7. IMPLEMENTATION PROGRAM AND PLAN EVALUATION

7.1 Implementation Program

1) Implementation Scheduling

Development phase and priority of the projects to maximize the benefits in intermediate stages have been determined with consideration of following criteria; economic viability, traffic volume, network configuration, urban development and especially financial constraints and sectorial priority between rail transit and road transport.

Total financial capability of Bangkok concerning transport infrastructure investment was estimated based on the allocation in the 6th Plan and expected future economic growth. It is considered that roughly 250 billion Baht will be available by year 2006 or for the 7th, 8th and 9th Plans. For each plan period, an amount of 70, 80 and 100 billion Baht was allocated, respectively.

Implementation scheduling was determined as follows:

a. Investment in rail transit projects will be mainly done in 8th and 9th Plan periods considering the large investment size and implementation difficulties.

b. Bus-ways which require relatively small investments will be implemented in the 7th and 8th Plan periods to meet urgent needs of public transport improvement.

c. Additional expressways will be implemented in the 8th and 9th Plan periods, because the ongoing SSE alone consumes a sizable amount.

d. Emphasis is placed on the investment of at-grade main roads and especially distributors. The completion of the outer ring road can be delayed.

2) Investment program

Based on the above-mentioned scheduling, the proposed projects are allocated to an annual investment program as shown in Figure 7.1.

A circular expressway (X121-123) and Asoke fly-over (X170) are allocated to the latter half of the 7th Plan period for starting preparation works. A bus-way planned above the Saen Saep canal (B091 and 095) is expected at the beginning of the 7th Plan period. Some main road projects are scheduled to start by the end of the present Plan period, both to alleviate the present traffic congestion and to provide a base for upper level structures like the expressway and bus-way.

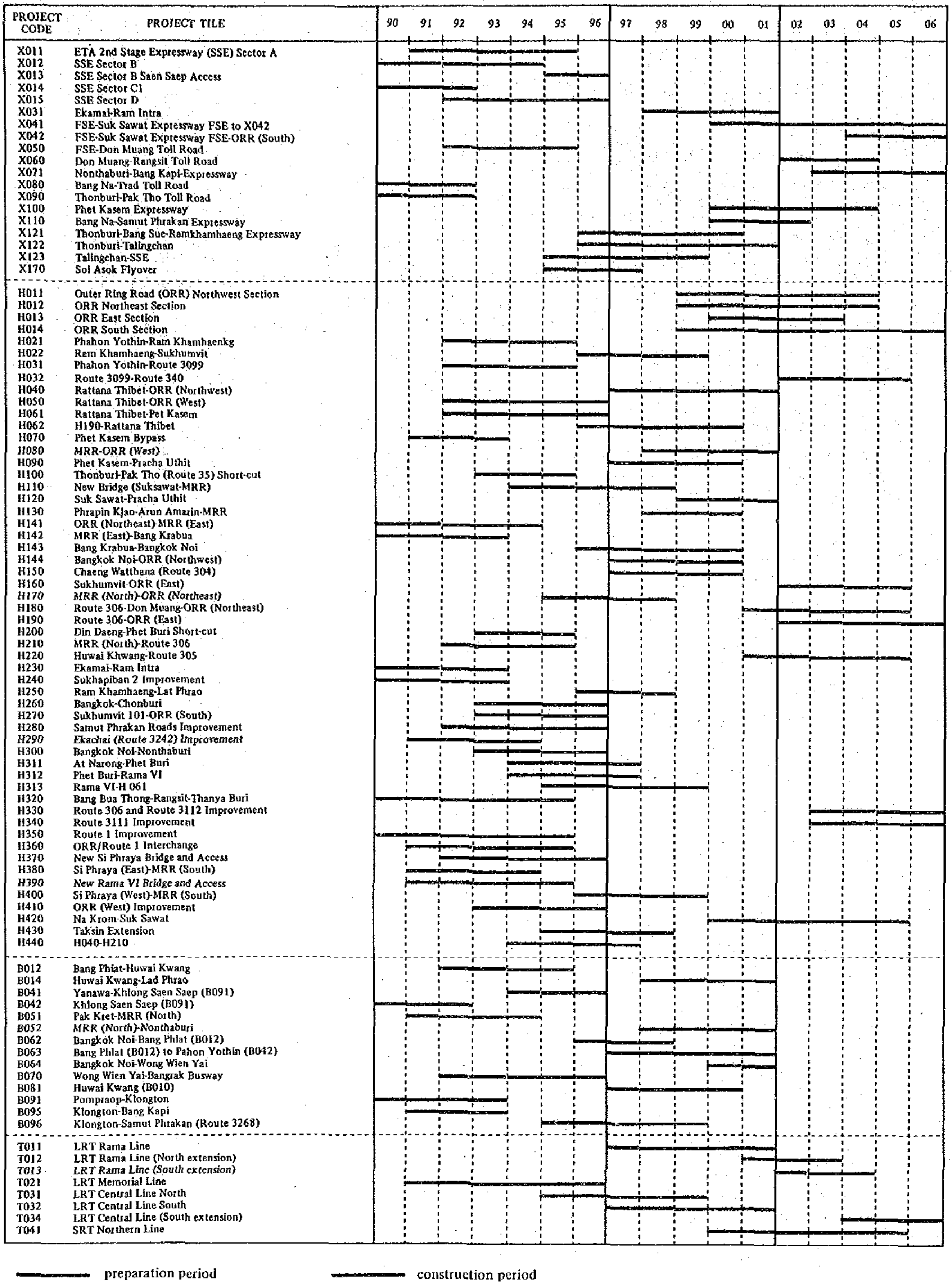


Figure 7.1 Investment Program

7.2 Plan Evaluation

The economic effects of the Road Master Plan are evaluated in time series based on the investment program. Costs include the facility maintenance costs as well as the investment costs. Benefits are assumed to be vehicle operating cost savings which are expected after the implementation of the plan.

The flow of cost and benefit during the accounting period of 1990 and 2006 is shown in Table 7.1.

The net benefit will be shifted to a positive balance at the end of the Seventh Plan period, and will maintain positive values at a level of 10 billion baht per year during the Eight Plan period. After 2002, it will widen rapidly to a level of 30 billion baht per year in 2006 excluding residual values.

As the evaluation indicators show, the master plan as a whole is considered to be economically feasible. The projects scheduled to be completed by the end of the Seventh Plan period are sufficiently viable, presenting the net present value of 17 billion baht and over 20% of the internal rate of return.

The master plan calls for considerable investments during the Seventh and Eighth Plan periods. These efforts will arrest the worsening of the present traffic condition, and lay the groundwork for a remarkable effect in the coming twenty-first century.

Table 7.1 Flow of Cost and Benefit

(Million Baht at 1989 price)

Year	Cost	Benefit	Net Benefit
1990	249	0	-249
1991	4813	0	-4813
1992	10277	0	-10277
1993	10595	2147	-8448
1994	11596	4160	-7436
1995	10986	5413	-5573
1996	7848	14918	7070
1997	5272	18944	13672
1998	7498	17565	10067
1999	8564	17222	8658
2000	7937	18287	10350
2001	7989	19770	11781
2002	7315	22619	15304
2003	7864	24320	16456
2004	9213	23707	14494
2005	7340	31760	24420
2006	-74335	35668	110003
Total	51021	256500	205479

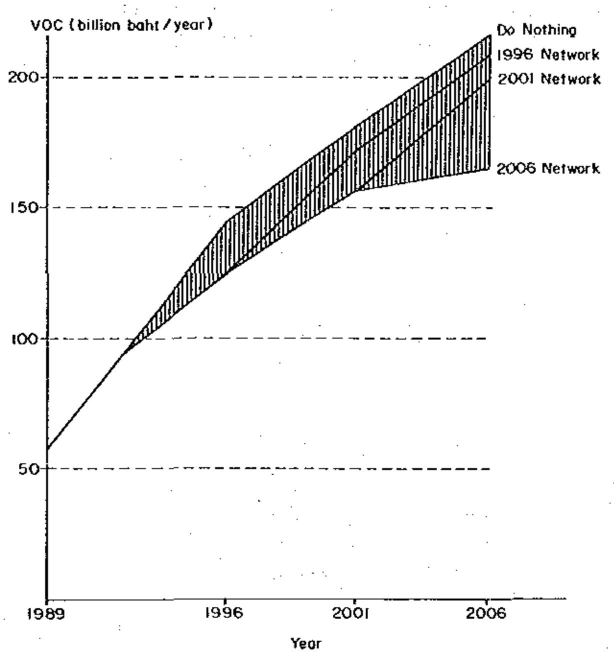


Figure 7.2 Benefit of Masterplan

Table 7.2 Evaluation Indicators

	NPV (million baht)	B/C	IRR (%)
Master Plan	26,878	1.65	22.0
7th Plan Period Projects	16,800	1.56	21.2

8. RECOMMENDATIONS

8.1 Proposed Transportation Network Development Programme

Traffic problems of Bangkok are already very serious, but will become even more serious in the future, unless fundamental measures are properly taken. Direct and indirect traffic costs are almost equivalent to 20% of Bangkok's gross regional product, caused by the prolonging of commuting hours, environmental deterioration, and discouragement of investments and tourism. One of the major factors which contribute to this situation is the deficiency in urban transportation system, particularly road and road transport.

In order to meet the future transportation demand of both private and public modes at certain service levels, the study revealed that a package of road projects, comprising expressways (a total of 184 km), segregated bus-ways (121 km), at-grade main roads (599 km) and distributors (56 km specifically identified only in and around the city centre) has to be implemented by year 2006, in addition to the development of the extended LRT system (91 km) and elevated Northern Line of SRT (45 km). All these projects are economically viable. However, it is noted that they have to be implemented with due consideration of project interaction and proper scheduling.

Particularly high economic returns are expected from the implementation of the at-grade main roads (primary and secondary roads) and distributors. They are also very important to support various elevated transportation infrastructures. Extensive bus-ways have been proposed to encourage the expansion of more attractive and competitive public transportation system, in integration with conventional bus system and the proposed rail transit systems. Although the technological aspects have not been fully studied and actual application cases are very limited, it is considered that the projects are worthy of further detailed studies.

The financial requirements of the proposed projects are approximately 240 billion Baht in 17 years between 1990 and 2006.

Table 8.1 Investment by sector and by period

(Million Baht at 1989 price)

Sector	1990-1996	1997-2001	2002-2006	Total
Expressway	30906	21011	18672	70589
At-grade main road	16787	9413	12726	38926
Bus-way	11217	4313	-	15530
Railway	13621	40918	60713	115252
Total	72531	75655	92111	240297

To implement the projects without delay, the following particular aspects should be duly considered:

a. Expansion of Financial Sources: This includes modification of budget allocation priority to metropolitan traffic improvement, increase of vehicle related taxes, introduction of new revenue sources such as toll facilities and area licensing scheme, promotion of BOT scheme, application of land readjustment system and direct beneficiary payment system, and so on.

b. Strengthening of Land Acquisition Capabilities: Land acquisition for the projects is becoming more and more difficult. The Government should work out effective method of land acquisition through adequate institutional, legislative, and financial measures, to ensure the smooth execution of the projects.

8.2 Transport System Management Measures

In order to maximize the use of the capabilities of the existing and proposed road network and facilities, there is a number of key policy issues that have to be duly considered and incorporated with the physical developments. They, among others, are:

a. Demand Management and Control: In addition to the expansion of the already existing various traffic control measures, policies need to be directed towards more effective management of the demand, such as restraints of private car ownership and utilization, improvement of public transportation, and more effective urban development control.

b. Integrated and Coordinated Transportation Planning and Policy Setting: Complex urban transportation problems cannot be settled by any single means. Benefits can only be fully tapped from coordinated implementation of various interactive projects. Proper organization and institutional support are necessary. Various information necessary for transportation planning is available but not well managed as a data base which can be readily and daily used by relevant agencies. To accelerate decision making process and better planning, a proper information management system should be worked out.

c. Strengthening of Bus Transportation: Bus will still be the primary public transportation mode even after the completion of the proposed rail transit system. However, without proper integration among the rail transit, bus and other transportation modes, the future public transportation would not become attractive nor competitive. Toward this, reorganization of bus routes and development of proper mode interchange functions and facilities at strategic nodes are particularly important.

8.3 Proposed Studies

This Study worked out medium to long-term directions of road development. In order, however, to implement the proposals effectively, more concrete plans need to be formulated by conducting the following studies :

a. Feasibility Study on Transportation Corridor Development: As urban development is aggressively taking place along major transportation corridors, proposed projects will be studied in a package and integrated with urban development.

b. Feasibility Study on New Ring Road: To meet the medium-term demand and encourage effective urban development, a new ring road between the Middle Ring Road and Outer Ring Road is worth studing.

c. Feasibility Study on Bus-ways: Stemming from the belief that bus-way will have a strong impact on Bangkok public transportation system, its feasibility should be thoroughly examined on engineering, operational and management aspects.

d. Feasibility Study on Secondary and Distributor Roads: Development of secondary and distributor roads in Bangkok is determined to be very important not only from the viewpoint of traffic efficiency but also because of its positive effects on urban and community development.

e. Study on Transportation Transfer Points: Future urban transportation system in Bangkok will be composed of various transportation modes such as rail transit systems, bus-ways, and roads. To encourage the integration of these modes within an effective urban transportation system, transportation transfer points where passengers terminate or transfer should be properly developed.

f. Study on Coordination of Elevated Facilities: Components of proposed elevated transportation system intersect at many locations. In order to use the air space effectively and preserve urban aesthetics and amenity, a study is necessary to determine the planning rules and principles for the development of facilities at these transportation nodes.

g. Study on Parking: Parking is an area which affects the use and control of private vehicles. Explicit policy should be formulated on the role and responsibility of the Government and private sector, design criteria, fare setting, etc.

h. Study on the Impact Management during Construction Period: Implementation of a large number of proposed projects will continuously have an adverse affect on the urban traffic flow. To minimize the negative impact, a separate traffic management system plan needs to be formulated which can be constantly adjusted according to the changes in construction schedule and magnitude of the projects.

PART 2

FEASIBILITY STUDY ON AREA TRAFFIC CONTROL SYSTEM

Part 2 Feasibility Study on Area Traffic Control System

Table of Contents

1. INTRODUCTION

1.1 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, where signals are currently manually controlled, is expected to have little effect in improving traffic flow in the area, as the existing system is considered to be unsuitable for this purpose.

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

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

1.2 Objective

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

The Study area consists mainly of the area within the Middle Ring Road, as shown in Figure 1.1.

1.3 Study Approach

This Study was carried out in two (2) Stages for a total of ten (10) months. The work flow is shown in Figure 1.2, and the activities are briefly described below;

(1) Stage 1

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

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

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

(2) Stage 2

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

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

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

Figure 1.1 Study Area

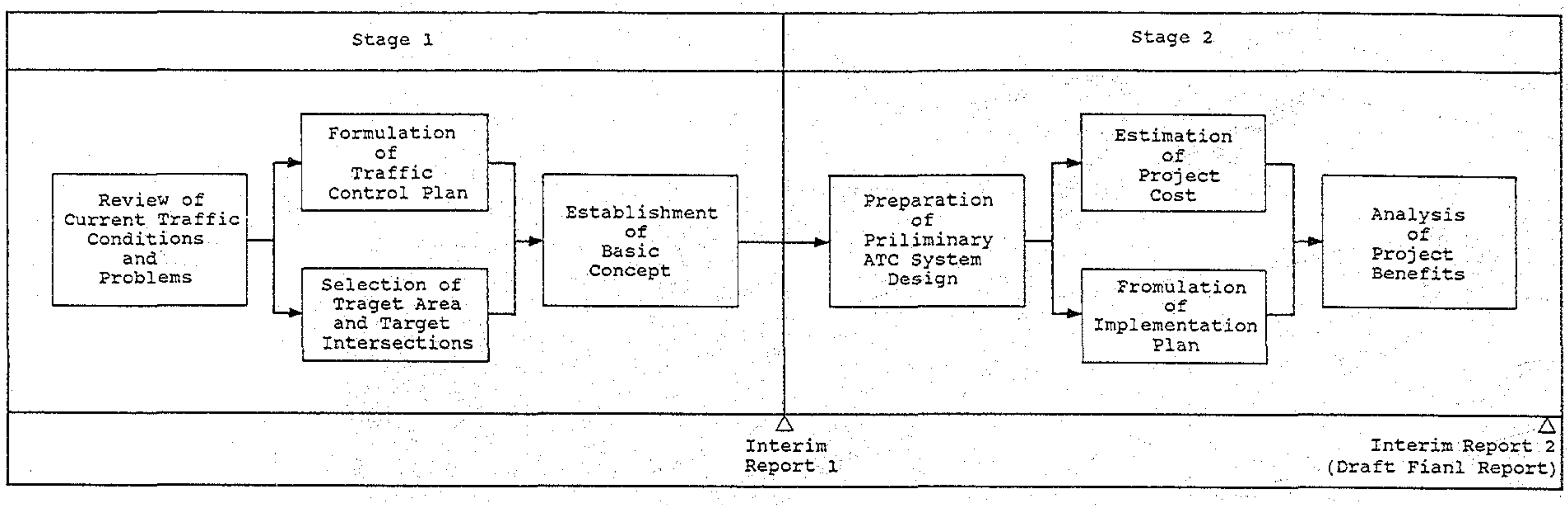


Figure 1.2 Work Flow of the Study

2. FRAMEWORK FOR ATC SYSTEM PLAN

2.1 Target Year

The target year for commencing the operation of the ATC system is set at 1993 when a part of the Second Stage Expressway is supposed to be completed.

2.2 Assumed 1993 Road Network

The road network to be served by ATC will comprise the existing roads and other roads which are presently under construction or planned and scheduled to be complete by 1993.

2.3 Area for ATC Planning

The ATC planning area was determined based on the analysis of the relationships between traffic volume and link length and that between current traffic congestion and future road network. The area covers 101 sq.kms and includes the following main areas (See Figure 2.1).

a) Middle Ring Road, Phetburi Road, Phrakanong Klongtan Road, Rama IV Road, Sathon Road, Phrachao Taksin Road, Chao Phraya River

b) Western and eastern parts of the Middle Ring Road

c) Lat Phrao Road - Lat Phrao 053 Road

d) Ramkham Haeng Road - Lat Phrao Road

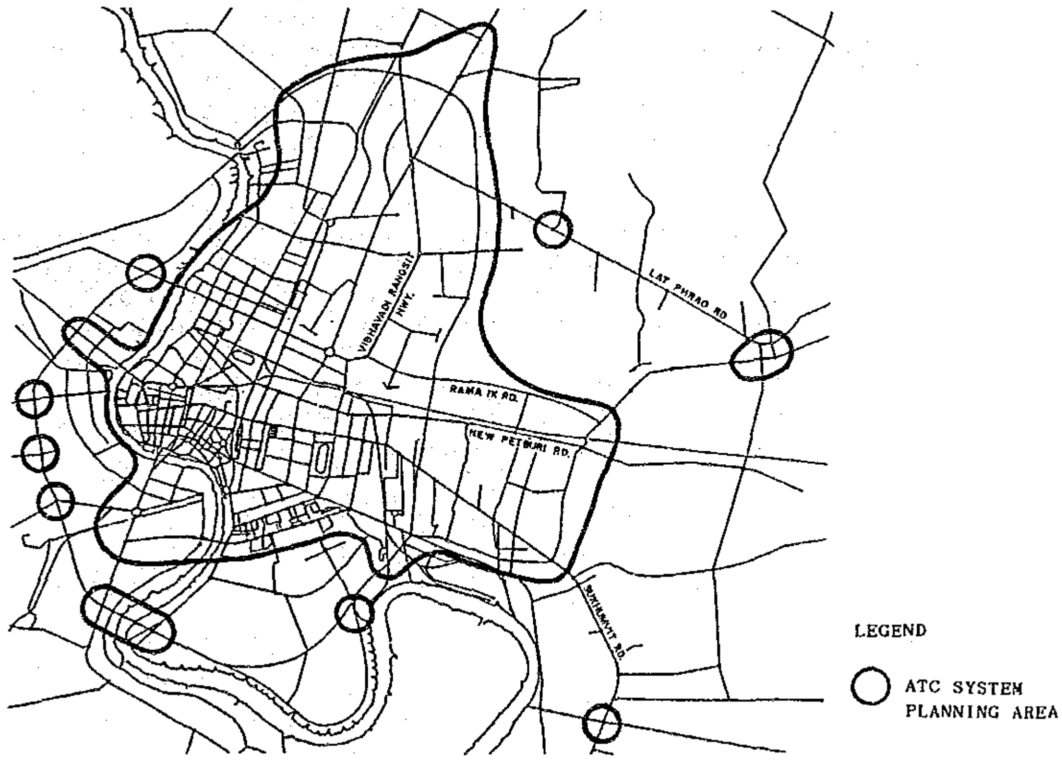


Figure 2.1 ATC System Planning Area

3. CURRENT TRAFFIC CONDITIONS

Traffic conditions on the existing road network have been analyzed based on the available data and various supplemental field surveys. Major problems identified regarding traffic flow and signal facilities are summarized below:

3.1 Traffic Flow Problems

Problems of existing traffic flow are briefly as follows:

a) CBD area enclosed by Rama IV, Middle Ring Road, Dindaeng, Ratcha Withi and Chao Phraya River, suffers from chronic traffic congestion due to the concentration of a substantial volume of traffic.

b) The traffic situation in the above area is particularly serious during morning and evening peak hours when major signalized intersections become saturated. Travel speeds during these periods fall to less than 10 km/h, vehicles come to a standstill at the intersections, and long queues are seen.

c) A large number of major signalized intersections have a saturation degree of more than 1.0.

d) Traffic volumes on major roads fluctuate in complicated and diverse patterns during a day. Large fluctuations are also seen from day to day. It is, therefore, extremely difficult to control such traffic by pre-timed signal control.

e) In the above mentioned CBD area, very heavy congestion is observed along 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.

f) There is a tendency of high accident frequency on Rama IV, Sukhumvit, Phetburi, Phaya Thai, and Si-Ayutthaya, where congestion is severe. The rear-end collision is the accident type which occurs most frequently.

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

3.2 Signal Facility Problems

Problems related to signal facility are summarized as follows:

a) Existing ATC system: During the last 10 years since the ATC system was introduced, its control parameters have been renewed only a few times. Responses to changes in traffic conditions have been neither timely nor effective.

b) Existing signal control facilities: Nearly all signalized intersections are manually controlled by traffic policemen. The absence of coordination and excessively long cycle durations result in the decrease in intersection capacities.

4. TRAFFIC MANAGEMENT STUDY

4.1 Study Objective and Method

1) Study Objectives

Major traffic circulation control measures currently practiced in Bangkok comprise one-way, unbalanced flow and bus lanes including contra-flow lane in built-up areas and/or on major arterials such as Sukhumvit, Phetburi, etc. Considering the fact that these soon to be altered circulation plans would greatly affect ATC planning, this study has been undertaken as a part of the feasibility study on the ATC system development. Specific objectives of the study are as follows;

a) Review and assessment of the existing traffic circulation control system.

b) Assessment of alternative traffic circulation control system.

2) Study Area

The study covers the area where the existing traffic circulation control system is to be altered; namely the area bordered by the Middle Ring Road in the east, built-up area in the west, Ratcha Withi and Asoke-Dindaeng in the north and Sukhumvit and Rama I in the south.

3) Work Items

The study is composed of the following tasks;

a) Review of existing traffic circulation control system.

b) Tabulation of flow control methods being conducted during peak hours.

c) Review of 1985 OD data by time period.

d) Preparation of OD tables for morning and evening peak hours.

e) Comparison and assessment of alternative traffic circulation plans for existing road network.

f) Determination of 1993 road network and turning movement control at new intersections.

g) Study of traffic circulation plan for 1993 road network.

4) Analysis Method

In order to evaluate the effectiveness of alternative traffic circulation control plans, a simulation model has been developed which can simulate the saturation level of a given intersection by estimating its delay time and queue length. The simulation model covers the area specified in Figure 4.1 and can be applied according to the following procedure;

a) Preparation of OD tables for morning peak (7:00-8:00) and evening peak (17:00-18:00) hours.

b) Determination of link/node conditions for each traffic circulation control alternative plan.

c) Building of peak-hour trip assignment model and preparation of necessary data for the simulation model.

d) Formulation of simulation model.

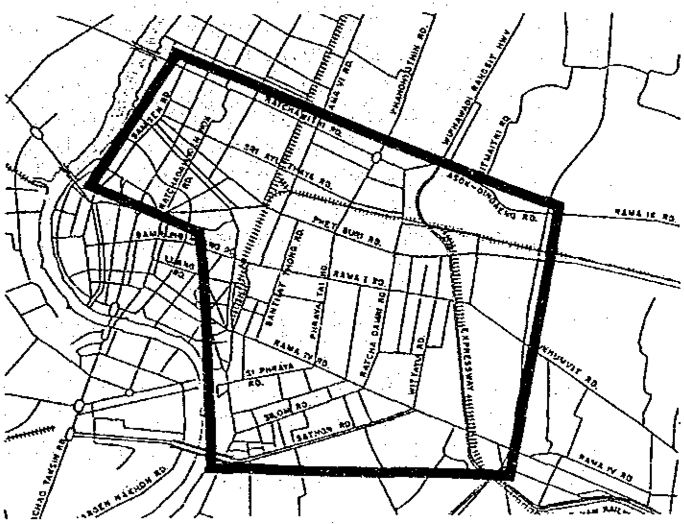


Figure 4.1 Analysis Area for Simulation Model

5) Evaluation Criteria

In order to assess the effectiveness of alternative traffic circulation control plans in the simulation study area as a whole and of the individual intersections or road sections, the following indices were selected;

a) Indices selected for the assessment of the simulation area:

- Total delay time
- Total queue length

b) Indices selected for the assessment of intersections/ road sections:

- Saturation degree and its distribution for intersections
- Average travel speed on relevant major roads

- Queue length at relevant major intersections/road sections
- Queue length on relevant expressway ramps

4.2 Review of Existing Traffic Flow Control System

The existing one-way system was implemented in two stages. Firstly, it was introduced to built-up areas where a large number of relatively narrow semi-arterials criss-cross each other. Then in February 1984, two one-way loops on arterial roads were introduced. Although, at present, contra-flow lanes, reversible lanes and fixed unbalanced flow are combined with the one-way system on arterial roads, the initial 1984 concept of clockwise one-way loops has been basically maintained.

Under the current traffic conditions where many intersections are seriously congested during peak hours, and some oversaturated intersections tend to paralyze the traffic circulation of the network, the increase in detour traffic due to the one-way operation inconveniences much of the traffic outside the one-way loops. Moreover, poor linkage between ETA expressway and connecting roads causes severe congestions at and around expressway ramps, reducing the advantages of expressways.

4.3 Preparation of Alternative Traffic Circulation Plans

Alternative plans aim at reducing the saturation degrees of intersections, delay time and queue length in the concerned areas, and improving the traffic flow to/from the expressways. The plans were prepared with particular consideration of the following aspects;

a) Alternative two-way unbalanced flow systems including reversible lanes to minimize the need of detours and load at intersections.

b) Reversal of existing one-way system to counter-clockwise operation which was suggested by Thai side (requested in Feb. 1989) to reduce the heavy traffic flow between the expressway and city centre during morning and evening peak hours.

On the basis of the above, five alternatives were initially identified and preliminarily assessed. They are shown in Figure 4.2 and described hereafter;

1 Existing system.

2 Fixed counter-clockwise one-way loop operation: reversal of current system (two contra-flow lanes to be provided on Sukhumvit and Phet Buri, respectively).

3 Reversible counter-clockwise one-way loop operation: proposal discussed in Feb. 1989, which induces a large number of sections with reversible lanes.

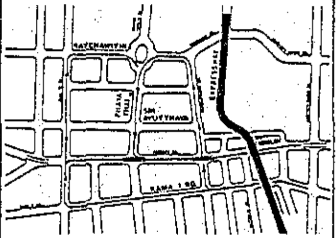
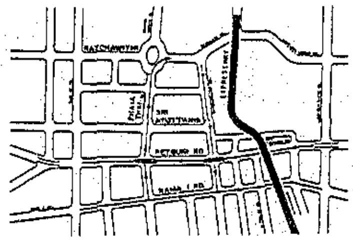
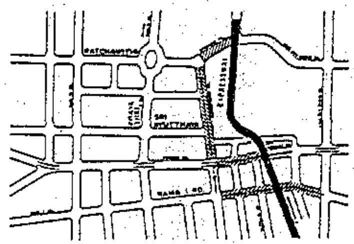
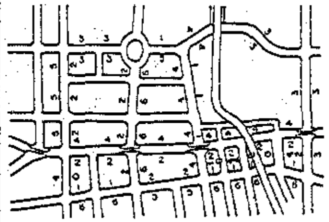
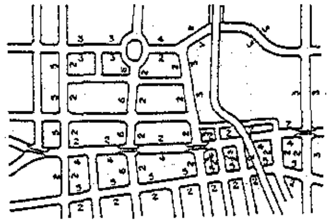
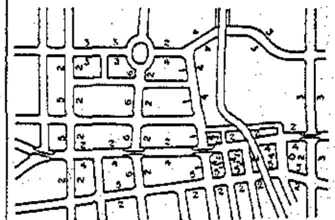
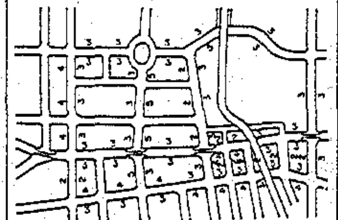
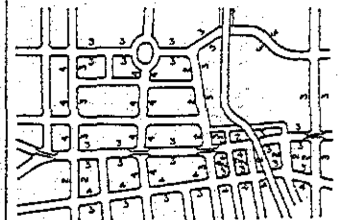
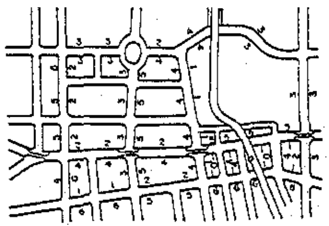
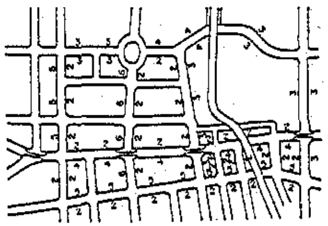
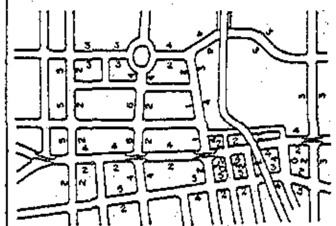
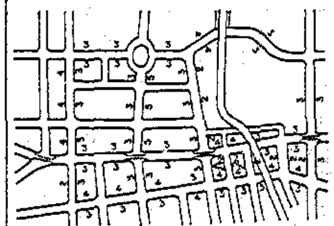
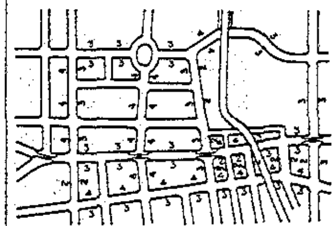
CASE		(1)	(2)	(3)	(4)	(5)
TYPE OF DIRECTION		ONE - WAY	ONE - WAY	ONE - WAY	TWO - WAY	TWO-WAY
REVERSIBLE		○ (MANUAL)	X	○	○	○
MAIN FLOW					 Link with reversible lane	
NO. OF LANE	MORNING PEAK HOUR					
	EVENING PEAK HOUR					

Figure 4.2 Traffic circulation Plan

4 Two-way reversible flow combined with two-way unbalanced flow determined on the basis of trip assignment studies.

5 A simplified version of above 4.

Of the above, alternatives 3 and 5 are found the most effective because lanes can be flexibly allotted to better meet traffic demand of morning and evening peak hours. Accordingly, the following alternatives were selected for more detailed evaluation:

Case 1; Existing System (or 1 in the above selected as base case)

Case 3; Counter-clockwise Circulation System (or 3 in the above)

Case 5; Two-way Reversible System (or 5 in the above)

4.4 Evaluation of Alternative Plans on Existing Road Network

The alternative cases were analyzed and compared. The characteristics are as follows;

1) Delay Time and Queue Length

Case 3 and Case 5 show better performance than the existing system during the morning as well as evening peak hours (See Table 4.1).

2) Saturation Degrees of Intersections

Of 32 major intersections located within the existing one-way system area, the number of intersections with saturation degrees of larger than 1.0 are 16, 15 and 14 under the existing system, Case 3 and Case 5, respectively, while those with saturation degrees of larger than 1.2 are 13, 8 and 5 for the respective three cases (See Table 4.2).

The analysis indicates that the existing system creates very severe congestions with the interactions among a number of oversaturated intersections complicating the problem and tending to oversaturate the entire network. On the other hand, it is less likely that Case 5 would cause oversaturation of the entire network.

3) Saturation Flow Rates at Major Intersections

Of the 32 intersections discussed in 2) above, 14 were further analyzed on their saturation degrees in the morning peak hour. Saturation degrees of Case 3 and Case 5 are smaller except for Ratcha Prarop/Sukhumvit intersection in Case 3. Case 5 lowers the saturation degrees at already saturated intersections, while congestions at undersaturated intersections increase under the existing system. This implies that Case 5 creates more balanced traffic flow within the entire network (See Table 4.3).

Table 4.1 Comparison of Total Delay Time and Queue Length of Alternatives Traffic Circulation Plans on Existing Road Network

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

Table 4.2 Comparison of Saturation Degrees of Major Intersections for Alternative Traffic Circulation Plans on Existing Road Network

Unit : No. of Intersection

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

Table 4.3 Comparison of Saturation Degrees of Major Intersections for Alternative Traffic Circulation Plans on Existing Road Network (Morning Peak Hour)

(Morning Peak Hour)

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

Table 4.4 Comparison of Queue Length for Alternative Traffic Circulation Plans on Existing Road Network for Morning and Evening Peak Hours

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

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

4) Queue Length at Major Intersections

Case 5 shows significant reduction in congestions on the expressway off-ramps during morning and evening peak hours. The performance is similar in Case 3 except on Sukhumvit ramp during the morning peak hour (See Table 4.4).

5) Overall Evaluation

The existing system is the least effective of the alternative plans. It creates a large number of oversaturated intersections as well as heavy congestion on the expressway and its access ramps.

Case 3 eliminates congestions on the expressway off-ramp on New Phetburi and increases travel speed on New Phetburi slightly. On the other hand, this alternative fails to improve conditions on Sukhumvit including the expressway off-ramp and deteriorates traffic conditions on part of the north-south arterials.

Case 5 shows better performance than Case 1 and Case 3 in terms of total queue length, intersection saturation level and average travel speed. This case dramatically eases the congestions on both New Phetburi and Sukhumvit off-ramps.

4.5 Evaluation of Alternative Plans on Future Road Network

1) Future Road Network

Further study was made on the alternative plans on future road network of 1993 when the proposed new ATC is supposed to be in operation. Major road additions to the existing network include ETA's Second Stage Expressway and new flyovers. Dindaeng/Ratcha Prarop flyover was excluded as suggested by BMA.

2) Alternative Traffic Circulation Plans Selected for Evaluation

For further study of alternative circulation plans on future road network, in addition to the alternatives selected based on the evaluation of the existing road network, the following alternative was included:

Case 5': This is a modified version of Case 5 requested by BMA. Considering that it might be difficult to introduce reversible lane operation in all four directions (Case 5), it is limited to only two sections. This plan consists of reversible lanes on Dindaeng and New Phetburi, and fixed unbalanced flow on Sukhumvit.

3) Total Delay Time and Total Queue Length

The performances of Case 5 and Case 5' are further improved when the cases are applied to the 1993 network compared to their application on the 1988 network (See Table 4.5).

Table 4.5 Total Delay Time and Total Queue Length of Alternatives Case 5 and Case 5'

Alternative Plans	Morning Peak Hour		Evening Peak Hour	
	Total Delay: vehicle.hrs	Total Queue Length:Kms	Total Delay: vehicle.hrs	Total Queue Length:Kms
1) Case 5 : 1993 Network	8,031 (0.83)	72.7 (0.78)	7,652 (0.84)	59.0 (0.77)
2) Case 5': 1993 Network	8,031 (0.83)	72.7 (0.78)	7,943 (0.88)	62.0 (0.81)
3) Case 5 : 1988 Network	8,978 (0.93)	79.7 (0.86)	8,476 (0.94)	64.0 (0.84)

Note: Figures in parentheses indicate the ratio against Case 1 (existing flow control system on 1988 network) = 1.00

4) Saturation Degrees of Major Intersections

Saturation degrees of most of the intersections on the 1993 network are more or less the same or lower than those on the 1988 network, with the exception of Rama IV/Rama I Intersection (See Table 4.6). This is likely because the Second Stage Expressway will be only partially open in 1993. It is expected that the saturation degrees of this intersection will be much lower when the expressway is fully opened.

5) Overall Evaluation

It is considered that the effectiveness of the two-way reversible plans (Case 5 and Case 5') recommended for the existing road network has been confirmed from the series of analysis made in this study.

The performance of Case 5' is slightly lower than that of Case 5. However, it is considered that Case 5' is the most effective plan for immediate implementation as a temporary measure of Case 5.

It may, however, be necessary to consider further improvement of traffic flow on Rama VI where saturation degrees and queue length at a number of intersections would slightly increase. In addition, considering that the analysis shows that Case 5' would create congestion at Din Daeng/Ratcha Withi intersection during the evening peak hour unless a flyover on the intersection is constructed, it would be desirable to introduce reversible lanes, at least partially, on the road in the future.

Table 4.6 Saturation Degrees of Major Intersections under Case 5 on 1988 and 1993 Road Networks during Morning Peak Hour

Intersections	1993 Network	Existing (1988) Network
Middle Ring Road & New Phet Buri Road	1.38	1.38
Middle Ring Road & Sukhumvit Road	1.06	1.09
Ratcha Prarop Road & New Phet Buri Road	0.74	1.08
Ratcha Prarop Road & Sukhumvit Road	0.89	1.10
Phaya Thai Road & Phet Buri Road	0.71	0.72
Phaya Thai Road & Rama I Road	0.83	0.88
Rama VI Road & Phet Buri Road	0.90	0.86
Rama VI Road & Rama I Road	1.50	1.24
Ratcha Withi Road & Rama VI Road	0.97	1.24
Victory Monument	0.98	1.41
Ratcha Withi Road & Dindaeng Road	1.06	0.86
Vibhawadi Rangsit Road & Dindaeng Road	1.02	1.12
Witthayu Road & New Phet Buri Road	0.71	1.10
Soi 3 & New Phet Buri Road	1.00	1.12
Soi 3 & Sukhumvit Road	0.55	1.07
Witthayu Road & Sukhumvit Road	0.73	0.91

5. ATC SYSTEM CONCEPT

5.1 Necessity and Objectives

The necessity and main objectives of ATC system are briefly as follows:

a) The improvement of signal control is one of the ways to make use of existing road facilities to a maximum extent and to increase road capacities. It is a cost effective method.

b) Efficiency of existing signalized intersections which are controlled manually by traffic policemen, can be further increased with the introduction of ATC system.

c) The most important aim of ATC system is to achieve the smooth flow of vehicular traffic. The ATC system can also contribute to the reduction in air pollution and traffic accidents through alleviation of traffic congestion.

5.2 Functions

The function of ATC system will include:

a) Area-wide coordinated signal control function
b) Information function
c) Data-Processing function
d) Monitoring function

5.3 Subject Intersections

In the ATC Planning Area, the intersections that are currently signalized and those that will be signalized were identified as those subject to control by the proposed ATC System.

A total of 235 intersections were identified, of which 198 are already signalized, 32 will be signalized (BMA Plan and ETA Expressway Second Stage Ramps), and five are U-turn signalized intersections evaluated by several conditions (See Figure 5.1).

The 235 intersections were divided into 54 key intersections selected on the basis of certain criteria including saturation degree, and 181 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 received from detectors.

5.4 Control Concept

1) Basic Principles

There are three major reasons why it is essential to have a traffic-responsive system for controlling traffic in Bangkok:

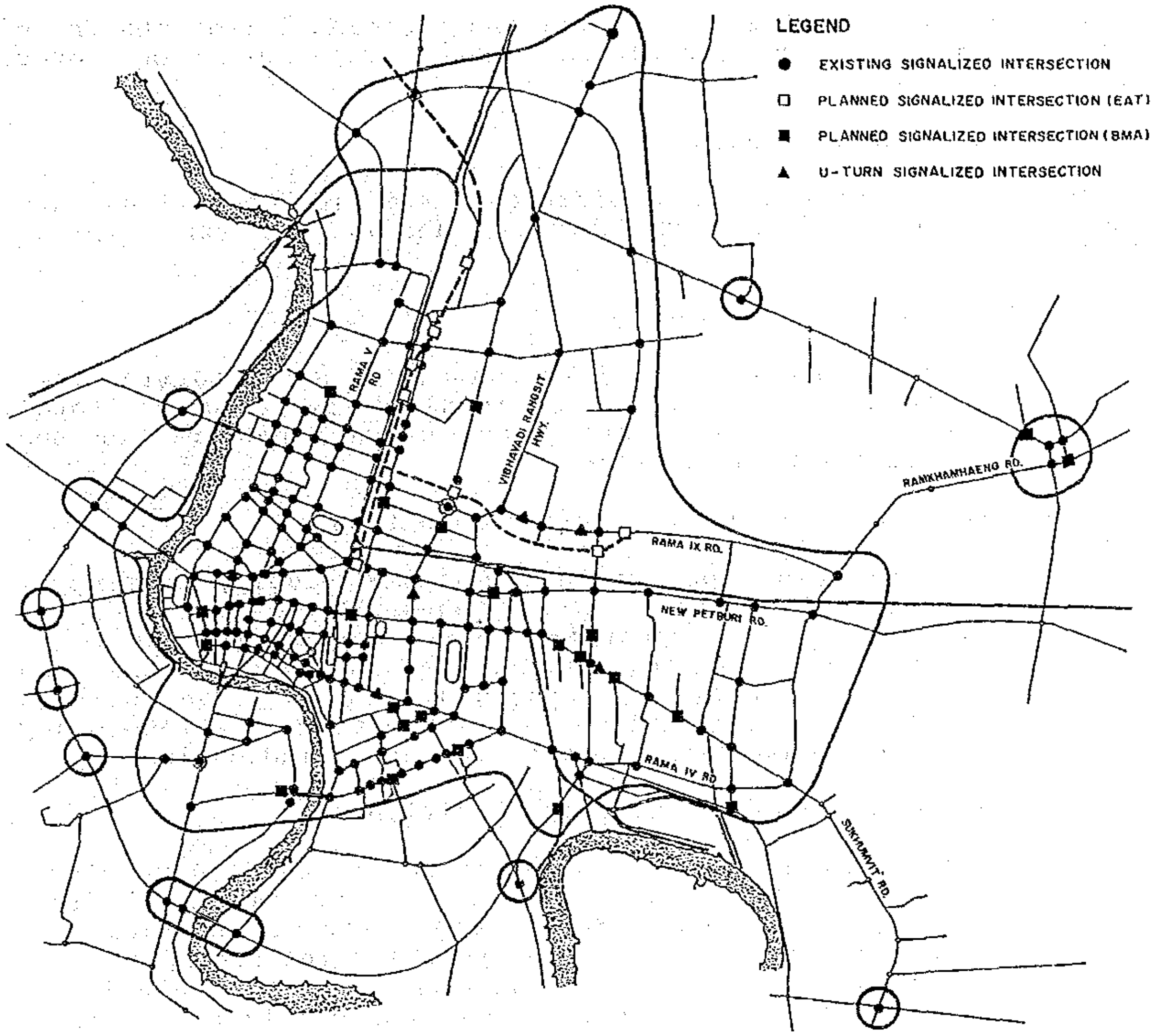


Figure 5.1 Signalized Intersections to be Covered by ATC

- There is a high degree of saturation.
- Splits must be precisely controlled to meet traffic demand fluctuations.
- Traffic demand fluctuations are highly random.

Traffic control system has to be designed such as to respond effectively to different traffic conditions in the city in terms of saturation degree, particularly to the long periods of nearly saturated and oversaturated conditions that take place in the afternoon.

The ATC system will automatically assess the saturation degree of key intersections based on on-line data received from detectors, and will apply different control methods depending on the degree of saturation. At the same time, control of ordinary intersections will be subordinated to that of neighbouring key intersections.

Traffic conditions at key intersections are classified into three types; namely under saturation, near saturation and over saturation.

2) Basic Control Methods

Basic control methods for different traffic conditions are summarized in Table 5.1 and Table 5.2 and briefly explained as follows:

(1) For Under Saturated

Cycles and offsets will be controlled so as to minimize performance index: e.g. total delay time or total number of stoppages within the overall network, or the weighted sum of the two.

(2) For Nearly Saturated Traffic Condition

Traffic demand per cycle fluctuates widely, causing queues to form and disappear repeatedly. Therefore, it is important to adjust the splits sensitively so as to respond quickly to traffic demand fluctuations and maximize intersection throughput. In addition, offsets should be progressive so that vehicles moving toward key intersections always receive the green indication.

(3) For Over Saturated Traffic Condition

Since there is a continuous store of vehicles needing clearance under conditions of over saturation, it is necessary to take queue length restrictions into account before determining cycle lengths and splits for maximum throughput. In addition, offset should be reverse-progressive since it is especially necessary, given the functions of key intersections, to allow vehicles to pass through key intersections smoothly.

Other control methods include the following:

- Turn-actuated control for minor right-turning traffic.
- Individual control for spill backed traffic resulting from accidents or excess demand.

3) Equipment and Devices

Necessary equipment and devices which comprise the ATC system are as follows:

a) Detectors: Detectors will be provided for the purposes of supplying data for determining control parameters. There are two types of detectors: the loop-inductive type and the ultrasonic type. The type that best fits the placement environment will be chosen.

Table 5.1 Control Strategies for Different Traffic Conditions

Item	Under saturation	Near Saturation	Over saturation
Cycle :(A)	Minimize Performance Index 1/	Maximize Throughput	Maximize Throughput
Split :(B)	Minimize Performance Index 2/	Maximize Throughput	Maximize Throughput
Offset:(C)	Progressive	Progressive	Reverse Progressive 3/

(A): Sub-area (group of intersections that are coordinated based on the same cycle length)
(B): Intersection
(C): Link
1/ : Performance index means total delay time or total no. of stoppages or their weighted sum.
2/ : Progressive offset means that vehicles moving toward key intersections always receive the green indication.
3/ : Reverse-progressive offset means that vehicles moving away from key intersections always receive the green indication.

Table 5.2 Control Methods for Different Traffic Conditions

Item	Under saturation	Near Saturation	Over saturation
Cycle	Plan selection1/	Plan selection	Plan selection
Split	Plan selection	Plan formation2/	Plan formation
Offset	Plan selection	Plan selection	Plan selection

1/: Plan selection means that one of the plans prepared off-line in accordance with forecast patterns of traffic condition is selected every 15 minutes or so based on data received from detectors.
2/: Plan formation means that signal control plan is prepared on the basis of cycle-to-cycle fluctuations in traffic demand as indicated by detectors.

b) Local Controllers: Local controllers will be installed at all intersections and linked to the control center on an on-line basis. Their functions are to control traffic signals in an appropriate manner and transmit data obtained from nearby detectors.

c) Central Processing Unit: The Central Processing is mainly composed of a host computer and a front-end processor.

Host Computer: The host computer calculates signal control parameters based on data supplied by detectors and in accordance with established control methods.

Front-End Processor: The front-end processor processes raw data received from detectors via local controllers and sends the processed data to the host computer.

d) Reversible Lane Control System: Reversible lane control systems will be provided in sections of reversible lane operation. It consists of an overhead sign and a signal aspect mounted on a gantry that spans the roadway.

e) Man-Machine Interface: This will include the following:

- Wall map display
- Operation consoles
- Graphic CRT
- Computer peripherals
- Others

f) Other Equipment: This will include the following:

- Uninterruptible power supply
- Air conditioner
- Modem and main distribution frame
- Radio broadcasting booth
- Radiotelephone

The proposed ATC system should be designed in such a way that it is cost-effective under the 1993 road network condition and has a flexible configuration to cater for future expansion.

4) Organization

In order to maintain the desirable effect of the proposed ATC system, it is necessary to provide an effective organization for operation and maintenance, wherein the future expansion and upgrading of the processing system and coordination among relevant organizations should be duly taken into account.

Qualified staff with sufficient technique and experience should be assigned to cover the following areas of activities; signal planning and system area extension, traffic survey, signal design, system operation and control among others.

Proper maintenance organization should also be provided to ensure effective regular and preventive maintenance.

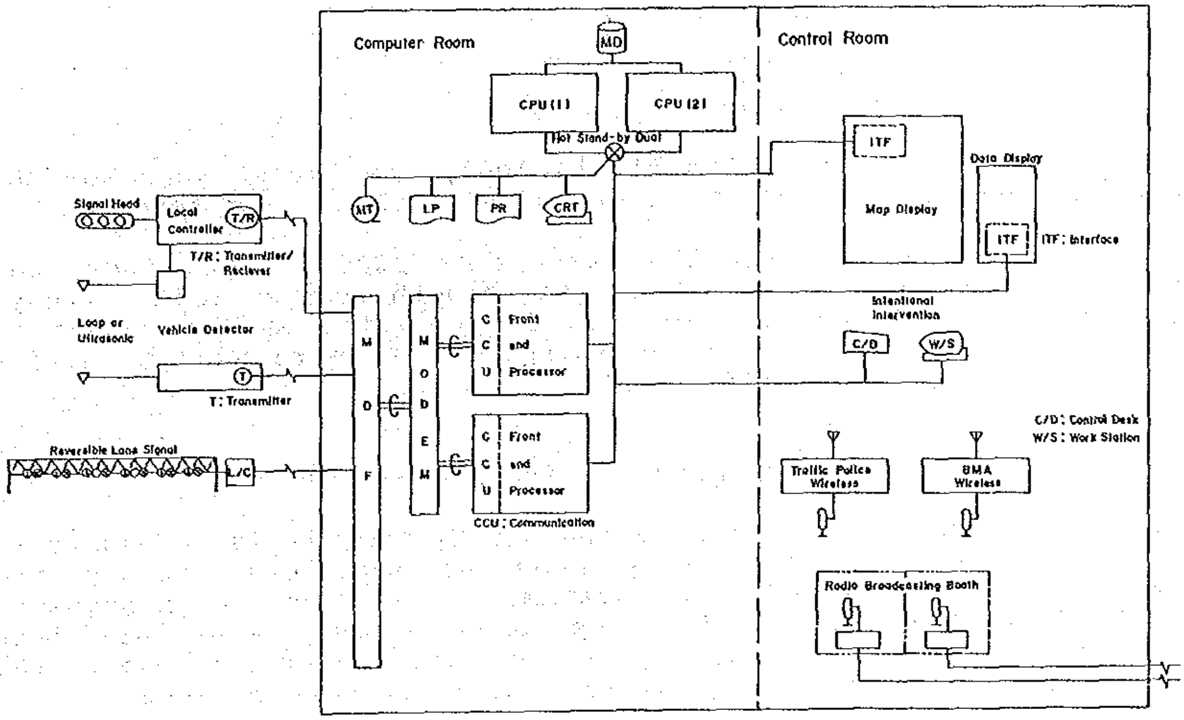


Figure 5.2 Conceptual ATC System Configuration Diagram for Bangkok Metropolitan Area

6. PRELIMINARY DESIGN

6.1 Future Traffic Volume

The volume of vehicular traffic in 1993, the target year for the commencement of the operation of the ATC System, was forecast.

The "Vehicles OD Distribution Matrix in 1985" (JICA Study) was adjusted in accordance with the growth rates (JICA Study) applicable to the volumes of traffic generated and attracted in each of the zones, and the resulting OD data were used to assign traffic to the 1993 road network.

6.2 Traffic Engineering Measures for ATC System

Along with the introduction of the ATC System, it is necessary to implement traffic engineering measures that can enhance the beneficial effects of the System. The traffic management facilities for intersection improvements and reversible lane system that should become necessary in conjunction with the installation of ATC System signal facilities were reviewed.

1) *Intersection Improvement*

a. Subject Intersections and Plan Conditions

The plan covers the 235 intersections that are to be controlled by the ATC System. The plan is primarily based on the conditions that intersection improvement works be implemented without increasing the existing road width and that the results of the 1993 traffic assignment that takes into account the Traffic Circulation Plan be used for the future traffic volume.

b. Improvement Plan

In conjunction with the reversible lanes to be introduced to existing signalized intersections, as called *for in the Traffic Circulation Plan*, a pavement marking plan for the intersections was prepared in order to achieve smooth traffic flow. 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 pedestrian safety.

Of the 235 intersections to be controlled by the ATC System, 91 intersections require improvement. Table 6.1 lists the improvements to be made at these intersections. Figure 6.1 shows the intersections that should be improved.

Table 6.1(1) Improvement Measures by Intersection

Int. No.[1)]	Type	App-roach	Main Projects[2)] I	II	III	Improvement Measures[3)] 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
6	B	4				o	o					
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
45	B	3								o		
49	B	4				o						One-Way
51	K	4			*	o	o					Elevated Road(Plan)
52	B	4					o					
54	B	4				o						One-Way
60	B	4					o		o			
62	B	4				o						
63	A	4			*		o					Elevated Road(Plan)
67	B	3	*			o		o				Change to Two-Way
69	K	4				o						
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

Note : 1) Int No.: Intersection No. is specified by Traffic Police
: 2) Main Projects
I : Traffic Ciculation System Plan
II : Planned Signalized Intersection
III : Right-turn Traffic-actuated Control
: 3) Improvement Measures
1 : Road Marking
2 : Exclucive 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

Table 6.1(2) Improvement Measures by Intersection

Int. No.[1]	Type	App-roach	Main Projects[2]			Improvement Measures[3]						Remark
			I	II	III	1	2	3	4	5	6	
83	C	6				o						One-Way
86	C	4				o						
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						Flyover
105	K	4	*			o		o			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
115	K	4	*		*	o	o	o			o	Reversible Lane, Elevated Road(Plan)
123	K	4			*	o			o			Flyover(Plan)
125	B	4				o		o				
127	K	4			*	o						
133	B	4			*		o					
134	K	4	*		*	o	o					Flyover, Elevated Road(Plan)
136	A	4			*	o						
143	K	5	*			o	o	o	o		o	Reversible Lane
145	K	4			*	o						
152	K	4			*	o						
157	A	4				o						Viaduct(Plan)
160	C	3				o						One-Way
163	K	4	*						o	o	o	Reversible Lane, Underpass(Plan)
164	B	4	*			o						
166	K	3					o					
170	K	4			*	o						Flyover
179	K	4			*	o						Flyover(Plan)
180	K	4			*	o						Flyover(Plan)
184	C	4	*			o	o	o				Change to Two-Way
188	C	4				o						One-Way
193	A	4					o					
195	A	6			*	o						
199	A	5				o	o	o				
207	B	4					o					
217	B	3				o						
218	B	4				o						
221	B	3				o						
234	B	5				o						Rail-Crossing
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				
805	U	2		*		o	o	o				
901	B	3		*		o						
905	C	3		*		o						
906	C	4		*		o		o				New Road

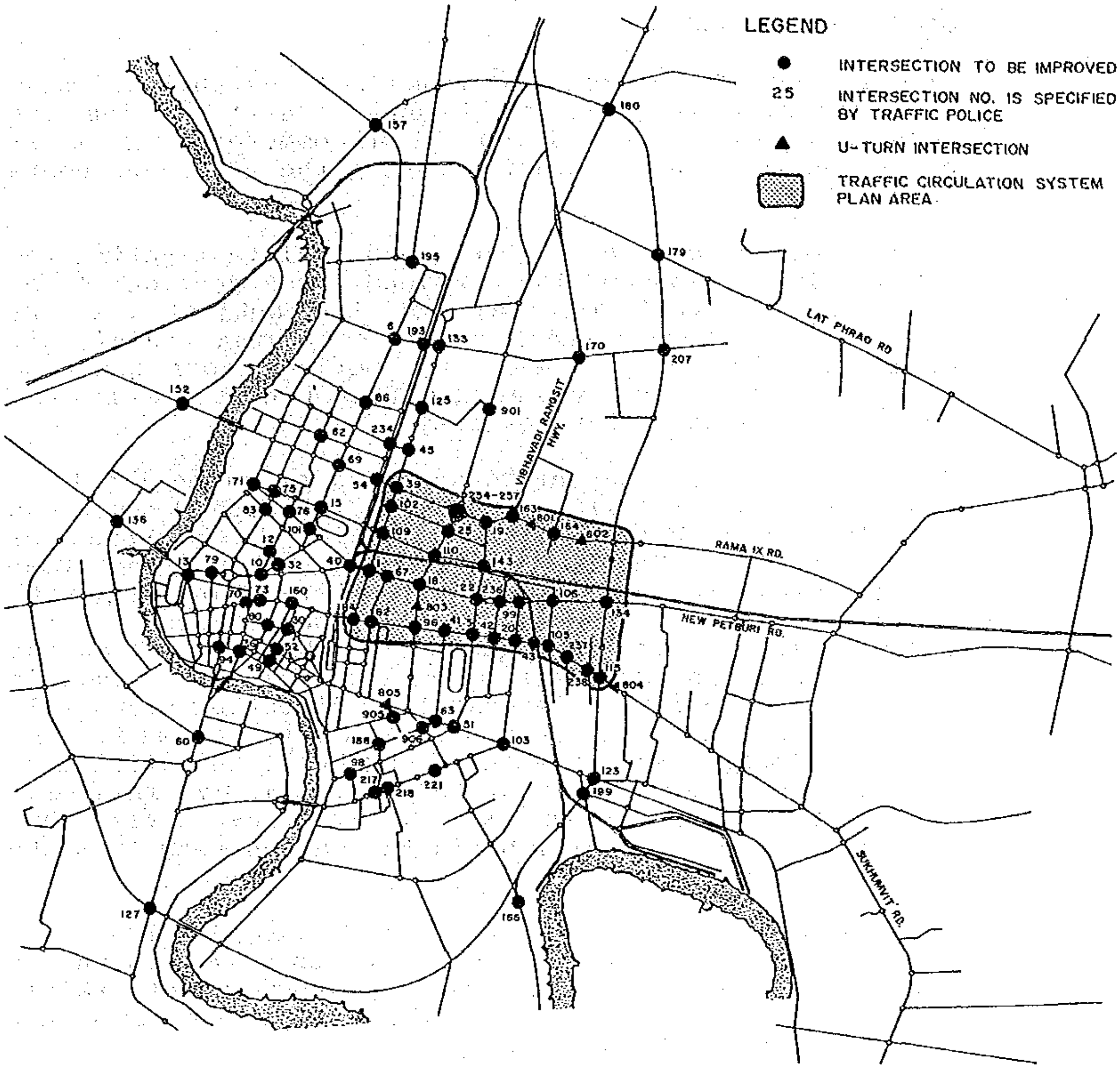


Figure 6.1 Intersections to be Improved

2) Reversible Lane Operation System

a. Subject Road Sections and Plan Conditions

The subject road sections consist of approximately 0.6 km on Dindaeng Road, 1.4 km on Ratcha Prarop Road, 0.9 km on Phetcha Buri Road, and 2.5 km on Sukhumvit Road. The main conditions of the plan follow Alternative 5 discussed in the evaluation of alternatives in Chapter 4 (Traffic Management Study for ATC System Planning).

b. Operating Method

Time periods for reversible lanes were established so that priority is given to inbound traffic during the morning hours (6:00 - 11:00) when commuter traffic is heavy and to outbound traffic during the afternoon hours (after 11:00).

These time periods were established by investigating the hourly fluctuations of the combined cross section volume on major east-west arterials of the subject area by inbound and outbound traffic, and reviewing the effects of reversible lane. These time periods correspond to the time periods currently applied to existing reversible lanes in Bangkok city.

The traffic operation method consists of directing the flow of vehicles with lane-use indicators such as signals and markings, implemented in the presence of traffic police. Reversible lane usage will be notified to drivers by overhead lane direction signals, variations in lane line color, and lane-use designators. Overhead lane direction signals will be provided at the starting and ending points of reversible lanes, and, in between these points, overhead lane direction signs will be attached to existing pedestrian bridges. At intersections, reversible lane usage will be notified by variations in lane line color and by lane-use designators. In areas outside the reversible lane section, guide signs will be installed upstream from the starting point.

Standard operation methods to be applied to intersections and other road sections are shown in Figure 6.2, and the quantities and locations of traffic facilities required for reversible lane operation are shown in Table 6.2 and Figure 6.3.

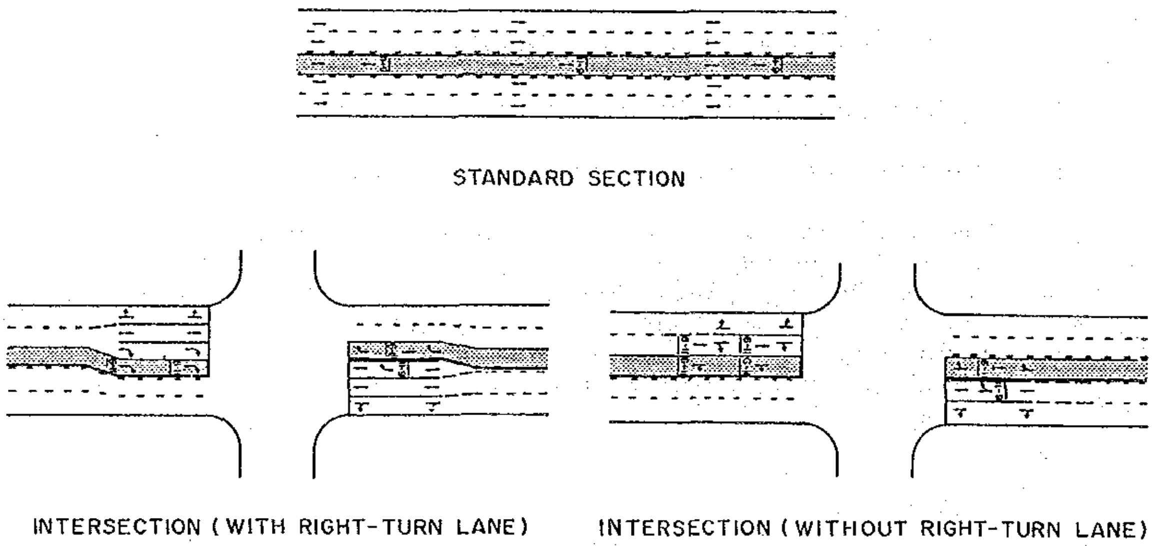


Figure 6.2 Standard Traffic Operation Method

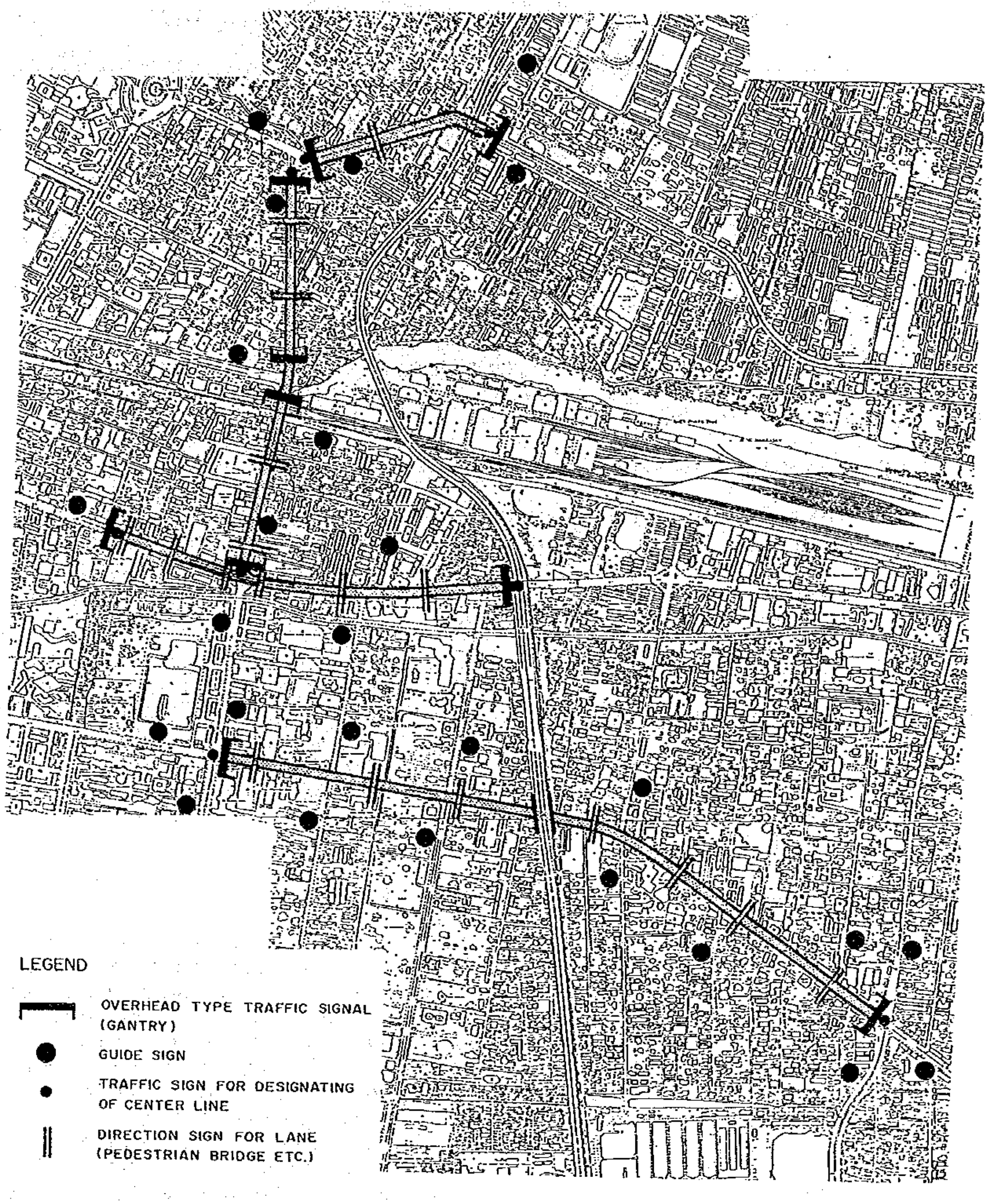


Figure 6.3 Locations of Traffic Facilities

Table 6.2 Traffic Facilities to be Installed

Road	Overhead Type Traffic Signal Head (Gantry)	Direction Sign for Lane (Pedestrian Bridge)	Traffic Sign for Designating of Center Line	Guide Sign	Road Marking (m^2)
DINDAENG	19(2)	9	2	4	160
PHETCHA BURI	16(2)	26	4	6	570
RATCHA PRAROP	11(4)	24	2	7	300
SUKHUMVIT	17(2)	48	2	14	560

( ); Number of Gantry Source: JICA Study Team

6.3 Vehicle Detectors

a) Functions of Vehicle Detectors

Vehicle detectors fulfill five functions related to area control, split control, vehicle actuated control, congestion indication, and traffic statistics, by detecting the presence of motor vehicles for the collection of traffic data.

b) Standard Location Plan Vehicle Detectors

The standard location of vehicle detectors for coordination, split control and flow rate-responsive control at key intersections is as shown in Figure 6.4 that of detectors for right-turn control is shown in Figure 6.5, and that of detectors for obtaining traffic statistics is shown in Figure 6.6.

c) Actual Location Plan Vehicle Detectors

A location scheme that takes into account cost and locational considerations and which does not undermine the functions of the ATC System was reviewed for the actual location plan of vehicle detectors. The number of vehicle detectors was reduced in the following manner: (a) if two or more detectors for different functions were assigned to the same location, these were combined into one detector; (b) the maximum queue length was forecast, and detectors for congestion indication were removed from sections with greater values; (c) where detectors were plotted on more than one lane at a given location, detectors other than the one on the representative lane were removed; (d) where more than one detector for right-turn control was allotted, the number was reduced.

The number of detectors required for the entire ATC System Area is shown in Table 6.3.

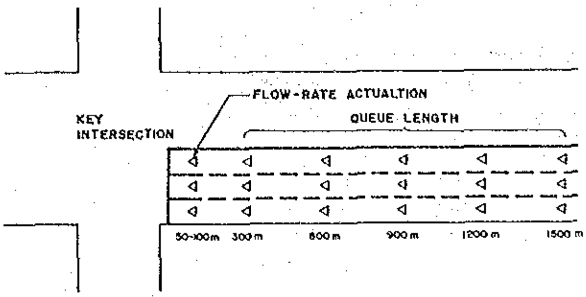


Figure 6.4 Location of Detectors for an Approach of Key Intersection

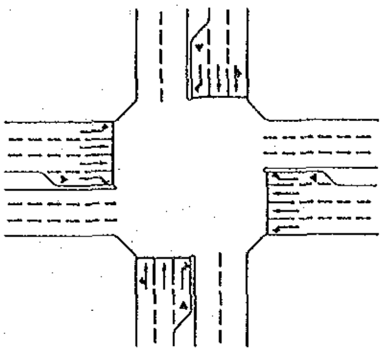


Figure 6.5 Location of Detectors for Right-turn Actuation

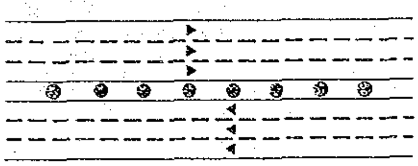


Figure 6.6 Location of Detectors for Statistic Use

d) Selection of Vehicle Detector Type

Two types of detectors were considered: inductive loop detectors and ultrasonic detectors. Selection between inductive loop and ultrasonic detectors was determined by taking into consideration the advantages of each and the special characteristics of the placement location. The main reasons for selecting one or the other are listed below. Table 6.3 shows the number of vehicle detectors by type. Figure 6.7 shows the type of detector.

Table 6.3 Number of Detector by Type

Functions	Loop	Ultra-sonic
- Coordinated Area Control & Split Control	32	264
- Vehicle Actuated Control	42	30
- Congestion Indication	0	10
- Compiling Traffic Statistics	0	45
Sub-Total	74	349
Total	423	

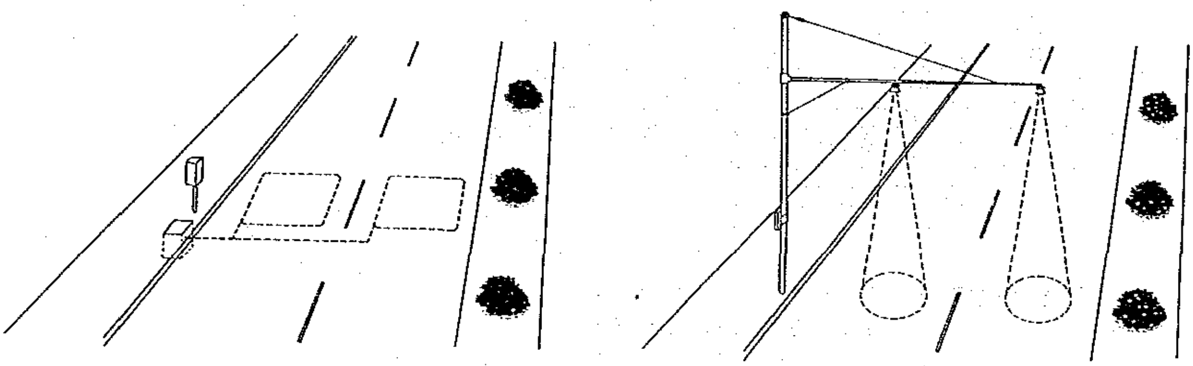


Figure 6.7 Types of Vehicle Detectors

o Reasons for Selecting Ultrasonic Detectors

- Where excavation works occur frequently, loop detectors can be severed time and again.

- Ultrasonic detectors require less time to install, which means that traffic restrictions need to be imposed only for a short time.

o Reasons for Selecting Loop Detectors

- Loop detectors were allotted to streets whose scenic beauty must be preserved.

- Loop detectors were allotted to streets with four or more lanes in each direction. However, wherever there is a pedestrian bridge, an ultrasonic detector was allotted.

- Since the presence of branches and leaves destabilizes the performance of ultrasonic detec tors, loop detectors were allotted to tree-lined streets with a thick cover of branches and leaves.

e) Concentration of Detector Pulses

To reduce the number of lines that must be borrowed from the TOT, local controllers equipped with transmitters collect the pulses emitted by a number of nearby detectors. Detectors located within 300 meters from an intersection are connected by cables to the local controller at the intersection. Concerning detectors located over 300 meters from an intersection, one of these dectors is equipped with a transmitter and connected to a nearby detector. Figure 6.8 shows a typical plan for concentrating detector signals.

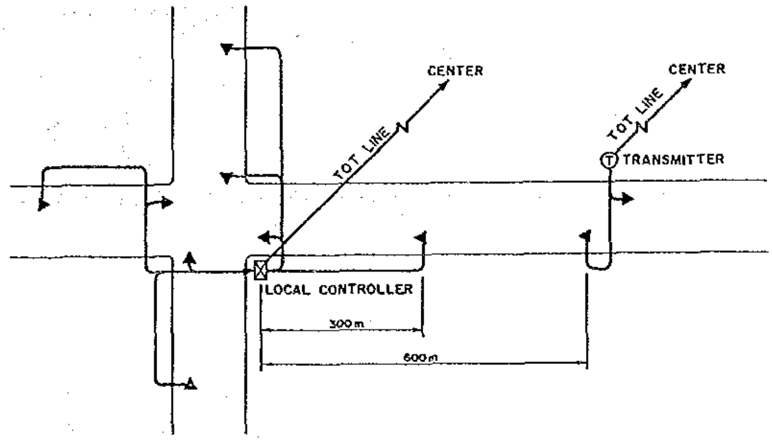


Figure 6.8 Detector Pulses Concentrating Plan

f) Standard Installation Plan

The standard installation plan for detectors is shown in Figures 6.9 and 6.10.

6.4 Local Controllers

a) Functions of Local Controllers

Local controllers share functions with the central computer, including the control logic discussed in Chapter 5, and fulfill the following functions: (a) on-line control of traffic signals, (b) vehicle actuated control, (c) backup functions, and (d) manual control.

b) Standard Installation for Local Controllers

To reduce the cost of equipment, existing facilities are used wherever possible. Signal poles, handholes and conduits are retained. Local controllers are replaced with those for on-line control. Where existing traffic lights have low visibility, lights mounted on tall poles are added. Junction boxes are also added. Cables are replaced with those that contain more strands of wire, and relay terminals are also provided.

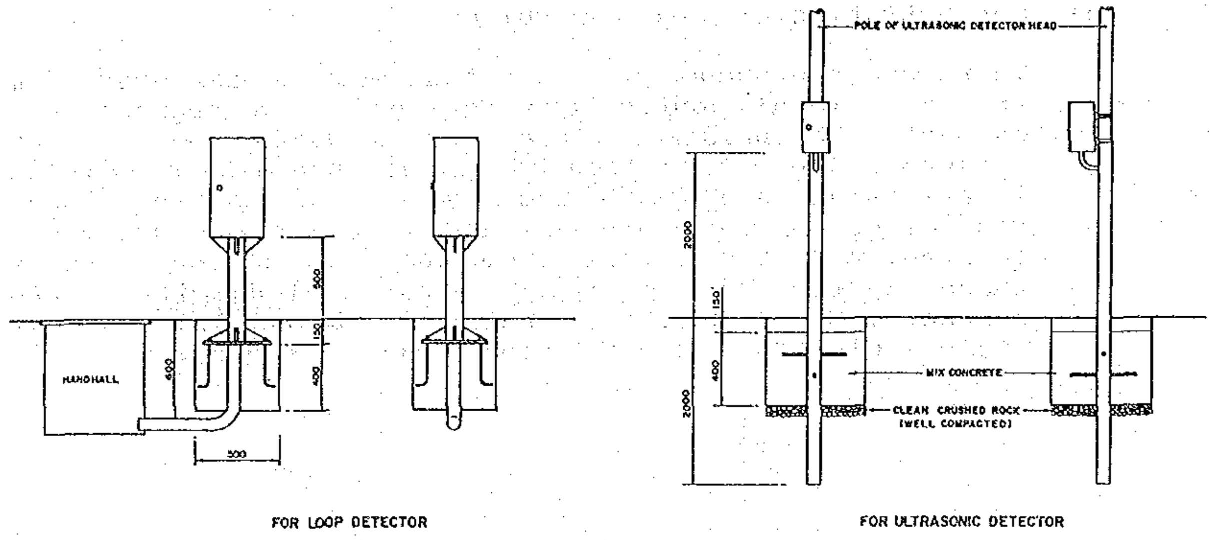


Figure 6.9 Standard Installation Plan for Detector Cabinets

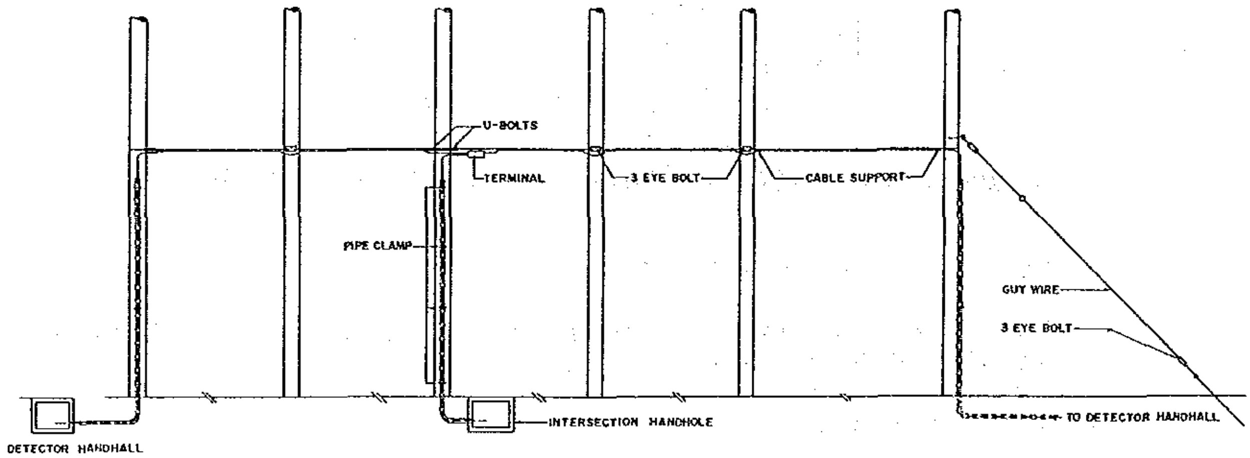
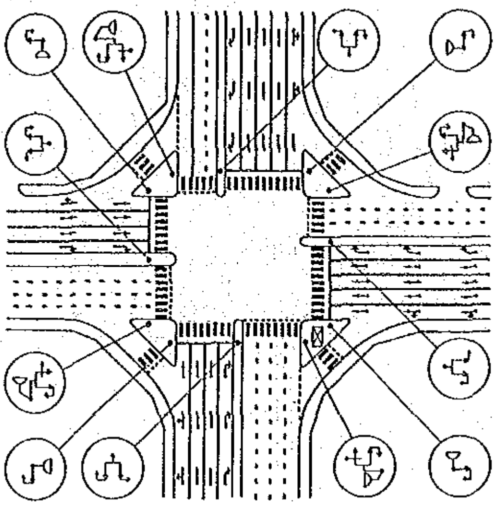


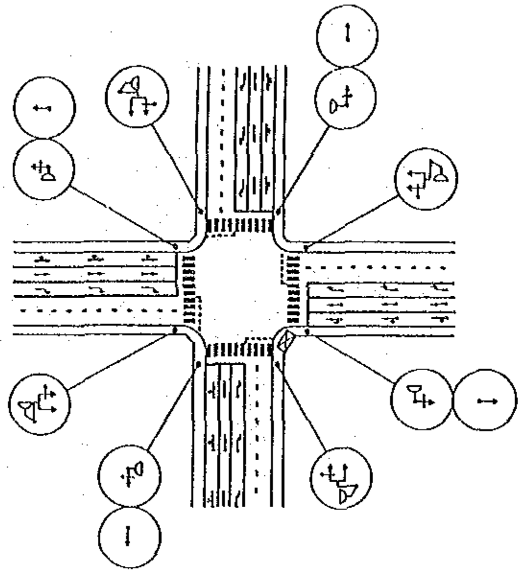
Figure 6.10 Aerial Cables

c) Standard Installation Plans Near Intersections

Standard installation plans near intersections are shown in Figure 6.11. The plans were reviewed by dividing intersections into six types: key intersections (K), intersections grouped according to the number of lanes on the major and minor approaches respectively (A - C), U-turn intersections (U), and ETA ramp junctions (ETA).



TYPE -K



TYPE -A

SYMBOLS FOR ASPECTS

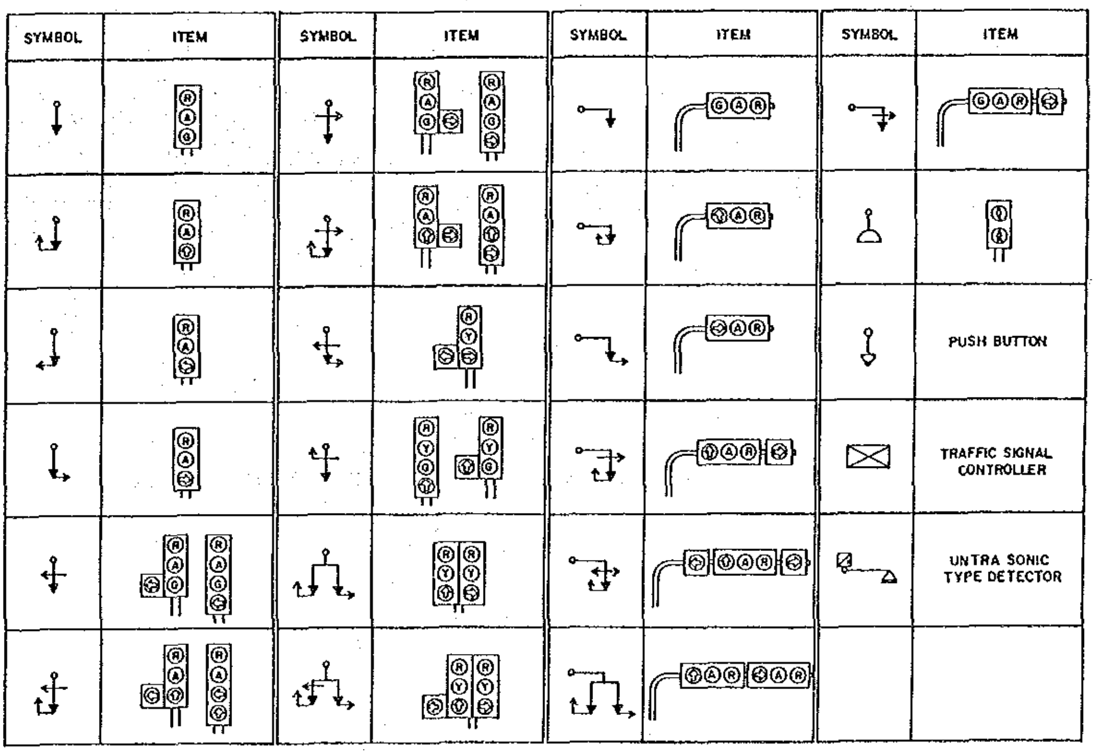
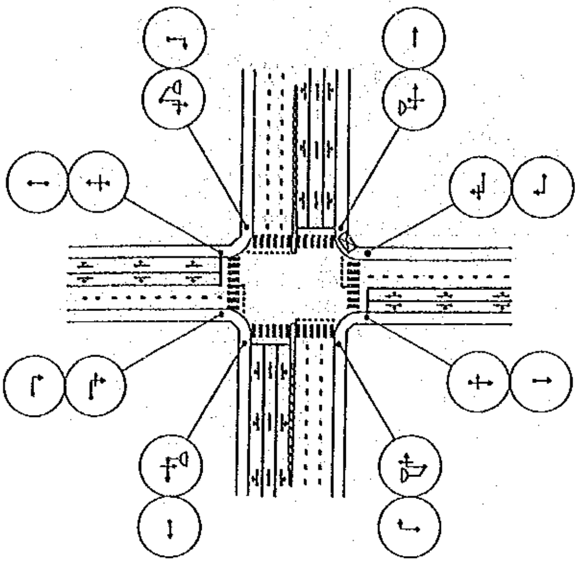
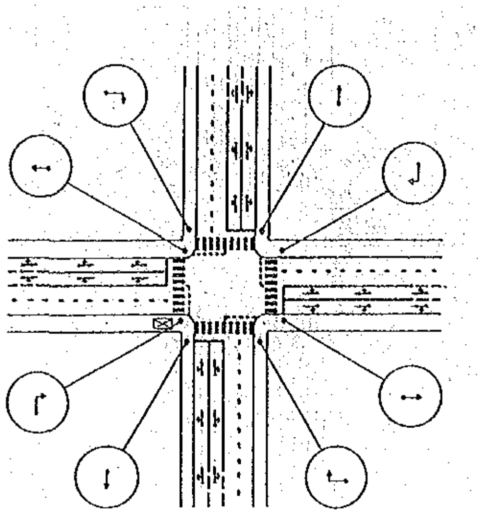


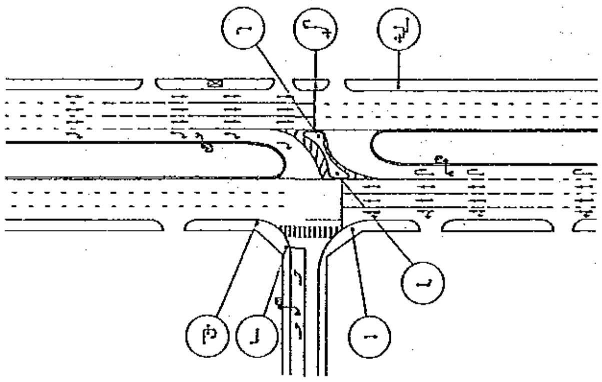
Figure 6.11(1) Standard Installation Plan around Intersection



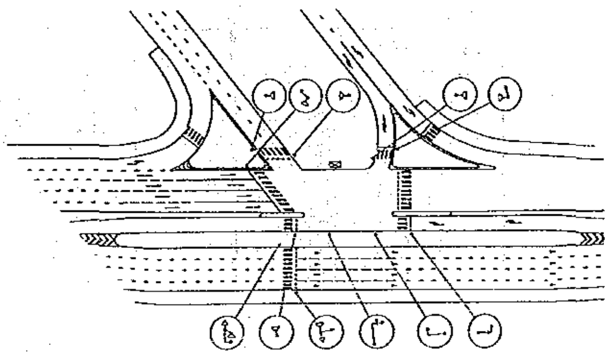
TYPE-B



TYPE-C



TYPE-U



TYPE-ETA

Figure 6.11(2) Standard Installation Plan around Intersection

6.5 Communication Network and Transmission System

a) Critical Demand for Data Transmission

There are four directions in which data are transmitted from transmitting equipment to equipment. Of these, the largest volume of data is transmitted from a local controller to the center, at roughly 8,000 bits.

b) Network Reliability

The communication network and backup system were considered in line with the target values for line reliability given by the TOT.

c) Network Design

The TOT's pulse code modulation (PCM) network is leased as the ATC System's exclusive line. A 2-wire method is used, and line configuration is 1:1. Figure 6.12 shows a rough plan of the communication network.

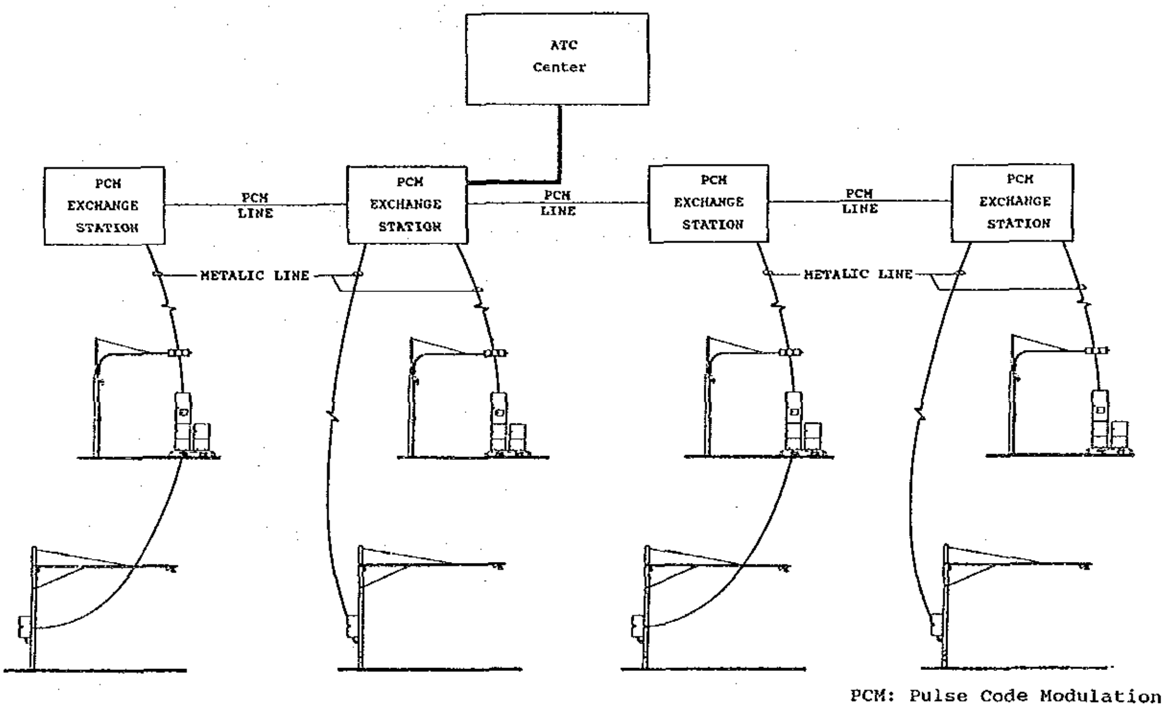


Figure 6.12 Network Design

d) Transmission System and Equipment

o Transmission System

The transmission system is as follows:

Line ---------------- 2-wire, transparent through PCM
Communication mode -- Full-duplex
Modulation method ---- Frequency shift keying (FSK) or
Phase shift keying (PSK)
Response mode -------- Synchronous response mode (SRM)
Protocol level ------- Data link level
Data length --------- Variable data length

o Transmission Equipment

Transmission equipment consist of communication control unit (CCU), gathered modems, main distribution frame (MDF), and terminal transmitter-receiver (TTR), as shown in Figure 6.13.

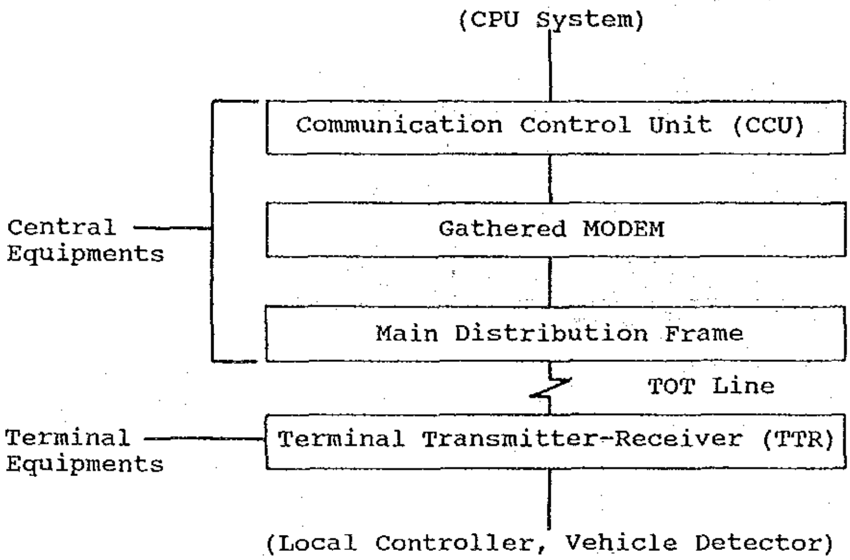


Figure 6.13 Transmitting Equipment

6.6 Man-Machine Interfaces

Equipment used in the ATC Center for sending instructions on how to deal with particular traffic conditions, for providing information useful to drivers such as congestion conditions, and for operating the ATC System are called man-machine interfaces.

a) Display Equipment and Their Functions

Display equipment consist of a wall-map display and character CRT displays. The wall-map display is used to show overall traffic conditions. It mainly shows degree of congestion and queue length, on-site manual operation, and intentional intervention from the ATC Center. It also shows incidents that limit the use of lanes and temporary traffic restrictions, as necessary. Character CRT displays show traffic data collected by the host computer.

b) Work Stations

Work stations are multipurpose traffic control consoles. They are used for intentional intervention, incident input/cancellation, various off-line jobs, and other communication tasks.

6.7 Central Processing Unit and Its Peripherals

a) Hardware Configuration

- o Hierarchy Structure

  A computer system with a hierarchy structure was chosen. Under this system, the work load is shared by the host computer and front-end processors.

- o Dual System Configuration

  A dual system was chosen for the host computer for backup and off-line job purposes.

- o Control Capacity and Future Expansion

  Considering the fact that the number of intersections subject to the ATC System is 235, the control capa city of the CPU is established as corresponding to roughly 300 intersections. Future expansion will be effected by increasing the number of front-end processors.

- o Equipment Composition

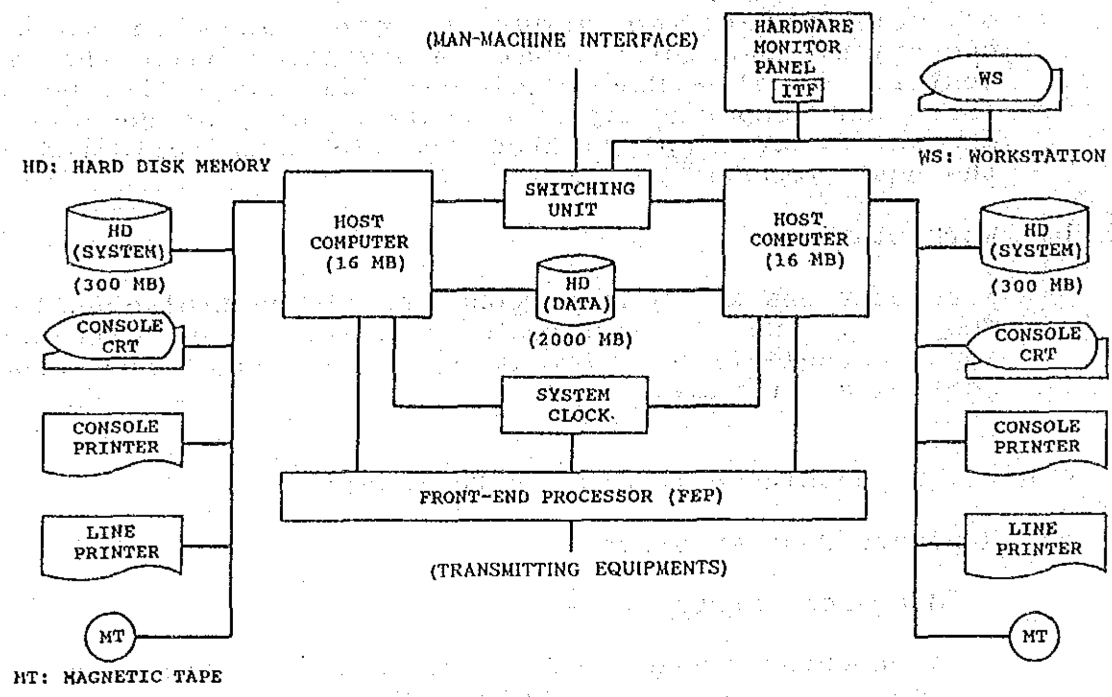
  The central processing unit is composed of a host computer and front-end processors. Figure 6.14 shows the hardware configuration.

b) Software Configuration

Figure 6.15 shows the software configuration.

6.8 Proposed ATC System for Bangkok

Combining all the matters discussed in the preceding sections results in the ATC System proposed for Bangkok (Figure 6.16).



Fiogure 6.14 Hardware Configuration

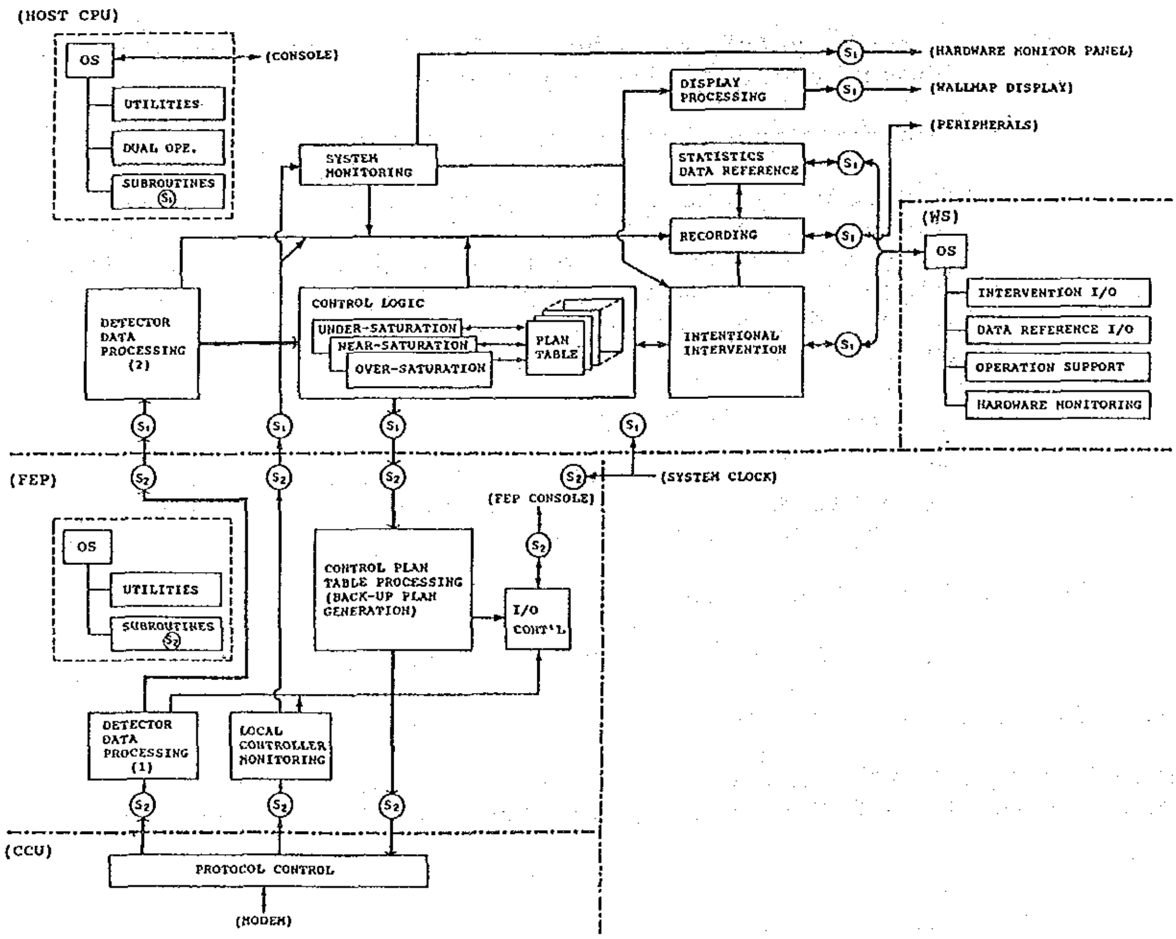


Figure 6.15 Software Configuration

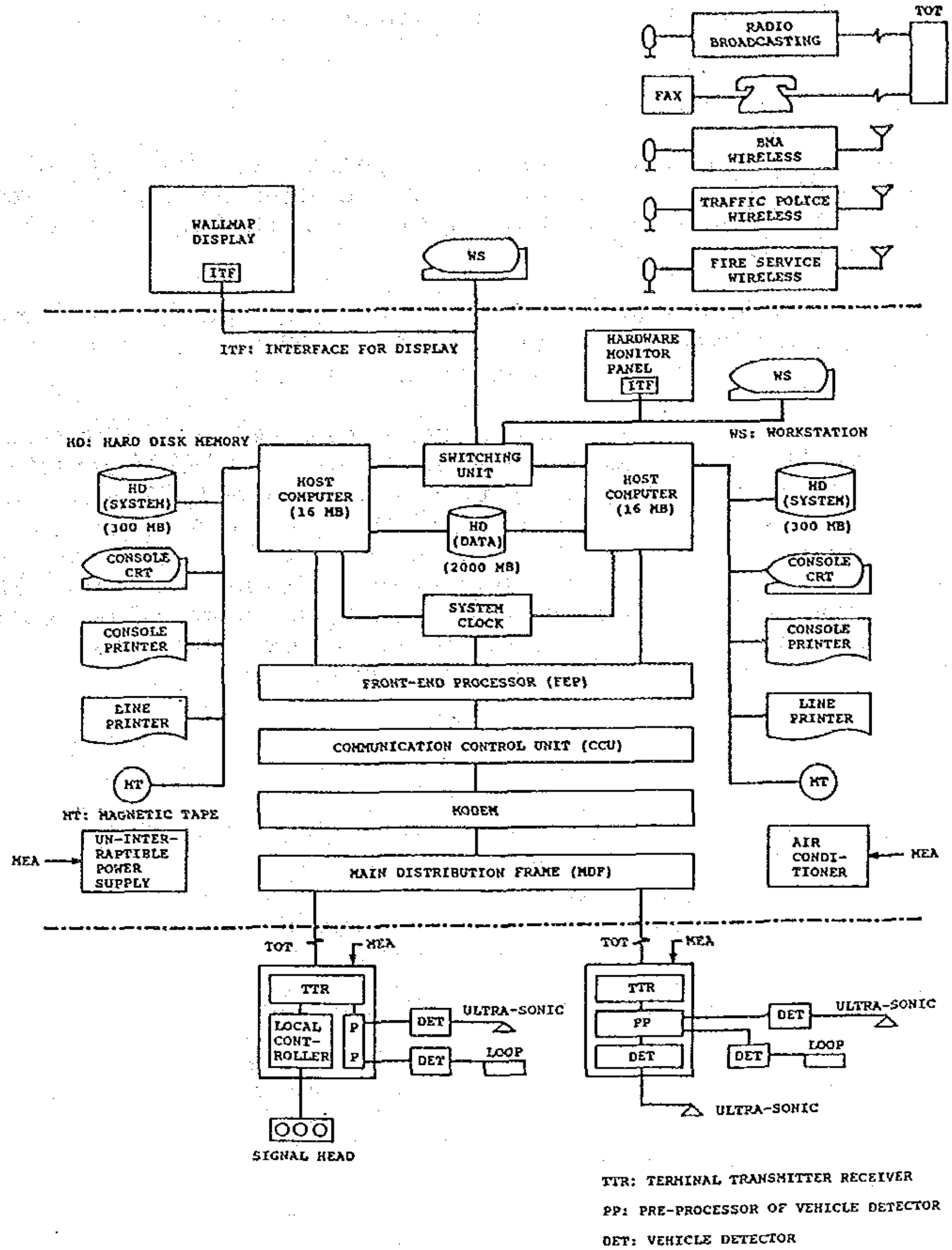


Figure 6.16 ATC System for Bangkok

7. PROJECT COST ESTIMATE AND IMPLEMENTATION PLAN

7.1 Implementation Plan

For the implementation of the ATC System in the study area, construction will be carried out in two stages (Stages I and II) with the aim of commencing System operation in 1993. The staged plan is shown in Table 7.1.

The target area for Stage I is as shown in Figure 7.1, and the number of subject intersections is 143. The number of subject intersections for Stage II is the remaining 92.

Target areas for Stages I and II were determined by evaluating the effects of the ATC System on vehicle delay time (reduction in total delay time per vehicle-kilometer travelled) in various parts of the study area. The entire ATC System Area was divided into seven zones centering on the area within the Middle Ring Road, with the number of subject intersections in each of the zones as nearly the same as possible. At the same time, care was given so that traffic flow characteristics and road network within a zone would be as uniform as possible.

Table 7.1 Staged Plan

1990	1991	1992
	Stage I	Stage II
Target Area	143 intersections	92 intersections
Terminal Equip-ment	- 143 local controllers - Vehicle detectors related to above	- 92 local controllers - Vehicle detectors related to above
Central Equip-ment	- Host computer and its peripherals - Control plans for 143 intersections - Software for 143 intersections - Wall-map display and hardware monitor panel for 143 intersections - Air conditioner, UPS - All man-machine interfaces - FEP's, CCU's and modems in quantities required to handle terminal equipment installed	- Control plans for intersections added - Software for 92 intersections - Interface lines for wall-map display and hardware monitor panel in quantities required to handle additional terminal equipment installed - FEP's, CCU's and modems in quantities required to handle additional terminal equipment installed

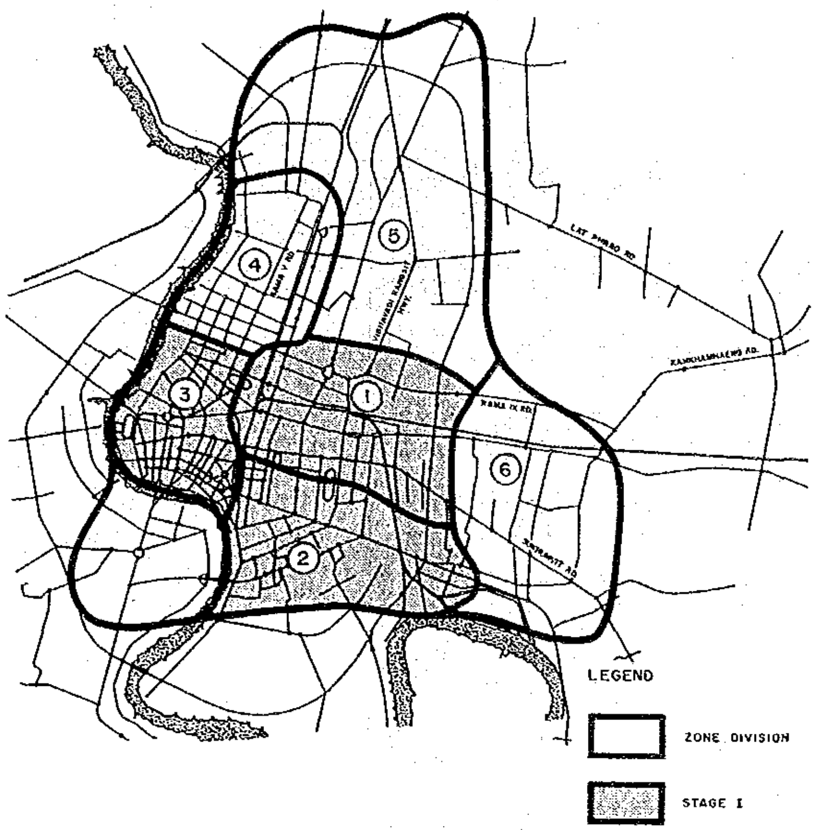


Figure 7.1 Zone division for Stage Plan

As a result of the foregoing evaluation, it was judged that it would be more advantageous to give Zones 1, 2 and 3 priority when introducing the ATC System. Accordingly, these zones were established as the target area for Stage I. Table 7.2 shows the evaluation results for each zone.

Table 7.2 Evaluation Index

Zone	Index (seconds per vehicle.km)
1	68
2	73
3	61
4	20
5	21
6	20
7	12

7.2 Project Cost Estimate

The project cost estimate for Bangkok's ATC System is given in Table 7.3.

Table 7.3 Cost Estimation on Bangkok ATC System Project

(Unit:Baht 1,000)

Stage	No. Description	1 Contral Equipmonts	2 ditto Install-ation	3 Inter-section Equipments	4 ditto Install-ation	5 Detector Equipments	6 ditto Install-ation	7 Adjustment work on site	8 Staff Training	9 Project Management cost	Sub Total	10 Profit	11 Tax	12 Contin-gency	13 Engineering Service	Total	Import Duty
I	Financial (Foreign)	261,615	0	112,080	0	29,893	0	10,688	2,522	52,548	469,352	0	0	21,206	30,010	520,568	(-)
	cost (Local)	63,043	3,420	40,193	17,478	11,896	11,406	0	242	4,910	152,588	68,375	28,717	12,138	3,334	265,152	(104,200)
	Tax	63,043	0	38,284	0	9,752	0	0	34	973	112,088	0	28,717	6,698	3,334	150,833	(104,200)
	Financial cost	324,658	3,420	152,279	17,478	41,789	11,406	10,688	2,764	57,458	621,940	68,375	28,717	33,344	33,344	785,720	(104,200)
	Economic cost	261,615	3,420	113,995	17,478	32,037	11,406	10,688	2,730	56,485	509,854	68,375	0	26,648	30,010	634,687	(-)
II	Financial (Foreign)	32,534	0	74,113	0	15,934	0	10,248	0	14,257	147,086	0	0	9,616	14,185	170,887	(-)
	cost (Local)	13,959	669	26,494	12,737	6,306	6,288	0	0	3,648	70,101	32,320	13,575	6,146	1,576	123,718	(51,098)
	Tax	13,959	0	25,064	0	5,196	0	0	0	591	44,810	0	13,575	3,263	1,576	63,224	(51,098)
	Financial cost	46,493	669	100,607	12,737	22,240	6,288	10,248	0	17,905	217,187	32,320	13,575	15,762	15,761	294,605	(51,098)
	Economic cost	32,534	669	75,543	12,737	17,044	6,288	10,248	0	17,314	172,377	32,320	0	12,499	14,185	231,381	(-)
Total	Financial (Foreign)	294,149	0	186,199	0	45,827	0	20,936	2,522	66,805	616,438	0	0	30,822	44,195	691,455	(-)
	cost (Local)	77,002	4,089	66,687	30,215	18,202	17,694	0	242	8,558	222,689	100,695	42,292	18,284	4,910	388,870	(155,298)
	Tax	77,002	0	63,348	0	14,948	0	0	34	1,564	156,898	0	42,292	9,959	4,910	214,057	(155,298)
	Financial cost	371,151	4,089	252,886	30,215	64,029	17,694	20,936	2,764	75,363	839,127	100,695	42,292	49,106	49,105	1,080,325	(155,298)
	Economic cost	294,149	4,089	189,538	30,215	49,081	17,694	20,936	2,730	73,799	682,231	100,695	0	39,147	44,195	866,268	(-)

Stage	Description	Inter-section Improvement	Operating cost
I	Financial (Foreign)	9,821	12,057
	cost (Local)	5,015	12,088
	Tax	2,173	2,840
	Financial cost	14,836	25,045
	Economic cost	12,663	22,205
II	Financial (Foreign)	553	13,226
	cost (Local)	281	12,015
	Tax	40	2,844
	Financial cost	834	25,241
	Economic cost	794	22,397
Total	Financial (Foreign)	10,374	-
	cost (Local)	5,296	-
	Tax	2,213	-
	Financial cost	15,670	-
	Economic cost	13,457	-

7.3 Operational and Maintenance Setups

In order to realize the full purpose of the above-mentioned ATC System, all its equipment must be kept in good condition. To achieve this, it is necessary to organize the System's operational and maintenance setups in an efficient manner.

a) Operational Management

Main tasks involved in operational management are those tasks related to the operation of the ATC Center, including sending instructions from the Center, information exchange, and System operation; and those tasks related to ATC System expansion, including investigation of traffic conditions and review of signal control parameters.

b) Maintenance Management

A contractor with thorough knowledge of the System and its equipment in general will be entrusted with and be responsible for maintenance management. Main tasks involved in maintenance management are equipment inspection and repair of failures.

c) Staff Requirements

Staff requirements for effecting the maintenance and operational tasks described above are as follows: senior traffic engineer (1 person), system engineer (1 person), electronic engineers (2 persons), and operators (5 persons).

8. EVALUATION OF ATC SYSTEM

8.1 Evaluation Method

Applying the cost-benefit analysis method, the ATC System introduced in the previous chapters is evaluated.

Costs consist of the initial investment cost and operating cost of the project. Benefits are defined as savings in the total vehicle operating cost (VOC) and travel time cost (TTC). These benefits are estimated based on the results of computer simulation of traffic flow for both cases of "with" and "without ATC system" control. Evaluation will be made for two cases; stage I alone, and the project as a whole (stages I and II).

8.2 Economic Cost Estimation

Total economic cost amounts to 866 million Baht, 80% of the financial cost (Table 8.1). Table 8.2 shows the investment schedule in terms of economic cost. After starting ATC operation, it will cost 22 million Baht every year for operation and maintenance of the System (Table 8.3).

Table 8.1 Economic Project Cost

(1,000 baht)

Stage	Financial Cost	Economic Cost
Stage I	785,720	634,887
Stage II	294,605	231,381
Total	1,080,325	866,268

Table 8.2 Modified Investment Schedule at Economic Price

(1,000 Baht)

		1990	1991	1992
Stage I	Engineering Cost	18,006	12,004	
	Construction Cost		521,322	
	(including`V ATC Center Cost)		(181,480)	
Stage II	Engineering Cost		5,674	8,511
	Construction Cost			300,751
	(including ATC Center Cost)			(116,758)
Total		18,006	539,000	309,262

Table 8.3 Operating Cost of ATC System

		(1,000 baht p.a.)
	Financial Cost	Economic Cost
Stage I	25,045	22,205
Stage II	25,241	22,397

Note; Operating cost includes maintenance cost

8.3 Benefits of ATC System

a) Traffic Flow Simulation

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, the first year of stages I and II ATC control.

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 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 8.4.

Table 8.4 Reduction of Total Delay Time and Stopping by ATC System

	Without ATC			With ATC		
	Morning 7-8:00	Daytime 13-14:00	Evening 17-18:00	Morning 7-8:00	Daytime 13-14:00	Evening 17-18:00
Total Delay Time (hours)	17,201 (1.00)	10,086 (1.00)	13,808 (1.00)	12,321 (0.72)	7,818 (0.78)	10,102 (0.73)
Total Number of Stopping (1000 times)	1,230 (1.00)	665 (1.00)	1,040 (1.00)	836 (0.68)	531 (0.80)	752 (0.72)

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

b) Economic Benefit of ATC System

Road network used for simulation consists of 781 links in total (stage 1 = 447 links, stage 2 = 334 links).

The sum of products of traffic volume and unit VOC plus TTC of each link will give the total hourly traffic cost in the simulated area. The difference of these traffic costs in "with" and "without ATC" case is regarded as the benefit of the ATC System.

The abovementioned calculation is conducted using such data as unit VOC/TTC, vehicle type compostion, and hourly fluctuation of traffic volume. Table 8.5 shows the estimated annual benefits in 1993 to 2007.

Table 8.5 Economic Benefits in 1993 to 2007

Stage I				Stage II				Stages I+II			
Year	VOC Saving	TTC Saving	Total	Year	VOC Saving	TTC Saving	Total	Year	VOC Saving	TTC Saving	Total
1993	181	540	722	1993	89	290	379	1993	271	830	1,101
1994	185	570	755	1994	91	306	397	1994	276	876	1,152
1995	189	599	788	1995	94	322	415	1995	282	921	1,203
1996	192	629	821	1996	96	337	433	1996	288	966	1,254
1997	195	654	848	1997	97	351	448	1997	292	1,004	1,296
1998	198	678	876	1998	99	364	462	1998	296	1,042	1,338
1999	200	703	903	1999	100	377	477	1999	301	1,080	1,380
2000	203	727	931	2000	102	390	492	2000	305	1,118	1,423
2001	206	752	958	2001	103	403	507	2001	309	1,155	1,465
2002	209	777	985	2002	105	417	522	2002	314	1,193	1,507
2003	212	805	1,017	2003	107	432	538	2003	318	1,237	1,555
2004	215	835	1,049	2004	108	448	556	2004	323	1,283	1,605
2005	218	866	1,082	2005	110	464	574	2005	328	1,330	1,656
2006	221	898	1,116	2006	112	482	592	2006	333	1,380	1,709
2007	224	931	1,151	2007	114	499	612	2007	338	1,431	1,763

8.4 Evaluation and Conclusion

To compare the benefits and cost of the ATC System, evaluation indicators such as internal rate of return (IRR), net present value (NPV) and benefit/cost ratio have been calculated as shown in Table 8.6 for the whole project (stage I and stage II) and in Table 8.7 for stage 1 only. Discount rate is 12% which is commonly used in Thailand as the capital opportunity rate.

The IRR of this project is extremely high at 75% and all the initial investment will be recovered within 12.1 months after commencement under the discount rate of 12%. NPV amounts to 5,631 million baht and B/C ratio is estimated at 8.3.

Though the fact that time has an economic value is undeniable, there are many arguments on how to measure it. In this study, time value is quantified based on the productivity of the economically active population in the study area. Even in cases when this unit time value is considered, objections may be voiced against applying this value to a small fraction of a few minutes of saved travel time.

Therefore considering only the VOC saving benefit which is tangible, the revised calculation of IRR will be 17.2% which indicates that the ATC project is still economically feasible.

Not many public investment projects of infrastructure have such high economic returns. Thus, high priority should be given to this project and it is strongly recommended to start this project immediately with preparation of detail design, implementation plan, and fund procurement.

Table 8.6 Evaluation of ATC Project (Stage I and Stage II)

(1,000 Baht)

Year	Cost	Benefit	B-C	B-C discounted by 12 % p.a.
1990	18,006		-18,006	-16,077
1991	539,000		-539,000	-429,688
1992	309,262		-309,262	-220,127
1993	22,397	721,658	699,261	444,393
1994	22,397	1,151,967	1,129,570	640,949
1995	22,397	1,203,027	1,180,630	598,144
1996	22,397	1,254,088	1,231,691	557,154
1997	22,397	1,296,225	1,273,828	514,478
1998	22,397	1,338,363	1,315,966	474,550
1999	22,397	1,380,500	1,358,103	437,273
2000	22,397	1,422,639	1,400,242	402,536
2001	22,397	1,464,776	1,442,379	370,223
2002	22,397	1,506,914	1,484,517	340,213
2003	22,397	1,622,050	1,599,653	327,321
2004	22,397	1,745,983	1,723,586	314,893
2005	22,397	1,897,384	1,856,987	302,915
2006	22,397	2,022,979	2,000,582	291,373
2007	22,397	2,177,544	2,155,147	280,254
Total	1,202,223	28,188,096	20,985,873	5,630,778

Internal Rate of Return (%)	75.1
Net Present Value (million B.)	5,631
Benefit/Cost Ratio	8.27

Table 8.7 Evaluation of ATC Project
(Stage I only)

(1,000 Baht)

Year	Cost	Benefit	B-C	B-C discounted by 12 % p.a.
1990	18,006		-18,006	-16,077
1991	533,326		-533,326	-425,164
1992	22,205		-22,205	-15,805
1993	22,205	721,658	699,453	444,515
1994	22,205	754,812	732,607	415,701
1995	22,205	787,965	765,760	387,958
1996	22,205	821,118	798,913	361,388
1997	22,205	848,494	826,289	333,724
1998	22,205	875,869	853,664	307,840
1999	22,205	903,245	881,040	283,671
2000	22,205	930,620	908,415	261,148
2001	22,205	957,995	935,790	240,194
2002	22,205	985,370	963,165	220,732
2003	22,205	1,016,543	994,338	203,461
2004	22,205	1,048,704	1,026,499	187,537
2005	22,205	1,081,881	1,059,676	172,856
2006	22,205	1,116,108	1,093,903	159,321
2007	22,205	1,151,418	1,129,213	146,842
Total	906,612	14,001,801	13,095,189	3,669,843

Internal Rate of Return (%)	73.9
Net Present Value (million B.)	3,670
Benefit/Cost Ratio	7.50

APPENDIX - OVERVIEW OF EXISTING ATC SYSTEMS IN THE WORLD

1. General

This Appendix presents a summary of existing ATC systems in selected counties including United Kingdom, France, Australia, USA and Japan.

2. United Kingdom

At present, there are 24 signal systems which can coordinate nearly 5,000 signal controllers altogether on fixed time plans. The largest system is in London, where computers in New Scotland Yard are connected over telephone lines with about 1,200 signal controllers.

Many of the fixed time signal systems use timing plans based on TRANSYT, an off-line optimization tool. Quite often the plans have been modified manually for partial updates to accommodate local changes in the traffic situation. Whilst overall fixed time signal systems have been proven to be highly cost effective, experience shows that it is difficult to devote resources to producing completely new signal plans as often as is desirable to maintain high efficiency. It is reported that the need for, but burden of updating fixed time plans is a key reason why in recent years in the U.K. most orders for new signal systems have specified traffic responsive control by SCOOT. In some places, conventional fixed time signal systems are being replaced by SCOOT which is a highly automatically traffic-dependent system.

3. France

In France more than 50 cities or almost all the cities with more than 80,000 inhabitants are now equipped with centralized traffic signal systems.

A typical example of control strategies in France is as follows; intersections in the control area are divided into a number of sectors based on the analysis of the coherence of the traffic in a given sector as compared to the others. A sector may comprise from 10 to 50 intersections. The strategies at the area level are based on the automatic selection of pre-computed traffic plans. The selection process works in two steps.

Firstly, the selection at the sector level is made in the following ways: Automatic analysis of the traffic every 3 minutes with either of two different processes are made depending on the level of congestion in the selected links. If the level of congestion in these links is under a given threshold, the most suitable pattern of parameters is selected. The measurements use a linear combination of occupancy and volume and they are smoothed over 12 minute periods. If the level of congestion in the selected links of the sector exceeds the threshold, then the selection process uses only a subset of the measurement points in

order to give a marked priority to the relief of the congestion in the selected links.
Next to the plan selection for each sector, some automatic local modification may be made by the central computer on a cycle by cycle basis for individual intersections using vehicle-actuation and congestion detectors.

4. Australia

There are about 5,500 traffic signals in Australia, most of which are installed in major cities with a population of 1 million or more. Control methods of the ATC systems in Australia can be classified into four types as follows:

1) fixed-time control which is still used in some parts of the Melbourne CBD,

2) traffic-adaptive selection of preset signal plans according to the information from strategically located detectors which is used in some arterial roads in Brisbane,

3) linked vehicle-actuated (VA) control in which VA intersection controllers are used in a fixed-time area control system, e.g. in parts of the Melbourne, Adelaide and Brisbane CBD's, and

4) traffic responsive control using the Sydney Coordinated Adaptive Traffic System (SCAT).

5. USA

From 1968 to 1975 in the USA, the Urban Traffic Control System (UTCS) project was established by the Office of Research of the Federal Highway Administration (FHWA). The objectives of this project was to develop and test new computer-based control strategies under real world conditions. The control strategy research associated with the UTCS project has been divided into three generations:

1) First generation control: prestored timing plans developed by off-line optimization techniques

2) Second generation control: computes timing plans on-line based on current traffic data

3) Third generation control: computes timing plans on a cycle-by-cycle basis

The Institute of Transportation Engineers prepared a report in January 1987 based on a survey of traffic signal systems in the United States and Canada. A total of 245 traffic signal systems were identified with 143 in operation, 58 under construction, and 44 in planning stage.

Most of the systems in operation today use conventional plan selection control (first generation control). The timing plans are established by using off-line optimization tools like TRANSYT. A few on-line control strategies based on current traffic data (the one and half- to the second generation control) are being applied experimentally in some of the systems.

6. Japan

Table A.1 shows the numbers of traffic signal controllers of various types in Japan as of March 1987. The total number of traffic signals is approximately 122,000 out of which 34,500 are in the area control systems in 74 cities. The control principle of area control is basically conventional traffic-adaptive plan selection type. Green times of the critical intersections, however, are usually controlled in the manner of traffic-responsive plan-formation methods.

A whole area of a system is divided into a number of sub-areas in such a way that the traffic condition varies in a similar manner within a sub-area. The signal timings that are cycle length, green splits and offsets are determined for each of the sub-areas individually in principle.

Ultrasonic vehicle detectors are usually used mainly because of maintenance reasons. The vehicle detectors are installed at 150 to 200 meters upstream of the stop lines of all the approaches of major intersections.

Table A.1 Traffic Signals in Japan (as of March 1987)

Types Control	Number of Traffic Signalized Intersection
1) Area Control (74 cities)	34,510
2) Coordinated (3,860 groups)	19,499
- traffic-responsive	5,247
- pretimed multi-program	12,584
- pretimed single-program	460
- coordinated push button	1,208
3) Isolated	67,795
- full traffic-actuated	1,039
- semi traffic-actuated	6,439
- bus/rail-responsive	390
- pretimed multi-program	39,223
- pretimed single-program	588
- push button	19,471
- others	645
Total	121,804

PART 3

STUDY ON COMMON UTILITY DUCT SYSTEM

Part 3 Study on Common utility Duct System

Table of Contents

1. INTRODUCTION

1.1 Background

The rapid expansion of social and economic activities and the concentration of population in the Bangkok Metropolitan area have entailed a sharp increase in the demand for public utilities such as telephone, electricity, water supply and drainage. These public utilities are so indispensable to sound urban lives, that they can be rightly termed as the life lines of the urban areas.

To cope with the ever increasing demands for public utilities, the relevant enterprises have been putting their efforts into both installing new facilities and improving existing ones. The number of telephone lines, for instance, has become fourfold in the past decade and it is still envisaged to double in the next few years.

Most of the public utilities in Bangkok have been and will continue to be installed underneath the roads, as is the case in other major cities around the world. The installation works necessitate excavations of road surface, adding to serious traffic congestions in the roads which are inherently insufficient for the present traffic needs.

Matters are further aggravated by the uncoordinated installation works which are undertaken at the convenience of the respective public utility enterprise, and thus lead to repeated road excavations. It should also be noted that even a minor obstruction to traffic flow at one spot can easily cause a serious traffic paralysis for substantially wider areas in Bangkok where road networks are chronically oversaturated.

A solution to this problem can be found in the common utility duct which is generally constructed underneath roads. Although there are different types of common duct, the basic concept of a common duct is to provide necessary space for placement and maintenance of different public utilities in one structure without causing any substantial obstruction to traffic, once it is constructed.

1.2 Objectives

The objectives of the study on common utility duct plan are to provide BMA with general knowledge and practice of common utility ducts together with basic engineering and administrative information and materials necessary for planning and facilitating common utility ducts in Bangkok.

In order to attain the objectives, the following works are carried out in this study;

1) General review as to the necessity of common utility duct in Bangkok;

2) Preparation of technical guidelines for planning and designing common utility ducts;

3) Production of materials necessary for proposing regulation/law proposals, and

4) Execution of case study plans of common utility ducts at selected road sections.

Common utility ducts, as described in the following paragraphs, offer considerable advantages both in terms of traffic engineering and economics. Common utility ducts sometimes vary in name from one country to the other either in accordance with their functions, or simply due to different naming practices.

A brief outline of the experiences and practices of various countries in the application of common utility ducts is attached in Appendix B to assist BMA in the discussion and introduction of common utility ducts in Bangkok.

1.3 Study Flow

This study was carried out in two (2) stages for a total of ten (10) months. The work flow is shown in Figure 1.1.

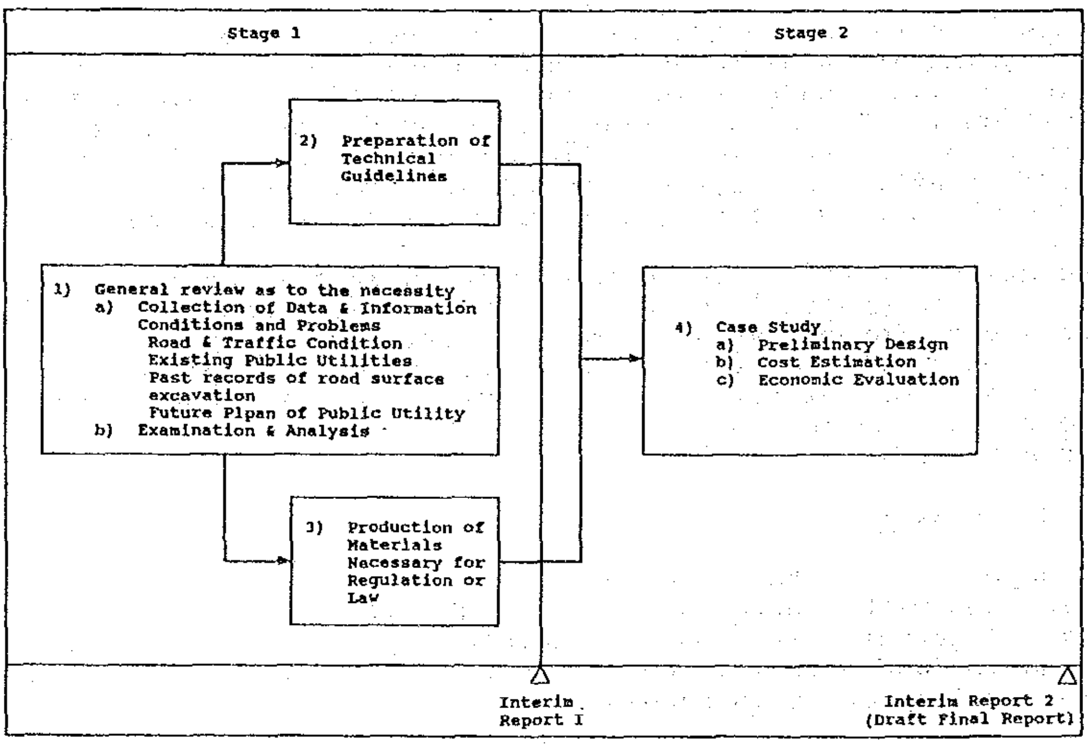


Figure 1.1 Work Flow of Study

2. GENERAL

2.1 Public Utilities in Bangkok

In Bangkok, the major public utilities constructed in road spaces include telephone and electricity cables and pipes for water supply and drainage. City gas supply system has not yet been developed.

1) Telephone

The primary cables connecting telephone exchanges and cabinets are laid underground, while feeder cables and service cables connecting to subscribers are installed overhead. The present underground cables account for about 50% of all the telephone cables in Bangkok. The present policy of TOT calls for placing primary cables underground and feeder and service cables overhead. TOT however, envisages to switch the overhead cables to underground cables in the areas where the preservation of aesthetic standards are called for.

2) Electricity

Electric power is transmitted from the EGAT-owned 230KV outer loop cable to MEA's terminal stations in Bangkok and then to distribution substations via 69KV subtransmission lines. From the distribution substations, 12KV distribution lines conduct electricity to transformers (customer substations) on electric poles where the voltage is dropped to 220V for distribution to users. Major consumers are, however, supplied directly with electricity from distribution substations by either 12KV or 24KV cables.

In large areas of Bangkok most of the 69KV and 12KV secondary transmission lines are overhead, but in the three districts of Bangrak, Pathumwan and Phranakhon where the need for aesthetic standards preservation is designated as high, approximately 20% of transmission lines are laid underground.

Amid the rapid urbanization taking place in Bangkok, MEA's efforts to expand electric power supply facilities have been facing problems such as difficulties in ensuring the right-of-way and access to consumers' buildings, preservation of aesthetic view and securing of safety. Thus MEA has been actively studying the possibility of expanding the underground lines.

3) Water Supply

City water runs through water pipes of 2.0 to 3.4 meters in diameter from the filtration plants in Bangken, Thonburin and Samsen to clean water reservoirs by pump stations in different parts of Bangkok, from where the water is supplied to users through trunk mains (ø400 - 1,500mm), distribution mains (ø100 - 300mm) and service pipes (ø50 - 75mm).

Distribution mains and service pipes are generally placed beneath sidewalks, while trunk mains are laid under carriageways adjacent to the sidewalks. Transmission pipes are installed within the land owned by MWA.

4) Drainage

The drain pipes and box culverts of 2,700 x 2,550mm are laid either beneath sidewalks or adjacent to carriageways, in accordance with their functions; branch lines or trunk lines.

2.2 Road Underground Facilities

Figure 2.1 shows the public utility installations underneath Silom Road, a trunk road in the heart of Bangkok. Two ducts with 24 pipes for power cables, 4 ducts with 32 pipes for telephone cables, 2 drainage pipes and 1 duct (ø1,500mm, ø400mm and 1500mm), and 3 water main pipes (ø600mm and ø300mm x 2), totaling 12 pipes and ducts are laid underneath either the sidewalks or carriageways. In the past pipes and ducts were laid beneath the sidewalks to avoid interference with vehicular traffic. Recently, however, new pipes have been laid beneath the carriageways due to congestion of spaces under the sidewalks.

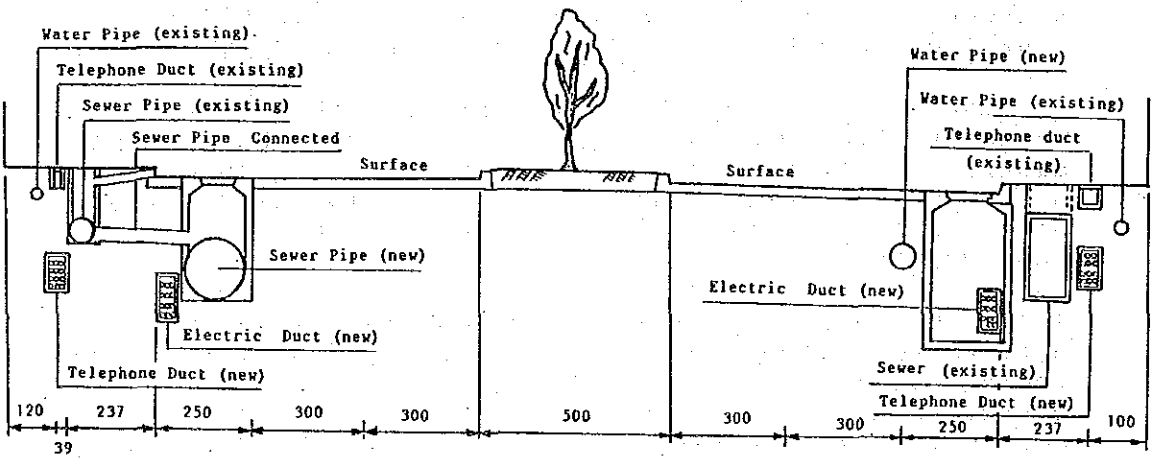


Figure 2.1 Public Utility Installation Beneath Silom Road

As the public utilities have been constructed on the basis of the individual expansion plans of each public utility enterprise, the roads in Bangkok are not necessarily properly used in view of utility accommodation space. Therefore it is hoped that efficient and orderly utilization with full coordination among concerned parties be attained in such a way so that not only public utilities but also construction of mass transit railways, expressways and sewerage system will be properly executed.

2.3 Future Demand for Public Utilities and Road Excavation Works

Excavations for public utilities installation are authorized for night time as a rule, however during excavation suspension in the day time, vehicle lanes are not restored to the normal state and road capacity suffers a drop due to restraints imposed on vehicle lanes.

Figure 2.2 shows the frequency of road surface excavations related to expansion and repair projects undertaken by public utility enterprises. The frequency tends to increase year after year. Summary of the expansion plans or the demand for public utility facilities is given below.

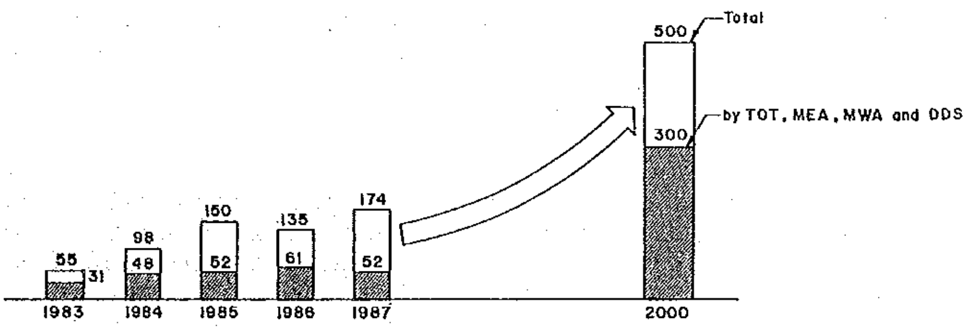


Figure 2.2 Excavation Works Number

1) Telephone circuits

It is planned to expand the telephone circuits (primary pair) from 870,000 in 1986 to 1,760,000 in 1992 (TOT data). The demand of telephone circuits is expected to increase to 2,100,000 in 1997 and 2,800,000 in 2002.

2) Power supply

According to the Master Plan Study executed by JICA, 1982, the distribution demand is expected to increase from 1.834 MVA in 1986 to 3.210 MVT in 1996 and to 4.260 MVA in 2001. In compliance with this demand an expansion plan for subtransmission lines calls for construction of additional lines of 68.8 km in length during the 1982/1991 period and of 214.1 km in length during the 1992/2001 period, and a distribution line expansion plan calls for increasing the number of lines from 345 in 1981 to 487 in 1991 (total cable length of 914 km) and construction of 770 additional distribution lines (total cable length of 1,538 km) in the year 2001. Of the planned subtransmission lines, a line length of 18.2 km will be laid underground. Feeder lines are likely to be laid underground in CBD and areas where the aesthetics standards are strict.

3) Water Supply

According to the Revised Master Plan of MWA, the demand of water supply (average daily demand of central system) shall increase from 2,097,000 CMD in 1985 to 3,214,000 CMD in 1995 and to 3,750,000 CMD in 2000. In compliance with the demand, MWA's Third Water Supply Project (1986 - 1990, Stage II Phase IA) consists of laying 1,000 km of distribution pipeline, and rehabilitation of 125 km of trunk pipeline and 1,000 km of service mains. The Fourth Water Supply Project (1988 - 1991, Stage II Phase IB) calls for laying 1,000 km of distribution pipeline.

4) Drain Pipeline

In Bangkok, a drainage pipeline network has been completed, and it is expected that rehabilitation of the network will have to be continued in the future. The JICA master plan prepared in 1981 calls for the construction of 36.8 km of trunk pipeline and 1,020 km of branch pipeline during a 20 year period following the start of a sewage system development plan.

5) Natural Gas

According to the PTT master plan, there will be an 8-16 inch natural gas distribution pipeline loop around Bangkok in the future and gas will be introduced into Bangkok by a 4-10 inch main distribution pipeline system from the loop and supplied to each consumer by a 1-6 inch pipeline.

With Bangkok's high pace of urbanization, road surface excavations necessitated by expansion plans for public utilities are likely to continue to increase in the future. Increased road surface excavations will obviously not only accelerate traffic congestion but undermine road structures, thereby seriously affecting the daily life of residents along the roads involved.

2.4 Classification of Common Utility Ducts

The ducts are classified broadly into trunk line common utility ducts and supply line common utility ducts. The simplest of the supply line common utility ducts which accommodates only power, telephone and other similar cables is customarily termed a cable box (CAB).

1) Trunk Line Common Utility Duct

Trunk line common utility ducts accommodate main cables (for example; cables connecting a terminal station with a distribution substation) and main pipes (for example, pipes leading from water supply treatment plant to a pump station) which are not intended to directly serve areas adjacent to adjacent to the road along which the common utility ducts are constructed. They are primarily constructed beneath roadways.

2) Supply Line Common Utility Duct

The common utility ducts accommodate cables and pipes which serve users of neighboring areas with power, water, gas and telephone and other public utilities. The public utility enterprises can serve users directly without having to dig roads when new supply demands arise. Thus supply line common utility ducts are normally constructed under sidewalks to facilitate the supply and avoid adverse effects on traffic movement.

3) Cable Box (CAB)

The cable box, a type of supply line common utility duct is an answer to the problem of high cost construction in normal common utility ducts. In general, the CAB system is of U-shaped pre-cast concrete structure with covers at the level of road surface and is built under sidewalks. Cable boxes accommodate not only power and telephone cables but also cables needed for new communication media which is expected to come into wide use with the progress of the highly information oriented society.

Figure 2.3 shows a schematic cross section for each common utility duct.

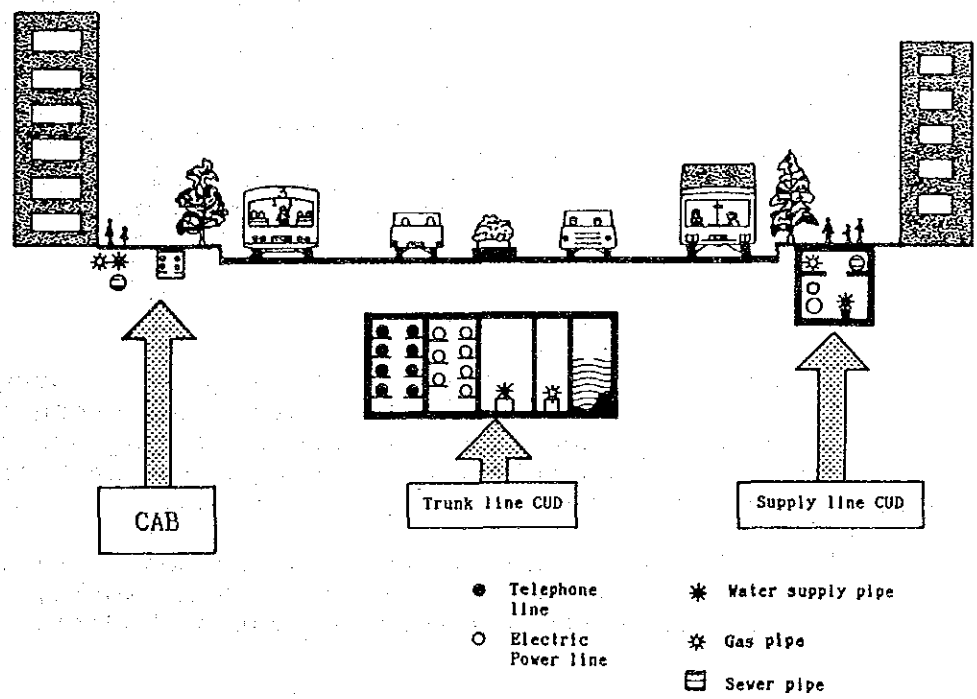


Figure 2.3 Schematic Cross Section of Common Utility Ducts

2.5 Benefits of Common Utility Duct

The benefits expected from common utility ducts are shown in Table 2.1.

Table 2.1 Expected Benefits of Common Utility Ducts

Benefits		Details of Benefits
Benefits to Authorities Responsible for Road Management	Smooth flow of road traffic	- Elimination of traffic congestion due to road surface excavations. - Avoidance of traffic accidents due to road surface excavations.
	Preservation of road structure	- Reduced maintenance and repair costs of roads. - Prevention of vibrations and noise due to deterioration of road surfaces.
	Prevention of public nuisance (noise and vibrations) due to construction works	- Noises and vibrations due to construction works can be prevented since they are undertaken in the duct.
	Effective utilization of road spaces	- Larger road spaces available as a result of concentration of public utility facilities. - Larger spaces available for planting and pedestrian traffic as a result of expansion of road spaces.
Benefits to public utility enterprises	Higher priority to expansion or renewal of public utility facilities	- Easier to expand or renew public utility facilities according to public demand and changes in land utilization.
	Increased safety of public utility facilities and stabilized supply of power, water and gas	- Visual inspection helps achieve, reliable maintenance which in turn ensures safety of public utility facilities and stable supply of power, water and gas.
Improved street scenery		- Improvement of street scenery as a result of laying overhead cables underground. - Improved street scenery contributes toward enhancing the value of cultural and tourist resources of Bangkok.

2.6 Necessity of Common Utility Duct

The need of constructing common utility ducts in Bangkok is obvious in the light of their benefits against the background of Bangkok's rapid socio-economic growth and resulting urbanization at a rapid tempo, growing road traffic congestion and execution of expansion plans for public utility facilities.

It should be, however, noted that a common utility duct construction involves a large scale of civil works, a long construction period as well as a large amount of budget.

Common utility duct planners should expect some traffic problems and financial difficulties, at the stage of initiating of common utility ducts and accordingly take precautionary measures to minimize traffic problems during their construction.

In effect, the need of common utility ducts, which will bring about a great benefit to the concerned agencies and the general public over a long period of time, can be appropriately assessed only in the long run.

3. TECHNICAL GUIDELINE

This technical guideline is prepared to provide a guide for planning and design of each type of common utility duct trunk-line, supply-line and CAB. The principal contents are; a) General Planning Consideration, b) Geometric Design, and c) Structural Design.

3.1 General Planning Consideration

In planning a common utility duct, it is necessary to study the conditions of utilities already built in roads, and to check the existence of other projects planned in the same roads. The existance of any such projects makes it necessary to have sufficient coordination, through consultation, among the relevant authorities.

Common utility ducts should be built separately from other large structures such as bridge piers, or a subway tunnel in consideration of their structural characteristic and convenience for maintenance.

3.2 Geometric Design

1) Inner Space

Standard section should be determined in consideration of the space required by each public utility enterprise calculated based on the installation plan and additional space for maintenance and replacement works.

Usually a height of 2.1 m should be provided for maintenance, in the trunk-line and supply-line duct.

2) Earth Cover

The utility duct underneath the carriageway should be of sufficient depth to be below the pavement thickness and to provide for space for pipes buried in the crossing direction.

The utility duct underneath the sidewalk should be considered with the pavement thickness.

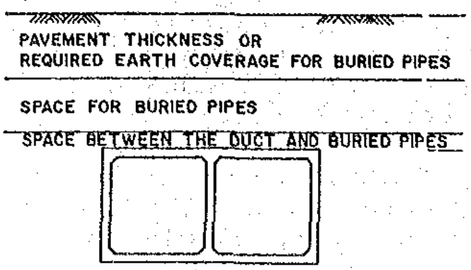


Figure 3.1
Minimum Earth Cover

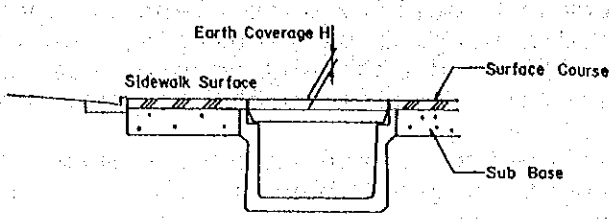


Figure 3.2
Earth Cover of CAB at Sidewalk

3) Alignment

Trunk-line ducts accomodating main cables and main pipes should be laid underneath the carriageway. Supply-line duct and CAB providing direct service to users should be laid underneath the sidewalk.

The CUD (common utility duct) horizontal alignment should, as a rule, follow with the road alignment.

In principle vertical gradient of a common utility duct shall be 0.2% or more to ensure effective drainage. The gradient shall be determined in considering the nature of the facilities contained, their maintenance, etc. and that it would accord with the gradient of the road as much as possible.

3.3 Structural Design

1) Loads

In designing the structure of a common utility duct, design loads should comprise; (a) Dead loads, (b) Live loads, (c) Earth pressure, (d) Hydraulic pressure, and (e) Buoyancy

For sections partly covered at the high groundwater level, the safety factor against buoyancy must be more than 1.2.

2) Allowable Stress

The design method of reinforced concrete members shall follow the SERVICE LOAD DESIGN of AASHTO.

3) Other Consideration

Trunk-line and supply-line ducts shall have ventilation openings and drainage system for maintenance purposes.

4. LEGISLATIVE ARRANGEMENT

4.1 General

To promote and facilitate the introduction of a common utility duct system, some legislative arrangements are required mainly on to the following items.

a) Designation of "common-utility-duct road" where no individual public utility is allowed other than in a common utility duct.

b) Restriction on excavations in the designated common utility duct road.

c) Development of plans for common utility ducts' construction.

d) Cost allocation among concerned parties, both for construction and operation.

4.2 Outline of Japanese Common Utility Duct Law

In 1925, the first common utility duct in Japan was constructed as part of the reconstruction projects in the wake of the Great Kanto Earthquake of 1923. Despite this post-earthquake tendency toward the construction of common utility ducts, no more were built in this country for nearly 30 years that followed.

In 1955, however, the necessity of construction of common utility duct systems in major cities came to be recognized as a means of preventing repeated digging of road surface, as part of measures against increasingly serious vehicular traffic congestion in urban areas, which resulted from a noticeable progress of the nation's motorization and rapid development of nation-wide road networks.

In 1963, the Common Utility Duct Law was promulgated, thereby the basis for the construction and management of the common utility ducts in Japan was settled. Under this law, common utility ducts are defined as road accessories and must be constructed at the cost of the road administrator. The facilities capable of being laid in common utility ducts are limited to electric cables, telephone cables, gas pipes, water pipes and sewage pipes.

Common utility ducts should be constructed on roads where traffic is heavily congested or expected to be heavily congested and which are designated by the Minister of Construction as "roads requiring the construction of common utility ducts". Works relative to occupancy of road on designated roads are, in principle, prohibited.

Once a road is designated as requiring the construction of common utility ducts, the road administrator shall refer to the public utility enterprises and announce the intention to construct a common utility duct, prepare the construction plan, finalize it after receiving the written views of the public utilities companies with regard thereto and finally commence the construction.

The ducts are not ordinary road accessories and the public utility enterprises are entitled to exclusive use of their respective portions of the ducts. It is considered appropriate for the public utility enterprises to share in the construction cost in because of the benefits derived by them from the use of common utility ducts. In this connection, Japan Development Bank loans are available to public utilities enterprises to help them bear their respective shares in the construction costs of common utility ducts.

For the maintenance of common utility ducts, maintenance regulations must be laid down by road administrators to keep them in good conditions.

5. CASE STUDY

5.1 Objective and Method

Survey results indicate that demand for public utilities is forecast to rise sharply over the next 10 years. Despite this expectation, utility enterprises have not established any coordinated set of long-term plans for the future. Under the current situation, each enterprise carries out expansion projects on an independent basis as the need arises. This procedure serves to aggravate traffic conditions in the city of Bangkok.

In view of the above situation, the need for a common utility duct (CUD) to accommodate all the necessary public utilities was mentioned in Chapter 2. Under this Case Study, a sample plan for such a duct was formulated and evaluated for a given section of road in the Bangkok area with the objective of providing a reference point for the establishment of CUD projects in the future.

5.2 Trunk-Line CUD

5.2.1 Subject Road

Roads below which the trunk-line CUD is to be planned must fulfill the following conditions:

- Population densities in areas along the road are high.
- Demand for public utilities is forecast to increase along with the further development of the roadside areas.
- Construction works to be necessitated by such increases in

demand are certain to obstruct the flow of vehicular traffic on the road.

It would also be desirable that the subject road is already included in a utilities trunk-line project.

Taking into consideration the above conditions, Phahon Yothin Road was selected for the trunk-line CUD in this Case Study from among the arterial roads located inside the Middle Ring Road and the 14 routes in the two districts surveyed (Pathumwan and Bangrak).

5.2.2 Preliminary Design

1) Preconditions

The preliminary design for the CUD is based on the following preconditions:

a) The subject route is the section between Klong Sam Sen and Soi Ari 7 on Phahon Yothin Road. The planned extension is 1,200 meters.

b) Foundation Structure

In case of bridges or buildings in such area as Bangkok, where the soft alluvial layer has a depth of more than 10 meters, deep foundations as piles are commonly used, to transmit the load to a more reliable underground layer.

But in case of underground structures, such as CUD or subway tunnels, it is generally not necessary to adopt deep foundations, for the structure does not cause any additional loading beneath the ground surface.

In the area where ground settlement is observed, care must be taken to avoid inconveniences due to unequal settlement. In such areas the use of a pile type foundation in CUD will keep the road above the CUD from sinking, but other parts of the road may sink. This will make it difficult to keep the pavement in good condition.

c) Concerning temporary system for excavation, the cut-and-cover method, which has been used many times in the past for underground works, will be adopted wherever earthcover is shallow.

d) Non-standard Sections

A trunk-line CUD must include openings for entrance/exit to allow periodic inspection and maintenance of the CUD itself as well as the utility installations. Ventilation ports are also needed to let in fresh air.

Since power and telephone cables are of limited lengths, space for joints is required. Gas pipes, moreover, must be housed in a separate room in order to absorb changes in temperature and stress, owing to the volatile nature of gas. In addition, sections where pipes and cables branch off must be larger than standard sections so as to secure enough space for turning.

All the above constitute non-standard sections of a CUD. It is obviously desirable from the standpoint of economy to minimize the number of non-standard sections. This can be done by organizing and combining the non-standard sections of each utility whenever possible. Accordingly, the following plan was established for the case study CUD:

- o Cable joint sections for power and telephone cables are provided every 400 meters or so.
- o One loop room is provided for gas pipes.
- o Assuming that cables and pipes will branch off at the intersections of the subject road, branching sections are established at three points.
- o Ventilators are provided every 200 meters or so, with alternating forced and natural ventilation.
- o One opening for entrance/exit is provided, at a location that coincides with a natural ventilation port.

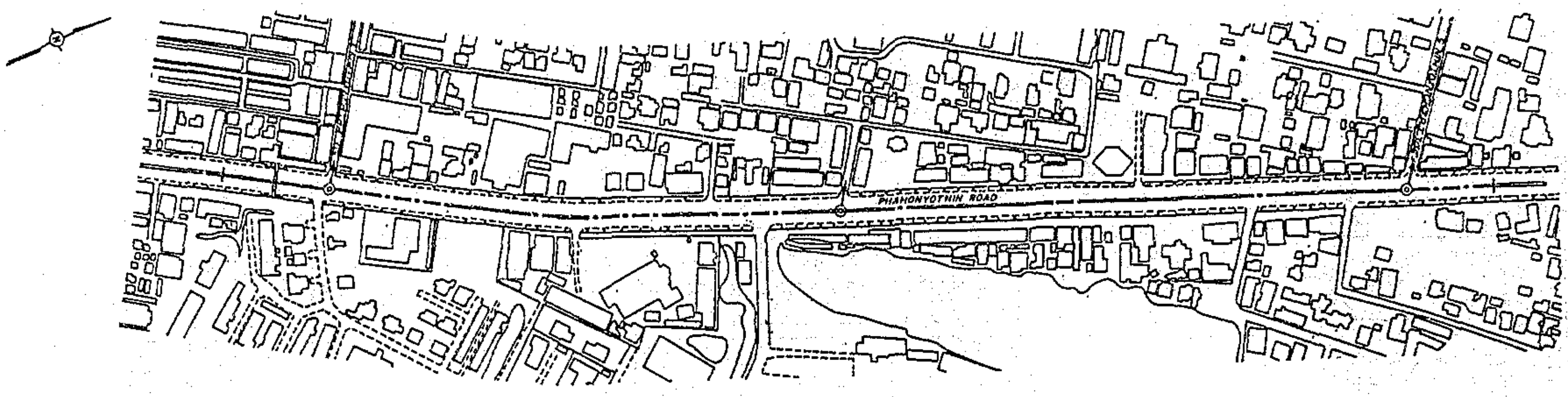
2) Accommodation Plan

An accommodation plan for the subject CUD was formulated so as to accommodate all the public utilities required, along with the necessary non-standard sections. A preliminary design was then drawn up on the basis of this accommodation plan. Based on the consideration that a standard cross section should be designed so as to house the utility installations with a minimum waste of space, six types of standard cross sections were selected. The accommodation plan is shown in Figure 5.1, and the six standard cross sections are shown in Figure 5.2.

Three Types were prepared for the 100-meters section from the starting point. Type F is applied when sewer system is included in the accommodation plan, and Types C or D are applied when it is not included.

3) Ventilation Plan

Ventilators are provided every 200 meters or so in the subject CUD, with alternating forced and natural ventilation. Gas pipes, however, are enclosed in a separate room and ventilated separately in order to ensure the safety of other facilities. Natural ventilation ports are also used as entrance/exit



P L A N
SCALE 1:4000

TOTAL DISTANCE (m)	1200 m			
SUB DISTANCE (m)	100 m	480 m	640 m	80 m
TELEPHONE	30 CABLES			60 CABLES
ELECTRICITY	15 CABLES	30 CABLES		
WATER PIPE	ø 900 mm			
GAS PIPE	NOT CONSIDERED		ø 250 mm	NOT CONSIDERED
SEWERAGE		NOT CONSIDERED		
TYPICAL SECTION	F	B	E	A

Figure 5.1 Accommodation Plan of Trunk Line CUD

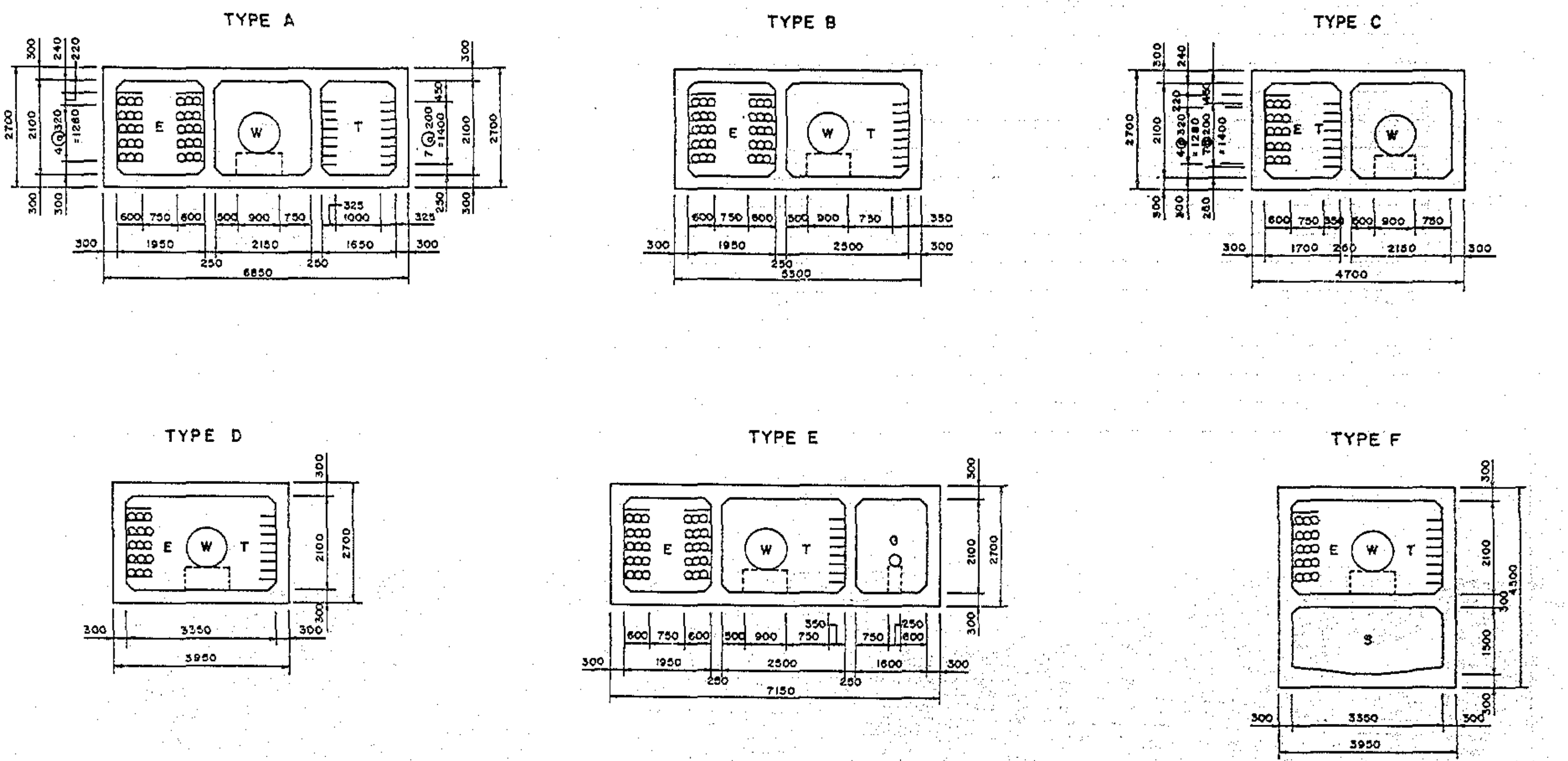


Figure 5.2 Selected Standard Cross Section

openings, with ladders for climbing in and out of the duct. One location will serve as an emergency exit and is provided with stairs. Since the noise of ventilation fans escapes from ventilation ports, ventilation ports are provided on the median, away from roadside residences. The ventilation plan is shown in Figure 5.3.

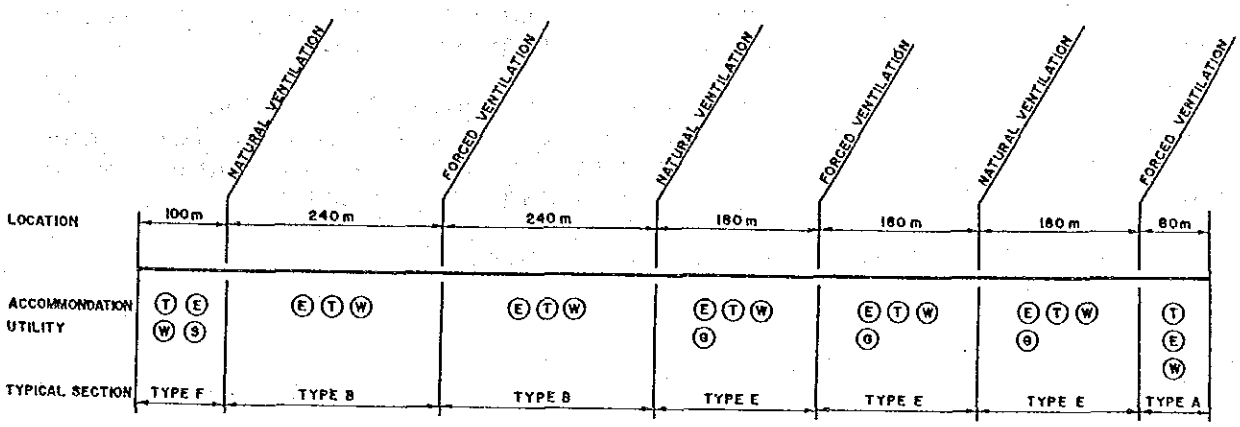


Figure 5.3 Ventilation Plan

4) Alignment Plan

a) Horizontal Alignment

Control points influencing the the horizontal alignment plan of a CUD are as follows:

- o Horizontal alignment of the road
- o Distance from road space boundary
- o Urban planning and other related projects

The Phahon Yothin Road does not have any particularly large objects buried under the carriageway. There are also no relevant projects being planned for the road. Thus, the horizontal alignment of the CUD was made to coincide with that of the existing road. Since the median can be used for entrance/exit and ventilation openings, the center line of the CUD was made to coincide with the center line of the road.

b) Vertical Alignment

The vertical alignment must be considered simultaneously with the horizontal alignment. In addition to the control points influencing the horizontal alignment, the vertical alignment plan must take into consideration the following factors:

- o Earth cover (distance from road surface to CUD top slab)
- o Gradient

Since there are no large transverse pipes buried under the subject route, the main control point in planning the vertical alignment of the CUD is earth cover. Since non-standard sections have larger cross sections than standard sections, the bottom of CUD must be at a greater depth. This means that the overall CUD will have to be placed further down from the road surface. Since this is undesirable from the standpoints of economy and ease of construction, areas near non-standard sections were made partially deeper and provided with stairs. This allows earth cover in the standard sections to be kept shallow.

In accordance with the guidelines, earth cover of 2.5 meters was secured for standard sections and at least 1.0 meter for non-standard sections. To allow drainage, the CUD was designed with a gradient of at least 0.2% in the standard sections.

The alignment plan is shown in Figure 5.4.

5.3 Supply-Line CUD

5.3.1 Subject Road

Routes to be provided with a supply-line CUD should fulfill the following conditions:

- o Roadside usage is already high and is expected to be further promoted in the future.
- o There is a need for securing the means to expand the capacity of public utilities in an efficient manner.
- o The heavy volume of traffic is causing, or is forecast to cause, congestion.
- o Sufficient road width has already been secured in accordance with urban planning projects, and there are no plans to widen the road further in the future.
- o The road is wide enough to allow the construction of a supply-line CUD.

Taking into account the above conditions, Rama I Road was selected for the supply-line CUD in this Case Study, from the two districts surveyed (Pathumwan and Bangrak). The road is one of the east-west arterials with Rama IV Road and New Petha Buri Road, and its average daily traffic is currently a high of 78,000 vehicles. Moreover, there are large durable structures along the road, including a hotel, department store, world trade center and hospital, and pedestrian traffic is quite high.

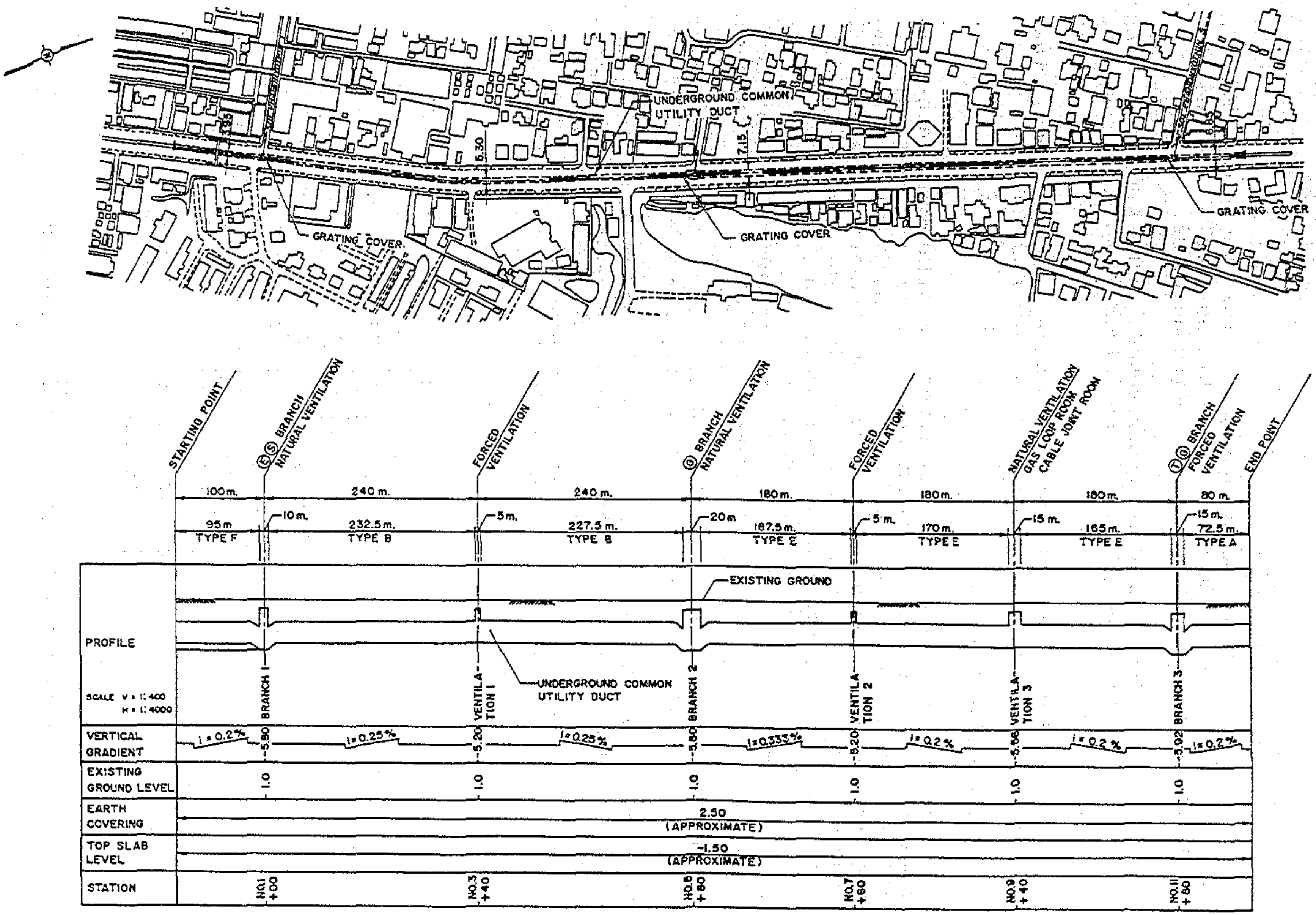


Figure 5.4 Plan and Profile of Trunk Line CUD

5.3.2 Preliminary Design

1) Preconditions

A preliminary design was prepared for the 700-meter section extending to the east and west of the Ratcha Damri intersection. The design is based on the following preconditions.

- Of the existing underground installations, trunk cables and pipes will be relocated to the trunk-line CUD.

- Since existing water pipes are supply pipes, they will be relocated to the supply-line CUD.

2) Accommodation Plan

There is a large number of underground installations below the sidewalks of the subject road, and it will be difficult to relocate all these pipes and cables. In addition, there are connector pipes leading from roadside housing toward sewer manholes located on the carriageway sides of the sidewalks. These connector pipes run at right angles to the road and are found about 50 cm beneath the sidewalks at 10-20 meter intervals, making it impossible to construct a large structure of continuous length immediately under the sidewalk surface anywhere between the dwellings and sewer trunk pipes in a position parallel to the sidewalks. Therefore, the CUD is placed below these connector pipes. This makes its earth cover roughly 1.0 meter.

The CUD houses low- and medium-tension power cables, telephone supply cables, and supply pipes (300 mm diameter) for water. Telephone cables include two cables for data communication (telex, etc.) provided by the Communication Authority of Thailand. The standard cross section is shown in Figure 5.5.

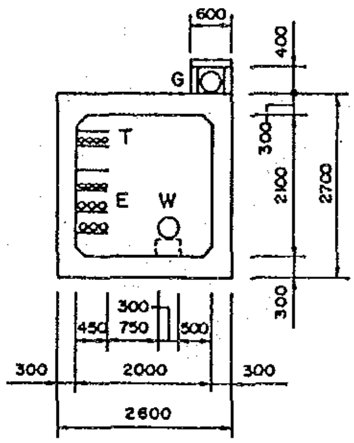


Figure 5.5 Section for Supply Line CUD

3) Ventilation Plan

As in the trunk-line CUD, natural and forced ventilation is provided every 200 meters or so in alternate positions. The ventilation port, as shown in Figure 5.6, is placed on the sidewalk.

4) Alignment Plan

a) Horizontal Alignment

Of the existing underground installations found below the sidewalks, water pipes take up a large space. Since the subject route to the west of Ratcha Damri intersection has sidewalks of sufficient width (over 6 meters), the alignment plan places the CUD near the center of the sidewalk in this section. To the east of the Ratcha Damri intersection (Phloen Chit side), the sidewalks are only 4 meters wide. In addition, there is a pedestrian bridge in front of the department store. Since these factors prevent the CUD from being placed under the sidewalk without hitting a sewer pipe, the CUD is designed to run below the carriageway in this section. Figure 5.7 shows the two placement positions.

b) Vertical Alignment

Minimum earth cover was established as 1.0 meter, taking into consideration the positions of existing trunk line installations below the ground. At intersections, the CUD dips downwards to pass under the transverse pipes; earth cover in this case is 2.5 meters. Minimum gradient is 0.2%. In addition, drainage facilities are provided at intersections owing to the deeper earth cover. Figure 5.8 shows the horizontal and vertical alignments of the CUD.

5.4 Project Cost and Implementation Plan

Project costs of the CUD were calculated on the basis of the preliminary designs. Economic costs necessary for economic analysis were also calculated.

5.4.1 Preconditions

The calculation of project costs was based on the following preconditions:

- o Unit construction costs are based on July 1989 prices.
- o The project cost consists of direct construction cost, indirect construction cost (administrative expenses, profits, etc.), contingency, and expenses for detailed design and construction supervision.

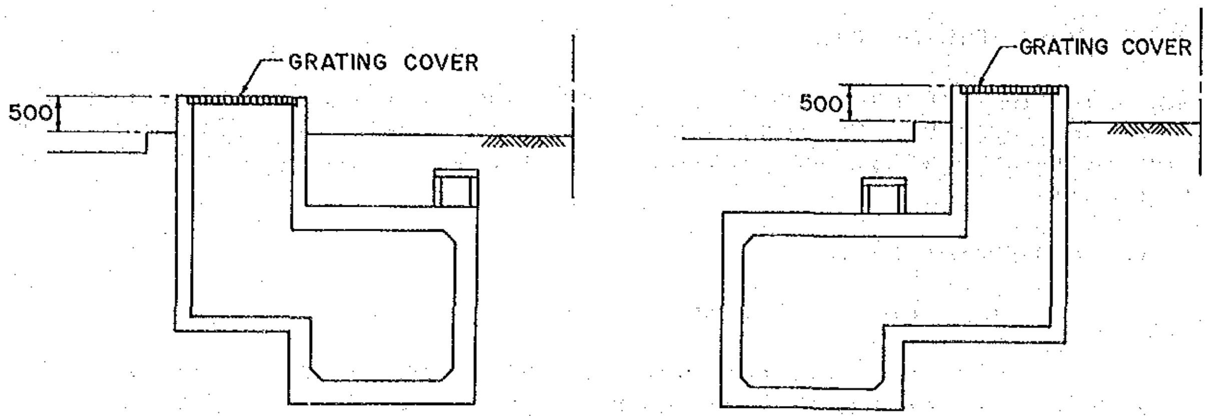


Figure 5.6 Section at Ventilation

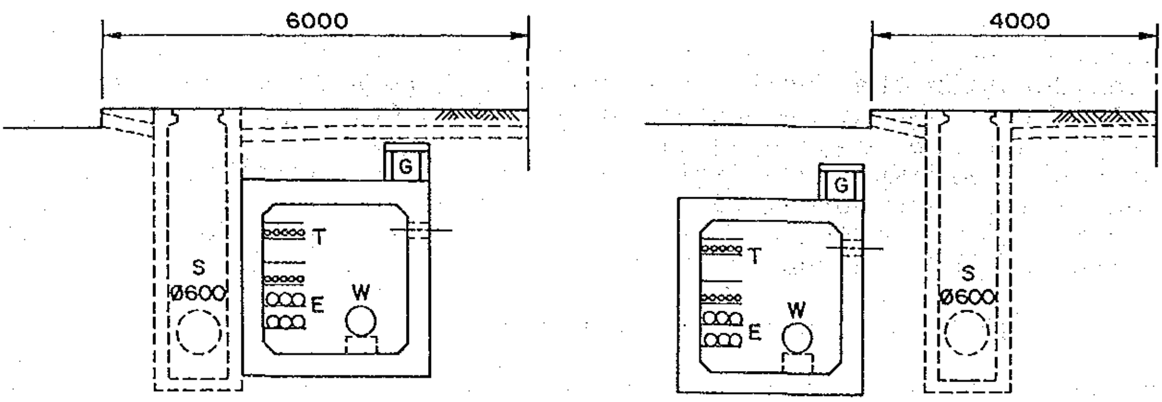


Figure 5.7 Relationship between CUD and Sewer Pipe

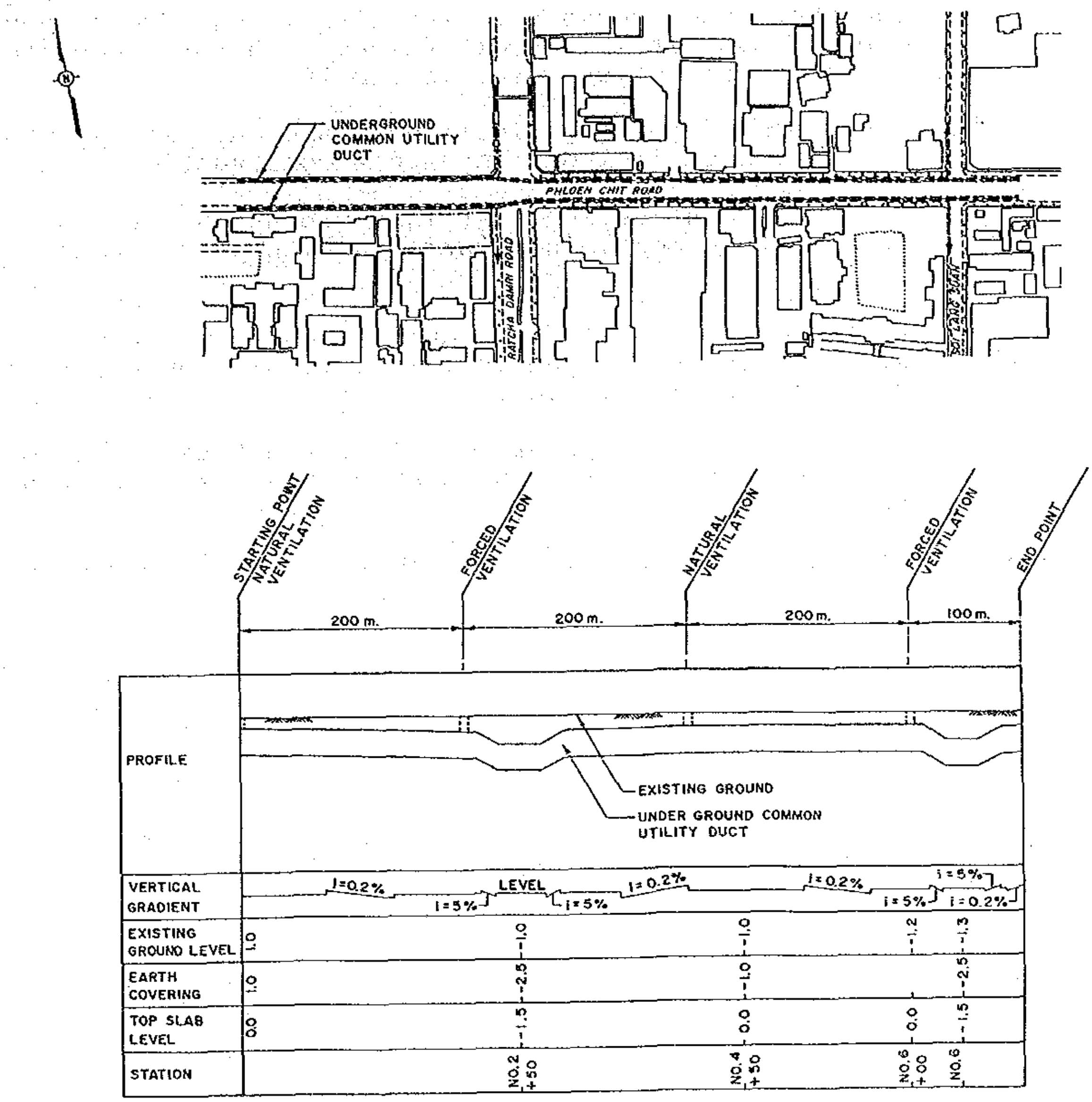


Figure 5.8 Plan and Profile of Supply Line CUD

- The unit cost of a job item is obtained by adding together the costs of materials, equipment and labor. Job items are determined with reference to recent construction works in Thailand.
- The cost of building incidental and accessory CUD facilities is included in direct construction cost.
- Indirect construction cost is given as 25% of direct construction cost, in accordance with past examples in Thailand.
- Expenses for detailed design and construction supervision are given as 10% of total construction cost (direct + indirect).
- Contingency corresponds to 10% of the total cost of construction, detailed design and construction supervision.

The above preconditions are outlined in Figure 5.9.

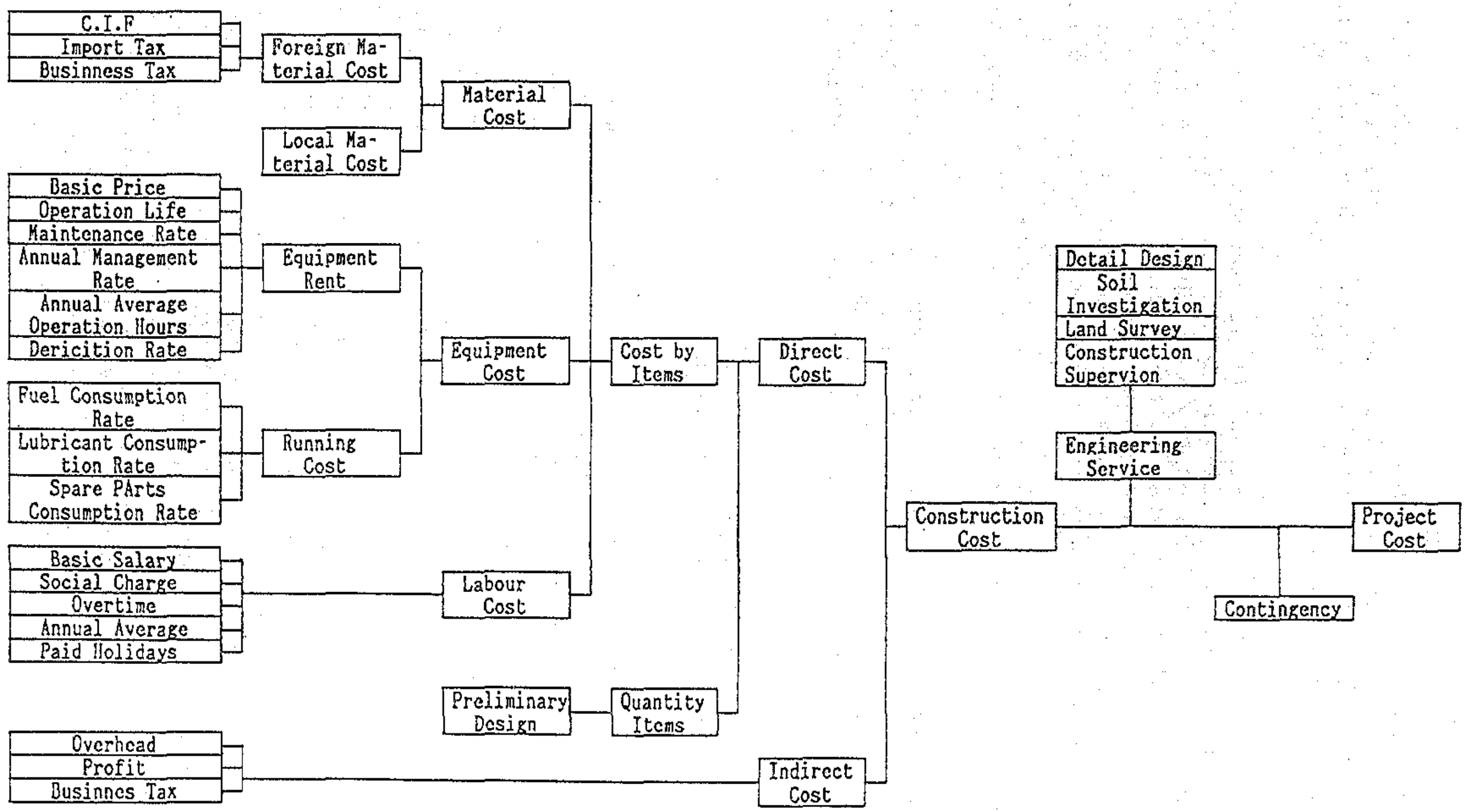


Figure 5.9 Cost Estimation Process

5.4.2 Project Cost

Construction costs of the CUD calculated on the basis of the foregoing are shown in Tables 5.1 and 5.2. The tables give construction cost by type of structure, broken down into foreign and local currency portions, with the former calculated in U.S. dollars.

The project cost of the trunk-line CUD is roughly $6 million in foreign currency plus 89 million baht in local currency. Corresponding figures for the supply-line CUD are $2 million and 29 million baht. These amounts are based on July 1989 prices and do not take inflation into account. Converting the foreign currency portion at the prevailing exchange rate of 25 baht per U.S. dollar and adding the result to the local currency portion, the project cost can be calculated in local currency: 251 million baht (foreign currency ratio: 65%) for the trunk-line CUD and 83 million baht (foreign currency ratio: 64%) for the supply-line CUD.

Project cost per meter is 210,000 baht and 117,000 baht for the trunk-line and supply-line CUD respectively. Temporary construction costs account for as much as 60% of the project cost. This is because materials used for temporary construction are mostly imported.

Table 5.1 Summary of Financial Cost of Trunk Line Common Utility Duct

Unit:1000 Baht

Section	Length (M)	Construction Foreign	Construction Local	Total	Per LM	Foreign (%)	Local (%)
Type F	95.0	10,870	5,937	16,807	177	64.7	35.3
Branch 1	10.0	1,230	702	1,932	193	63.7	36.3
Type B	460.0	47,350	25,891	73,241	159	64.6	35.4
Venti 1	5.0	628	356	984	197	63.8	36.2
Branch 2	20.0	2,687	1,517	4,204	210	63.9	36.1
Type E	502.5	57,556	31,443	89,000	177	64.7	35.3
Venti 2	5.0	746	431	1,177	235	63.4	36.6
Venti 3	15.0	2,214	1,288	3,502	233	63.2	36.8
Branch 3	15.0	2,155	1,264	3,419	228	63.0	37.0
Type A	72.5	8,713	4,822	13,535	187	64.4	35.6
Total	1,200.0	134,149	73,652	207,800	173	64.6	35.4
Engineering Service		13,415	7,365	20,780		64.6	35.4
Contigency		14,756	8,102	22,858		64.6	35.4
Grand Total	1,200.0	162,320	89,118	251,438	210	64.6	35.4

Table 5.2 Summary of Financial Cost of Supply Line Common Utility Duct

Unit:1000 Baht

Section	Length (M)	Construction Foreign	Construction Local	Total	Per LM	Foreign (%)	Local (%)
Type 1	210.0	11,079	6,235	17,314	82	64.0	36.0
Type 2	340.0	20,850	11,627	32,477	96	64.2	35.8
Type 3	150.0	11,732	6,326	18,057	120	65.0	35.0
Total	700.0	43,660	24,188	67,848	97	64.4	35.6
Engineering Service		4,366	2,419	6,785		64.4	35.6
Contigency		4,803	2,661	7,463		64.4	35.6
Grand Total	700.0	52,829	29,267	82,096	117	64.4	35.6

5.4.3 Implementation Plan

Since the CUD will be built below the subject roads (including sidewalks), there is no need to purchase new land. However, since there are many public utility installations currently buried under the roads, a survey of such facilities is necessary. Accordingly, a year was allocated for the preparation and design period. Concerning the construction period, time frames were established for each CUD section according to the volume of work required. Tables 5.3 and 5.4 show the implementation schedules for the trunk-line and supply-line CUD respectively.

Table 5.3 Trunk Line CUD Implementation Schedule

SECTION/YEAR	1990	1991	1992	1993	1994	1995
E/S & Preparation	------					
TYPE F		———	———			
BRANCH 1		———				
TYPE B		———	———	———		
VENTI 1		———	———			
BRANCH 2		———	———			
TYPE E		———	———	———		
VENTI 2			———	———		
VENTI 3			———	———		
BRANCH 3				———		
TYPR F			———	———		

LEGEND ——— CONSTRUCTION

------ E/S & Preparation

NOTE : E/S;ENGINEERING SERVICE

Table 5.4 Supply Line CUD Implementation Schedule

SECTION/YEAR	1990	1991	1992	1993	1994	1995
E/S & Preparation	------					
TYPE 1		———	———			
TYPE 2		———	———			
TYPE 3		———				

LEGEND ——— CONSTRUCTION

------ E/S & Preparation

NOTE : E/S;ENGINEERING SERVICE

5.5 Evaluation

5.5.1 Evaluation Method

The CUD case study will be evaluated by the unit-year cost benefit analysis, which compares the case with the CUD project ("with" case) and the case without it ("without" case). The CUD consists of a number of various subsections. Each section will be independently evaluated, in addition to evaluation of the whole project. The work flow is shown in the following figure.

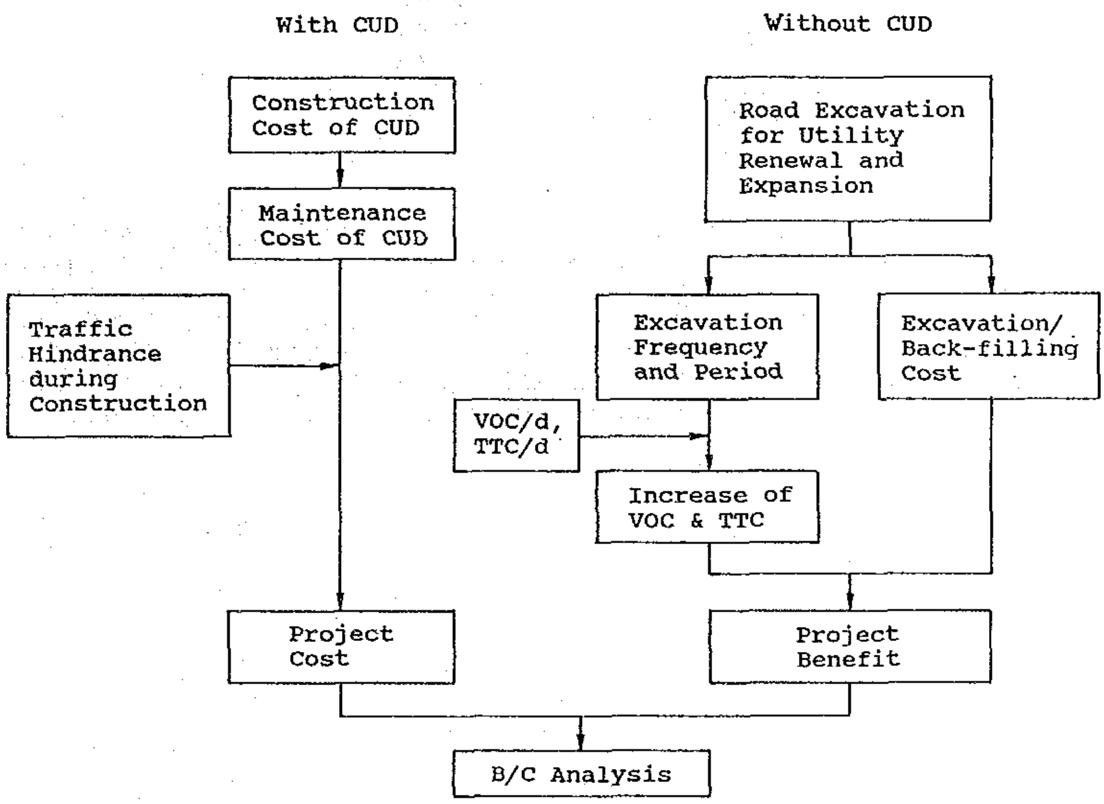


Figure 5.10 Work Flow of Cost Benefit Analysis on CUD Project

5.5.2 Evaluation of Trunk-Line CUD

The calculated benefit to cost ratio (B/C) is shown in Table 5.5.

Table 5.5 B/C Ratio of Trunk Line CUD Project by Section

Section	B/C Ratio
1	0.42
2	0.66
3	0.96
4	0.23
Whole Project	1.16

The B/C ratio is 1.16 overall, but it is extremely small for section 1 and section 4. This is because there is a large amount of traffic interference cost incurred over the long construction period compared with a short CUD length. A construction of only a short 80 or 100 meter CUD is not practical. Therefore, assuming a 1,200 meter CUD prepared for each type and a three-year construction period, costs and benefits are calculated as follows.

Table 5.6 Cost, Benefit and B/C Ratio of Trunk Line CUD Project by Type

Unit:B1000

	Type F	Type B	Type E	Type A
Cost				
Construction Cost	211164	191620	215398	227715
Traffic Hindrance Cost	247380	247380	247380	247380
Cost during Const. Period	458544	439000	462778	475095
Annual Equivalent Cost	55037	52691	55545	57023
Annual Maintenance Cost	422	383	431	455
Annual Equiv. Project Cost	55459	53074	55976	57478
Benefit				
Reduction of Excavation Cost	42576	34170	38251	34170
Mitigation of Congestion	641209	404054	487064	404054
Benefit from Avoiding Excav.	683785	438224	525315	438224
Annual Equiv. Project Benefit	85929	55874	67264	55874
B/C Ratio	1.55	1.05	1.20	0.97

Type F includes sewage lines, and type E includes gas lines. Therefore, benefits are expected from installing them together in a CUD, and the B/C ratio will be greater than that of type B and type A. Although type B and type A share the same benefit, the construction cost for type A is greater. Therefore, the B/C ratio of type A becomes lower.

The traffic hindrance cost share during construction, of the total project cost will become greater than the actual construction cost portion. The maintenance and administration cost is negligible compared with the construction cost and the traffic hindrance cost.

As to the benefit, the traffic congestion cost reduction effect is much larger than the excavation and back-filling construction cost reduction effect. This benefit varies greatly depending on the period and frequency of individual construction works. The benefit will decrease or increase, if actual period or frequency are respectively less or more than the assumed construction period and frequency.

In this evaluation, it is assumed that the road should be excavated at least once in 20 years for renewal and expansion of individual utilities. It often happens, however, that no renewal is made even when the economic service life is reached, and that the excavation frequency becomes lower than the assumption.

In order to raise the economic effect, it is important to decrease the traffic interference during the construction period by improving the construction method and procedure.

5.5.3 Evaluation of Supply Line CUD

The calculated B/C ratio is shown in Table 5.7.

Table 5.7 B/C Ratio of Supply Line CUD Project by Type

Type	B/C Ratio
1	0.28
2	1.15
3	1.01
Whole Project	1.52

For type 1, the CUD is unfavorable because no traffic interference factor is included and only the construction cost is compared. In the central part of the city where there is a heavy traffic volume, the traffic interference cost is significant compared with the construction cost in case of the CUD and also in case of individual construction. In other words, it is a comparison of invisible cost and benefit.

Therefore, in order to increase the economic effect, a careful study should be made on the reduction of the construction period and the construction method so that the traffic congestion cost reduction, which is one of the purposes, may not be sacrificed. The construction cost, even if running a little higher, may be controlled under an amount one digit smaller compared with the traffic interference cost.

5.5.4 Sensitivity Analysis

The benefit of a CUD project varies greatly with the frequency and period of excavation for renewal or expansion of individual urban utilities. Similarly, the disadvantage during the construction period of CUD depends on its length.

Considering this fact, the change of B/C ratio is studied by varying the frequency of individual civil works and their lane closure period for each CUD alternative case construction period.

1) Trunk-Line CUD

The annual equivalent cost of the Trunk-Line CUD presented in the Case Study is 57,774 thousand baht on condition that the construction period is three (3) years (Base Case). If the construction period is reduced to 2.5 years (Case 1) and to 2 years (Case 2), the annual equivalent cost will be reduced to 52,342 thousand baht and to 46,903 thousand baht, respectively. This is because the traffic hindrance cost will decrease, although the construction cost is unchanged.

The traffic hindrance and period of individual civil works should be more than 29 months within 10 years, in order that the annual equivalent benefit exceeds 57,774 thousand baht (B/C ratio is over 1) in the Base Case.

This value will be lower in proportion to the decrease in the annual equivalent cost of CUD in Cases 1 and 2.

Table 5.8 shows the above mentioned facts. It can be deduced from the table that a trunk-line CUD project of 3 year construction period as presented in the Case Study will be economically feasible on condition that individual excavations with average 1.5 months long lane closure are occurring more than once a year, or if average 7.3 months long, more than once every 5 years on Phahonyothin Road.

If the duration of traffic hindrance by individual excavation is 80% of the above mentioned level, that is, 1.2 months long once a year, or 6 months long once every 5 years, the construction period of CUD should be reduced to 2 years (2/3rd of that in the Base Case).

Table 5.8 Individual Excavation Frequency and Traffic Hindrance Period by Case for B/C Ratio of 1 (Trunk Line CUD)

Unit:month

Excavation Frequency	Traffic Hindrance Period		
	Base Case	Case 1	Case 2
Once during 10 years	14.5	13.2	11.9
9	13.1	11.9	10.7
8	11.6	10.6	9.5
7	10.2	9.2	8.3
6	8.7	7.9	7.1
5	7.3	6.6	5.9
4	5.8	5.3	4.8
3	4.4	4.0	3.6
2	2.9	2.6	2.4
1	1.5	1.3	1.2

2) Supply-Line CUD

In the Supply-Line CUD Case Study, the annual equivalent project cost is estimated at 48,636 thousand baht with a construction period of 2 years. This case is called the Base Case and cases in which the construction period of CUD is shortened to 1.7 months and to 1.5 months are called Case 1 and Case 2, respectively.

If the reduction of construction period does not affect the construction cost, the annual equivalent costs are 41,899 thousand baht in Case 1 and 38,530 thousand baht in Case 2, respectively.

The required excavation frequency and lane closure months for B/C ratio of 1 by case are shown in Table 5.9.

As Ploenchit Road is located in the central part of Bangkok and a closure of its lanes has a serious impact on the traffic condition, possibility that a CUD project becomes feasible seems to be comparatively high, if the duration of traffic hindrance by individual excavation is not very large.

In the Base Case, the CUD project will be feasible on condition that individual excavations of significant month long traffic hindrance occurs once a year, or 5 month long, once every 10 years.

In Case 2 of 1.5 year construction period, the feasibility of the project will be realized at about 80% level of excavation frequency.

In addition, if a reduction of the construction period raises the construction cost of CUD, the annual equivalent cost will decline, because the cost of construction is extremely smaller than that of traffic hindrance.

For example, if the construction cost rises by 20% in Case 1 and by 50% in Case 2, the annual equivalent cost will decline to 43,541 thousand baht and to 42,636 thousand baht, respectively.

As described before, the CUD traffic hindrance period and individual excavation are vital to the feasibility of CUD project. Therefore, it is important to make effort to reduce the construction period of CUD which causes traffic hindrance.

Table 5.9 Individual Excavation Frequency and Traffic Hindrance Period by Case for B/C Ratio of 1 (Supply Line CUD)

Unit:month

Excavation	Traffic Hindrance Period		
Frequency	Base Case	Case 1	Case 2
Once during 10 years	5.0	4.4	4.0
9	4.5	4.0	3.6
8	4.0	3.5	3.2
7	3.5	3.1	2.8
6	3.0	2.6	2.4
5	2.5	2.2	2.0
4	2.0	1.8	1.6
3	1.5	1.3	1.2
2	1.0	0.9	0.8
1	0.5	0.4	0.4

5.6 Conclusions and Recommendations

The case studies of common utility ducts (CUD) have revealed that two kinds of benefits by CUD (savings in excavation cost and transportation cost) could exceed the initial cost for CUD construction. Uneconomic conditions caused by traffic hindrance are extremely grave, especially in the central part of Bangkok where there is heavy traffic. As road traffic demand is deemed to continuously increase and congestion becomes more serious in the Metropolitan Region, CUD network development will become one of the most important long-term subjects.

On the other hand, the CUD network development will require a huge amount of investment. According to the case studies, construction cost per one meter is estimated to be 160 to 230 thousand baht for trunk line CUD and 80 to 120 thousand baht for a supply line CUD. This means that to develop 20 km trunk line and 80 km supply line CUD for example, total required investment will reach 12,000 million baht at 1989 price.

While investment demand for various types of urban infrastructure has been sharply increasing, capacities of financial resources are severely limited. Therefore, development priorities should be carefully determined among various urban needs. In any case, CUD network is to be gradually developed in accordance with a long-term comprehensive plan. In order to secure the first step concerning CUD development, the following actions are recommended.

(1) Formulation of CUD Masterplan

Each common utility enterprise should develop a long-term plan, if such a plan does not already exist, to establish the future network. Based on those long-term plans of various utilities, a CUD masterplan should be formulated. For this purpose a body consisting of representatives of all the organizations concerned should be set up with the objectives of coordinating planning, construction and maintenance of CUD.

(2) Technical Research on CUD Construction

Bad influence on road traffic by excavation works should be minimized through the study and application of suitable construction methods and traffic management systems. The shield method is promising and its technical and economic aspects should be examined, especially for the central area where there is heavy traffic.

The measures against ground settlement must be studied to avoid negative influence to CUD by unequal settlement. The necessity for solid foundation work for CUD should be studied carefully in this context.

In addition, appropriate measures against rainwater should be considered to prevent surface water from entering into CUD, because of the low ground level and strong rainfall intensity in Bangkok.

(3) Promotion of Pilot CUD Project

In order to confirm the advantages and clarify the issues of CUD, it is recommended to promote a CUD pilot project along a road section, selected from the viewpoints of excavation demand, traffic volume and aesthetic importance.

The pilot project should initially cope with supply lines rather than trunk lines, judging from the present land use and the conditions of the telephone and power cable networks in Bangkok.

(4) Legislative Arrangement

Laws and/or regulations of CUD should be established to prohibit any road surface excavation on the road section designated as CUD road and to clarify the responsibility of financing to and maintenance of CUD.