide a continuous flyover gives the largest effects of all in terms of both engineering and economic aspects. This plan will allow the main traffic flow of 2,700 PCU/hr. at the Silom intersection in peak hours to be transferred to the flyover. As Mass Trasit System is planning here, the close coordination with ETA is required.

In terms of engineering effects, saturation degree, queue length and stopped delay can be reduced from 1.09 to 0.78, from 300 m to 50 m, and 240 seconds to about 40 seconds, respectively at the Rama IV/Silom intersection. In terms of economic effects, this plan can yield the net benefit of nearly 600 million Baht with the B/C ratio of 2.6 and the IRR of 0.23 in 10 years.

It is concluded that this plan can be designated to be excellent.

ii) Ratchadamnoen Klang/Ratchadamnoen Nai Intersection

The proposed plan is to improve this intersection by providing an underpass along Ratchadamnoen Klang Road to the approach of the Phrapinklao Bridge, in order to preserve the existing historical and environmental conditions around Sanam Luang. By this plan the main traffic of about 3,400 PCU/hr. in peak hours at this intersection will be transferred to the underpass.

This plan will improve the saturation degree, queue length and stopped delay from 0.99 to 0.80, 450 m to 30 m and 670 sec. to 30 sec. respectively on the main flow in peak hours. It also yields the net benefit of 110 million Baht with the B/C ratio of 1.6 and the IRR of 0.107 in 20 years although in 10 years the B/C ratio is nearly break-even.

This plan can be regarded as the plan of necessity bearing moderate improvement effects with the environmental conditions being given the first priority.

iii) Dindaeng/Ratchaprarop Intersection

The plan is to provide a combination of a flyover at this intersection and

Table 5.1.2 Summary of Evaluation by Engineering Factors

Name of Intersection	Saturation Degree	Max. Queue length (m)	Max. Stopped delay (sec./veh)	Main Traffic flow (PCU/Hour)	Remarks
1. Rama IV/Si Phraya-Sathon Rd.	1.09 0.78	300 50	240 40	2,700	Evening Silom Inter-section, Flyover
2. Ratchadamnoen Klang/ Ratchadamnoen Nai Rd.	0.99 0.80	450 30	670 30	3,400	Morning Underpass
3. Dindaeng/ Ratchaprarop Rd.	0.88 0.51	500 70	240 30	4,000	Morning Flyover
4. Pradiphat/ Phahon Yothin Rd.	0.75 0.69	550 60	350 30	2,500	Morning Flyover
5. Petburi/Rama VI Rd.	1.00 0.74	550 20	260 10	3,500	Morning Flyover
6. Pracharat II/ Prachachuen Rd.	1.06 0.68	120 30	150 30	1,700	Morning At-Grade
7. Sukhumvit/Rama IV Rd.	0.91 0.37	650 40	340 20	3,800	Morning Flyover
8. Petburi/Ramkham-haeng Rd.	1.20 0.81	800 30	760 30	4,100	Morning At-Grade
9. Rama IV/Kasemrat Rd.	1.04 0.82	550 50	420 40	3,900	Morning At-Grade

Note : Upper figure = Before improvement
Lower figure = After improvement

Table 5.1.3 Summary of Economic Evaluation of Proposed Plans

(Unit: Cost & Benefit; Baht in million)

Plan No.	Imp. Alt. No.	Improvement Location (Intersection)	Const. Period (Year)	Initial Cost	O/M Cost (per year)	Evaluation Period: 10 Years							Evaluation Period: 20 Years						
						Cost (C)	Benefit (B)			Evaluation			Cost (C)	Benefit (B)			Evaluation		
							Time Saving	VOC Saving	Total Benefit	Net Benefit (B-C)	B/C	IRR		Time Saving	VOC Saving	Total Benefit	Net Benefit (B-C)	B/C	IRR
P-1	3	Rama IV / Si Phraya - Sathon	2	361.7	3.9	377.09	912.86	81.24	994.10	617.01	2.64	0.233	396.51	1651.03	146.94	1797.97	1401.46	4.53	0.268
P-2	3	Rachadamnoen Klang / Nai	3	134.4	4.2	150.14	133.83	12.58	146.41	-3.74	0.98	0.031	171.05	260.75	24.51	285.26	114.21	1.67	0.107
P-3	2	Din Daeng / Rachaprarop	3	98.5	3.7	113.30	212.52	39.74	252.26	138.96	2.23	0.189	131.72	414.07	77.43	491.50	359.78	3.73	0.234
P-4	3	Pradipat / Phahon Yothin	2	76.7	1.1	81.64	168.40	64.50	232.90	151.25	2.85	0.255	87.12	304.57	116.65	421.22	334.10	4.83	0.287
P-5	2	Petburi / Rama VI	2	45.6	1.2	51.90	179.47	61.38	240.85	188.94	4.64	0.397	57.87	324.59	111.01	435.60	377.73	7.53	0.415
P-6	1	Pracharat II / Pracha Chuen	1	24.1	0.5	27.65	26.86	10.50	37.36	9.71	1.35	0.107	30.14	45.67	17.85	63.52	33.38	2.11	0.160
P-7	3	Sukhumvit / Rama IV	2	70.4	1.5	77.96	156.17	20.30	176.47	98.51	2.26	0.207	85.42	282.45	36.71	319.16	233.74	3.74	0.245
P-8	1	Petburi / Ramkhambeng	1	30.5	1.0	37.61	288.87	121.04	409.91	372.30	10.90	0.951	42.59	491.16	205.80	696.96	654.37	16.37	0.952
P-9	1	Rama IV / Kasemrat	1	36.5	0.6	40.76	73.27	32.10	105.37	64.60	2.58	0.272	43.75	124.59	54.57	179.16	135.41	4.09	0.299

Source: JICA Team Estimation

Remarks:
1. Costs and Benefits are calculated at 1986 price.
2. Rate of discount: 5% per annum.
3. Traffic flow and volums are set at 1986 level.
4. Weighted average time value: 22.1 Baht per vehicle-hour.
5. VOC stands for vehicle operating cost, comprising the costs of fuel, oil, tyres, depreciation, maintenance for parts and labour, interest and age depreciation.

an underpass crossing under the Expressway in east-west direction on the same road.

By this improvement, saturation degree, queue length and stopped delay will be reduced from 0.88 to 0.51, 550 m to 70 m, and 240 sec. to 30 sec., respectively on the main flow peak hours by transferring the main traffic flow of about 4,000 PCU/hr. to the flyover and connecting underpass. The net benefit yielded by this plan accounts for about 130 million Baht with the B/C ratio of 2.2 and the IRR of 0.19 in 10 years.

This plan is regarded as a highly effective one.

iv) Pradipat/Phahon Yothin Intersection

A three lane with one resersible lane flyover is proposed in the north-south direction at this intersection. It is located in the north commercial area of Bangkok. This plan will let the main traffic flow of about 2,500 PCU/hr. in the peak hours to be transferred to this flyover, by which saturation degree, queue length and stopped delay will be reduced from 0.75 to 0.69, 550 m to 60 m and 350 sec. to 30 sec. respectively. The net benefit for 10 year period accounts for about 150 million Baht with the B/C ratio of 2.8 and the IRR of 0.26.

This plan is considered to be fairly effective.

v) Petburi/Rama VI Intersection

The improvement plan is to extend the existing flyover to the eastward 530 m. crossing over this intersection. By this plan saturation degree, queue length and stopped delay will be reduced from 1.00 to 0.74, 550 m to 20 m, and 260 sec. to 10 sec. on the main flow in peak hours whose traffic volume counted at 3,500 PCU/hr.
The economic net benefit yielded in 10 years accounts for 180 million Baht with the B/C ratio of 4.6 and the IRR of 0.40. It is to be mentioned that this plan requires close coordinations with ETA's second stage expressway plan.

This plan is regarded as highly effective both in engineering and economic factors.

vi) Pracharat II/Pracha Chuen Intersection

This plan is to construct a new road along Khlong Prapa by land acquisition of about 2,800 sq. m. By implementation of this plan, saturation degree, queue length and stopped delay of the main traffic flow of about 1,700 PCU/hr. in peak hours will be improved from 1.06 to 0.68, 120 m. to 30 m., and 150 sec. to 30 sec. Due to the need for land acquisition which raises the project cost, the net benefit and the B/C ratio are relatively small. In 10 years, but they will be 9 million Baht and 1.3 respectively, and the IRR is 0.107.

This plan can be said effective in engineering aspects factors.

vii) Sukhumvit/Rama IV Intersection

This plan is to provide a flyover on Sukhumvit Road, by which the main traffic flow with about 3,800 PUC/hr. in peak hours will be transferred, and saturation degree, queue length and stopped delay will be reduced from 0.91 to 0.37, 650 m. to 40 m. and 340 sec. to 20 sec. respectively.

The net benefit yielded by this plan will be 98 million Baht with the B/C ratio of 2.2 and the IRR of 0.21 in 10 years.

This plan can be said fairly effective both in engineering and economic factors.

viii) Petburi/Ramkhamhaeng Intersection

This plan is to widen the road widths of four-leg roads as one of at-grade improvement plans requiring only a small land acquisition. Implementation of this plan will improve the main traffic of 4,100 PUC/hr. in the peak hours by reduction of saturation degree, queue length and stopped delay from 1.20 to 0.81, 800 m to 30 m., and 760 sec. to 30 sec. respectively. The net benefit yielded in 10 years accounts for about 370 million Baht with the B/C ratio of 10.9 and the IRR of 0.95.

This plan is considered to be fairly effective both in engineering and economic factors.

ix) Rama IV/Kasemrat Intersection

This plan is to improve the alignment of offset intersection by providing a new road branching from Soi Ari, by which saturation degree queue length and stopped delay of the main traffic flow of 3,900 PCU/hr. in the peak hours will be improved from 1.04 to 0.82, 550 m to 50 m, and 420 sec. to 40 sec. respectively. The net benefit in 10 years accounts for 64 million Baht with the B/C ratio of 2.5 and the IRR of 0.27.

This plan is considered to be fairly effective in engineering and economic factors.

x) Petburi / Soi Asok Intersection

This plan is to increase the number of lanes by channelization, by which smooth traffic flow will by secured.

It is concluded that all the ten improvement plans worked out and evaluated in this study prove to be effective from comprehensive viewpoints of evaluation, although there are some varieties in the extent of their effectiveness.

5.2 Rama IV/Si Phraya - Sathon Rd., No.020-023

(1) General description

In Rama IV road, Rama IV/Sathon Rd. intersection was selected for improvement planning. But it is closely related with neighboring three intersections in Rama IV road, namely from the east, Si Phraya, Surawong and Silom roads (Figure 5.2.1). Therefore, the four intersections are studied together in this section. These four are most congested ones in Rama IV road. Especially in the evening peak hours, due to congestion at Sathon and Silom intersections, the traffic flow is almost stopped for nearly 10 minutes at each intersection.

In August 1986, Belgian government signed a letter of intent to donate a temporary flyover at Sathon intersection. If it is completed, it will ease the congestion to some extent but seems to be not a final solution to these most congested areas.

(2) Traffic flow

Traffic flow at each intersection is shown in Figure 5.2.2. Major traffic flow is east - west direction. The more east the intersection is located, the more the traffic volume is (p.m. peak). The queue length is shown in Figure 5.2.3. In the evening peak hours, it is found that the road surfaces in Rama IV road is almost occupied by the long queues of vehicles.

Figure 5.2.4 shows the traffic flow of Sathon intersection. In the morning peak hour, west bound (inbound) traffic is more than east bound (outbound) and vice versa in the evening. The characteristic feature of the intersection is a large turning movement to/from Sathon road. It is because the Sathon road leads to the Taksin bridge and it is one of the most important roads which connect Bangkok with Thonburi side.

(3) Constraints

1) Distance between intersections

Distance between four intersections are as follows.

Si Phraya - Surawong - Silom - Sathon
600 m 350 m 900 m

Distance between Surawong and Silom is only 350 m.

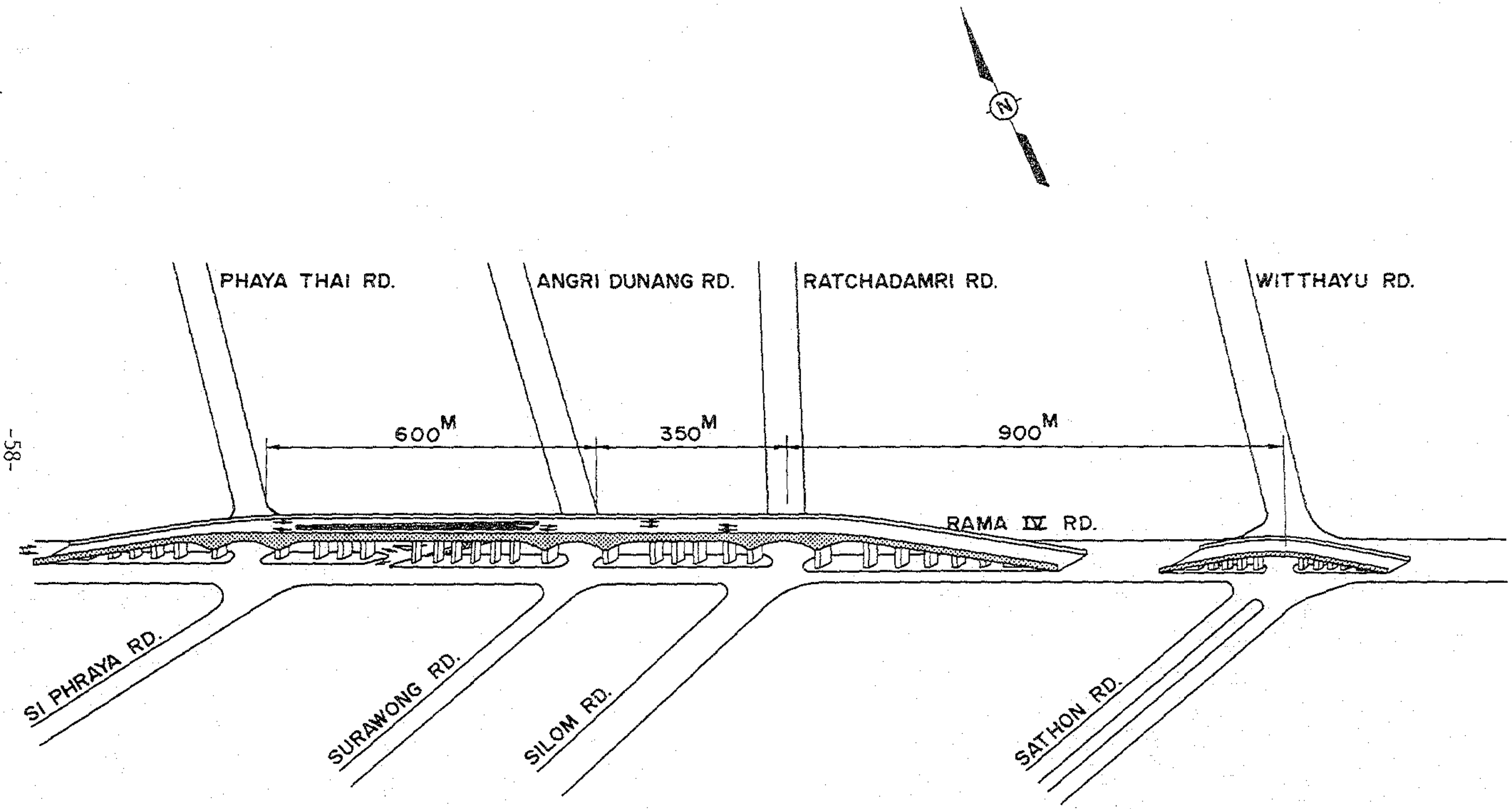


Figure 5.2.1 No. 023 Rama IV/Si Phraya-Saton Rd.
Conceptual Plan (Recommended Flyover Improvement)

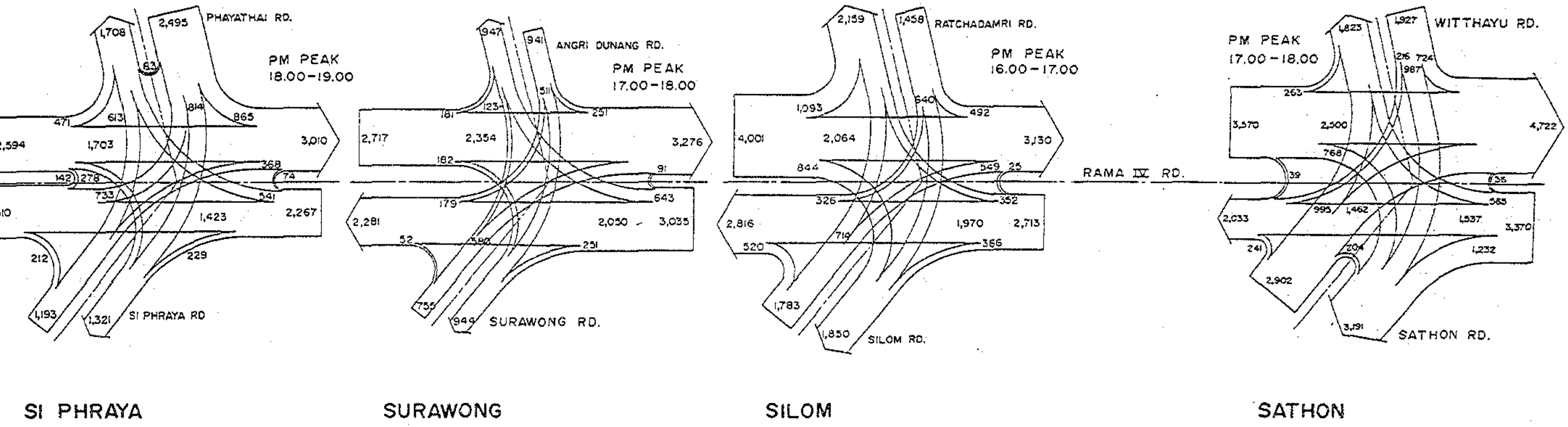


Figure 5.2.2 Traffic Flow at Four Intersections in Rama IV Rd.

(AT EACH PM PEAK HOUR)
UNIT : PCU/hr

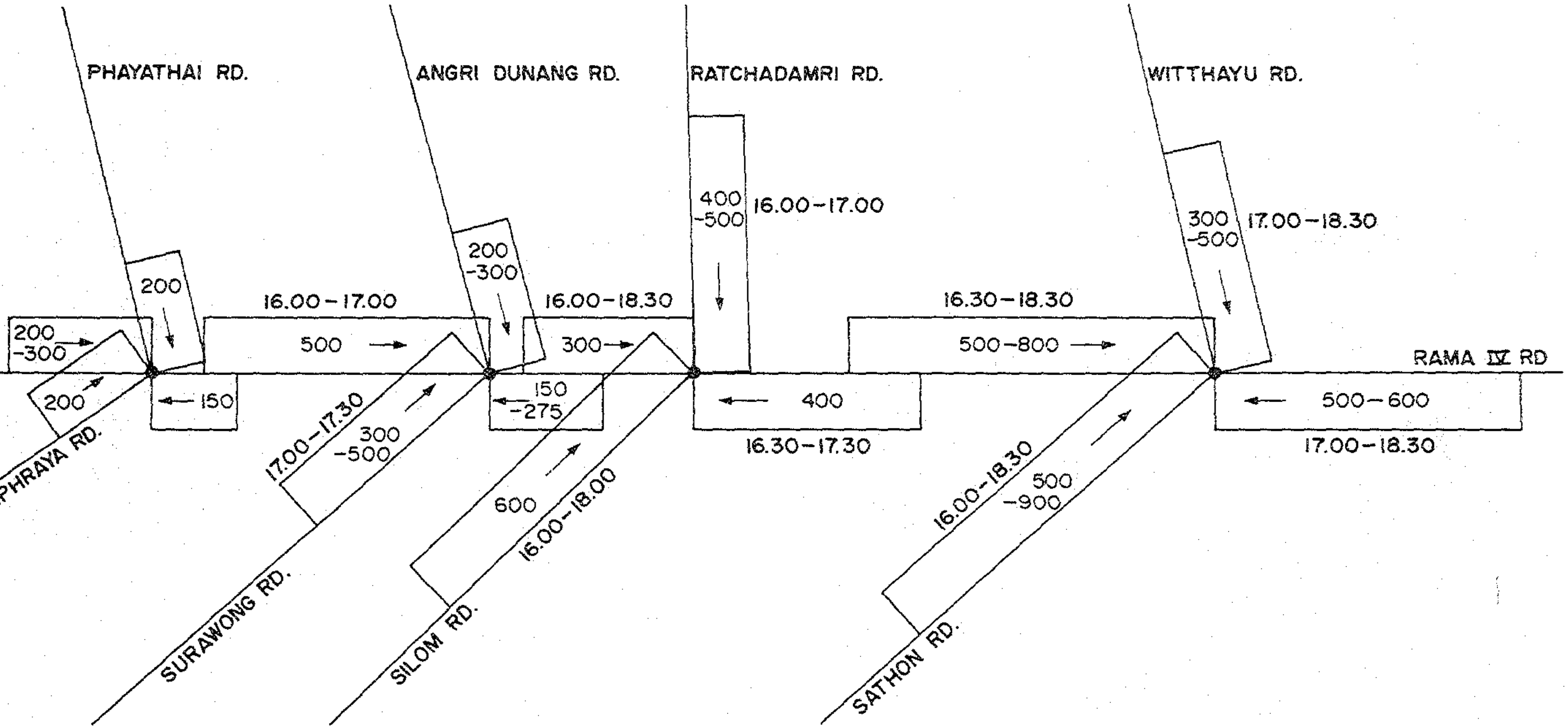
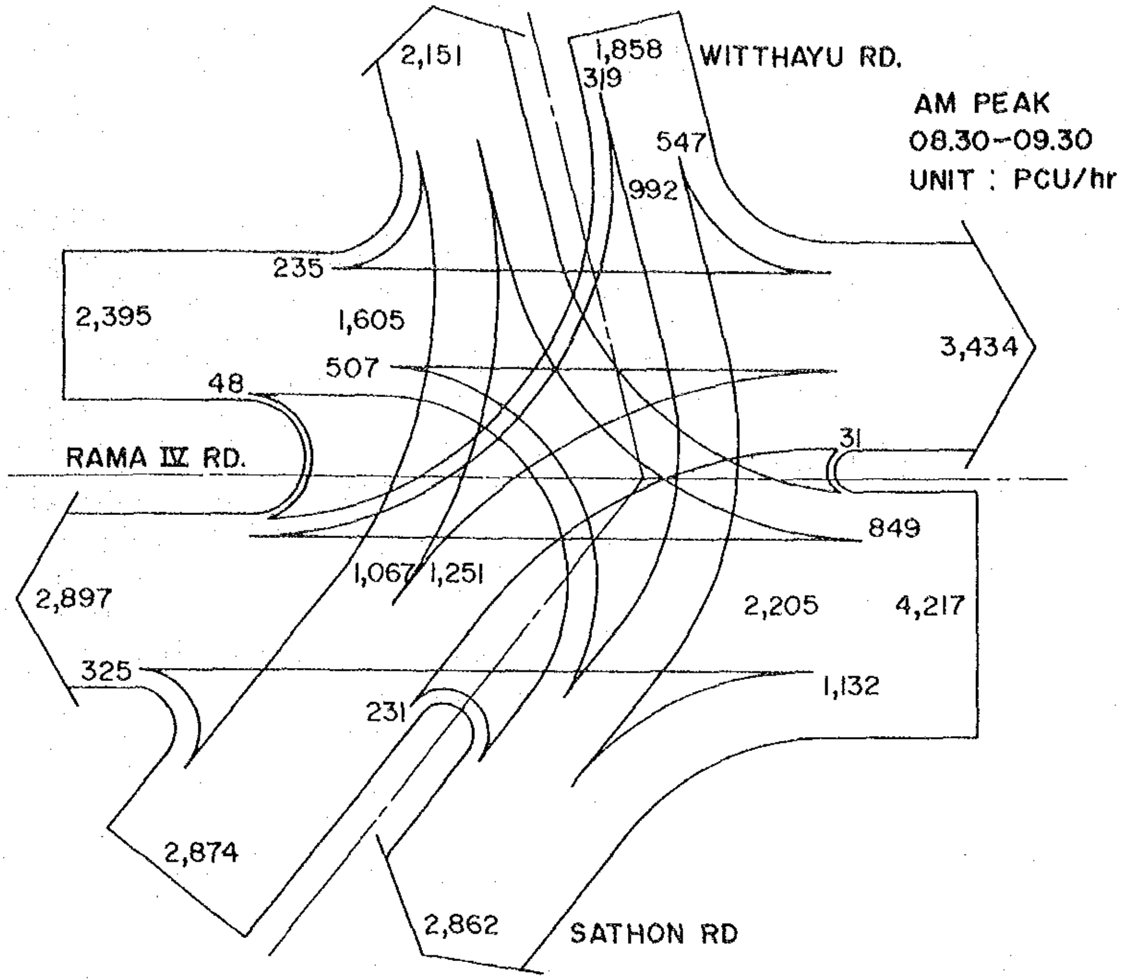


Figure 5.2.3 Queue Length (PM. Peak Hour), Unit : M at Rama IV Intersections



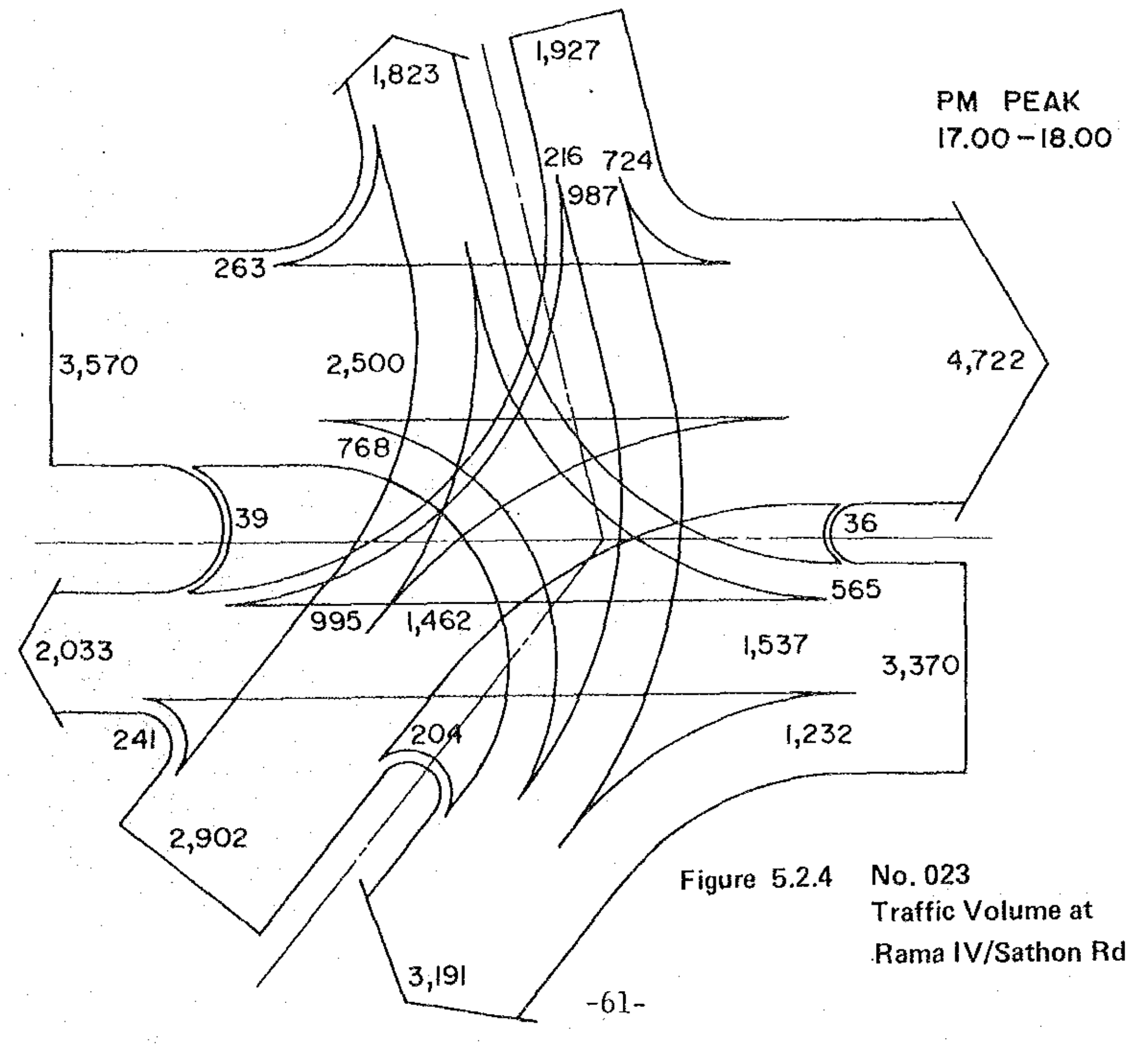


Figure 5.2.4 No. 023
Traffic Volume at
Rama IV/Sathon Rd.