5.2 Suburban Transportation Planning

5.2.1 Policy

The basic policy to establish the transportation planning in the suburban area is "To provide some public mass transportation system for all of the area of GBA until to the year 2000".

For the purpose of establishing the suburban transportation system, following projects are considered to have been completed:

1) First Stage Expressway System
2) First Stage Mass Transit System
3) Outer Bangkok Ring Road
4) Future Planning Roads which are mentioned in the "Greater Bangkok Plan".

5.2.2 Basic Concepts used to Establish the Transportation System for the Suburban Area

The basic concepts used to establish the distribution of vehicle traffic and person-trips for each main route of traffic is as follows:

a) Through Traffic Routes of GBA

  i) The Outer Bangkok Ring Road was considered to play the role as a trunk road.

  ii) For the purpose of excluding the through traffic from the First Stage Expressway, the new road in the north-side of GBA should be considered as providing the same level of services as the Outer Bangkok Ring Road.

  iii) Through traffic on the existing SRT will be excluded from the examination.

b) Inter-zonal Traffic Routes (Generated Traffic from GBA and Attracted to the outside of GBA and vice versa.)

  i) The connection of the First Stage Expressway directly to the Outer Bangkok Ring Road is recommended and assumed.

  ii) The future planning roads will be examined as distributors.

  iii) Since the existing SRT within the GBA mainly deals with Inter-zonal traffic, it is considered.

c) Intra-zonal Traffic Routes of GBA

  i) The traffic on the future urban planning roads to be constructed was considered.

  ii) The approach road to the station of MTS, to be constructed, was taken into consideration.

  iii) The purpose and type of use of each planning road in the GBA was defined.

iv) The sections of the existing SRT providing transport for intra-zonal traffic were discussed.

v) Since the planned road network and proposed MTS mainly deal with intra-zonal traffic, they were considered in this category.

5.2.3 Necessity of Suburban MTS

(1) Existing Transportation Conditions

Recently, the rate of population increase for GBA has been more than 4 percent per year. This fact is not only due to the expansion of population in the CBD area but also to the expansion of residential population into the suburban area.

The main cause of traffic congestion problems especially on the radial roads from the suburban area to the CBD is due to the excessive concentrated development in the CDB area.

This tendency is conspicuous especially in the morning peak period when almost all the radial roads, from suburban area to central area within 10kms from the central area are fully occupied by vehicles.

The main existing mass transportation system from the suburbna area to the central area of Bangkok is bus. The inadequacy of the bus system (which uses congested roads) and the lack of an alternative rapid mass transit system from the suburban area to the central area intensifies the traffic congestion.

The traffic congestion in the central area of Bangkok (especially within 10kms from the city center) consists not only of intra-zonal traffic but also of traffic from the suburban area to the central area. According to the survey results of BTS, the trip distribution is as follows.

Table 5-25 TRIP DISTRIBUTION RESULTS

Traffic Flow Patterns	%
Intrazonal Traffic Volume of Core Area	44
Interzonal Traffic Volume between Core Area and Outside Area	34
Interzonal Traffic Volume Through Core Area	22
Total	100

Note: Core Area indicates the area within about 10 kms from the city center.

The existing congestion problems occuring in the area within about 10kms of the city center are summarized below. The main purpose of establishing the suburban MTS is to solve these transportation problems in the central area and to prevent their re-occurance in the future by connecting the suburban areas with the first stage MTS.

Summary of Causes of Existing Traffic Problems in Bangkok:

a) Urban Traffic Congestion

1. Inadequate supply of traffic corridors to meet current traffic volume.
2. Excessive congestion during the peak-hours
3. Inconsistancy of traffic regulation
4. Mixture of traffic modes with different speed

b) Inadequate Urban Transport Facilities and Systems

1. Absolute insufficiency of trunk highways
2. Poor access road network
3. Lack of rapid transit system
4. Deficiency of parking space area
5. Lack of road markings
6. Lack of sideworks and pedestrian crossings

c) Urban Environmental Problems

1. Accumulation of traffic noise
2. Air pollution by noxious vehicle fumes

d) Problematic land use patterns

1. Excessive Concentration of land use in a single center
2. Sprawl development of residential areas

e) Problematic community divisions

1. Partition of land by Chao Phraya river
2. Partition of district by waterways (Khlongs)

(2) Future Transportation Problems and the Necessity of Mass Transit System

According to the results obtained in Chapter 4, the main indices for GBA are summarized as in Table 5-26.

Table 5-26 SUMMARY OF GROWTH INDICES FOR GBA (2000/1977)

	*Central Area	Suburban Area	GBA Average
Residential Population	** 1.43	2.60	1.82
Economically Active Population	1.80	2.58	2.11
Workers at Work places	1.68	3.82	2.11
Traffic Relevant Students	4.53	8.41	5.81

Note: * The Central Area consists of the zone No. 1-9, 21, 30-36, and 41-43
** Figures indicate the magnification from the year 1977 to the year 2000.

These figures clearly indicate that growth rates in the suburban area are more rapid than in the central area.

In order to meet future demand, the short term strategy is to improve the transportation facilities in the urban area; however, there are real limits to constructing new roads or to expanding the width of the existing roads in the urban area. Realistic long term strategy must focus on the suburban area as well as the urban area.

In the suburban area, upgrading of the suburban road network was recommended according to the master plan of Bangkok. However, since the road capacity in the central area is limited, such improvement of the road network in the suburban area should parallel improvements in the urban system in order to avoid increasing the traffic flow into the urban area.

The central attracting tendency of the C.B.D. will probably not change in the foreseeable future since the residential area (Mixed use low density area) of GBA in the year 2000 will expand about 2.23 times from the area in 1977 and probably increase the generated traffic from the suburban area to the central area.

Even after completion of the first stage MTS in the central area, generated commuter trips will be concentrated in the short peak period, not only on the roads in the urban area, but also in the suburban area. Especially on the trunk radial roads, the road congestion will become as serious as on exisiting roads in the central area.

According to the results of estimated traffic volume in the year 2000, the average congestion ratio in the peak hour for the total road network including the completion of all planning roads and the first stage MTS shows near-congestion or over-congestion in the whole system as follows:

		Average Congestion Ratio
The total road network in GBA		0.82
On radial roads in GBA	Total	0.95
	Inside CBD	1.38
	Outside CBD	0.84
At the boundary of the CBD outside the Middle Ring Road	Total	1.14
	East Side*	1.30

* On the road from Thonburi Pakto to Super Highway

In conclusion, all the above considerations point to the necessity of the establishment of the suburban MTS. The first stage MTS and the suburban MTS should of course be constructed in parallel.

5.2.4 Alignment and Mode for Suburban Mass Transit System

(1) Location of Mass Transit Alignment

The locations of suburban MTS are based on the future land use plan, future road network and the first stage MTS which is under examination. According to the policy for the settlement of the suburban MTS as described in the previous section 5.2.1, the following concepts were considered.

(a) Providing the Public Mass Transit Service to the Whole Area of GBA including the expansion of residential area in future.

To provide sufficient transportation facility to meet the magnitude of future traffic demand, mass transit systems such as heavy railways will be required. Since railways do not cover every minute grid point in the GBA area, the connection between specific suburban stations and the central area will be by suburban MTS. Distribution within suburban area from MTS stations will be performed by bus system using future planning roads.

(b) Ensuring the Approach Facilities to Large Development Projects such as Housing Estates and Industrial Complexes

Based on the future land use planning of GBA, the future generated and attracted traffic volume was estimated.

Fig. 5-5 shows the existing main road network on the future land use map. From this map, it is clearly seen that the areas which will have insufficient road density in the future are mainly concentrated to the east of the GBA.

(c) Defining Traffic Potential Areas and Examination of the Future Traffic Demand Based on the Future Land Use Plan.

According to future land use plan of GBA the traffic potential areas which will generate and attract the traffic in large quantities, were settled as in Fig. 5-6 and Fig. 5-7 which show the forecast person trip demand. These figures indicate that the future traffic flow from the suburban area to the central area of GBA is large compared with the traffic volume within suburban area. Fig. 5-8 shows the congestion ratio on the road network during morning peak period. Congestion was measured by examining the alternative of not constructing the suburban MTS. Based on these figures, the major congested areas and routes in future were abstracted as follows:

i) Central area of GBA (within 10km)
ii) Phra Khanong and Sam Rong area
iii) Bang Kapi and Min Buri area
iv) Phra Pra Daeng area
v) Phasi Charoen area

(d) Implication for the Suburban MTS to Supplement the Existing SRT

To get maximum effectiveness under the minimum investment, the operation system for the suburban MTS should supplement the existing SRT. This consideration of course should depend on the estimated traffic volume.

(e) Implications for the Suburban MTS to Connect Directly to and Supplement the First Stage MTS

With due consideration for the establishment of first and second stage MTS (see Fig. 5-9) and the traffic potential areas (see Fig. 5-6) and the expected future traffic demand, the considerable suburban MTS alignment was settled as in Fig. 5-10. These route alignments are divided into sub-sections for the purpose of more detailed analysis. The Fig. 5-11 shows the considerable total maximum mass transit networks in GBA. Some of these alignments would be eliminated if not serving future optimum mass transport traffic demand.

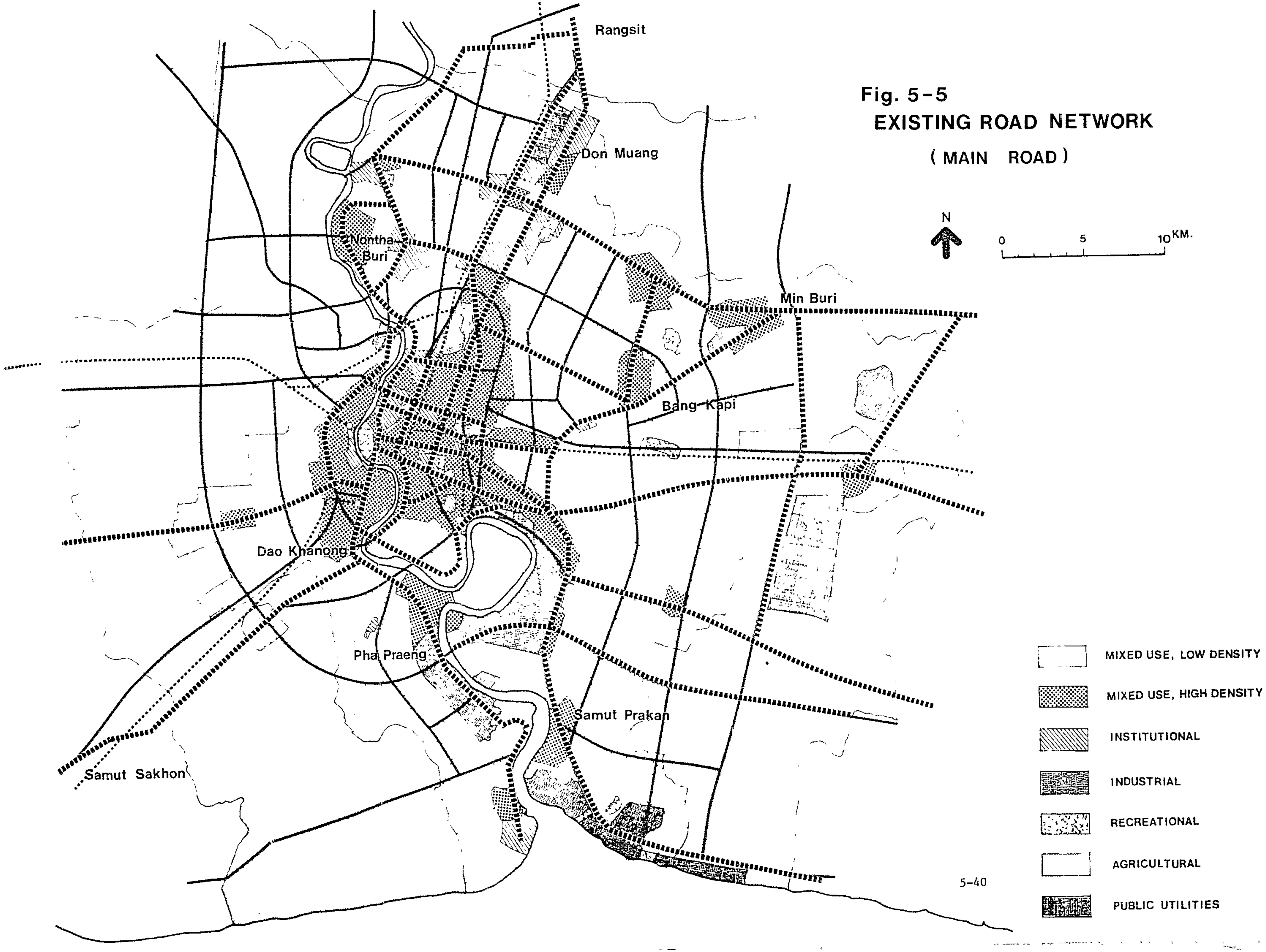
According to policy for establishment of the mass transit system in suburban area, the future major highway network is proposed as in Fig. 5-12.

The considerable total mass transit system to be established is summarized in Fig. 5-13.

Fig. 5-5

EXISTING ROAD NETWORK

(MAIN ROAD)



The established total mass transit system in GBA has the following concepts:

1) Establishment of the mass transit system cope with peak concentration of demand to the central area.

2) Establishment of the trunk express network system as a traffic distributor.

3) Establishment of the future urban planning road network as supplemented to the above mentioned systems.

(2) Mass Transit Mode Selection

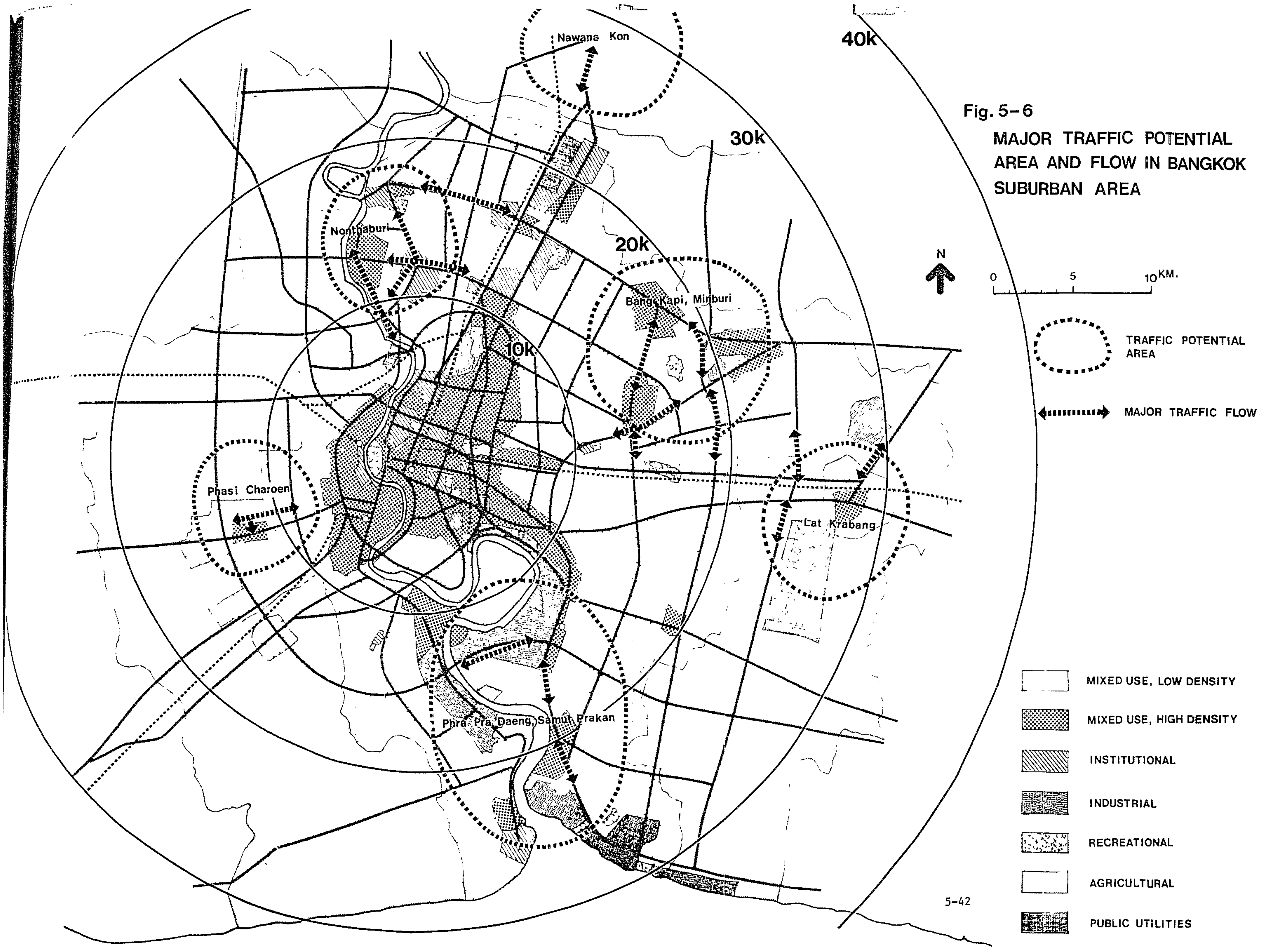
For the purpose to establish the mode of suburban MTS the following items were examined and are discussed in detail in the following Chapter 6-2.

a) Comparison of Transport Modes in Use
b) Forecast Traffic Demand
c) Construction, Maintenance and Operation Cost
d) The Mode of First Stage MTS
e) Possibility for Transfer between Various MTS Modes
f) Operation Distance

Examination of various modes of transport available for the suburban MTS are also described in Chapter 6-2, and basically the heavy railway system was chosen as the mass transit system in the suburban area same as the system to be adopted for the first stage mass transit system in Bangkok urban area.

Fig. 5-6

MAJOR TRAFFIC POTENTIAL AREA AND FLOW IN BANGKOK SUBURBAN AREA



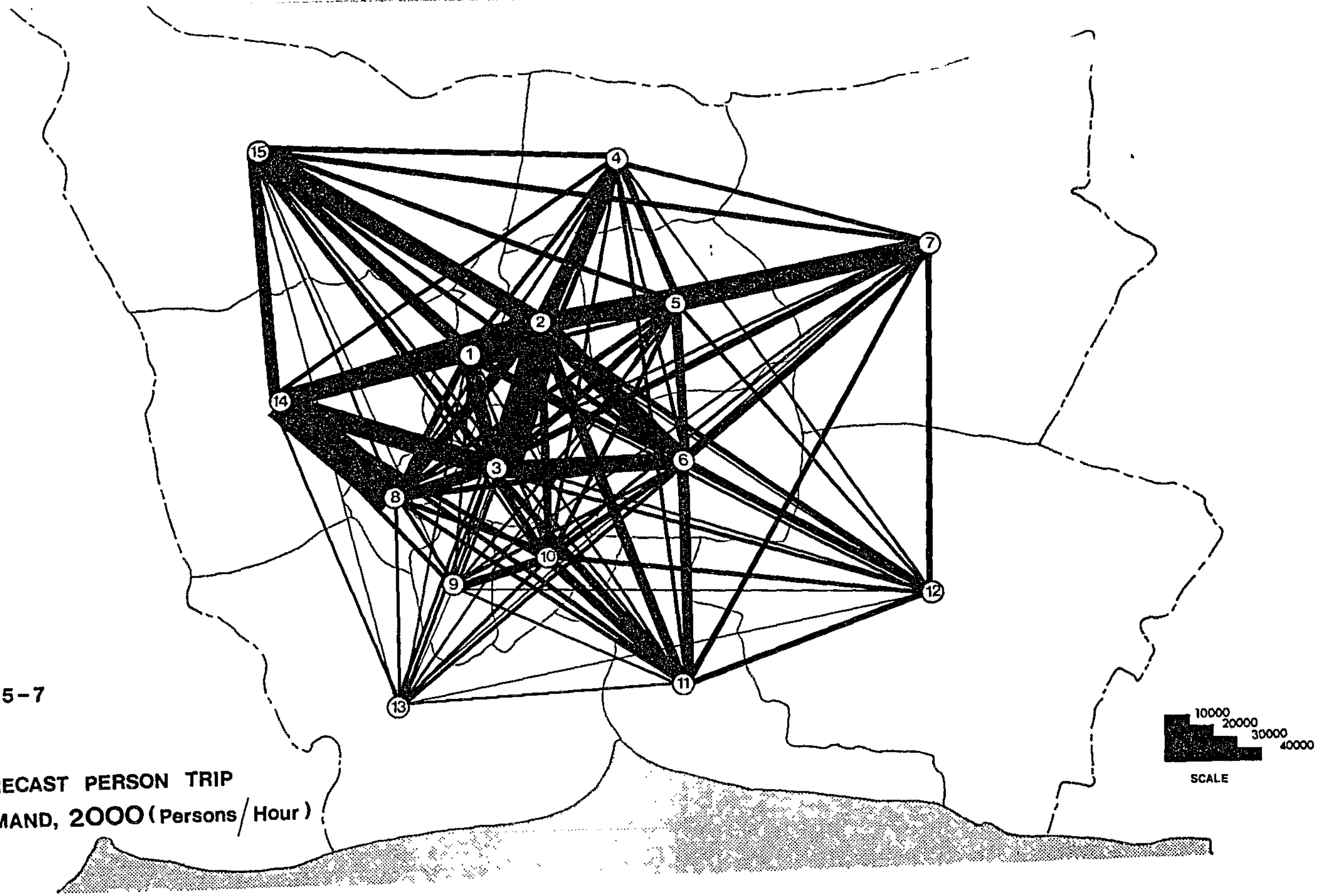


Fig. 5-7

FORECAST PERSON TRIP DEMAND, 2000 (Persons/Hour)

Fig. 5－8

TRAFFIC CONGESTION RATIO, 2000

(Suburban Mass Transit System Not Constructed)

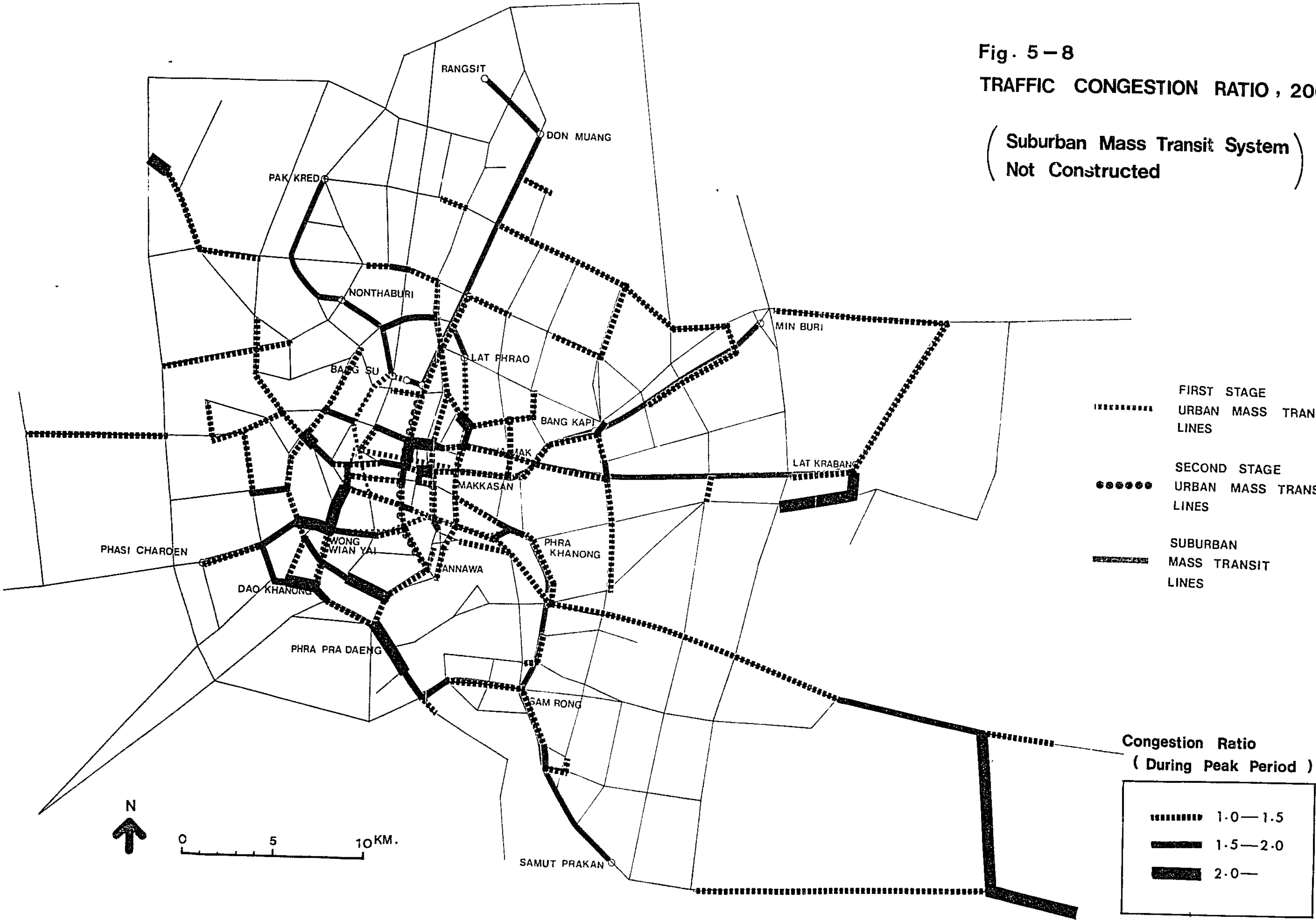


Fig. 5-9
FIRST & SECOND STAGE
URBAN MASS TRANSIT LINES

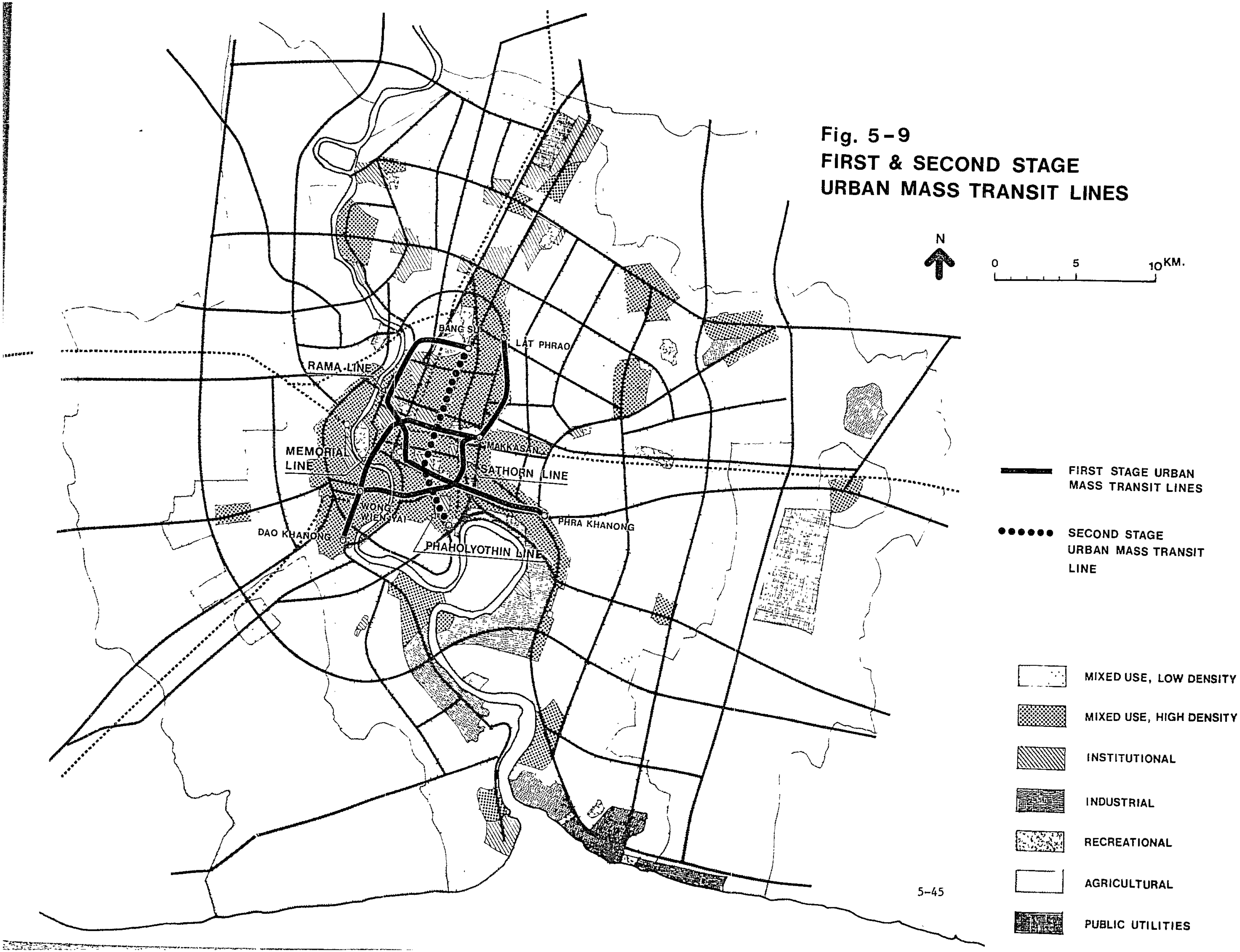
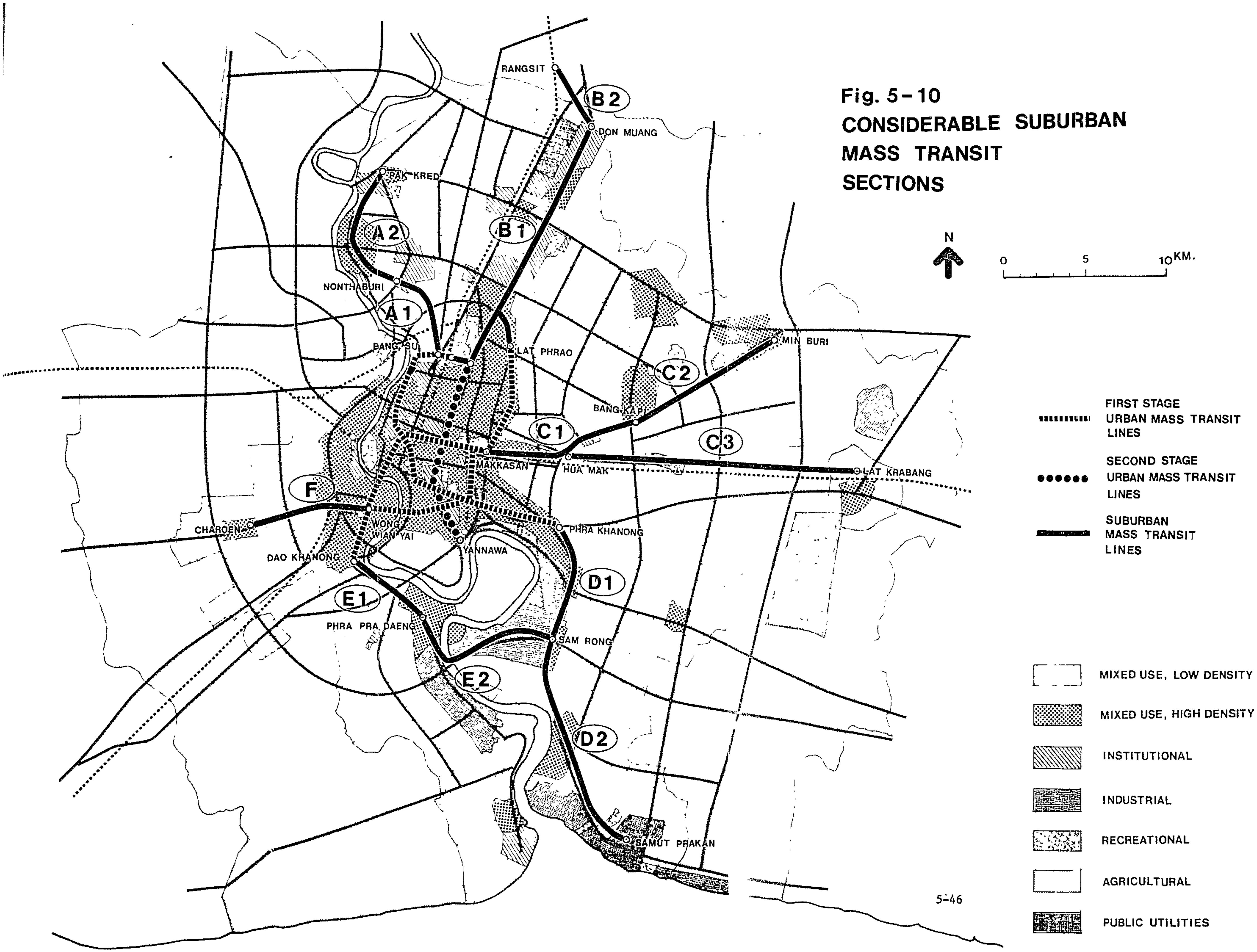


Fig. 5-10 CONSIDERABLE SUBURBAN MASS TRANSIT SECTIONS



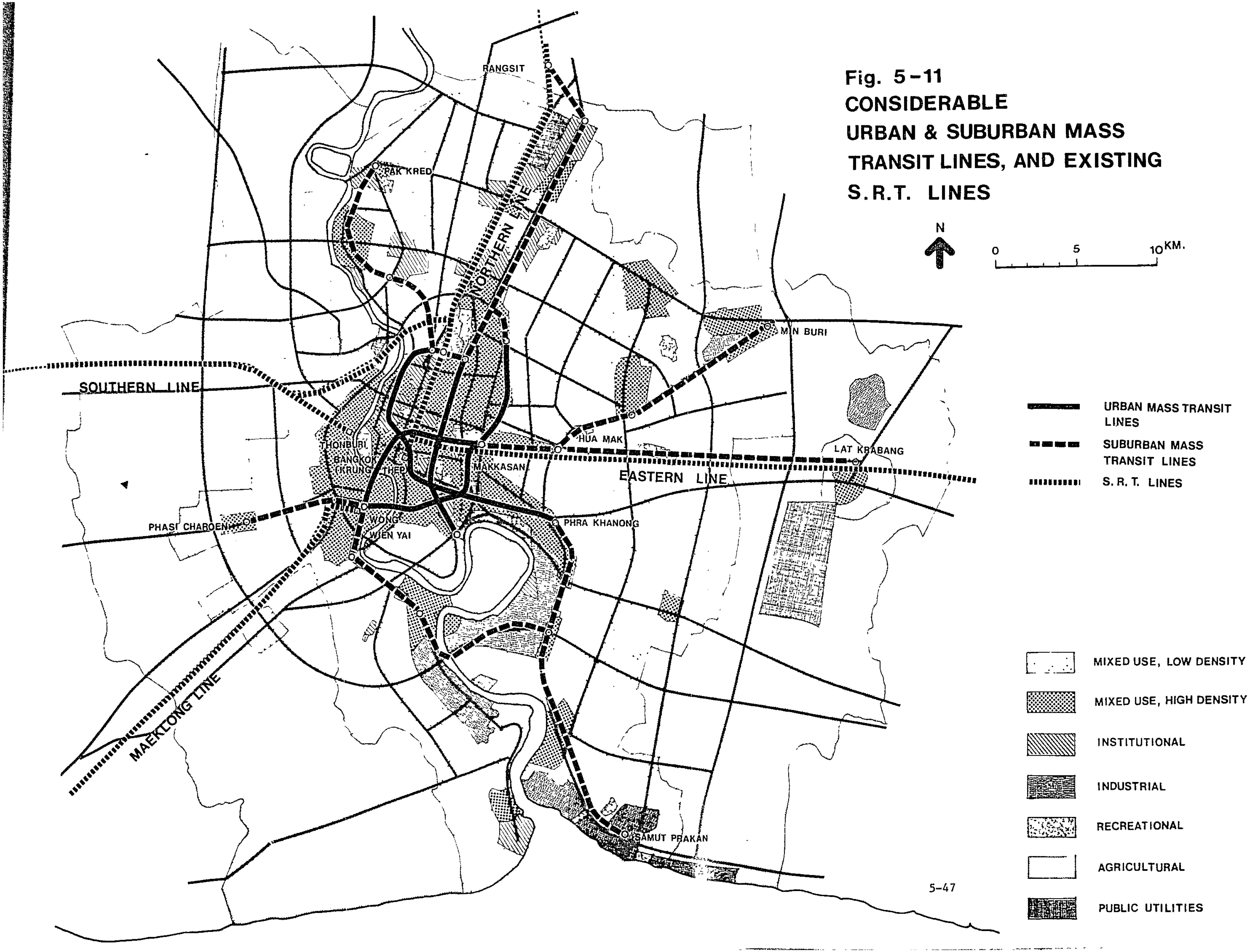


Fig. 5-11
CONSIDERABLE
URBAN & SUBURBAN MASS
TRANSIT LINES, AND EXISTING
S.R.T. LINES

Fig. 5-12
FUTURE MAJOR HIGHWAY NETWORK

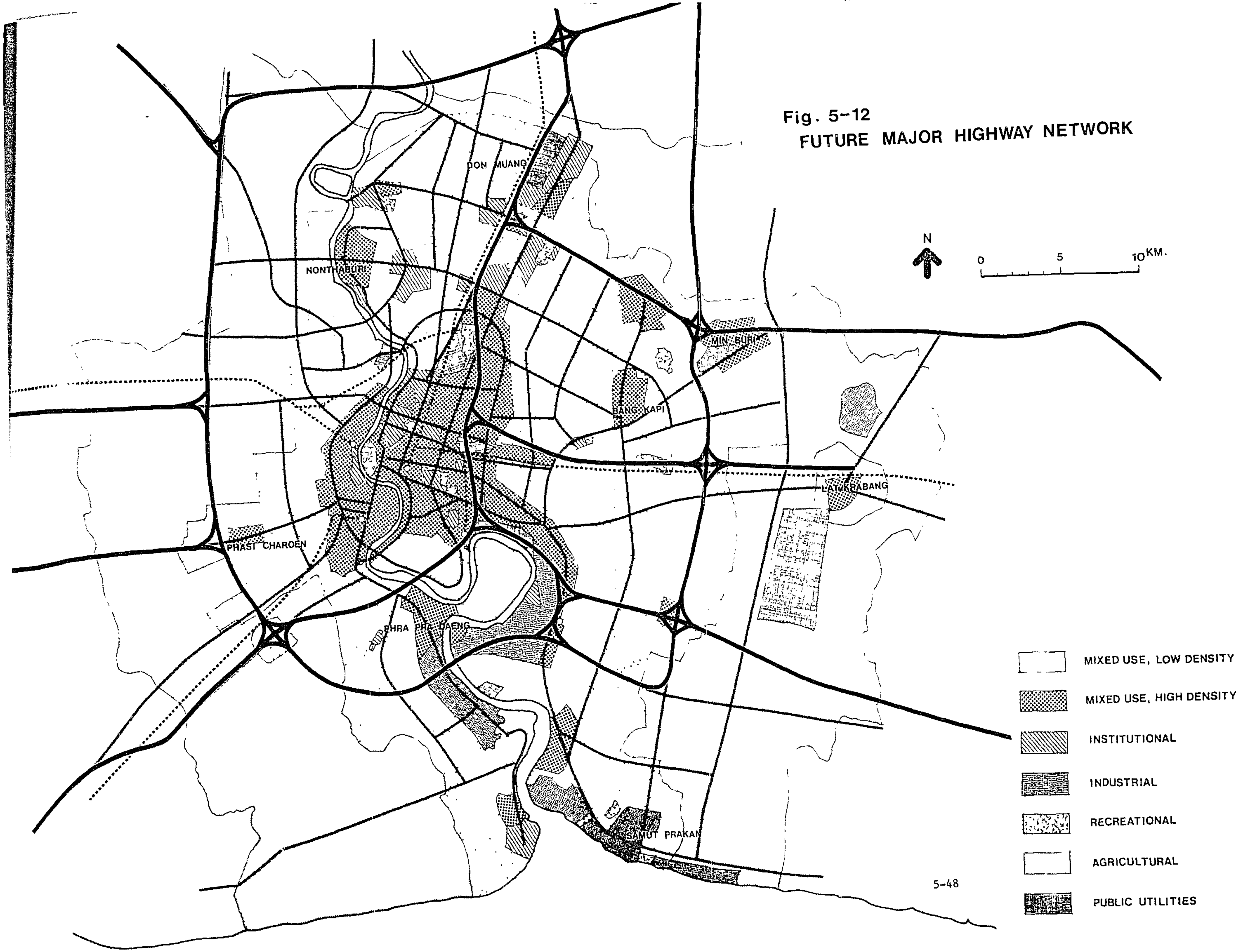


Fig. 5-13
MASS TRANSPORT AND
MAJOR HIGHWAY SYSTEMS IN BANGKOK

5.3 Forecast of Future Traffic Demand

5.3.1 Methodology

In this section the future traffic volumes on the Suburban Mass Transit System and on the future road network were estimated, based on the future O-D matrices in the year 2000, and transportation systems established in the previous section 5-1 and 5-2.

The basic concept used for the forecast of future traffic volumes is summarized as follows:

1) Establishment of the future Person Trip (P.T.) O-D matrix

2) According to the passenger car ownership, P.T. O-D matrices are divided into two matrices.

   a. P.T. O-D matrix for car-owning passengers
   b. P.T. O-D matrix for non-car-owning passengers

3) Settlement of considerable mass transit network

4) Using the modal split model to divide P.T. O-D Table for Mass Transit and P.T. O-D Table for Sedan.

5) P.T. O-D Table for Mass Transit are divided into P.T. O-D Table for Mass Transit System, Railway and Bus.

6) P.T. O-D Table for Sedan and Bus are converted to Vehicle Trip O-D Table using passenger occupancy rate.

7) Traffic Assignment for road network

   Established O-D matrices for sedan, bus, truck are assigned on the road network.

8) Traffic Assignment for MTS Network

   Established O-D matrices for MTS were assigned to the MTS network.

5.3.2 Transportation Network

(1) Road Network

In accordance with the future road network described in the Greater Bangkok Plan and the Plan of Highway Department, the basic road network was established. The basic road network is shown in Fig. 5-14. All sections between intersections were given link numbers and all intersections were given node numbers for the purpose of the computer runs. The total length of the road adopted in this study is approximately 2,400kms.

(2) Mass Transit Network

This network consists of First Stage Mass Transit Network, existing railway network and considerable Final Stage Mass Transit Network described in the previous section 5.2. For the purpose of the computer runs, all sections between the stations and terminals were given link numbers and all stations and terminals were given node numbers. The total length of suburban mass transit system is approximately 120 kms, of which 50 kms is the first stage mass transit system. Fig. 5-15 shows the mass transit network in GBA. The location of the stations for the mass transit system is assumed (for the purpose of computer runs) to be constructed on trunk roads which cross the mass transit system line.

5.3.3 Traffic Assignment

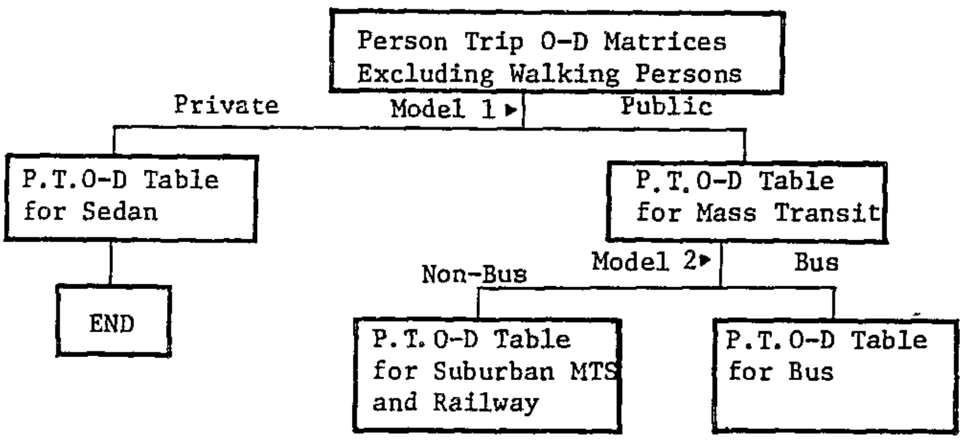
(1) Modal Split

For the purpose to establish the O-D matrices for various transport modes, the following procedure was adopted.

a) Method of Dividing Total Traffic Volume into Transport Modes.

The conceptual flow to determine the transport mode division is shown in the following.

Fig. 5-16 CONCEPTUAL FLOW DIAGRAM FOR TRANSPORT MODE DIVISION



Note : Model 1 First Division: Private/Public Users

Model 2 Second Division: (MTS + Railway)/Bus Users

b) Determination of Modal Split Diversion Curve

The purpose of modal split analysis is to determine the trips made by public transport as opposed to those made by

Fig. 5-14 LINK AND NODE NUMBERS FOR ROAD NETWORK, GBA

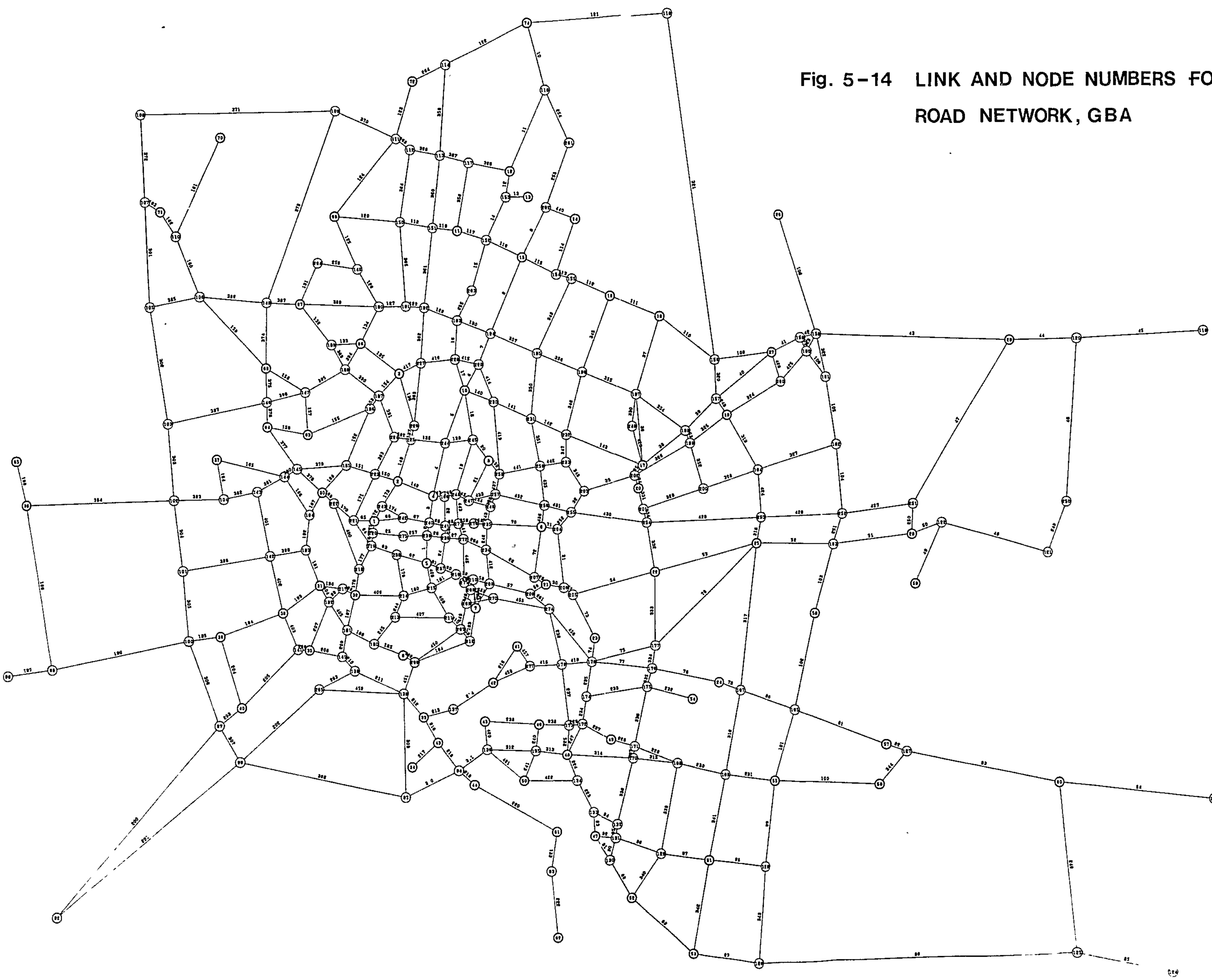
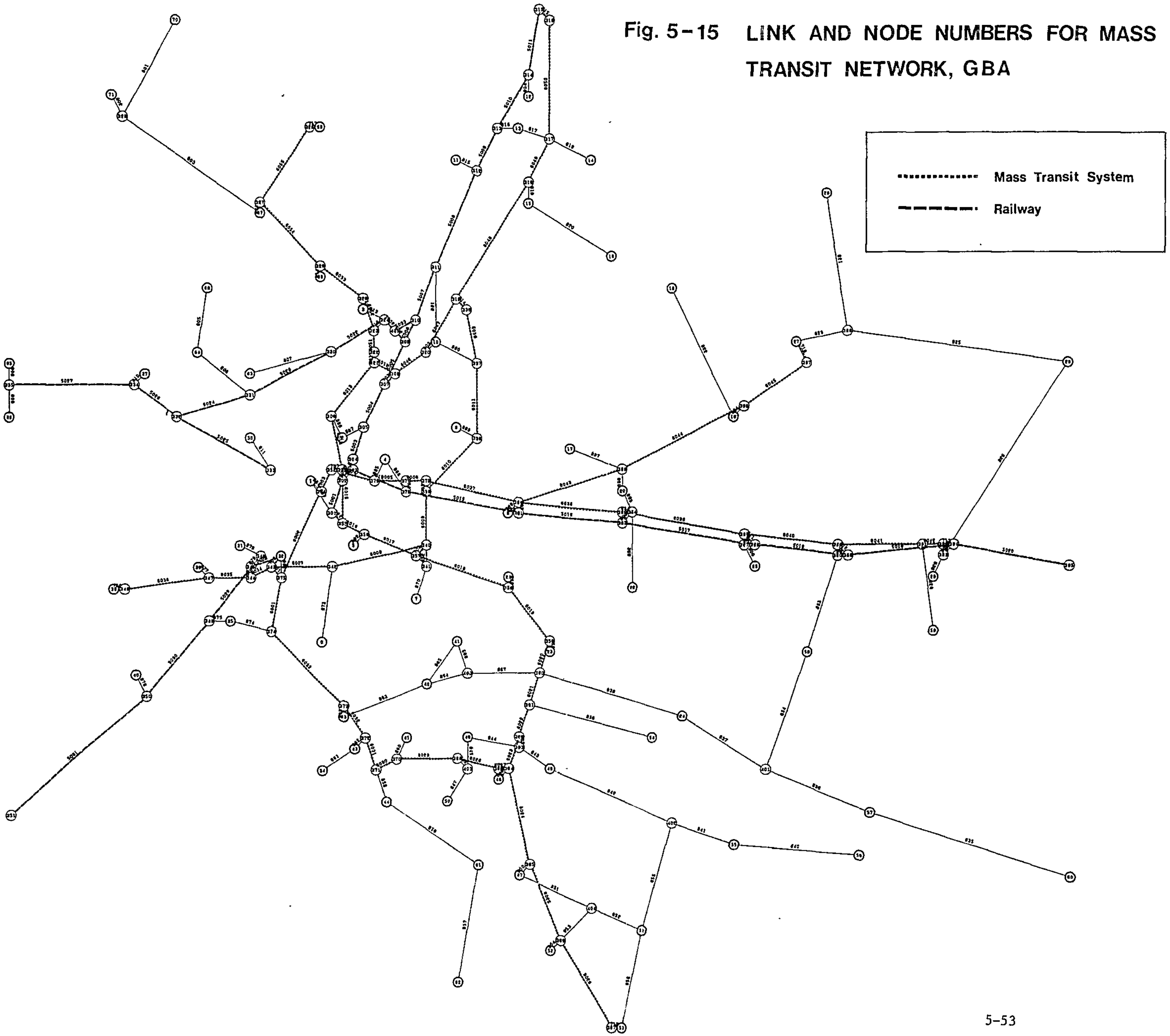


Fig. 5-15 LINK AND NODE NUMBERS FOR MASS TRANSIT NETWORK, GBA



private car. It has been assumed that the majority of trips by non-car-owing households will be made by public transport. Therefore, the diversion curve for public mass transit users and private car users was determined, and subsequently, the diversion curve for mass transit system (including railway) users and bus users was determined. Fig. 5-17 and 5-18 show the diversion curves and the parameters determined both by the survey results of BTS and the comprehensive transportation study for Tokyo metropolitan area; that is, ratio of using some transportation system is determined according to the ratio of travel time by each transportation system. In the case of diversion curve for mass transit (Ref. Fig. 5-17), the person who belong to the non-car-owing household, if the travel time from the origin to the destination by mass transit is exactry same by private transit (it means the ratio is 1.0), 95 percent of person will use the public mass transit and if the person belong to the car-owing household, 70 percent of person will use the public mass transit. For the diversion of mass transit system and bus system, four alternative models as shown in Fig. 5-18 have been considered.

(2) Traffic Assignment Alternatives

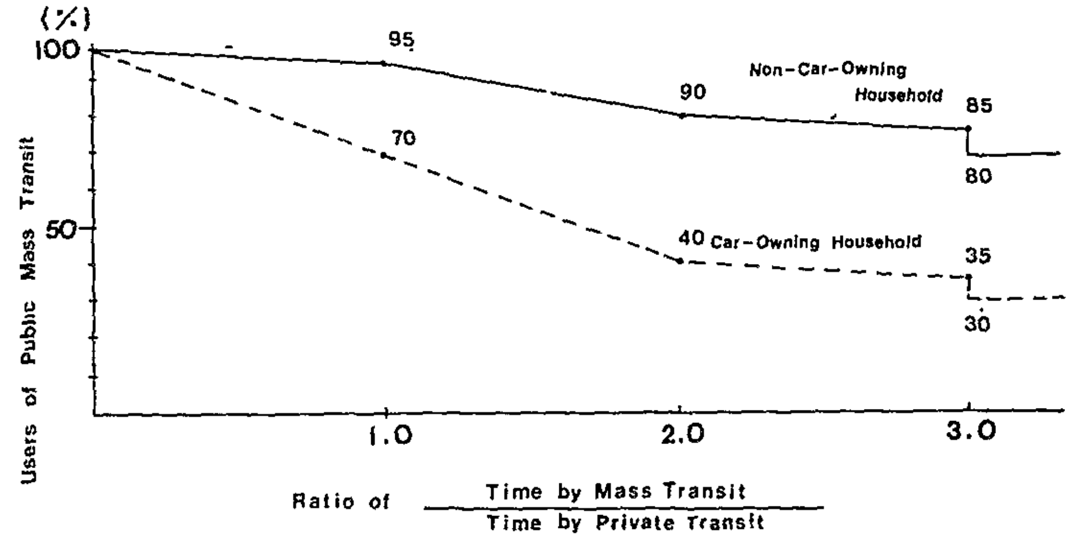
To evaluate the traffic assignment results for mass transit system, many alternative cases were considered as follows:

Table 5-27 POSSIBLE TRAFFIC ASSIGNMENT ALTERNATIVES

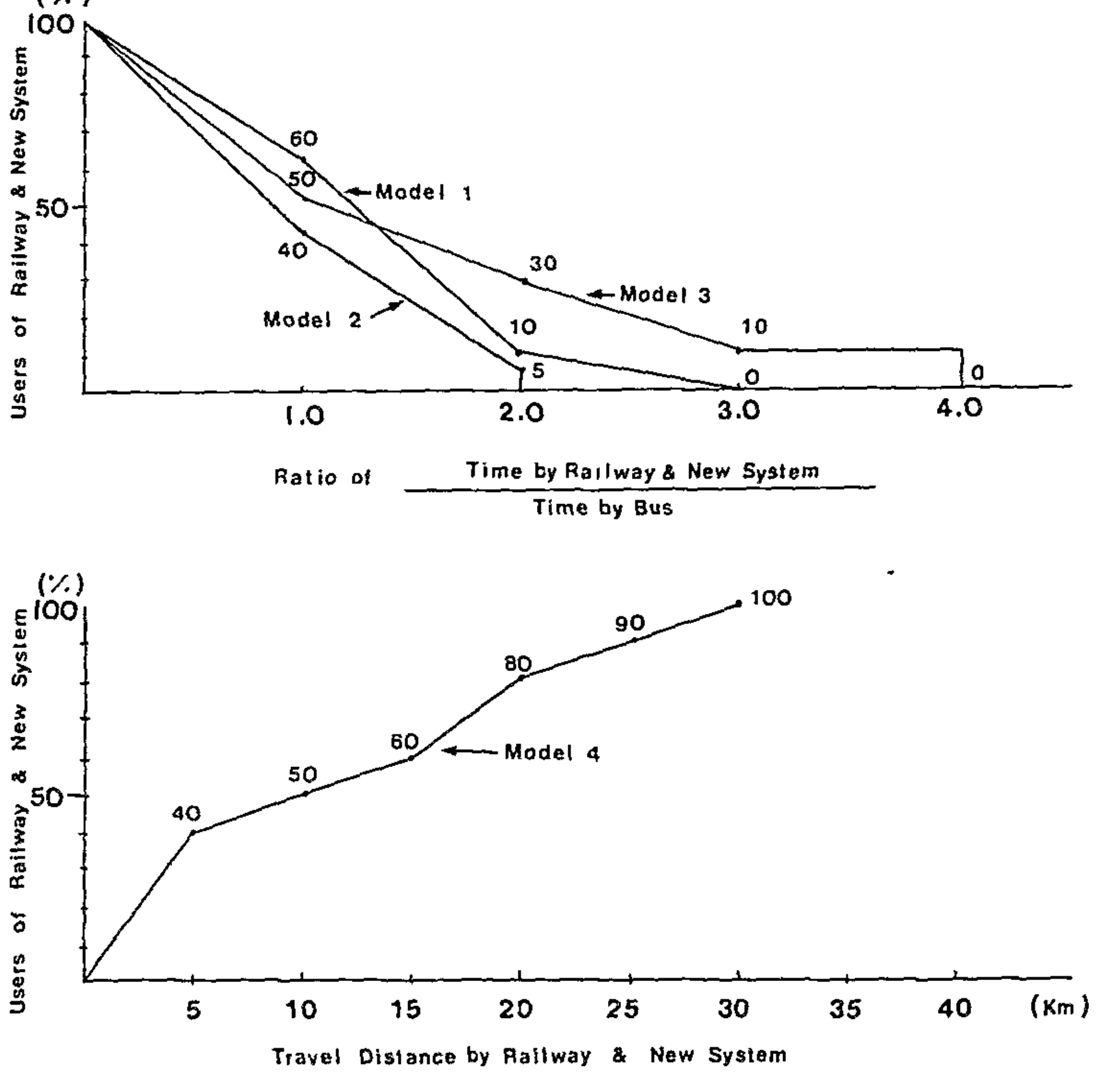
<table>
<tr><th>Type of Alternatives</th><th colspan="2">Alternatives</th><th>Number of Cases</th></tr>
<tr><td rowspan="3">Stage Construction of Suburban Mass Transit System</td><td colspan="2">1 Not Constructed</td><td>1</td></tr>
<tr><td colspan="2">2 All Sections Constructed</td><td>1</td></tr>
<tr><td colspan="2">3 Alternatives for Construction (Refer Fig. 5-19)</td><td>7</td></tr>
<tr><td rowspan="3">Tariff System on New System and Railway</td><td colspan="2">1 Toll Free</td><td>1</td></tr>
<tr><td rowspan="2">2 Sectional Tariff System</td><td>0.078Bh/km</td><td rowspan="2">2</td></tr>
<tr><td>0.296Bh/km</td></tr>
<tr><td rowspan="2">Modal Split Model</td><td colspan="2">1 Diversion for Public and Private Transport</td><td>1</td></tr>
<tr><td colspan="2">2 Diversion for MTS and Bus</td><td>4</td></tr>
</table>

(2000)

◂ ① Fig. 5-17 DIVERSION CURVE FOR MASS TRANSIT



◂ ② Fig. 5-18 DIVERSION CURVE FOR RAILWAY AND NEW SYSTEM



It is neither sensible nor necessary to make assignment for all possible combinations of alternatives, therefore, 15 cases as described in Table 5-28 have been selected to test the consequence and necessity of the system. For the purpose of evaluating the priority of each section, the construction alternatives were determined and are shown in Fig. 5-19.

(3) Settlement of Tariff of Mass Transit System

The tariff ratio of existing mass transit systems are summarized as follows:

Railway (SRT)	Ordinary ticket	0.150 Bh/km
	Commuter ticket	0.060 Bh/km
Bus		0.148 Bh/km

According to the survey result of SRT, about 80 percent of the passengers of SRT on the peak period are commuters. In this study, using this ratio, the average tariff of SRT calculated as following formula: Tariff for Commuting Passenger x Composition ratio of Commuting Passenger + Tariff for Ordinary Passenger x Composition ratio of Ordinary Passenger = 0.060 x 0.8 + 0.150 x 0.2 = 0.078

The total length of the mass transit system will be approximately 170 kms, so in this study the tariff collection system of the suburban mass transit should be set by the sectional tariff system although there is a possibility of a flat tariff system in the case that only the first stage mass transit lines opens or only some sections of the initial stage of suburban mass transit system open.

The alternative tariff rates assumed are based on the tariff ratio of the existing SRT as follows:

Alternative 1	Same ratio as existing SRT	0.078 Bh/kms.
Alternative 2	Same ratio as existing Bus	0.148
Alternative 3	Twice ratio as much as Bus	0.296

Since the tariff system and rate of the First Stage Mass Transit System is under examination, in this study for the purpose of computer run, the tariff system and ratio of the First Stage Mass Transit is assumed to be the same as suburban mass transit system.

(4) Method of Assignment

a) Road Network

The established future O-D matrices for Sedan, Bus and Truck are assigned on the future road network as mentioned previous paragraph. For the purpose of simulating route choice in this study, the method based on traffic capacity limitation

Fig. 5-19 CONSTRUCTION ALTERNATIVES FOR TRAFFIC ASSIGNMENT

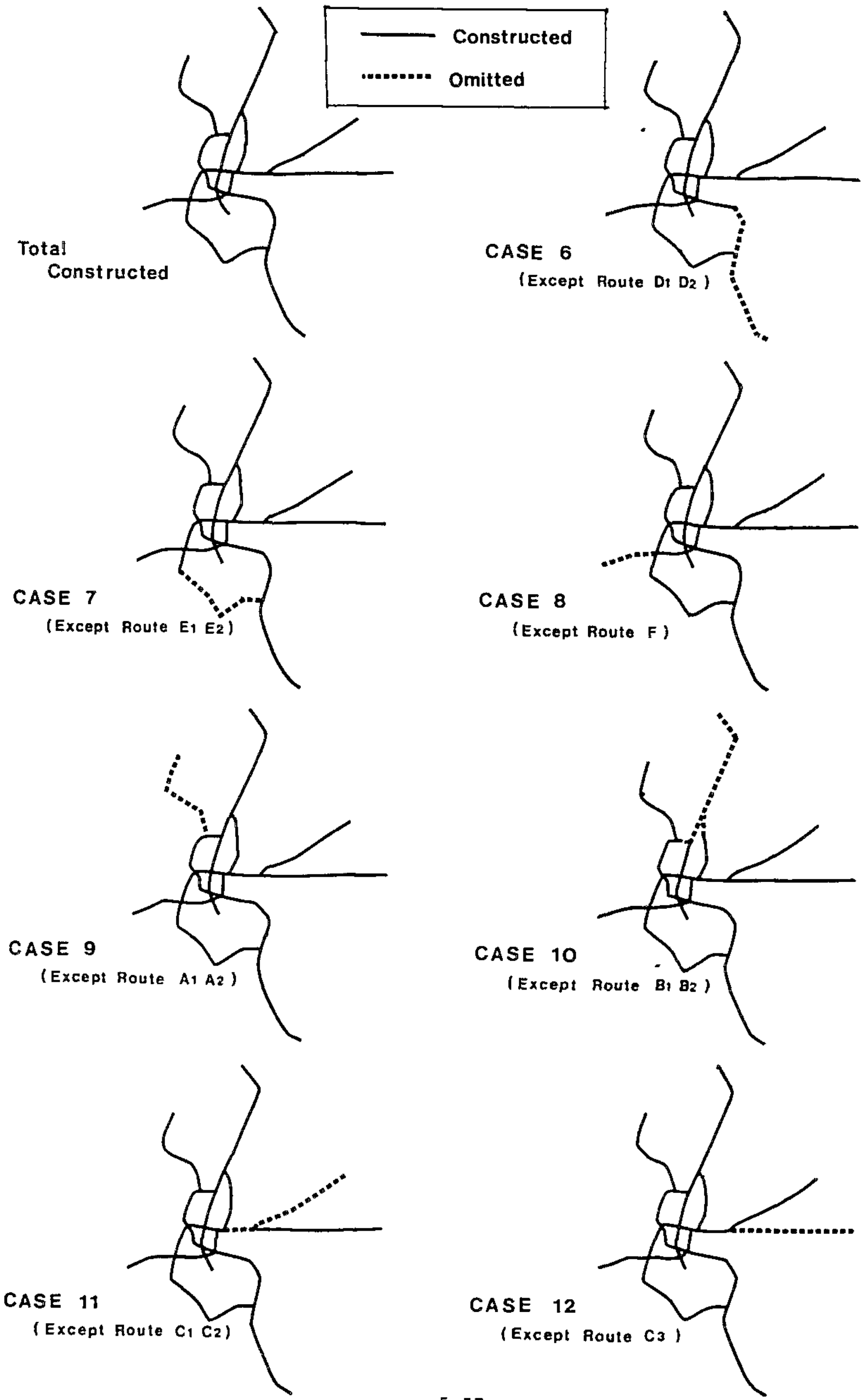


Table 5-28 SELECTED ALTERNATIVES FOR TRAFFIC ASSIGNMENT

Modal Split Model No.	Tariff of BSTS \ Construction Stage of BSTS	All Sections Constructed	Not Constructed	Stage Construction (Following Sections are Omitted)						
				D_1, D_2	E_1, E_2	F	A_1, A_2	B_1, B_2	C_1, C_2	C_3
1	0.296 Bh/Km	1								
2	0.078 (SRT)	2	5	6	7	8	9	10	11	12
	0.148 (Bus)	13								
	0.296 (2xBus)	14	5'							
3	0.296	4								
4	0.296	3								

* BSTS : Bangkok Suburban Transportation System

(the Q-V method) was preferred. The main reasons to adopted this model are as follows:

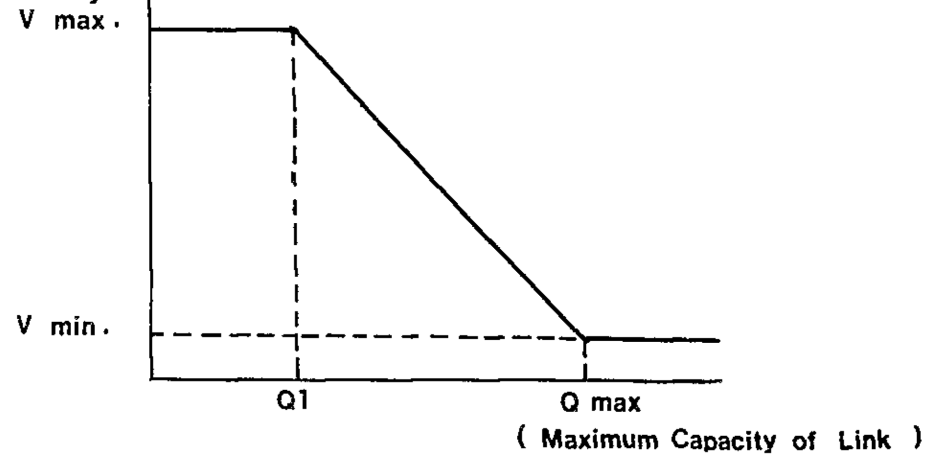
1. Construction of mass transit system will reduce the road traffic congestion which could be reflected in this model.

2. For the purpose of carrying out the benefits from saving in vehicle operating costs, travel time costs and a saving in vehicle congestion costs, the Q-V method is convenient.

3. Many alternative routes can be compared at the same time and the optimum route can be selected.

The conceptual method of Q-V is as shown in Fig. 5-20; that is, travel speed is determined according to the condition of road congestion and the traveller will select a route which minimizes his perceived cost of travel.

Fig. 5-20 LINK SPEED/FLOW CURVE



When the traffic volume is below Q1, a vehicle may be able to travel at the maximum speed (V max), and when the traffic volume exceed Q1 the travel speed decreases.

According to the results of travel speed survey as mentioned Chapters 1 and 2 and the speed flow curve previously established in a recognized standard (such as AASHO), the traffic capacity limitation conditions of the road network were divided into 14 different categories according to the nature of the road as shown in Table 5-29.

To simulate more closely with the actual traffic flow pattern (namely, the traveller selecting his route so as to minimize his travel cost and selects his route according to the road congestion), the assignment was broken down into five steps, so that the degree of congestion could be reassessed at each separate step.

Table 5-29 TRAFFIC CAPACITY LIMITATION OF ROADS
IN Q-V TRAFFIC ASSIGNMENT

Model No.	Type of Road	Location	No. of Lanes	FREE FLOWING		CONGESTED FLOW	
				V max. (km/hr.)	Q1 (Veh./hr.)	V min. (km/hr.)	Q max (Veh./hr.)
1	Ordinary Road	Urban Area	2	30	100	5	730
2			4	35	700	10	3,520
3			6	40	1,050	20	5,280
4		Suburban Area	2	45	130	10	850
5			4	50	850	15	4,240
6			6	55	1,600	20	6,360
7	Town Planning Road (Improved)	Urban Area	2	40	140	10	940
8			4	50	830	20	4,210
9			6	50	1,250	20	6,180
10		Suburban Area	2	50	140	10	940
11			4	60	1,000	20	5,000
12			6	60	1,880	20	7,500
13	Expressway	Urban Area	6	60*	2,250	20	9,000
14		Suburban Area	6	60*	3,060	20	10,200

Note: * these figures including the toll resistance.

b) Mass Transit Network

To determine the future transport facilities of mass transit system in the suburban area, the future demand for the mass transit system was examined. The method to estimate the future traffic volume on the mass transit was the "All-or-Nothing method". The basic procedure of "All-or-nothing method" is to allocate all the trips for a zone pair to the links forming the minimum time path between the two zone centers and to repeat the procedure for all zone pairs.

The reasons to adopt this method is due to the density of the mass transit network. Especially since the proposed suburban mass transit alignment is shaped in a radial manner, the assigned passenger volume on the alignment of suburban mass transit could be directly estimated using this method.

(5) Results of Traffic Assignment

a) Items of Calculation by the Computer

The following items were calculated by the computer in various alternative cases and the detail results are shown in Appendix and the attached computer output.

i) O-D matrices for each type of transportation mode

ii) Required travel time for each link both MTS and road network

iii) Travel speed for each link of road network

iv) The assigned traffic volumes for each link

v) The accumulated assigned traffic volume both MTS and road network

vi) Degree of congestion for each link of road network

vii) Vehicle-kilometers, vehicle-hours, passenger-kilometers and passenger-hours for each link

viii) Total vehicle-kilometer, vehicle-hours, passenger-kilometers and passenger-hours for all trips.

ix) Mass transit passenger volume between each station

x) Average passenger volume on the Mass Transit System

xi) Revenue by the passenger volumes between each station and the amount of the revenue, both SRT and Suburban Mass Transit System.

b) Generated and Attracted Trips

The comparison of estimated generated and attracted trips in the various alternative cases are summarized in Table 5-30.

Table 5-30 SUMMARY OF GENERATED AND ATTRACTED TRAFFIC VOLUME

Case No.	Modal Split Model No.	Construction Alt.	Tariff of MTS (Bh/km)	Person Trips on MTS (including SRT)*** (Trips/Hr.)	Vehicle Trip Ends (Veh./Hr.)			
					Sedan	Bus	Truck	Total
1	1	Total	0.296	357,761	249,006	15,580	49,596	314,182
2	2	Total	0.078	353,245	249,006	15,792	49,596	314,394
3	4	Total	0.296	515,301	249,006	8,938	49,596	307,540
4	3	Total	Toll Free	223,656	290,492	10,170	49,596	350,258
5	2	Not Constructed	*0.078	**260,957	326,072	17,388	49,596	393,056
5'	2	Not Constructed	*0.296	**206,958	326,072	19,784	49,596	395,452
13	2	Total	0.148	315,810	249,006	17,466	49,596	316,068
14	2	Total	0.296	253,566	249,006	20,262	49,596	318,864

Note: Case 6 ∿ 12 indicate the alternative cases of construction
* Tariff for First Stage MTS
** This figure shows the passenger volume on the First Stage MTS
*** Number of passengers by heavy railway in Tokyo Metropolitan Area was about 1.8 million/Hr., 1974

Comparing the results of both alternative cases of suburban mass transit system to be constructed or not constructed (i.e., only the first stage urban MTS constructed) and also changing the toll rate of the mass transit system, the ratio of modal split was as in Table 5-31.

Table 5-31 PERCENTAGE OF TRIPS BY MODE UNDER DIFFERENT CONDITIONS

(Unit: %)

Case No.	Modal Split Model No.	Construction Alternative	Tariff of MTS (Bh/km)	Person Trips for the MTS	Vehicle Trips			
					Sedan	Bus	Truck	Total
5'	2	Not Constructed	* 0.296	100%	100%	100%	100%	100%
14	2	Total Constructed	0.296	123	76	102	100	81
5	2	Not Constructed	* 0.078	126	100	88	100	99
2	2	Total Constructed	0.078	171	76	80	100	80

Note: * Tariff for First Stage MTS.

According to the results, the total construction of the Suburban Mass Transit System will reduce the total generated and attracted vehicle trips by 20 percent. Comparing with the alternatives with the project and without the project, the total number of passenger using the Mass Transit System will increase about 20 percent as induced traffic volume. A significant decrease in the toll rate from 0.296 to 0.078 have the conspicuous effect on the Mass Transit System of increasing the number of trips by about 40 percent.

c) Total Person-Hours on the Mass Transit System and Vehicle-Hours and Vehicle-Kilometers on the Road Network

The estimated person-hours on the mass transit system and vehicle-hours and vehicle-kilometers on the road network calculated from the traffic assignment is shown in Table 5-32 and the percentage of the modal split ratio for the alternatives is summarized in Table 5-33.

Table 5-32 SUMMARY OF TRAFFIC ASSIGNMENT

Case No	Modal Split Model	Constructed Aid	Tariff of MTS (Bh/km)	Person Hours (Including the time of Approaching the Station)	Vehicle - Kilometers (kms/Hr.) Sedan	Vehicle - Kilometers (kms/Hr.) Bus	Vehicle - Kilometers (kms/Hr.) Truck	Vehicle - Kilometers (kms/Hr.) Total	Vehicle - Hours (minutes/Hr.) Sedon	Vehicle - Hours (minutes/Hr.) Bus	Vehicle - Hours (minutes/Hr.) Truck	Vehicle - Hours (minutes/Hr.) Total
1	1	Total	0.296	529,207	2,057,388	118,218	1,758,619	3,934,225	2,746,200	150,009	2,613,781	5,509,990
2	2	Total	0.078	417,828	2,057,005	125,540	1,759,046	3,941,591	2,747,150	158,001	2,618,042	5,523,193
3	4	Total	0.296	951,082	2,055,800	38,315	1,757,638	3,851,753	2,720,063	53,816	2,606,140	5,380,019
5	2	Not Constructed	0.078	396,074	2,716,885	141,443	1,761,950	4,620,328	3,800,740	184,095	2,660,015	6,644,850
5'	2	Not Constructed	0.296	369,059	2,719,289	161,530	1,762,026	4,642,845	3,809,043	212,808	2,660,808	6,682,704
13	2	Total	0.148	428,725	2,058,410	141,958	1,758,864	3,959,232	2,752,499	179,347	2,619,164	5,551,010
14	2	Total	0.296	424,390	2,059,516	168,271	1,759,208	3,986,995	2,760,540	214,189	2,620,153	5,594,882

With the completion of the Suburban Mass Transit System, the vehicle-hours and vehicle-kms on the road networks decline about 15 percent and person-hours on the Mass Transit System increase 5 to 10 percent.

Table 5-33 COMPARISON OF THE RESULTS OF TRAFFIC ASSIGNMENT UNDER DIFFERENT CONDITIONS

(Unit: %)

Case No.	Modal Split Model No.	Construction Alternative	Tariff of MTS (Bh/km)	Person-Hours on the MTS	Vehicles-Kms on the Road Network	Vehicle-Hour on the Road Network
5'	2	Not Constructed	* 0.296	100%	100%	100%
14	2	Total Constructed	0.296	115	86	84
5	2	Not Constructed	* 0.078	107	100	99
2	2	Total Constructed	0.078	113	85	83

* Tariff for First Stage MTS

d) Cross-Sectional Traffic Volume on the Mass Transit System

The estimated cross-sectional passenger volume on the Mass Transit System for the various alternatives for the year 2000 are as shown in Table 5-34.

Table 5-34 AVERAGE CROSS-SECTIONAL PASSENGER VOLUME ON THE SUBURBAN MASS TRANSIT SYSTEM, 2000

(Unit: Persons/Hr.)

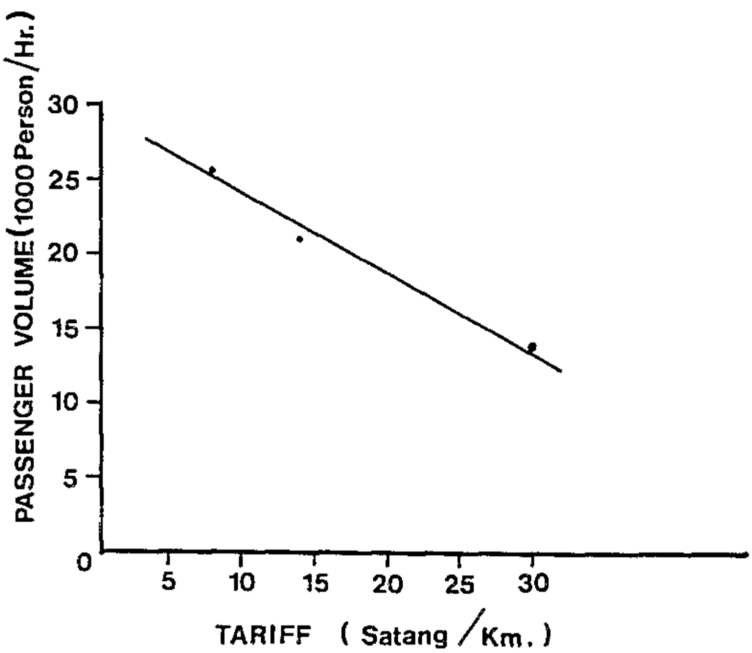
	Case No.	1	2	3	13	14	Average
	Modal Split Model No	1	2	4	2	2	
	Construction Alternative	Total	Total	Total	Total	Total	
	Tariff of MTS (Bh/km)	0.296	0.078	0.296	0.148	0.296	
* Suburban Mass Transit System Section	A1	21,217	37,947	33,768	25,879	14,624	26,687
	A2	21,390	21,823	33,753	19,074	15,010	22,210
	B1	7,525	18,315	10,761	11,186	5,233	10,604
	B2	-	1,234	-	-	-	245
	C1	27,512	49,367	51,505	40,841	19,536	37,752
	C2	31,775	34,637	57,032	30,587	22,640	35,334
	C3 **	17,485	20,550	29,570	18,211	12,583	19,680
	D1	39,989	42,939	63,274	37,996	27,681	42,376
	D2	15,795	17,222	23,958	15,141	11,229	16,669
	E1	30,776	34,541	48,350	29,630	21,331	32,926
	E2	18,842	23,346	26,494	20,394	13,024	20,420
	F	16,226	18,146	21,903	15,655	11,481	16,682
	Average	19,935	25,687	32,315	21,347	14,036	22,494

Note: * Refer Fig. 5-10.
** The figures on the section C3 indicates the total passenger volume of C3 and SRT eastern line.

The average passenger volume of each section on the Suburban Mass Transit System (SMTS) under the different conditions is more than 20 thousand passengers per hour. These results indicate the necessity of the rapid mass transit system in the suburban area (refer Chapter 6-2). The average percentage of cross-sectional passenger volume on the SMTS under different tariff system is shown in Table 5-35.

Table 5-35 CHANGE IN PASSENGER VOLUMES UNDER DIFFERENT TARIFF CONDITIONS

Case No.	Tariff		Average Cross-Sectional Passenger Volume	
	Baht/Km	Index (%)	Persons/Hr.	Index (%)
2	0.078	100	25,687	100
13	0.148	190	21,347	83
14	0.296	379	14,036	55



According to this table, a significant increase in the tariff rate does have a proportional effect on the passengers on the SMTS.

e) Conversion to the Daily Passenger Volume

Estimated future passenger volumes in the peak period were converted into the average daily passenger volume. According to the past survey results in GBA, the traffic concentration rates in the peak period are shown in Table 5-36.

Table 5-36 TRAFFIC CONCENTRATION RATE IN THE PEAK PERIOD

-	Peak 3-Hours Traffic Concent-ration Rate (6:00 - 9:00)	Highest Peak Hour Traffic Concentration Rate (7:00 - 8:00)	Remarks
* BTS	26.6%	-	Person Trip Survey Result, 1972
** DTCP	19.3%	36.6%	Vehicle Trip Survey Result at the Intersections in the Central Area, 1977
'77-Outer Bangkok Ring Road	11.8%	33.8%	Vehicle Trip Survey Result at Cross-sections in the Suburban Area, 1977
'78-Outer Bangkok Ring Road	15.9%	37.9%	Cross-sectional Traffic Survey Result at the Bridge over Chao Phraya River/1978

Note: * Bangkok Transportation Study
** Dept. of Town and Country Planning

Based on these survey results, the passenger concentration rate in the peak 3-Hours (6:00 - 9:00) was assumed as 25 percent and highest peak hour (7:00 - 8:00) concentration rate was assumed as 35 percent. Accordingly, the daily passenger volume concentration rate was calculated using the following formula:

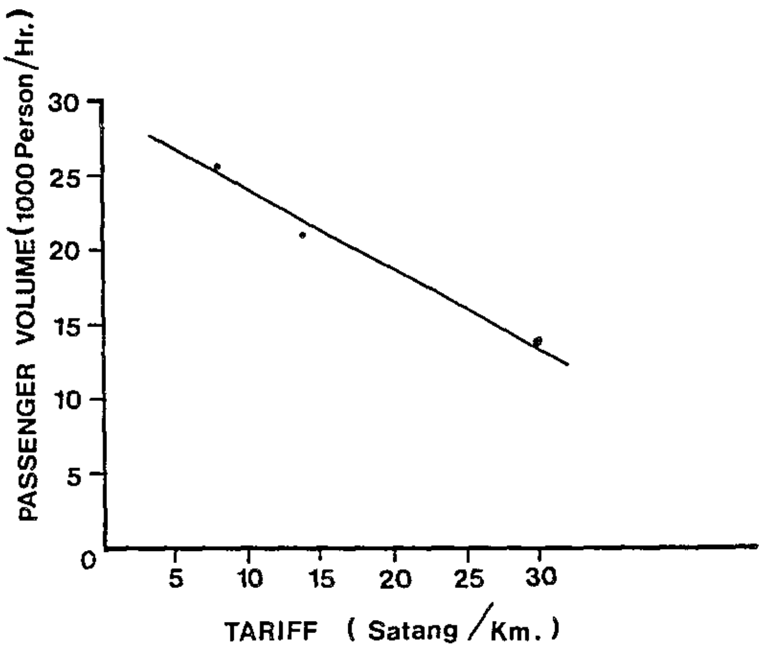
Expansion Factor for Daily Passenger Volume (α)

$$\alpha = \frac{100}{25 \times \frac{35}{100}} = 11.429$$

The concentration ratio for peak hour was calculated as 8.8 percent compared with the result of the report of the first stage MTS as 8.0 percent.

Table 5-35 CHANGE IN PASSENGER VOLUMES UNDER DIFFERENT TARIFF CONDITIONS

Case No.	Tariff		Average Cross-Sectional Passenger Volume	
	Baht/Km	Index (%)	Persons/Hr.	Index (%)
2	0.078	100	25,687	100
13	0.148	190	21,347	83
14	0.296	379	14,036	55



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'77-Outer Bangkok Ring Road	11.8%	33.8%	Vehicle Trip Survey Result at Cross-sections in the Suburban Area, 1977
'78-Outer Bangkok Ring Road	15.9%	37.9%	Cross-sectional Traffic Survey Result at the Bridge over Chao Phraya River/1978

Note: * Bangkok Transportation Study
** Dept. of Town and Country Planning

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Expansion Factor for Daily Passenger Volume (α)

$$\alpha = \frac{100}{25 \times \frac{35}{100}} = 11.429$$

The concentration ratio for peak hour was calculated as 8.8 percent compared with the result of the report of the first stage MTS as 8.0 percent.

f) Estimated Passenger Volume by year on the Suburban MTS

The number of passengers on the suburban MTS was examined based on both the established person trip O-D matrices, (1977 and 2000) and the estimated indices for the year 1990. The basic assumptions for the examination of passenger volume by year are as follows:

i) The passenger concentration ratio in the peak hour is assumed to be constant year by year.

ii) The composition ratio of number of workers and traffic-relevant students in the peak hour is assumed as constant.

The main data examined in Chapter 4 are summarized in the following Table 5-37.

Table 5-37 SUMMARY OF MAIN INDICES

(Unit: million)

	1977	1990	2000
Residential Population	5.56	7.93	10.11
Employed Population	1.50	2.36	3.18
Workers at Work Places	1.55	2.43	3.27
Number of Students	0.23	0.85	1.33

Source: Chapter 4 in this report

From this table, the following growth rates of passenger volume were estimated and compared with the results of first stage MTS report as shown in Table 5-38 below.

Table 5-38 GROWTH RATES OF PASSENGER TRAFFIC

Year	1977	1990	2000	Remarks
*BSTP	0.422	0.725	1.000	
First Stage MTS	0.388	0.744	1.000	Growth rates of the passenger-kms on the heavy railway

Note: * Bangkok Suburban Transportation Project

g) Summary and Overall recommendations for the Suburban MTS

The forecast results of traffic assignment are summarized in the following Table 5-39A and B, and the estimated traffic volume on the transportation network are shown in AP5-6.

Table 5-39A SUMMARY OF TRAFFIC ASSIGNMENT, 2000
BASIC TARIFF OF SUBURBAN MTS: (0.078 Baht/km)

	Unit	Total System Constructed	Not Constructed	Difference		Remarks
				Actual	%	
Number of Passengers on the MTS	Trips/Hr.	353,245	260,957	92,288	135.4	
Generated & Attracted Vehicle Trips	Trip Ends/Hr.	314,394	393,056	-78,622	80.0	
Revenue from MTS	Mill. Baht/Year	3,356	1,038	2,318	323.3	Excluding SRT
Person-Hours on the MTS	Person-Hrs.	417,828	396,074	21,754	105.5	Including the time of Approaching the Station
Vehicle-Kms on the Road Network	Vehicle-Kms	3,941,591	4,620,328	-678,737	85.3	
Vehicle-Hours on the Road Network	Vehicle-Hrs.	92,053	110,748	-18,695	83.1	

Table 5-39B SUMMARY OF TRAFFIC ASSIGNMENT, 2000
BASIC TARIFF OF SUBURBAN MTS: (0.296 Baht/km)

	Unit	Total System Constructed	Not Constructed	Difference		Remarks
				Actual	%	
Number of Passengers on the MTS	Trips/Hr.	253,566	206,958	46,608	122.5	
Generated & Attracted Vehicle Trips	Trip Ends/Hr.	318,864	395,452	-76,588	80.6	
Revenue from MTS	Mill. Baht/Year	6,465	2,104	4,361	307.3	Excluding SRT
Person-Hours on the MTS	Person-Hrs.	424,390	369,059	55,331	115.0	Including the time of Approaching to the Station
Vehicle-Kms on the Road Network	Vehicle-Kms	3,986,995	4,642,845	-655,850	85.9	
Vehicle-Hours on the Road Network	Vehicle-Hrs.	93,248	111,378	-18,130	83.7	

According to these tables the following matters are summarized.

i) The percentage difference for each items is almost same in both tariff cases.

ii) The increase in the tariff ratio will have a significant influence on the number of passengers and revenues of the suburban MTS. As the tariff increases from 0.078 to 0.296 Baht/Km, the number of passengers will decrease about 50 percent, but revenues will double.

iii) In every case, the construction of the suburban MTS will reduce the vehicle trips, vehicle-hours and vehicle-kms on the road network by about 20 percent each.

iv) The construction of the suburban MTS will produce increased revenue when compared with only the revenues from the first stage urban MTS. The suburban MTS will increase twice to four fold depending on the rate of tariff (0.078 and 0.296 Baht/Km respectively). Further-more, the following recommendations are made for the over-all proposal.

v) The construction of suburban mass transit system will produce beneficial results for reducing the traffic congestion not only in the suburban area but also the central urban area.

vi) In order to fulfill its maximum function, the mode of the suburban MTS should be same as the first stage urban MTS.

vii) The tariff system for both the first stage MTS and the suburban MTS should be considered as a single system. If the tariff system of MTS is almost same as the existing SRT, all of the suburban alignment which was proposed in this study is reasonable from the view-point of traffic volume.

viii) The eastern section (Sections No. C3) of the suburban MTS should use of the existing SRT facilities with some improvement in order to increase effectiveness.

ix) The northern section (Section No. B1, B2) of the suburban MTS should supplement existing SRT facilities. Even if the super highway will expand to be a ten-lane highway, the mass transit system should be considered for the airport passengers and the expansion of the residential area along the alignment of these sections in future.

x) In meeting the future traffic demand from the Thonburi area, the suburban MTS and the existing southern line of SRT should cooperate closely.

xi) The priority for the construction of the suburban MTS should be determined based on the comprehensive evaluation such points as benefits, revenues and traffic volumes (See Chapter 8).

xii) The future mass transit feeder system will basically be the bus system. Fig. 5-21 to 5-24 show the trunk bus routes established by the future traffic forecasting and these trunk bus routes will be considered a settlement of a exclusive bus lanes.

For the purpose to evaluate the settlement of a exclusive bus lane, the following matters should be considered, even if these matters are out of this study.

(1) The effect on automobile traffic using the remaining lanes if one is taken away for bus use.

(2) The extent of the benefit to the highway users in buses.

(3) The added cost to the highway users in automobiles.

(4) The expected shift of automobile users to buses as a result of preferential treatment.

(5) The possible effect on abutting land use.

(6) The benefit to the community by encouraging a reduction in the number of automobiles operated during the peak period and a reduction in the number of packing spaces needed.

According to these figures, the tariff system of suburban MTS will exert a tremendous influence on the bus passenger volume and Fig. 5-25 shows the major bus route network in future. This figure was established by the estimated future bus traffic volume, existing bus route network and the necessity to ensure the accessibility from residential area to the MTS station as a function of feeder bus system.

Fig. 5－21
FUTURE TRUNK BUS ROUTE , 2000
(MORE THAN 200 VEH./HR.)

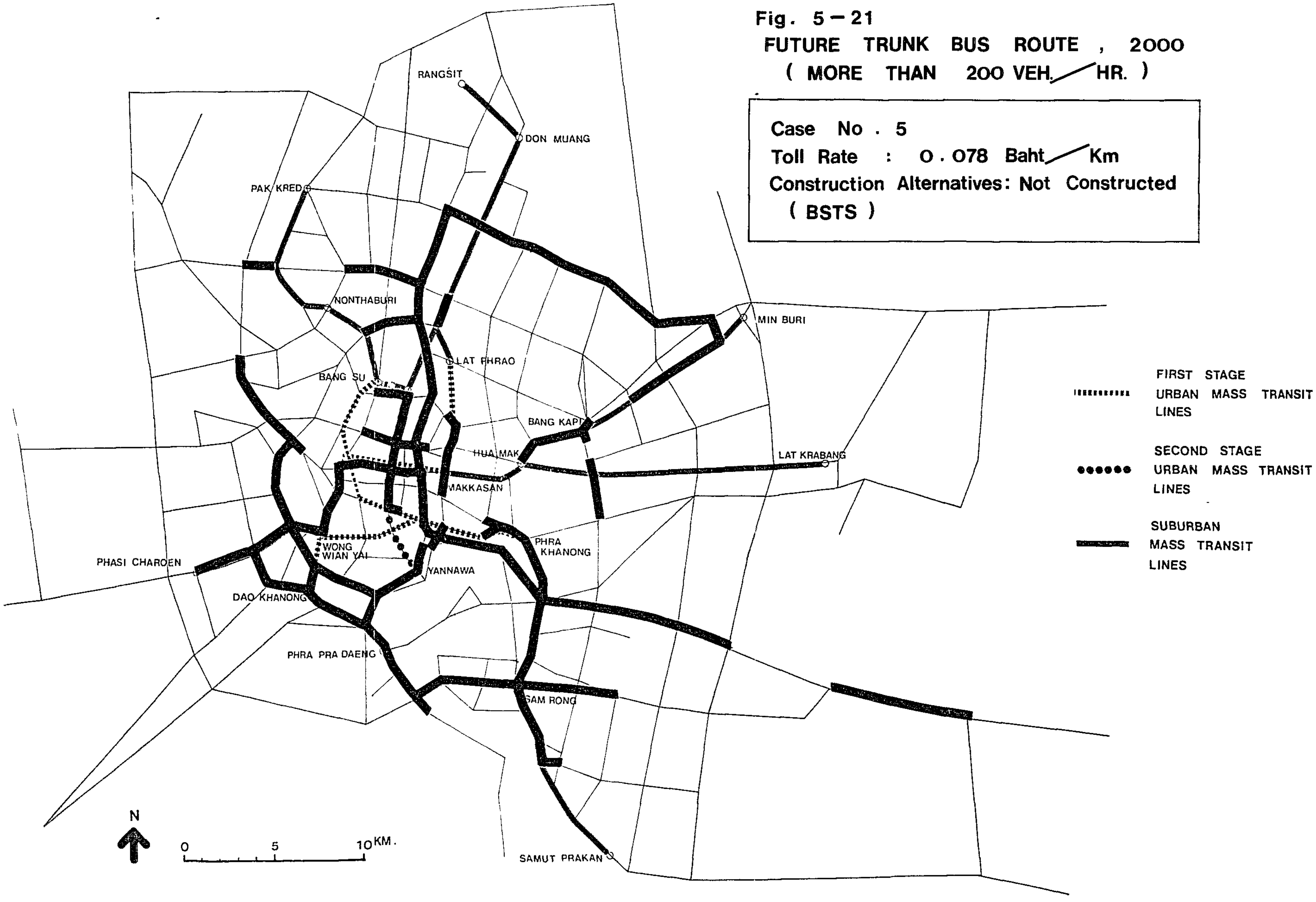


Fig. 5 — 22
FUTURE TRUNK BUS ROUTE , 2000
(MORE THAN 200 VEH./HR.)

Case No. 2
Toll Rate : 0.078 Baht/Km.
Construction Alternatives: Whole System Constructed (BSTS)

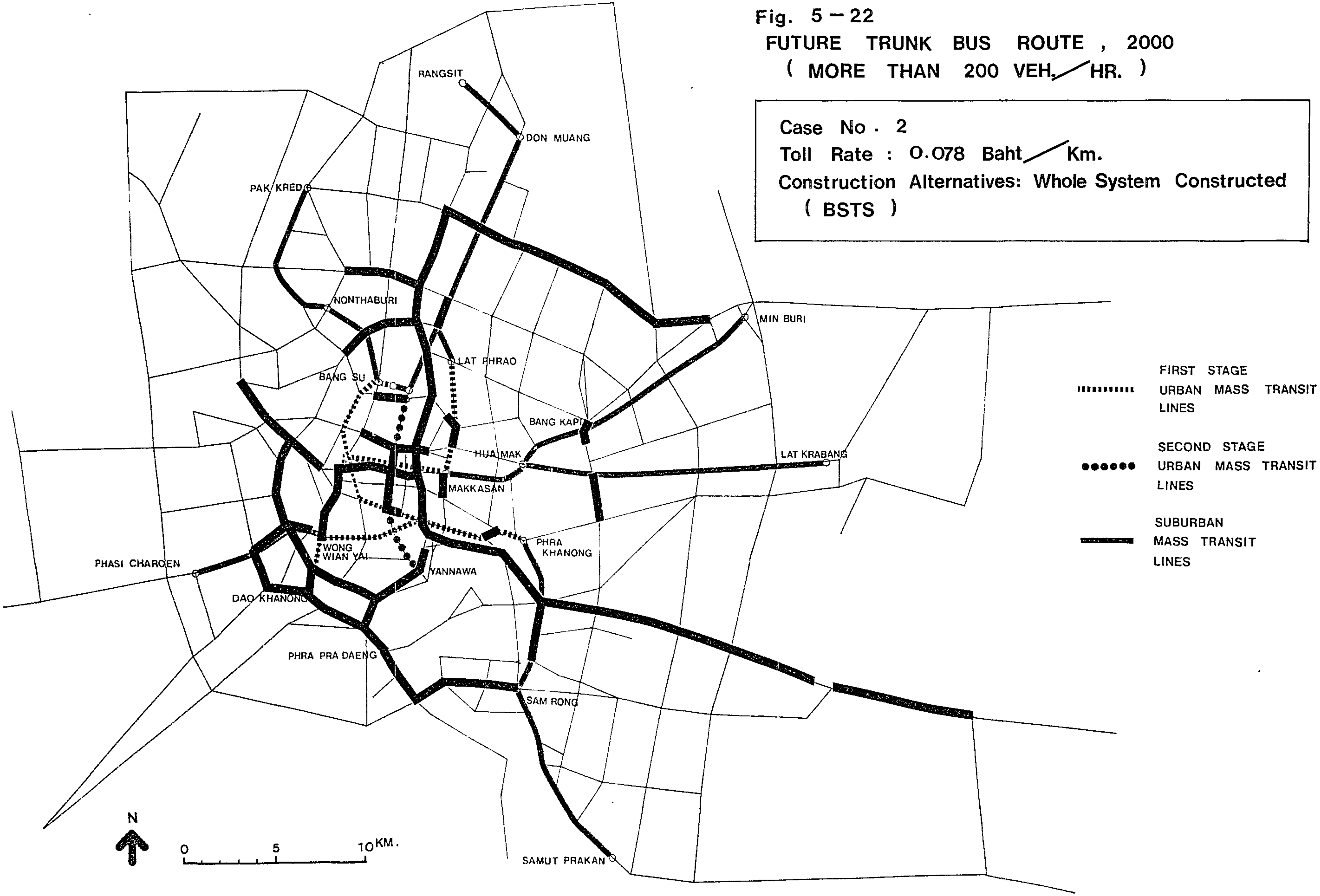


Fig. 5-23
FUTURE TRUNK BUS ROUTE, 2000
(MORE THAN 200 VEH./HR.)

Case No. 5'
Toll Rate : 0.296 Baht/Km.
Construction Alternatives: Not Constrcted
(BSTS)

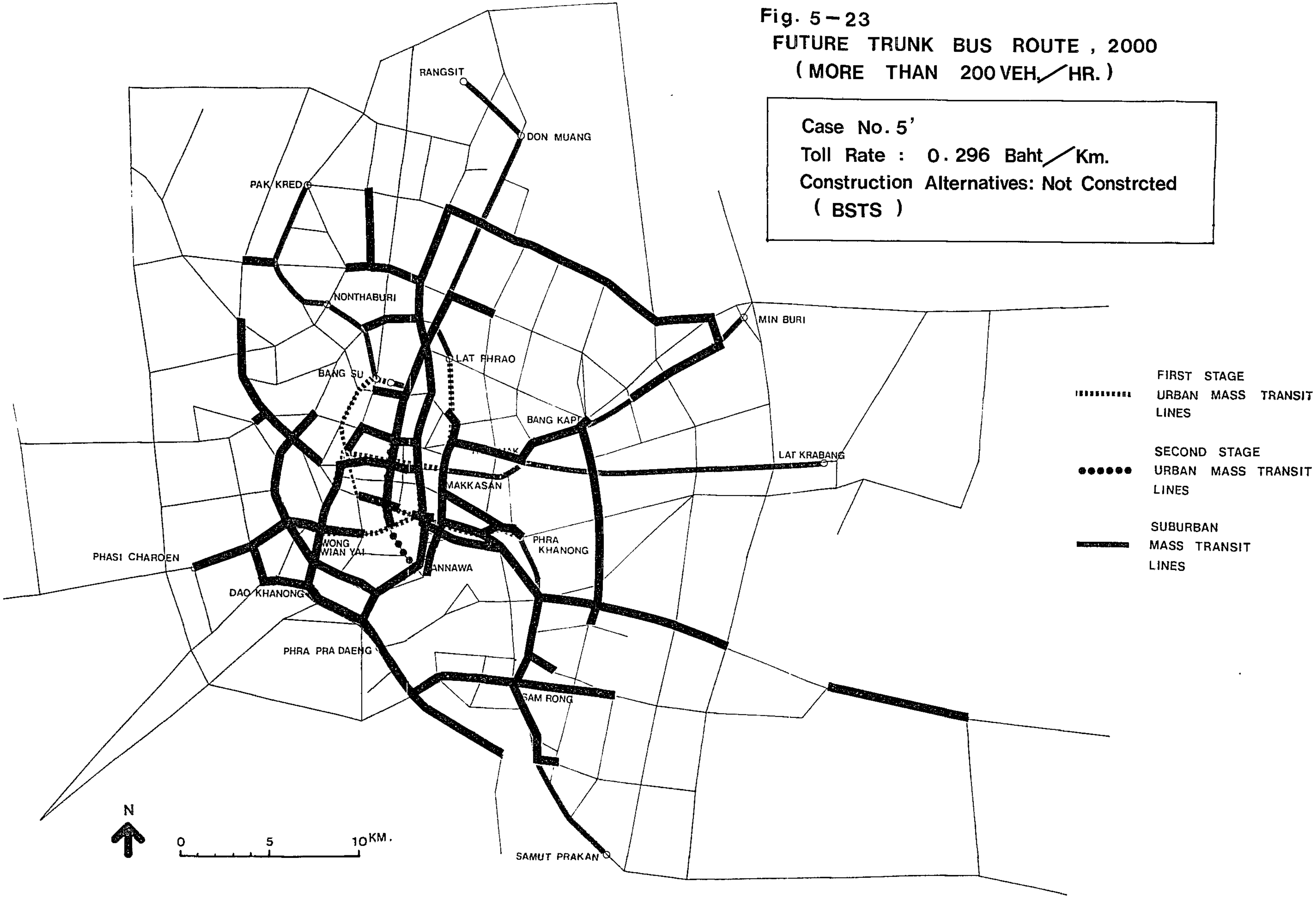
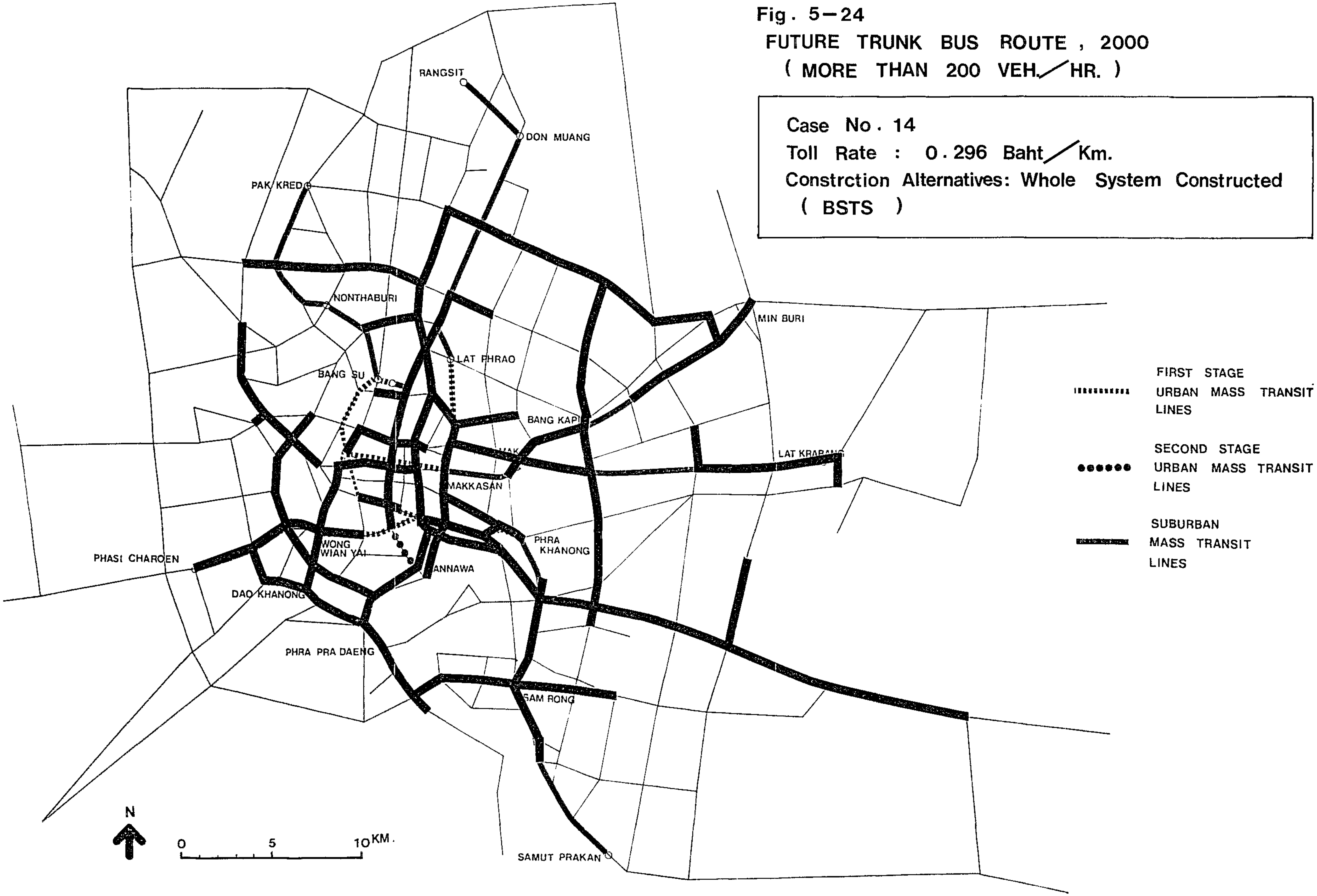


Fig. 5-24
FUTURE TRUNK BUS ROUTE, 2000
(MORE THAN 200 VEH./HR.)

Case No. 14
Toll Rate : 0.296 Baht/Km.
Constrction Alternatives: Whole System Constructed
(BSTS)



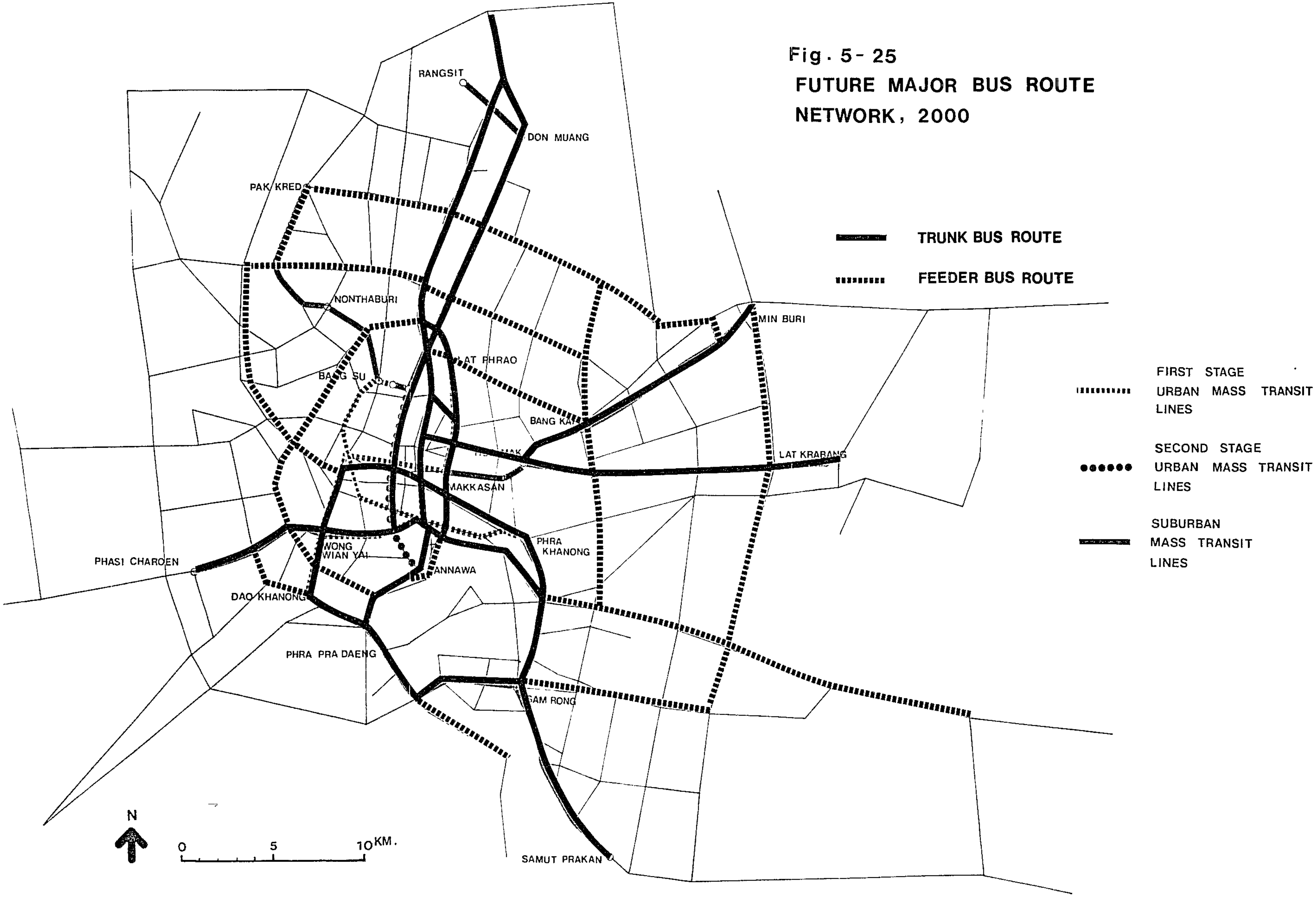


Fig. 5-25 FUTURE MAJOR BUS ROUTE NETWORK, 2000

CHAPTER 6

TRANSPORTATION FACILITIES PLANNING

August 1979

Chapter 6 TRANSPORTATION FACILITIES PLANNING

6.1 Route Alignment

6.1.1 Suburban Mass Transit System

The consultants' study on major traffic potential areas and its flow in Bangkok suburban area reveals that substantial traffic will be generated in four major traffic potential areas. a) In the Nonthaburi area, traffic demand is expected to radiate in all directions. b) In the Minburi and Bang Kapi areas north-south traffic demand is expected to predominate. c) In the east, it is expected that Nong Ngu Hao airport area together with a scheduled housing area will generate growing traffic bound to the eastern railway or the M.T.S. d) In the Sam Rong area, there is an important potential area for industry so that traffic will grow north and south along the highway No. 6 as well as in the direction of east and west.

The above mentioned areas are shown in Fig. 5-6. As mentioned before, in the center of Bangkok Metropolis, the Expressway Network is now under construction and the First Stage MTS feasibility study of detailed design is now being prepared.

In order to establish the most effective mass transportation system for the suburban area, based on the study concepts described in Sections 1 and 2, the consortium have taken the present developments and future prospects into consideration for establishing a desirable network for recommendation.

The network will have six spoles or main radiating routes which extend the First Stage Mass Transit System to the traffic potential areas including that of housing scheme, industrial development etc.

These extension plans are shown in Fig. 5-10.

The consortium, further recommends a rapid completion of upgrading the missing link in the north, which connects the east and west sections of the planned Outer Ring Road for catering to suburban intra-regional transportation. This link must have the same standard as the ORR which is expected to be constructed with a separate budget.

On the basis of above description, the amount of extension routes required has been claculated and is summarized in the following table.

SUMMARY OF SUBURBAN MTS EXTENSIONS

(1) SUBURBAN MASS TRANSIT SYSTEM ROUTE LENGTHS

Route	Location	Length (km)	Note
North			
Route A1	Ban Khlong Prem	5.0	Alternative-1
Route A2	Bang Khen	9.4	Elevated Heavy Rail System
Route B1	Tambon Bang Khen	17.8	
Route B2	Ban Khlong Chan	3.8	
		36.0	Alternative-2
East			
Route C1	Bang Kapi	10.1	At-Grade Heavy Rail System
Route C2	Bang Kapi	11.0	
*Route C3	Bang Khlong Sakae	20.7	
		41.8	Alternative-3
South			System of Alt.-1 and Alt.-2 combined
Route D1	Phra Khanong	7.3	
Route D2	Samut Prakan	15.0	
Route E1	Bang Khun Than	5.0	
Route E2	Samut Prakan	10.1	
		27.4	
West			
Route F	Phasi Choroen	8.3	
Total		123.5	

* Note: In the course of study, Route C3 was taken into account, but after analysis it was ruled out of the system.

(2) OUTER RING ROAD NORTHERN LINK LENGTH

	Route	Location	Length (km)	Standard
Northern-Line	West-side Section	Ban Bang Phum - Ban Pak Khlong Pathum Thani	3.43	The same as the Outer Ring Road.
Northern-Line	East-side Section	Bang Khen - Ban Baen Phichit	2.36	
	Total		5.79	

Note: Since it is assumed that the Outer Ring Road will be financed by a separate budget, its cost was excluded from this study.

6.1.2 Railway Commuter Service

The purpose of railway transportation is to provide a long distance travel mode. However, the railways have already become a commuter service, and according to the analysis of transportation statistics from the State Railway of Thailand (SRT), the number of commuter passengers is rapidly increasing. The growth ratio of commuter passengers in the study area in 1977 increased to 467% compared with that in 1968. (Refer to Table 3-8). The main reason for this growth is the attraction of a specially reduced economical fare.

The alignment for sections of a more planned commuter service on the SRT has been decided after considering future traffic volume and is shown in Table 6-1 below.

Table 6-1 COMMUTER SERVICE SECTIONS IN THE YEAR 2000

Name of Line	Section	Distance	Comments
Southern Line	Alt.1 Bang Su - Nakhon Pathom Alt.2 Thonburi - Nakhon Pathom	56km 48km	Construction of Double-Track, Improvement of Signalling and Tele-Communication
North & North-eastern Lines	Bangkok - Ayuthaya	72km	Improvement of Signalling and Telecommunication Construction of New Station
Eastern Line	Bangkok - Hua Ta Khe	31km	Construction of Double-Track. Improvement of Signalling and Telecommunication

6.2 Selection of Mass Transport Mode for the Surburban Area

In general, modes of transport vary in terms of transport speed, capacity, punctuality, safety, comfort, accessibility, financial return, etc. The following sections aim to select the best mode of suburban transport for the existing situation in Bangkok in terms of transport distance, speed, capacity and costs. Based on the findings in subsequent paragraphs and the limited time available for this suburban mass transit study, a heavy railway has been recommended as the most suitable mode of transportation for the suburban area and for connection with the first stage heavy railway mass transit system in the urban area.

6.2.1 Comparison of Travel Time and Distance for Different Systems

Fig. 6-1 shows the relationship between the travel time and distance for most conventional and new transport systems.

The suburban mass transit system has been proposed to cover an area of about 10 to 50 kilometers and to be connected with the urban mass transit system. Outside the suburban area, the existing railway is expected to be sufficient to serve commuters travelling to the CBD from less than 120 kilometers.

Assuming that the maximum tollerable travel time for a commuter is less than 100 minutes in one direction, Fig. 6-1 shows that the urban mass transit railway would meet the requirement of travel distance between 10 and 50 kilometers, and the express or limited express train would meet the requirement of more extensive commuting distances of upto 120 kilometers. The new guideway system would serve shorter travel distances of 5 to 20 kilometers.

6.2.2 Transport Capacity by Mode of Transport

Transport capacity also differs with mode of transport and headway. As shown in table 6-2, the volume of passenger demand for the Bangkok suburban mass transit system was estimated to be from a low of 6,000 per peak hour and direction to a high of 30,000 per peak hour and direction excluding sections B1 and B2 which are exceptional and are discussed separately.

Table 6-2 AVERAGE* SUBURBAN PASSENGER DEMAND PER PEAK HOUR AND DIRECTION BY SECTION IN 2000

Suburban section	Highest Demand (Case 2)	Lowest Demand (Case 14)
A1	22,768	8,774
A2	13,094	9,006
B1	10,989	3,140
B2	740	0
C1	29,620	11,722
C2	20,782	13,584
** C3	12,330	7,350
D1	25,763	16,609
D2	10,333	6,737
E1	20,725	12,799
E2	14,008	7,814
F	10,888	6,889

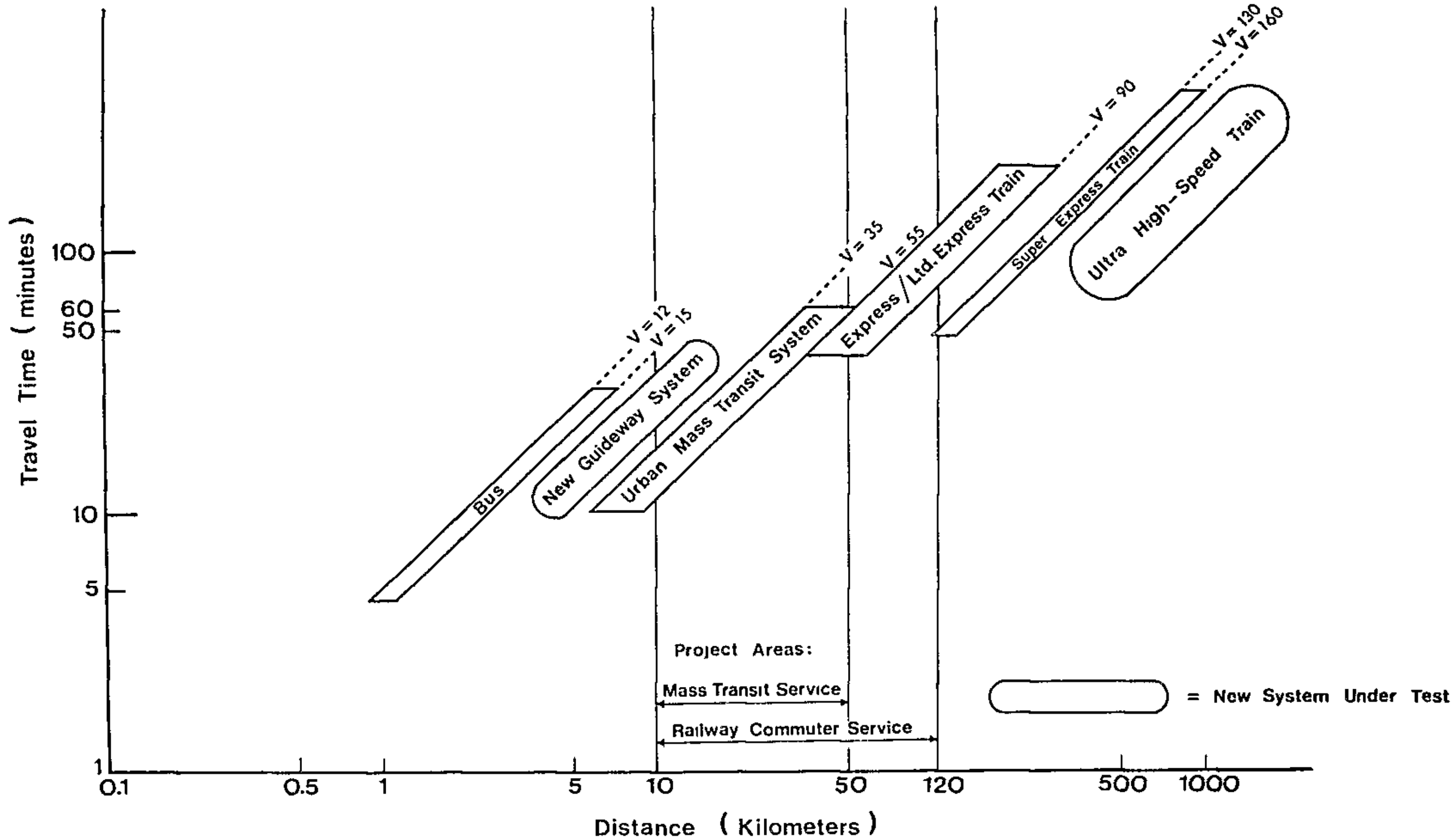
Note * . Calculation is made as follows $\frac{\Sigma P_i D_i}{\Sigma D_i}$, where i = segment i of a section, P_i = Passengers in the segment i, D_i = Distance of the segment i.

** : Refer to Page 6-2.

Fig. 6 - 1

Comparison of Typical Ranges for Different Transport Modes

(V = Scheduled Speed Km./hr.)



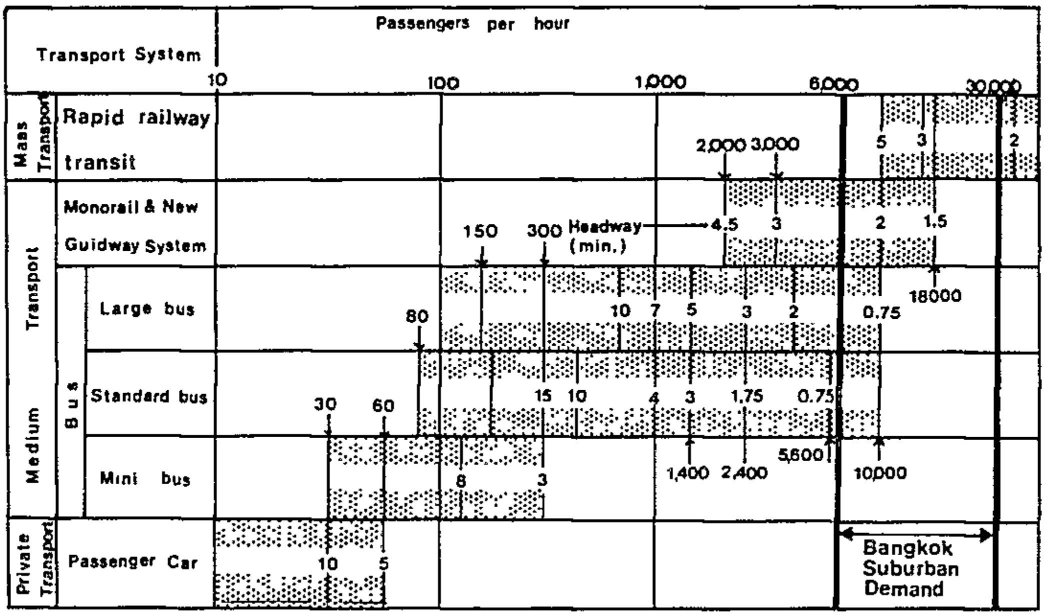
Ref: Bouladon's Equation:

Travel Time = $7.62 \times \text{distance}^{0.46}$

Source: "Transportation System for Major Activity Centers", - Proceedings of the Second Technology Assessment Review, July 1971 -, OECD

Fig. 6-2 shows the general relationship found in Japan between the traffic demand and the transport mode used. According to this figure, the rapid railway transit (urban mass transit), monorail and new guideway systems are the most adequate alternative modes to meet the suburban demand. However, when the travel distance of the suburban commuters is additionally considered, the rapid railway transit is more highly recommendable than the monorail or new guideway systems. Furthermore, transit time from the suburban to the urban systems will be quicker if the systems are both the same, thus providing a time savings to commuters.

Fig. 6-2 COMPARISON & TRANSPORT CAPACITY FOR
VARIOUS MODES OF TRANSPORT



Source: "Transportation & Economy" Feb., 1979 Vol. 39. No. 2

6.2.3 Cost-Volume Comparison of Different Transport Systems

In terms of transport time, distance and capacity discussed so far, the most adequate modes for the suburban mass transit system are the following:

Light rail,
Heavy rail,
Monorail and
New guideway system

The following cost analysis of the above transport modes is based on figures found in the report of the First Stage Mass Transit System in Bangkok. In this report, the "H-Bahn" system was used as a model of the new guideway system. Low, medium and high levels of transport capacity for each mode were defined as follows:

Table 6-3 CAPACITY LEVEL BY MODE OF TRANSPORT

Mode	Capacity level	Train formation (veh. units/train)	Headway (min.)	Capacity (pass./hr.)
Light rail	1	2	2.5	11,400
	2	3	2	21,500
	3	3	1.5	28,700
Heavy rail	1	3	3 .	23,200
	2	3	2.5	27,800
	3	3	1.5	46,300
Mono-rail	1	4	3	25,200
	2	4	2.5	30,200
	3	4	2	37 800
New Guide-way	1	2	3	5,300
	2	2	2	8,000
	3	2	1.5	

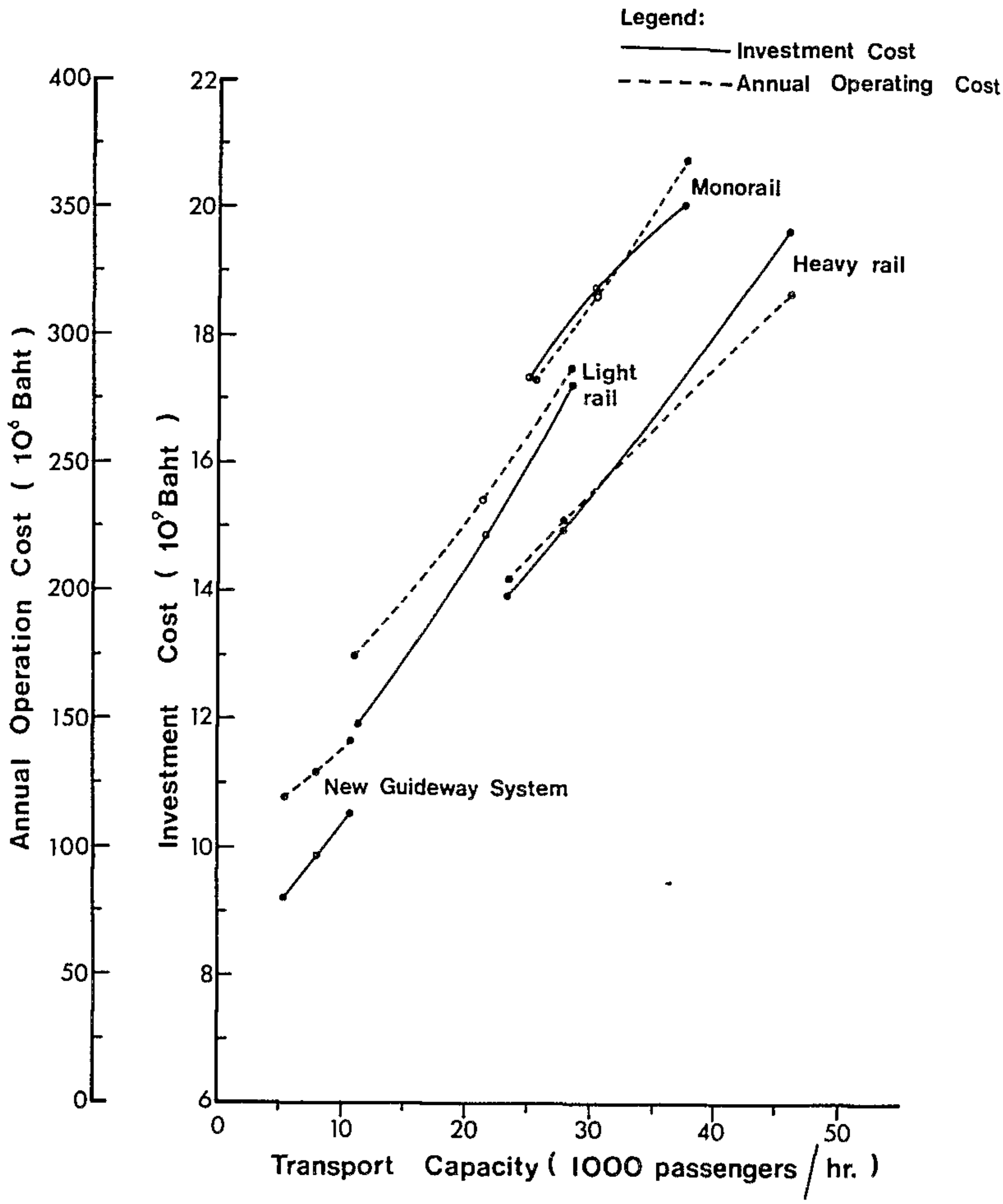
Source: "First Stage Mass Transit System in Bangkok ' Vol. I, Dec., 1978

The cost components of the investment cost and the annual operation cost are further brokendown in the Appendix, Tables AP6-1 and AP6-2. The dominant cost components of the investment cost are the civil engineering cost and the rolling stock costs which account for more than 75 percent of the total investment for each mode.

The difference in the investment cost between the urban mass transit and the suburban mass transit largely depends on the land acquisition cost and whether the track is elevated or at-grade. Although the urban mass transit is to be an elevated system in most of the routes, the suburban mass transit can be an at-grade system. Therefore, civil engineering costs for the suburban light rail or the heavy rail will be less than those of the urban system. However, the at-grade system will require more land space than the elevated system. If it is assumed that construction cost difference between the at-grade system and the elevated system is equal to difference in land acquisition cost between the two, the cost-capacity relationship established for the urban mass transit system can be applied to the suburban mass transit system. According to Fig. 6-3, when peak traffic demand is over about 20,000 passengers per hour, a heavy rail is most economical for both investment and operation costs compared to a monorail and a light rail; when peak traffic demand is less than about 10,000 passengers per hour, the new guideway is more economical than the other modes. For a peak traffic demand between 10,000 and 20,000 passengers per hour, a heavy rail is also more economical than a light rail since at the capacity level of 15,000 passengers per hour (about two-thirds of the capacity level-1 of the heavy rail) the required number of rolling stocks would be reduced to two-thirds of that in the capacity level-1 and the total investment cost would drop to 12,063 million Baht even with other costs kept constant.

From the viewpoint of transport capacity, the monorail or the new guideway system could be acceptable for some routes of the suburban system. Noretheless, these systems generally serve for the short or medium travel distance and are supplemental to a trunk line transport system. In addition, the transit time from one mode to another is time consuming largely because of passenger congestion at transfer stations.

Fig. 6-3 COST-CAPACITY COMPARISON OF DIFFERENT TRANSPORT SYSTEMS



Therefore, if the all routes of the suburban system are considered as radial trunk lines for a mass rapid transit network in Bangkok, the heavy railway mode would be most suitable in terms of the discussion presented so far.

For the B1 and B2 sections which have a low passenger demand and are considered as a feeder system of the suburban rapid mass transit, there is the possibility of introducing the monorail or the new guideway system into these two sections.

According to the proposed construction schedule, B1 and B2 sections are to be open to traffic in 1993. However, since the project-life span is 20 years, the terminal year of the project would be the year 2013 and would therefore serve a passenger demand which will be much higher than that calculated for the year 2000.

In addition, since the Bangkok suburban mass transit system is expected to provide radial service for the trunk commuter transport, the necessity of having a northern line consisting of the B1 and B2 sections will be inevitable. Therefore, even the B1 and B2 sections should be incorporated into the suburban mass transit system using the same mode as the urban mass transit system, namely the heavy rail mode.

From the overall point of views discussed, the heavy rial system is recommended as the mode of the suburban mass transit.

6.3 Train Operation Planning

6.3.1 Planning for Mass Transit System

(1) Principle of Planning

The route of MTS is divided into various sections, i.e., A1, A2 B1, C1, C2, D1, D2, E1, E2 and F as shown in Fig. 5-10.

Planning train operations for these sections will be based on the following principles considering the First Stage MTS which has been studied already.

i) Trains shall be operated directly as much as possible so as to enable passengers who travel between suburban area and center of city transfers free/routes from their origin to their destination.

ii) By adoption of the above mentioned system, it is possible to minimize the train turn-around time. Accordingly, the operation ratio of rolling stock can be improved.

iii) In order to maximize the load factor, trains making turn-arounds en-route will be provided in communities with large traffic volumes.

iv) In order to minimize the need for transfer, identical type of rolling stock in the MTS for urban area shall be used for suburban area as well.

(2) System of Train Operation

Based on the preceding principles, train operation routes will be defined as follows:

i) C2 route - C1 route - Memorial Line - E1 route - E2 route

ii) F route - Sathorn Line - B1 route
(Some trains will operate from F route to the Sathorn Line only.)

iii) B1 route - Rama Line - D1 route - D2 route.
(Some trains will operate from the Rama Line to D1 route only.)

iv) A1 route - A2 route.

(3) Speed

The maximum speed will be 80 km/h, which is identical as the speed of the First Stage MTS; the schedule speed will be 40 km/h. The schedule speed is somewhat higher than in the First Stage MTS, i.e., 37.1 km/h for Rama line; 37.7 km/h for Sathorn line; and 35.8 km/h for Memorial line. The higher speed is due to the longer distance between stations in the suburban area.

(4) Headway

The number of units composing one trian will be three, as in the First Stage MTS. In rush-hours, headway will be determined so as to enable the train to transport the traffic volumes required in Chapter 5. (See Tables 6-6 and 6-7).

(5) Operating Hours

The operating hours of MTS were planned considering the pattern of activities in Greater Bangkok Area and the time required for maintenance of each facility to be as follows:

Starting time	4 o'clock a.m.
Terminating time	12 o'clock p.m.

(6) Number of Cars Required

(a) Dimension and Capacity

Identical dimension and capacity of vehicles for the First Stage MTS will be applied with the main specifications as follows:

Gauge	:	1,435 mm
Maximum Speed	:	80 km/h
Axle Arrangement	:	BB + BB
Seating Capacity of unit	:	98 persons
Standing Capacity of unit	:	288 persons

As one train is composed of 3 units, the total capacity will be 1,158 persons.

(b) Running Time

Running time on each MTS route is calculated by the route length and schedule speed as shown in Tables 6-4 and 6-5 respectively.

(c) Number of Cars Required

The number of cars required for operation is calculated by the following formula:

$$N_0 = \frac{2(t_0 + t_,)}{h} \times n$$

N_0: Number of cars required for operation
t : Running time (minutes)
$t_,$: Turning time (to be 3 minutes)
h : Headway (minutes)
n : Number of cars

If the ratio of reserve rolling stock is 15%, the number of cars including reserve is given by the following formula:

$N_{t} = 1.15 \times N_0$
N_{t}: Number of cars including reserve

The number of cars required for each different route is also shown in Tables 6-4 and 6-5.

Table 6-4 NUMBER OF CARS REQUIRED FOR THE YEAR 2000 (CASE 2 - LOWEST DEMAND)

Route	Route length (km)	Running time (min)	Maximum traffic flow (pass/h)	Number of required trains per hour	Headway (min)	Number of required cars for * operation	Number of cars including reserve
A1 } A2 }	14.4	21.6	21,312	19	3.0	(17) 102	118
B1	17.8	26.7	11,330	10	6.0	(10) 60	70
C1 } C2 }	21.1	31.7	22,465	20	3.0	(23) 138	160
D1 } D2 }	22.3	33.5	25,474	22	2.5	(30) 180	208
E1 } E2 }	15.1	22.7	20,544	18	3.0	(18) 108	124
F	8.3	12.5	21,696	19	3.0	(11) 66	76

* Remarks: Figure in the Brackets shows number of train sets required for operation.

Table 6-5 NUMBER OF CARS REQUIRED FOR THE YEAR 2000 (CASE 14 - HIGHEST DEMAND)

Route	Route length (km)	Running time (min)	Maximum traffic flow (pass/h)	Number of required trains per hour	Headway (min)	Number of required cars for * operation	Number of cars including reserve
A1 } A2 }	14.4	21.6	14,370	13	4.5	(11) 66	76
B1	17.8	26.7	3,277	3	20.0	(3) 18	22
C1 } C2 }	21.1	31.7	15,303	14	4.0	(18) 108	124
D1 } D2 }	22.3	33.5	16,995	15	4.0	(19) 114	132
E1 } E2 }	15.1	22.7	12,829	11	5.0	(11) 66	76
F	8.3	12.5	12,266	11	5.0	(7) 42	48

* Remark: Figure in the Brackets shows number of train sets required for operation.

6.3.2 Planning for Railway Commuter Service

(1) Sections of Commuter Service

Commuter trains based at Bangkok Station as a terminal shall be operated in the following sections:

Eastern line	:	Bangkok - Prachinburi
Northeastern line	:	Bangkok - Saraburi
Northern line	:	Bangkok - Lopburi
Sourhern line	:	Bangkok - Ratchaburi and Thonburi - Ratchaburi

(2) Type of Train Set

Diesel railcars will be used instead of trains hauled by a locomotive for commuter trains for the following reasons:

i) As acceleration is higher than that of the trains hauled by the locomotives, operating time can be shortened.

ii) As coupling and decoupling is easier, longer operation to cope with traffic volume is possible.

iii) As there is no need to couple/decouple the locomotive, turning time at terminal station can be shortened.

Electrification seems to be unnecessary in this project considering traffic demand.

The type of rolling stock and dimensions shall be the same as the ones used by SRT and standard train formation shall be composed of 3 units 6 cars.

(3) Headway and Number of Trains Required

A result of calculation made on traffic volume in rush-hours regarding Case 2 and Case 14, the required number of trains and headway to cope with the traffic volume is shown in Table 6-6.

Furthermore, the headway in daytime shall be 2-3 times greater than in rush-hours, and in early morning and midnight shall be 3-4 times greater than in the rush-hours.

(4) Number of Cars Required

The required number of rolling stock needed for the operation of each relevant section in the GBA, (i.e., Bangkok - Hua Ta Khe (Eastern line), Bangkok - Khlong Rangsit (Northern line), Bangkok - Sala Ya (Southern line)) is shown in Table 6-7.

The indicated speed in this calculation is 45 km/h and the required time for turning at terminal station is 3 minutes.

In order to serve the number of diesel railcars, it is necessary to increase the capacity of the shed and capability of inspection and maintenance.

The expansion of the shed will be stated hereafter, but improvement of Makkasan Workshop is also needed for the sake of increasing of capability of inspection/maintenance.

Table 6-6 NUMBER OF TRAINS REQUIRED AND HEADWAY

Line	Section	Traffic Volume per hour(pass.)		Number of trains Required per hour		Headway (min)	
		Case 2	Case 14	Case 2	Case 14	Case 2	Case 14
Eastern	Makkasan - Hua Ta Khe	12,692	7,476	10.2	6.0	5.5	10.0
	Hua Ta Khe - Prachinburi	3,553	2,581	2.8	2.1	21.4	28.5
Northeastern & Northern	Bang Su - Khlong Rangsit	9,707	15,300	7.8	12.2	7.5	4.5
	Khlong Rangsit - Ban Phachi Jn.	7,961	6,296	6.4	5.0	9.0	12.0
	Ban Phachi Jn. - Saraburi	738	626	0.6	0.5	60	60
	Ban Phachi Jn. - Lopburi	962	837	0.8	0.7	60	60
Southern	Bang Su - Sala Ya	18,708	16,980	15.0	13.6	4.0	4.0
	Sala Ya - Nakhon Pathom	11,960	9,878	9.6	7.9	6.0	7.5
	Nakhon Pathom - Ratchaburi	3,959	3,270	3.2	2.6	18.0	23.0

Note: Case 2 (lowest demand) and Case 14 (highest demand)

Table 6-7 NUMBER OF RAILCARS REQUIRED

Line / Item		Eastern Line Bangkok - Hua Ta Khe	Northeastern & Northern Lines Bangkok - Khlong Rangsit	Southern Line Bangkok - Sala Ya
Route length		30.94 km	28.53 km	27.19 km
Running time (one way)		41.3 min	38.0 min	36.3 min
Round time		88.6 min	82.0 min	78.6 min
Headway	Case 2	5.5 min	7.5 min	4.0 min
	Case 14	10.0 min	4.5 min	4.0 min
Number of train sets required for operation	Case 2	16	11	20
	Case 14	9	18	20
Number of railcars required for operation	Case 2	96 (48)	66 (33)	120 (60)
	Case 14	54 (27)	108 (54)	120 (60
Number of railcars including reserve	Case 2	108 (54)	78 (39)	132 (66)
	Case 14	60 (30)	126 (63)	132 (66)

Remark: Figure in the brackets shows number of units of railcars.
Note: Case 2 (lowest demand) and Case 14 (highest demand)

6.4 Facility Planning

6.4.1 Facility for Mass Transit System

(1) System components

For the proposed Mass Transit System the following components shall be examined:

Operations
Vehicles
Workshops

In addition to these, power supply for electrically driven systems, and signalling & telecommunications equipment for the system are to be taken into consideration.

(2) Operations, Vehicles and Workshop

In the project system, a "capacity level" was employed first. It was assumed that one train will be formed of 3 units and that each unit will consist of 2-vehicles (i.e., a total of 6-vehicles per train). Although several capacity levels might be compared in general, in this study only the one level which has three minutes of headway was used. (Capacity level-1)

A vehicle unit for the heavy rail is presumed to have a capacity of 386 passengers including 98 sitting and 298 standing. The size of the body is preliminarily assumed to be 18 m long and 2.9 m wide.

On the basis of this, the capacity of one train will be 23,200 passengers per hour. The most appropriate schedule of operation together with calculation of required number of vehicles has been examined to see whether the schedule can adequately cater to the traffic demand of the project.

The number of vehicles was calculated as 756 including reserves required.

For maintenance of rolling stock, the size and capacity of workshops were determined according to a planned maintenance system, vehicle dimensions and the number of vehicle units. The arrangement was considered to be the same as that for a conventional rail system. Location of workshop should be decided in the light of operational requirements, possibilities for expansion and the availability of a suitable site. Since it was not possible to determine the exact location of workshop in the study, only the cost required was estimated for the purpose of economic analysis.

(3) Power Supply Facilities

Based on present technology, direct current supply is the most favorable solution for the proposed system. The necessary power will be taken from the MEA grid to the rectifier substations through high voltage lines. In the rectifier substation, the high voltage is transformed to the system operating voltage, rectified and passed to the individual line supply sections.

Regarding the selection of the voltage, the higher the voltage, the lower the costs for the stationary equipment. It is said that there is a limit for the selection of voltage which is influenced by the vehicle design and protection requirements. For the proposed system the operating voltage of 1,500 V DC is assumed.

In order to carry the electricity between the substation and vehicle, a catenary system is considered to be the most favorable solution from the viewpoint of construction and maintenance. This system is applied to the project.

Taking into consideration above mentioned equipment (i.e., power transfer station, power transmission system, rectifier substation, and catenary system), together with an information and functional control center, required personnel, and material and supplies for maintenance, the whole plan of power supply system has been visualized. The costs are estimated in Section 6.5.1.

(4) Signalling and Telecommunication Facility

In order to maintain smooth operation of the MTS, a signalling system is required for train protection and operational control.

Several signal boxes can be monitored from a central location if remote control operation is possible. This also applies to the center for the telecommunication systems.

Of the two applicable signalling systems, (i.e., the conventional fixed signals with automatic train stop (ATS), and the continuous automatic train control (CATC) with cab-signalling), the CATC has proved to be more efficient and is recommended.

Personnel requirements for train protection and telecommunication system has been studied by dividing them into operation and maintenance. The costs of the equipment and personnel are estimated on the basis of above mentioned requirements.

6.4.2 Facility for Railway Commuter Service

In planning facilities for commuter service by SRT, full utilization of existing facilities is made. The scale of the railway investment program is based on the results of railway transportation demand in the year 2000.

(1) New Stations

The location of new stations should be decided by the result of future passenger flow. More detailed investigation in the next stage of this study will be required to thoroughly evaluate the proposed location for new stations.

According to this study, the railway line requiring new stations are as follows.

NEW STATIONS REQUIRED:

a) North & Northeastern Line

From/to Bang Su - Chiang Rak Noi 5 stations

b) Eastern Line

From/to Makkasan - Hua Ta Khe 5 stations

The size of station yard will follow the standard design of SRT, but length of platform should be longer than the standard design because the length of a commuter train is about 120 m. The design of station yard for new station is shown in Fig. 6-4.

(2) Double-Track

Construction of double-track is considered necessary when the number of trains exceed the track capacity of single track. Comparison of present track capacity with the required number of trains in the year 2000 is shown as Table 6-8.

Table 6-8 COMPARISON OF TRACK CAPACITY AND FORECAST TRAIN VOLUME

(Trains/Hour)

Line	Track Capacity in 1977	Number of Trains Required in 2000*	Track Deficiency
Southern Line	7	15 - 23	8 - 16
North & Northeastern Line	16	8 - 12	-
Eastern Line	4	6 - 10	2 - 6

* Number of trains is based on the future passenger volume.

According to this study, construction of the proposed sections of double-track is recommended as follows:

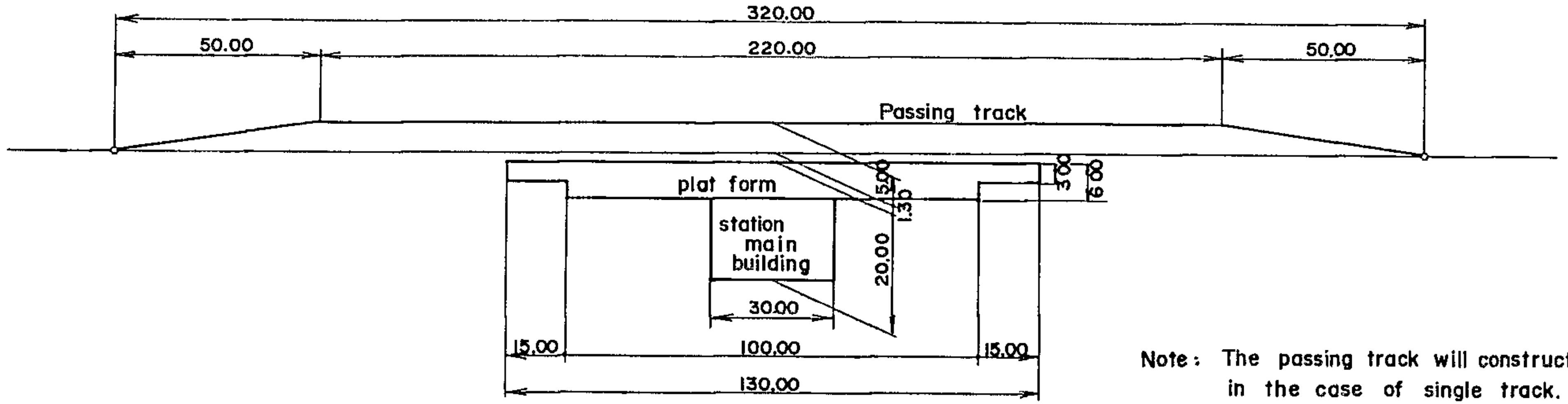
a) Southern Line : From Bang Su Stn. to Nakhon Pathom Stn. or from Thonburi Stn. to Nakhon Pathom Stn. (Alt. 1 or Alt. 2)

b) Eastern Line : From Bangkok Stn. to Hua Ta Khe Stn.

A typical cross section for double-track is shown in Fig. 6-5.

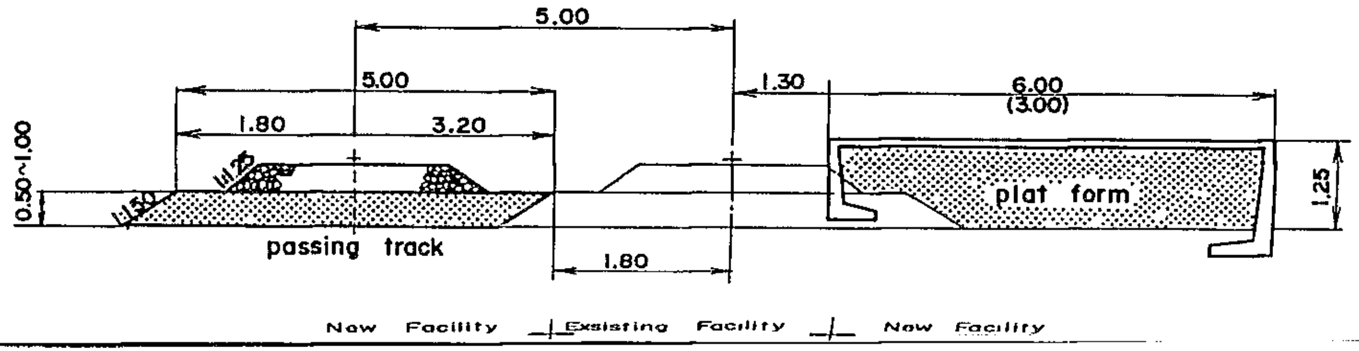
Fig. 6-4 STANDARD STATION YARD

Plan of station yard



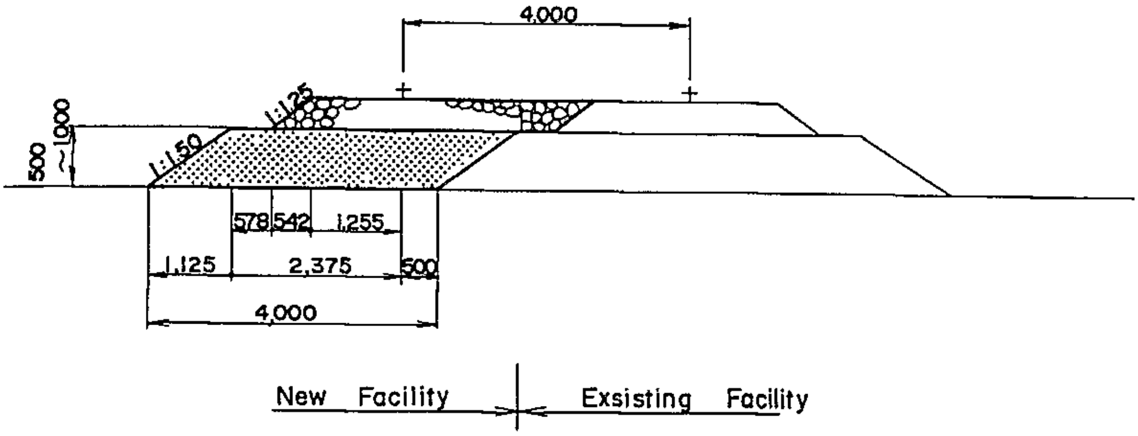
Note: The passing track will construct in the case of single track.

Cross section of station yard



Scale :

Fig. 6-5 CROSS SECTION FOR DOUBLE-TRACK



(3) Improvement of Signalling and Telecommunications

It is necessary to improve the signalling system in some sections in conformity with the increased number of trains to accommodate increasing traffic volumes.

The sections which will require a sophisticated signalling system in the year of 2000 are shown in Table 6-9.

Modernization of a telecommunication system should be planned for the whole of SRT system; consequently, no particular comment is made in this report as a special system is not required for the suburban project alone.

(4) Improvement of Bangkok Station Yard

As mentioned previously, commuter trains and diesel railcars increase with commuter traffic demand. It is therefore necessary to improve Bangkok Station in the following respects:

i) Increasing of the amount of arrival/departure tracks

ii) Expanding the diesel railcar shed space

For the above improvements, curtailment of an existing passenger carriage yard and a passenger carriage shed is necessary. It is necessary to plan suburban facilities in parallel to the planning which has been under the study by SRT to relocate the passenger carriage yard from Bangkok Station to Bang Su Station.

Table 6-9 PROPOSED SIGNALLING SYSTEM

Line	Section	Proposed system		Existing system
		Lowest Demand (Case 2)	Highest Demand (Case 14)	
Eastern	Makkasan - Hua Ta Khe	automatic	automatic	token
	Hua Ta Khe - Prachinburi	token	token	token
Northeastern & Northern	Bang Su - Khlong Rangsit	tokenless	automatic	tokenless
	Khlong Rangsit - Ban Phachi Jn.	tokenless	tokenless	tokenless
	Ban Phachi Jn. - Saraburi	tokenless	tokenless	tokenless
	Ban Phachi Jn. - Lopburi	tokenless	tokenless	tokenless
Southern	Bang Su - Sala Ya	automatic	automatic	tokenless
	Sala Ya - Nakhon Pathom	automatic	automatic	tokenless
	Nakhon Pathom - Ratchaburi	tokenless	tokenless	tokenless

6.5 Cost Estimates

6.5.1 Introduction

This section presents an estimate of costs for major material items for the suburban Mass Transit System and the Railway Commuter Service. Global estimates for each system are based on unit costs and quantities for labor, equipment, materials and supplies.

Unit costs employed were analysed by the Team and verified by comparison with the latest study report which has been agreed to and accepted by Thai Government for the First Stage Mass Transit System at the end of 1978.

(1) Financial Cost

Total investment costs are based on actual site-delivered prices that will be paid for each cost item. The site-delivered price for imported items is not that listed on official price lists, but the CIF price in foreign currency at the port of entry converted into local currency at the official exchange rate plus duty (if any) and the costs of inland transport. The prices are generally calculated at the end-of-1978 levels and no consideration was made for fluctuation which might occur at later stage.

The unit costs of the major material items are as shown in Table 6-10.

Table 6-10 UNIT COST OF MAJOR MATERIAL ITEMS

Material	Unit	Domestic Supply and Cost	Foreign Supply and Cost
Sand	(Baht/m^3)	110 - 120	
Ballast	(Baht/m^3)	120 - 130	
Cement	(Baht/ton)	790 - 905	
Processed Steel	(Baht/ton)	7,500	
Rail	(Baht/ton)		8,500 - 9,500
Gasoline	(Baht/Liter)	4.69	
Ready Mixed Concrete	(Baht/m^3)	630 - 635	

(2) Economic Cost

Economic evaluation for this study is to determine whether this project will contribute to the over-all economy of Thailand based on a comparison of costs and benefits. Costs cover the commitments and consumption of resources (including labor) for the project and benefits are the savings (created or acquired). In this sense, tax payments are considered as transfer payments, and not as resource consumption. Thus, amounts equivalent to the taxes paid and included in costs must be subtracted from the costs. Since the true economic value of the resources to the national economy are not accurately reflected in the actual site-delivered prices, adjusted economic cost of fuel and major material were calculated and are as shown in Table 6-11, -12.

Table 6-11 ECONOMIC COST OF FUEL

(Unit: Baht/liter)

	Regular Petrol	Heavy Oil	Lubricant
Retail Price	4.69	2.64	18.00
Excise tax, business tax	2.02	0.24	1.56
Economic Cost	2.67	2.40	16.44

Table 6-12 ECONOMIC COST OF PRICNIPAL MATERIAL

Material	Unit Cost	Unit	Rate of Tax (%)	Economic Cost
Sand	110 - 120	Baht/m^3	8.0	101.2 - 110.4
Ballast	120 - 130	"	8.0	110.4 - 119.6
Cement	790 - 905	Baht/ton	1.5	778.2 - 891.4
Steel	7,500	"	15.0	6,375.0

6.5.2 Project Cost for Mass Transit System

The costs consist of four main items: Cost of civil engineering, electrical/mechanical engineering, land acquisition and operating costs.

The costs are calculated on the basis of total payments made for each cost item up to the project site. For imported items, this means the price list value plus insurance and freight to the port of entry (converted into local currency at the official exchange rate), with duty and costs of inland transport added.

(1) Financial Cost

a) Civil Engineering Cost

Civil engineering costs of proposed MTS cover the open line section, station, permanent way, diversion and relocation of public utilities, and workshop.

Two alternatives costs for the open line section and station were compared: an elevated system and an at-grade system. Permanent-way costs include track and switches. Costs of civil engineering for workshops and marshalling yards was estimated for capacity level-1 as described in 6.4.1(2) in this report.

Total costs were then calculated to conform with the following criteria.

- To the construction cost, 8% was added for the engineering design and supervision fee and 1% was added for insurance claims.

- Project contingency is assumed to be 10% of the construction costs.

Tables 6-13 and 6-14 present civil engineering costs for the two alternatives.

b) Electrical/Mechanical Engineering Cost

These costs cover rolling stock, power supply, signalling & telecommunications and workshop equipment.

i) Rolling Stock

The individual costs for vehicle units includes costs for transport and insurance as follows:

- Mechanical part	11.60 (million Baht)
- Electrical part	7.65
- Assembly of the electrical part	1.45
Sub-total:	20.70
- Transport	2.07
Total:	22.77

Based on the number of vehicles to be used as determined in Section 6.3.1, the cost for rolling stock is given as follows:

Number of units x unit price = Cost of rolling stock

756/2 x 22.77 = 8,607 million Baht.

ii) Power Supply System

Power taken from the grid is transmitted to the rectifier substation via high voltage lines. In the rectifier substations the high voltage is transformed to the system operating voltage, rectified (1500 V, DC) and passed to the individual line supply sections. The vehicles will be supplied via catenary for the heavy rail system. (V max. = 100 km/h)

The calculation of power-supply system investment cost is given below assuming that equipment will be imported and locally assembled with 63% of the cost for the foreign portion and 37% for local portion.

POWER SUPPLY SYSTEM INVESTMENT COSTS:

	Capacity level-1 (Million Baht)
Transfer station	132
Power transmission	120
Rectifier substation	690
Catenary control center	510
Remote control center	55
Low voltage equipment	15
Total:	1,522

iii) Signalling and Telecommunication System

Heavy rail continuous automatic train control (CATC) with signalling in driver's cab will be employed. The following shows the investment costs for this equipment.

Signalling equipment supply and installation	880	million Baht
Telecommunications supply and installation	180	"
Total	1,060	"

iv) Workshop Equipment

The investment costs for workshop equipment for heavy rail with capacity level-1 is preliminarily estimated at 42 million Baht.

c) Land Acquision Cost

Since the location of the extended Mass Transit System is basically planned so that the alignment runs along the highways planned for the year 2000 or on existing Khlongs, it is therefore assumed that the main right-of-way will be acquired in a separated budget and that only some small additional part of land used for Mass-Transit System development will be purchased as project investment. The unit price of land was checked with the land price list for the areas concerned.

d) Operating Costs

Operating costs are broadly classified into personnel, energy and material costs. The cost of each component item is given as follows:

i) Personnel Costs

- Personnel costs of system operation for capacity level-1 capacity were calculated assuming that the operating staff consist of drivers whose annual wage is 33,000 Baht, as well as station staff and operating and supervisory staff and is estimated to be 130.50 million Baht/year.

- Personnel Cost for the Workshops
  The annual personnel cost per man was analyzed and total personnel cost were estimated to be 39.76 million Baht/year.

- Personnel cost for power supply was calculated separately non-administrative and for administrative personnel. The total was found to be 17.43 million Baht/year.

- Personnel costs for the signalling and telecommunication system are calculated to be 14.86 million Baht/year.

- Personnel cost for track and structure maintenance. In estimating the cost required for personnel for this purpose, it was assumed that the staff will consist of 4-engineers, 16-technicians or foremen, 64-skilled workers, and 12-administratives personnel. The total staff of 96 will cost of 3.51 million Baht/year.

- Personnel cost for staff training
  This costs for staff training for the heavy rail system are estimated to be 3.20 million Baht/year.

ii) Energy and Material Costs

- This cost item covers the energy consumption and energy costs of stations, workshops and vehicles. A summary of total energy cost for heavy rail system is given as 294.40 million Baht/year.

- Maintenance costs for structures and permanent way.
  The annual maintenance costs for structures and permenent ways are estimated to be 26.1 million Baht and 13.9 million Baht respectively or 40.0 million Baht total per year.

- Materials and supplies for maintenance of signalling and telecommunication systems will cost 3.20 million Baht/year.

- Materials and supplies for power supply system were analyzed to cost 4.48 million Baht/year.

- Administration materials and supplies
  Total costs of this item are estimated to be 4.26 million Baht/year.

The summary of operating cost items mentioned above is as follows:

a.	Personnel Costs	209.26 million Baht
b.	Energy and Material Costs	346.34 "
	Total:	555.60 million Baht

Above mentioned cost estimates are broken-down in Table 6-15.

(2) Economic Cost

For each item of material used for investment and maintenance, tax and duty have been checked and deducted as shown in Table 6-11, 6-12. For main construction material items, these unit cost have been combined as unit costs for construction and maintenance items of the project.

Table 6-16 to 6-18 present the estimated economic costs for the project on the same items covered in the financial cost estimate.

Since the rolling stock was assumed to be imported, it was considered appropriate to calculate a cost reduction of 15 percent as custom duty from the cost of rolling stock for the purpose of economic analysis.

The estimated cost of acquisition of land was based on the actual value of similar land purchases made in the past. It was considered that these costs may be greater than the economic value of the land, since in many cases the knowledge that a highway or railway is to be built in the area tends to inflate land prices. Therefore, an attempt was made to determine a normal land value taking into account an estimation of the tax value for the land in the concerned area and the normal land sales in the area over the past years. As a result a reduction of 15 percent in the cost of acquiring of land was considered to be a conservative estimate for the purpose of the economic analysis.

Table 6-13 SUBURAN MASS TRANSIT SYSTEM
CIVIL ENGINEERING COST (FINANCIAL COST) (Unit: million Baht)

Alternative 1 (Elevated)

Route	Section	Open Line Section	Station No.	Station	Permanent Way	Diversion and Relocation of Public Utilities	Civil Engineering Work Shop	Engineering Supervision (8%)	Insurance Claim (1%)	Contingency (10%)	Total Amount
Northern Route	Section A_1 = 5.0km	258.5	1	13.9	35.38	5.0	-	24.92	3.12	31.15	371.97
	A_2 = 9.4	486.0	2	27.8	66.89	9.4	-	46.98	5.87	58.73	701.67
	B_1 = 17.8	920.3	3	41.7	126.65	17.8	-	88.18	11.02	110.22	1,315.87
	B_2 = 3.8	196.4	2	27.8	26.96	3.8	110.0	28.97	3.62	36.22	433.77
	36.0	1,861.2	8	111.2	255.88	36.0	110.0	189.05	23.63	236.32	2,823.28
Eastern Route	C_1 = 10.1km	522.2	2	27.8	71.53	10.1	-	50.32	6.29	62.89	751.13
	C_2 = 11.0	568.7	2	27.8	77.87	11.0	-	54.60	6.82	68.26	815.05
	**C_3 = 20.7	1,070.2	2	27.8	146.59	20.7	-	101.00	12.63	126.25	1,505.17
	41.8	2,161.1	6	83.4	295.99	41.8	-	205.92	25.74	257.40	3,071.35
Southern Route	D_1 = 7.3km	377.4	2	27.8	51.46	7.3	110.0	37.12	4.64	46.40	662.12
	D_2 = 15.0	775.5	2	27.8	105.70	15.0	-	73.92	9.24	92.40	1,099.56
	E_1 = 5.0	258.5	1	13.9	37.80	5.0	-	25.22	3.15	31.52	375.09
	E_2 = 10.1	* 627.2	1	13.9	70.87	10.1	-	49.36	6.17	61.70	839.30
	37.4	2,038.6	6	83.4	265.83	37.4	110.0	185.62	23.20	232.02	2,976.07
Western Route	F = 8.3km	429.1	1	13.9	57.70	8.3	-	40.72	5.09	50.90	605.71
Grand Total	L = 123.5km	6,490.0	21	291.9	875.40	123.5	220.0	621.31	77.66	776.64	9,476.41

Note: * Costs of open line section E_2 include the cost of a bridge across the River Chaop Phraya.

** *In the course of study, Route C_3 was taken into account, but after analysis it was ruled out of the system.*

Table 6-14 SUBURBAN MASS TRANSIT SYSTEM
CIVIL ENGINEERING COST (FINANCIAL COST) (Unit: million Baht)

Alternative 2 (At-Grade)

Route	Section	Open Line Section	Station No.	Station	Permanent Way	Diversion and Relocation of Public Utilities	Civil Engineering Work Shop	Engineering Supervision (8%)	Insurance Claim (1%)	Contingency (10%)	Total Amount
Northern Route	Section A_1 = 5.0km	135.2	1	8.60	35.38	5.0	-	14.73	1.84	18.42	219.17
	A_2 = 9.4	254.3	2	17.20	66.89	9.4	-	27.83	3.48	34.78	413.88
	B_1 = 17.8	481.5	3	25.80	126.65	17.8	-	52.14	6.51	65.18	775.58
	B_2 = 3.8	102.8	2	17.20	26.96	3.8	110.0	20.86	2.61	26.08	310.31
	36.0	973.8	8	68.80	255.88	36.0	110.0	115.56	14.44	144.46	1,718.94
Eastern Route	C_1 = 10.1	273.2	2	17.20	71.53	10.1	-	29.76	3.72	37.20	442.71
	** C_2 = 11.0	297.5	2	17.20	77.87	11.0	-	32.29	4.04	40.35	480.25
	C_3 = 20.7	560.0	2	17.20	146.59	20.7	-	59.56	7.44	74.45	885.94
	41.8	1,130.7	6	51.6	295.99	41.8	-	121.61	15.20	152.00	1,808.90
Southern Route	D_1 = 7.3	197.5	2	19.0	51.46	7.3	110.0	22.02	2.75	27.52	437.55
	D_2 = 15.0	405.8	2	19.0	105.70	15.0	-	43.64	5.45	54.55	649.14
	E_1 = 5.0	135.2	1	9.5	37.80	5.0	-	15.00	1.88	18.76	223.14
	E_2 = 10.1	* 378.2	1	9.5	70.87	10.1	-	29.09	3.64	36.37	537.77
	37.4	1,116.7	6	57.0	265.83	37.4	110.0	109.75	13.72	137.20	1,847.60
Western Route	F = 8.3	224.5	1	9.5	57.70	8.3	-	24.00	3.00	30.00	357.00
Grand Total	L = 123.5km	3,445.7	21	186.9	875.40	123.5	220.0	370.92	46.36	463.66	5,732.44

Note * Costs of open line section F_2 include the cost of a bridge across the River Chaop Phraya

** Refer to Table 6-13

Table 6-15 SUBURBAN MASS TRANSIT SYSTEM
ELECTRICAL/MECHANICAL ENGINEERING COST (FINANCIAL COST) (Unit: million Baht)

Either Alternative 1 or 2 (Elevated or At-Grade)

Route	and Section	Rolling Stock Veh.No.	Rolling Stock	Power Supply	Signalling and Telecommunication	Workshop Equipment	Land Cost Area m^2	Land Cost Cost	Operating Cost
Northern Route	A_1 = 5.0km		466.8	61.6	42.9	1.7	30,000	21.0	22.50
	A_2 = 9.4		876.5	115.8	80.6	3.2	56,400	28.2	42.28
	B_1 = 17.8		660.5	219.3	152.7	6.1	106,800	63.6	80.08
	B_2 = 3.8		136.6	46.8	32.6	1.3	22,800	2.3	17.09
	36.0	188	2,140.4	443.5	308.8	12.3	216,000	115.1	161.95
Eastern Route	C_1 = 10.1		865.3	124.4	86.6	3.4	60,600	42.4	45.44
	C_2 = 11.0		956.5	136.8	95.2	3.7	66,000	26.4	49.48
	** C_3 = 20.7		-	255.0	177.6	7.0	124,200	49.7	93.13
	41.8	160	1,821.6	516.2	359.4	14.1	250,800	118.5	188.05
Southern Route	D_1 = 7.3		774.2	89.9	62.6	2.5	43,800	30.7	32.84
	D_2 = 15.0		1,593.9	184.8	128.7	5.1	90,000	9.0	67.48
	E_1 = 5.0		466.8	61.6	42.9	1.7	30,000	27.0	22.50
	E_2 = 10.1		945.0	124.4	86.7	3.4	60,600	53.2	45.44
	37.4	332	3,779.9	460.7	320.9	12.7	224,400	119.9	168.26
Western Route	F = 8.3	76	865.3	102.2	71.2	2.8	49,800	44.8	37.34
Grand Total	L = 123.5km	756	8,607.0	1,522.6	1,060.3	41.9	741,000	398.3	550.60

Note: * The cost of rolling stock was calculated by the traffic volume in the year 2000.

** Refer to Table 6-13.

Table 6-16 SUBURBAN MASS TRANSIT SYSTEM
CIVIL ENGINEERING COST (ECONOMIC COST) (Unit: million Baht)
Alternative 1 (Elevated)

Route	Section	Open Line Section	Station No.	Station	Permanent Way	Diversion and Relocation of Public Utilities	Civil Engineering Work Shop	Engineering Supervision (8%)	Insurance Claim (1%)	Contingency (10%)	Total Amount
Northern Route	A_1 = 5.0km	232.7	1	12.51	31.85	4.50	-	22.52	2.82	28.15	335.05
	A_2 = 9.4	437.4	2	25.02	60.22	8.46	-	42.49	5.32	53.11	632.02
	B_1 = 17.8	828.2	3	37.53	114.02	16.02	-	79.66	9.96	99.58	1,184.97
	B_2 = 3.8	176.8	2	25.02	24.27	3.42	99.0	26.28	3.29	32.85	390.93
	36.0	1,675.1	8	100.08	230.36	32.40	99.0	170.95	21.39	213.69	2,542.97
Eastern Route	C_1 = 10.1	470.0	2	25.02	64.39	9.09	-	45.48	5.68	56.84	676.50
	C_2 = 11.0	511.8	2	25.02	70.11	9.90	-	49.35	6.17	61.69	734.04
	** C_3 = 20.7	963.2	2	25.02	131.98	18.63	-	91.10	11.39	113.88	1,355.2
	41.8	1,945.0	6	75.06	266.48	37.62	-	185.93	23.24	232.41	2,765.74
Southern Route	D_1 = 7.3	339.7	2	25.02	46.33	6.57	99.0	41.32	5.17	51.66	614.77
	D_2 = 15.0	698.0	2	25.02	94.96	13.50	-	66.51	8.31	83.14	989.44
	E_1 = 5.0	232.7	1	12.51	31.85	4.50	-	22.52	2.82	28.15	335.05
	E_2 = 10.1	* 573.5	1	12.51	63.99	9.09	-	44.44	5.55	55.55	764.63
	37.4	1 843.9	6	75.06	237.13	33.66	99.0	174.79	21.85	218.50	2,703.89
Western Route	F = 8.3	386.2	1	12.51	51.9	7.50	-	36.65	4.58	45.81	545.15
Grand Total	L = 123.5km	5,850.2	21	262.71	785.87	111.18	198.0	568.32	71.06	710.41	8,557.75

Note: * Costs of open line section E_2 include the cost of a bridge across the River Chao Phraya.
** Refer to Table 6-13

Table 6-17 SUBURBAN MASS TRANSIT SYSTEM
CIVIL ENGINEERING COST (ECONOMIC COST) (Unit: million Baht)

Alternative 2 (At Grade)

Route and Section		Open Line Section	Station No.	Station	Permanent Way	Diversion and Relocation of Public Utilities	Civil Engineering Work Shop	Engineering Supervision (8%)	Insurance Claim (1%)	Contingency (10%)	Total Amount
Northern Route	A_1 = 5.0km	121.5	1	8.6	31.85	4.50	-	13.32	1.66	16.64	198.07
	A_2 = 9.4	228.4	2	17.2	60.22	8.46	-	25.14	3.14	31.43	373.99
	B_1 = 17.8	432.5	3	25.8	114.02	16.02	-	47.07	5.89	58.83	700.13
	B_2 = 3.8	92.3	2	17.2	24.27	3.42	99.0	18.89	2.36	23.62	281.06
	36.0	874.7	8	68.8	230.36	32.40	99.0	104.42	13.05	130.52	1,553.25
Eastern Route	C_1 = 10.1	245.43	2	17.2	64.39	9.09	-	26.89	3.36	33.61	399.97
	C_2 = 11.0	267.30	2	17.2	70.11	9.90	-	29.16	3.64	36.45	433.76
	** C_3 = 20.7	503.01	2	17.2	131.98	18.63	-	53.67	6.71	67.08	798.28
	41.8	1,015.74	6	51.6	266.48	37.62	-	109.72	13.71	137.14	1,632.01
Southern Route	D_1 = 7.3	177.39	2	17.2	46.33	6.57	99.0	27.72	3.46	34.65	412.32
	D_2 = 15.0	364.50	2	17.2	94.96	13.50	-	39.21	4.90	49.02	583.29
	E_1 = 5.0	121.50	1	8.6	31.85	4.50	-	13.32	1.66	16.64	198.07
	E_2 = 10.1	* 348.93	1	8.6	63.99	9.09	-	26.17	3.27	32.71	492.87
	37.4	1,012.32	6	51.6	237.13	33.66	99.0	106.42	13.29	133.02	1,686.44
Western Route	F = 8.3	201.69	1	8.6	51.9	7.50	-	21.58	2.70	26.97	320.94
Grand Total	L = 123.5km	3,104.45	21	180.60	785.87	111.18	198.0	342.14	42.75	427.65	5,192.64

Note: * Costs of open line section E_2 include the cost of a bridge across the River Chao Phraya.

** Refer to Table 6-13.

Table 6-18 SUBURBAN MASS TRANSIT SYSTEM
ELECTRICAL/MECHANICAL ENGINEERING COST (<u>ECONOMIC COST</u>) (Unit: million Baht)
Either Alternative 1 or 2 (Elevated or At-Grade)

Route	Section	Rolling Stock Veh.No.	Rolling Stock	Power Supply	Signalling and Telecommunication	Workshop Equipment	Land Cost Area m^2	Land Cost Cost	Operating Cost
Northern Route	A_1 = 5.0km		396.8	55.4	38.6	1.5	30,000	17.9	20.22
	A_2 = 9.4		745.2	104.2	72.5	2.9	56,400	24.0	38.02
	B_1 = 17.8		561.4	197.4	137.4	5.5	106,800	54.1	71.98
	B_2 = 3.8		116.1	42.1	29.3	1.2	22,800	1.9	15.37
	36.0	188	1,819.5	399.1	277.8	11.1	216,000	97.9	145.59
Eastern Route	C_1 = 10.1		735.5	112.0	77.9	3.1	60,600	36.0	40.85
	C_2 = 11.0		812.9	123.1	85.7	3.3	66,000	22.4	44.48
	** C_3 = 20.7		-	229.5	159.8	6.3	124,200	42.2	83.72
	41.8	160	1,548.4	464.6	323.4	12.7	250,800	100.6	169.05
Southern Route	D_1 = 7.3		658.1	80.9	56.3	2.3	43,800	30.7	29.53
	D_2 = 15.0		1,354.8	166.3	115.8	4.6	90,000	9.0	60.66
	E_1 = 5.0		1,396.8	55.4	38.6	1.5	30,000	27.0	20.22
	E_2 = 10.1		803.3	112.0	78.0	3.1	60,600	45.2	40.86
	37.4	332	3,213.0	414.6	288.7	11.5	224,400	111.9	151.27
Western Route	F = 8.3	76	735.5	92.0	64.1	2.5	49,800	38.1	33.57
Grand Total	L = 123.5km	756	7,316.4	1,370.3	954.0	37.8	741,000	248.5	499.48

Note: * The cost of rolling stock was calculated by the traffic volume in the year 2000
** Refer to Table 6-13