3.2.3 Future Scheme for Urban Transport

The investment plan for infrastructure in Bangkok Metropolitan Area is presented in Fig. 3.2.8.

The road development is planned by BMA, DOH and DPW, most of which will be completed by 1986, the final year of the Fifth Plan.

The expressway and railway transit systems are planned and constructed by ETA.

A part of the expressway system (27 km in total length) has been opened to traffic, and a feasibility study for the second-phase plan was completed in 1983. In the meanwhile, a construction plan for the railway network (59 km in total length) aiming at easing urban transport congestion, has not entered the actual implementation stage due to the vast amount of initial investment required.

3.2.4 Establishment of Commuter Area

(1) Housing development in Bangkok Metropolitan Area

Bangkok, with a rapid increase of population, experiences a serious housing shortage; 300 slum areas with 400,000 population have been reported.

To cope with this situation, the Thai Government established the NHA in 1973, to facilitate housing construction for low/medium income classes. By 1980, NHA had constructed 43,000 housing units, mainly in Bangkok, and improved 4,700 slum units. Fig. 3.2.9 shows housing development projects completed by NHA to date and new construction projects up to 1988.

Based on these projects, the zone 20 to 30 km from the city center is expected to develop as suburban built-up areas.

(2) Regional development program

The Greater Bangkok Area had a resident population of 6 million in 1980, which is projected to increase to 8.7 million in the year of 2,000 under the plan by DTCP.

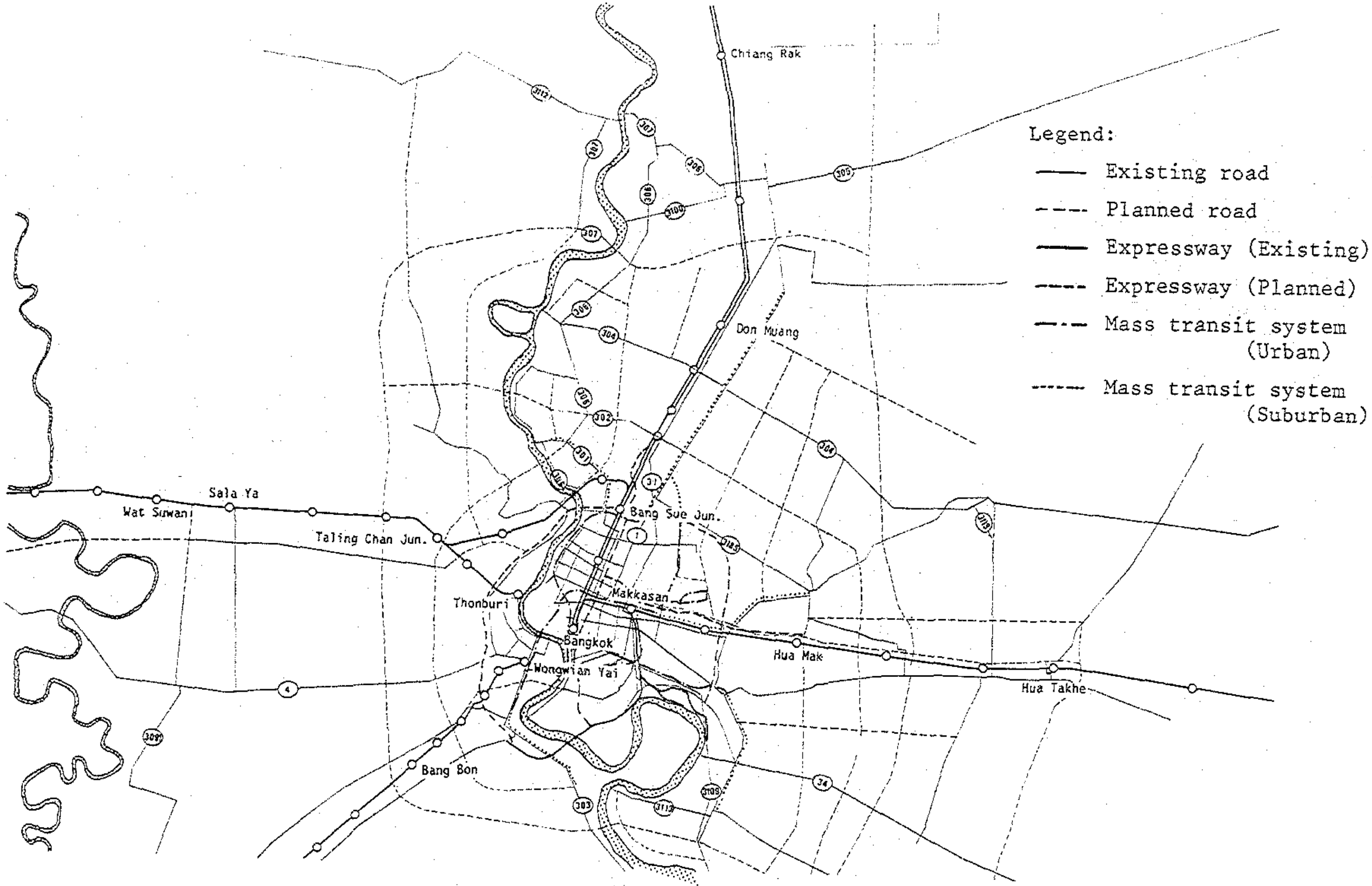
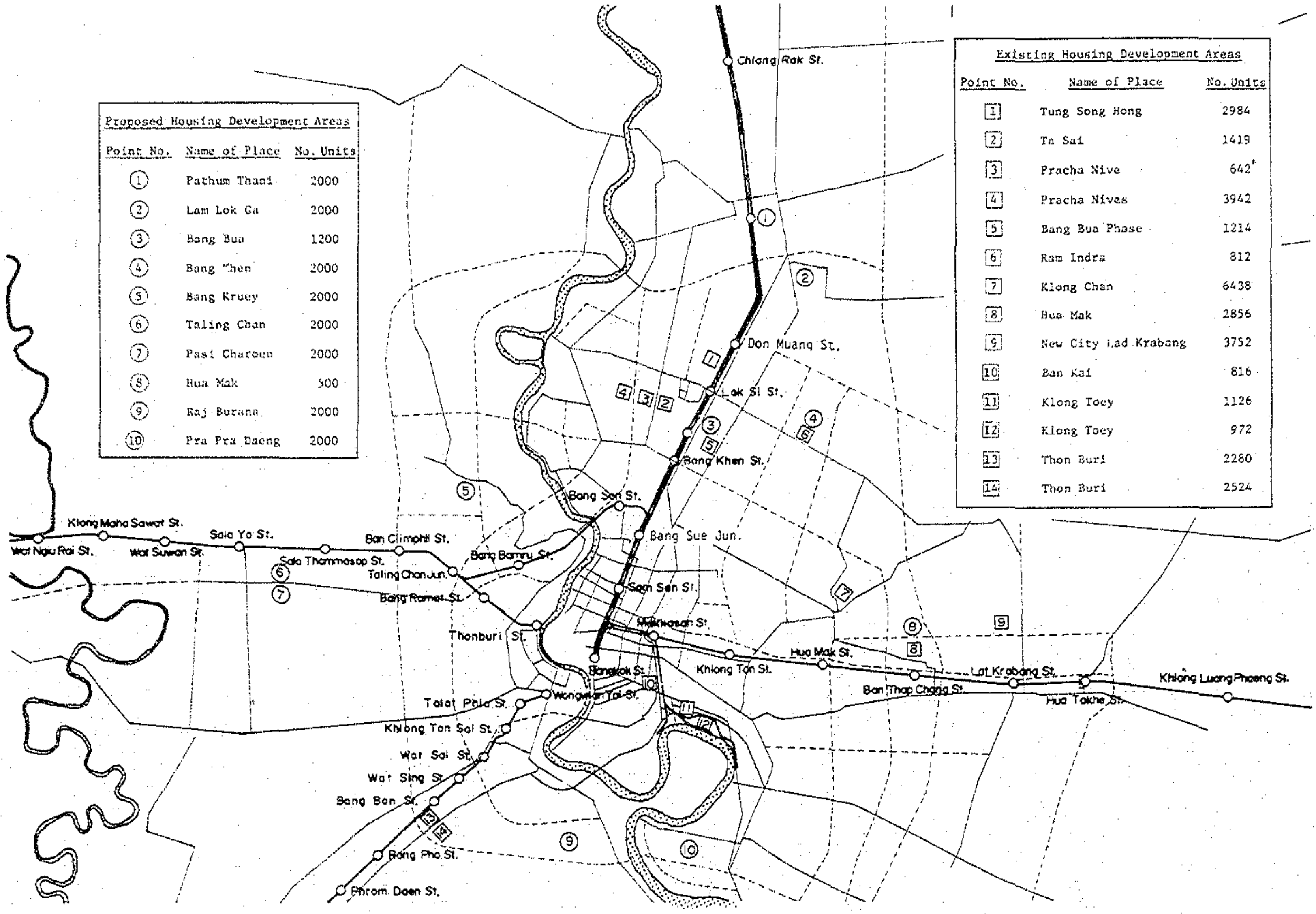


Fig. 3.2.8 Planning of Urban Transport System



Proposed Housing Development Areas

Point No.	Name of Place	No. Units
1	Pathum Thani	2000
2	Lam Lok Ga	2000
3	Bang Bua	1200
4	Bang "hen	2000
5	Bang Kruey	2000
6	Taling Chan	2000
7	Pasi Charoen	2000
8	Hua Mak	500
9	Raj Burana	2000
10	Pra Pra Daeng	2000

Existing Housing Development Areas

Point No.	Name of Place	No. Units
1	Tung Song Hong	2984
2	Ta Sai	1419
3	Pracha Nive	642
4	Pracha Nives	3942
5	Bang Bua Phase	1214
6	Ram Indra	812
7	Klong Chan	6438
8	Hua Mak	2856
9	New City Lad Krabang	3752
10	Ban Kai	816
11	Klong Toey	1126
12	Klong Toey	972
13	Thon Buri	2280
14	Thon Buri	2524

Fig. 3.2.9 Location of Housing Projects

DTCP has decided a direction of the regional development which forms the basis of land use planning. The planning area contains six provinces including the Greater Bangkok Area and its surrounding districts, with three types of land use classification as shown in Fig. 3.2.10.

(i) Inner area

This is a built-up area containing the Study Area and its vicinity, extending 20 to 25 km from the city center.

(ii) Green area

This is located in between the inner and outer area to protect the outer area from urban sprawl. Agricultural activity, recreational facilities, scenic zones, housing and canals are planned in this area. This area is located 25 to 30 km from the city center.

(iii) Outer area

This is located outside the green area, and it is intended to induce agricultural activity and industrial lot development.

DTCP is preparing a land use plan for the year 2,000 as shown in Fig. 3.2.11.

(3) Commuter area

Judging from the various plans, the current commuter area is within a 30 km zone which is expected to become built-up areas. In terms of the existing railway, this commuter area includes Sala Ya of the Southern Line, Chiang Rak of the Northern Line, and Hua Takhe of the Eastern Line.

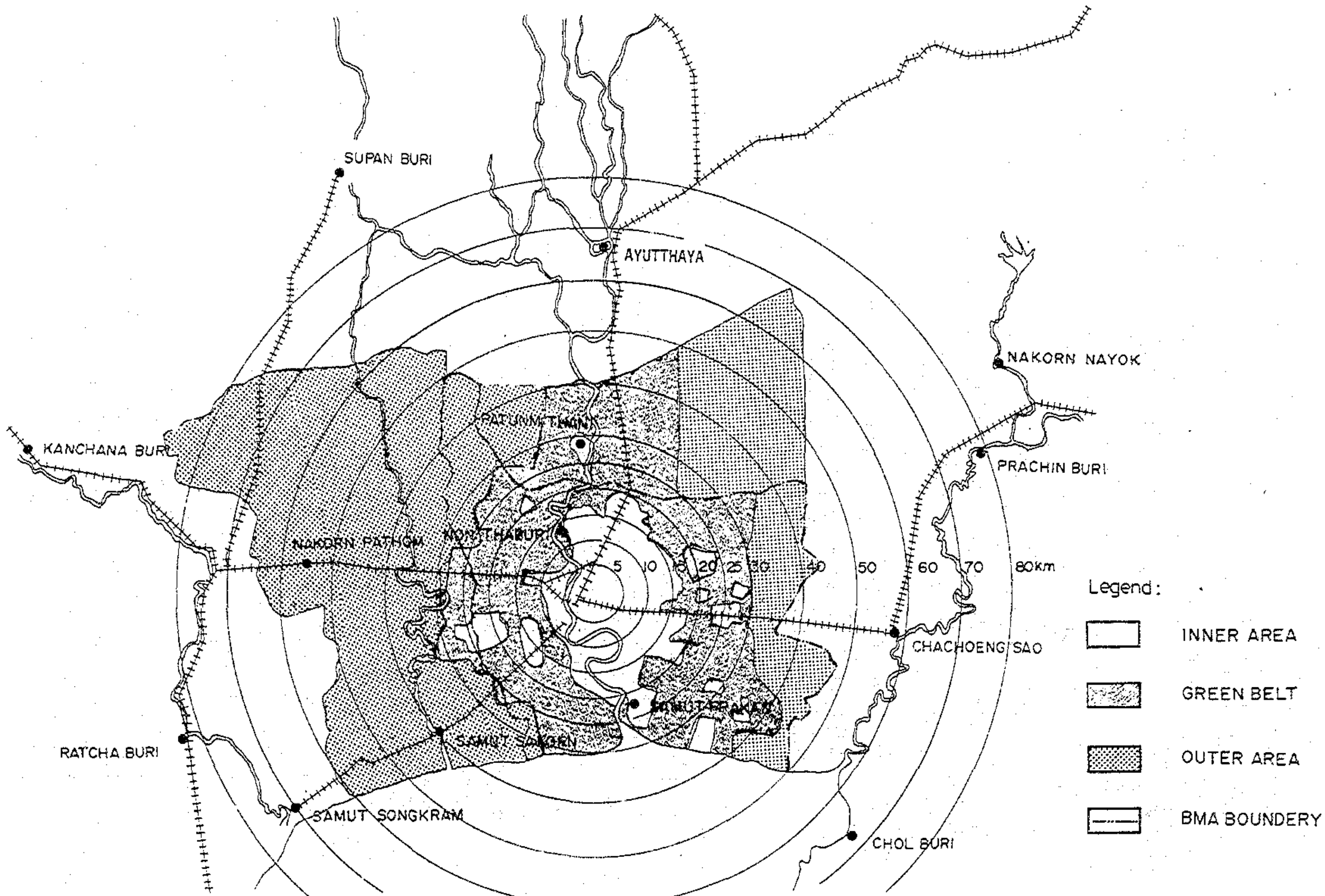


Fig. 3.2.10 *Structural Plan of Bangkok Metropolis*

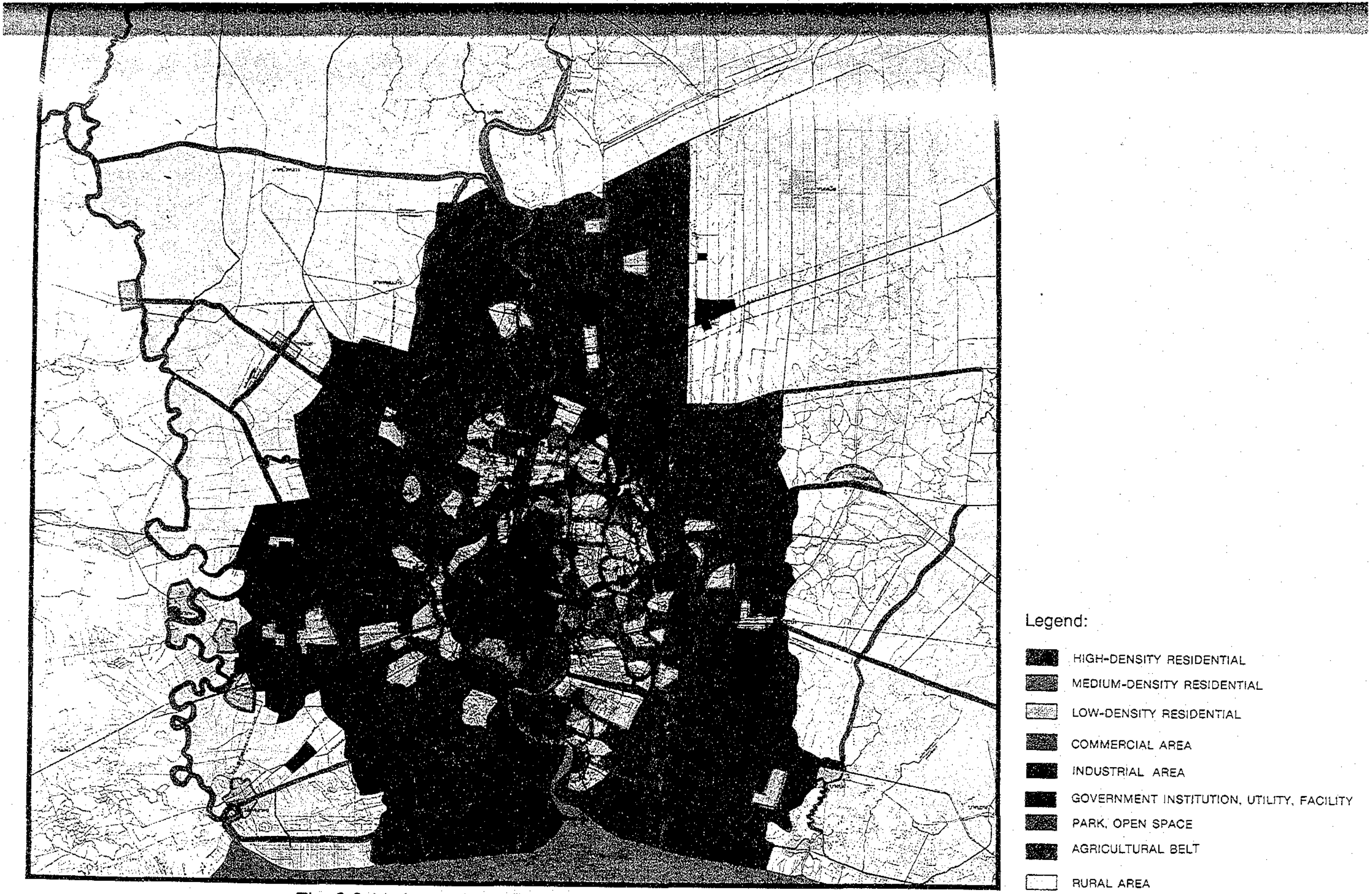


Fig. 3.2.11 Land Use Planning in the Year 2000 (Draft 1982)

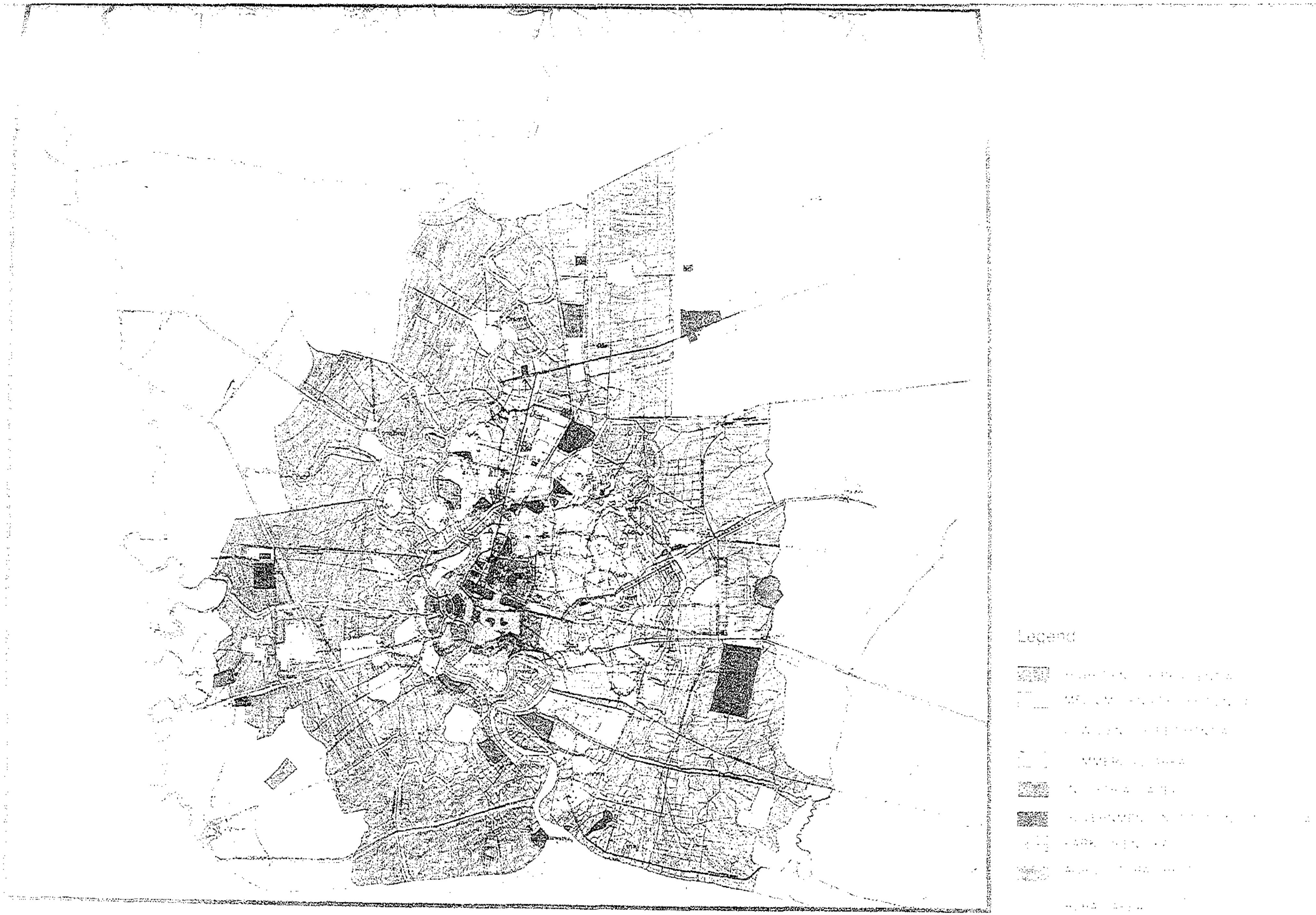


Fig. 3.2.11 Land Use Planning in the Year 2000 (Draft 1982)

3.3 Present Condition of Railway Transportation

3.3.1 General Status of Train Operation

(1) General status

Table 3.3.1 shows the general status of SRT railway transportation, both passenger and freight, during the past 10 years. The following points are noteworthy in this table.

(i) Passenger transportation

Transport capacity has increased by 1.44 times in terms of passenger train-km, and by 1.6 in terms of passenger car-km.

Accordingly, the average number of cars per train consist has increased from 9.9 cars to 10.9 cars.

On the other hand, the number of passenger cars has increased only by 1.18 times. This indicates that SRT has dealt with increase in traffic demand by improving transport efficiency in such ways that car-km per car in service per day was increased by 1.45 times and the number of passengers per car by 1.38 times, or from 32 passengers to 44 passengers.

Under such circumstances, it is reasonable not to expect much in further increasing car-km per car in service per day nor improving loading factor.

(ii) Freight transportation

Tonnagè carried by one train has increased by approximately 1.32 times or from 265 tons to 350 tons, by modernization of motive power tractive system and enlargement in size of freight cars to improve transport efficiency. With traffic volume remaining constant, freight train-km, freight car-km and the number of freight cars are gradually declining.

Table 3.3.1 General Status of Railway Transportation

		1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	Remarks
Passenger Train	A. Passenger-kms (million passenger-km per year)	(100) 4,412	(106) 4,694	(122) 5,376	(128) 5,640	(128) 5,628	(128) 5,649	(137) 6,039	(159) 7,029	(201) 8,861	(215) 9,483	
	B. Passenger train-kms (thousand-km per year)	(100) 13,637	(104) 14,245	(106) 14,449	(111) 15,198	(117) 15,990	(118) 16,150	(124) 16,952	(130) 17,734	(137) 18,740	(144) 19,615	
	C. Passenger car-kms (thousand-km per year)	(100) 136,291	(101) 138,286	(104) 142,118	(111) 150,759	(117) 159,237	(121) 164,675	(130) 177,483	(139) 189,215	(150) 204,762	(157) 213,873	Including Bogie van-car, Bogie postal-car, Bogie restaurant-car
	D. No. of passenger cars (in service)	(100) 830	(96) 795	(98) 819	(97) 810	(103) 857	(110) 917	(110) 912	(111) 924	(114) 947	(118) 980	
	E. Car-kms per day (km per day)	(100) 457	(101) 463	(105) 478	(116) 530	(127) 588	(131) 598	(137) 626	(138) 634	(146) 667	(145) 662	
	F. No. of cars per train consist	9.9	9.7	9.8	9.7	10.0	10.2	10.5	10.7	10.9	10.9	$F = \frac{C}{B}$
	G. No. of passenger per car (persons)	(100) 32	(106) 34	(119) 38	(116) 37	(109) 35	(106) 34	(106) 34	(116) 37	(134) 43	(138) 44	$G = \frac{A}{C}$
Freight Train	A. Ton-kms (million ton-km per year)	(100) 2,242	(92) 2,070	(102) 2,296	(105) 2,353	(112) 2,505	(130) 2,912	(118) 2,651	(122) 2,747	(125) 2,805	(116) 2,601	
	B. Freight train-kms (thousand km per year)	(100) 9,081	(93) 8,422	(91) 8,250	(88) 7,970	(91) 8,274	(98) 8,894	(93) 8,446	(86) 7,843	(87) 7,933	(84) 7,612	
	C. Freight car-kms (thousand km per year)	(100) 374,495	(91) 339,114	(86) 322,650	(90) 338,638	(86) 321,006	(83) 312,465	(91) 342,292	(94) 352,940	(95) 357,269	(94) 355,045	
	D. No. of freight cars (in service)	(100) 8,546	(102) 8,732	(102) 8,746	(101) 8,599	(92) 7,886	(95) 8,148	(91) 7,781	(88) 7,506	(91) 7,802	(94) 8,064	
	E. Car-kms per day (km per day)	(100) 106	(88) 93	(80) 85	(84) 89	(81) 86	(80) 85	(86) 91	(93) 99	(97) 103	(90) 96	
	F. Net ton-kms per train-km (ton)	(100) 265.9	(99) 264.9	(107) 282.8	(111) 295.7	(114) 302.9	(124) 329.4	(118) 313.9	(135) 357.3	(133) 352.9	(129) 341.6	$F = \frac{A}{B}$
	G. Net ton-kms per car-km (ton)	(100) 6.0	(102) 6.1	(118) 7.1	(117) 7.0	(130) 7.8	(155) 9.3	(130) 7.8	(130) 7.8	(132) 7.9	(122) 7.3	$G = \frac{A}{C}$

(2) Number of trains operated

SRT transportation is characterized by a large number of long-distance trains with long train consist to carry out efficient transportation.

Table 3.3.2 shows the average number of cars per passenger train from Bangkok Station.

Table 3.3.2 Number of Trains and Average Number of Cars per Train Consist from Bangkok Station

(Each direction per day)

		No. of trains	Average number of cars per train
Express	PC	5	15.2
Rapid	PC	10	14.2
Ordinary	PC	10	11.2
	DRC	8	4.1
Commuter	DRC	18	4.7
Mixed	PC	1	5.0
Total		52	8.7

Note: PC is passenger car
DRC is diesel railcar

The number of passenger and freight trains operated in each section is shown in Fig. 3.3.1 and Fig. 3.3.2, respectively.

Various information relevant to train operation is presented in the following appendices for reference to train planning.

Appendix 3.3.1 General Status of Train Operation
3.3.2 Train Operation Chart by Line
3.3.3 Train-km per Day by Line
3.3.4 Monthly Number of Passengers by Each Line (Seasonal Fluctuation in Traffic Volume)
3.3.5 Train Running Speed by Kind of Train and by Line (scheduled Speed)
3.3.6 Train Diagram in the Proposed Elevated Section

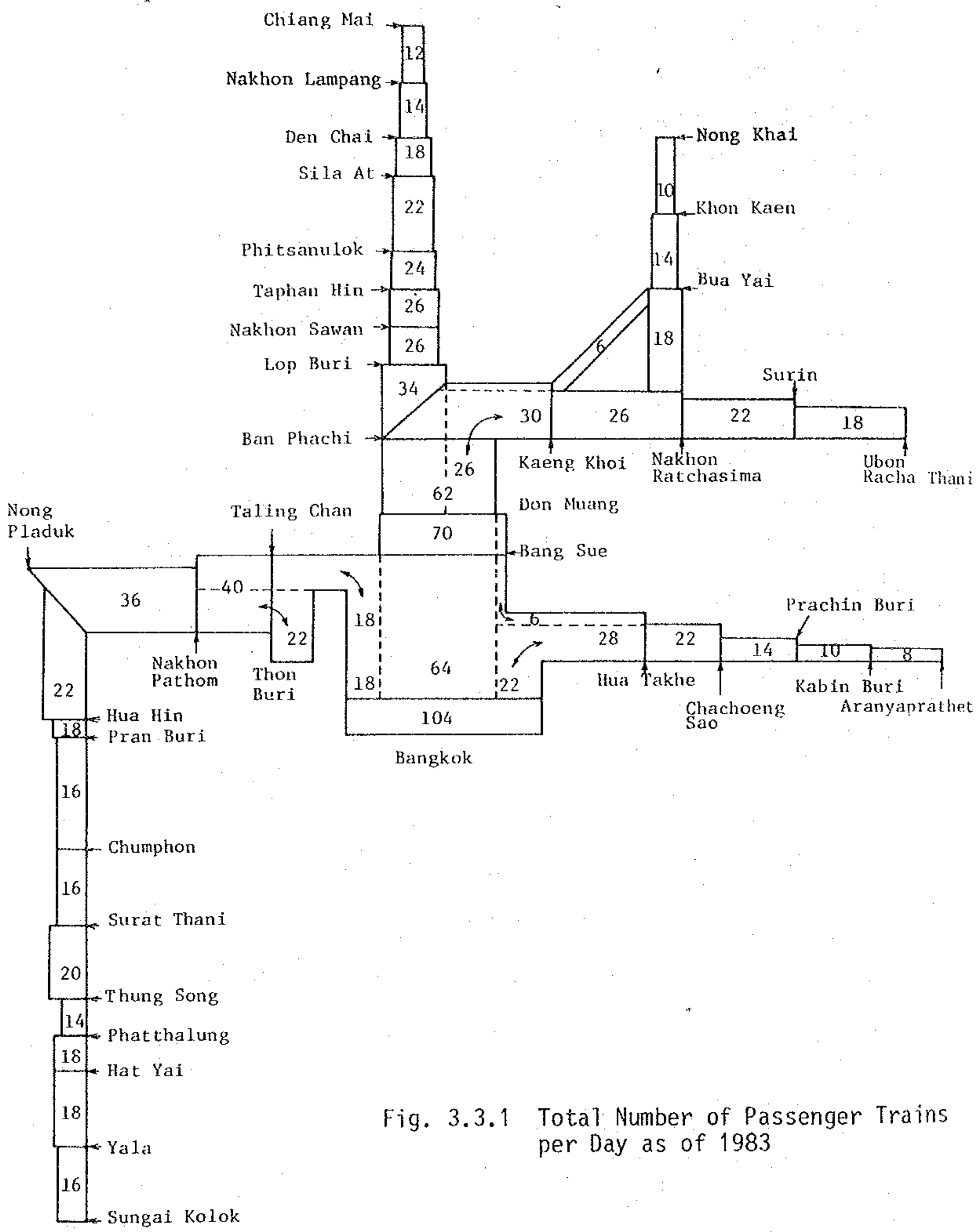


Fig. 3.3.1 Total Number of Passenger Trains per Day as of 1983

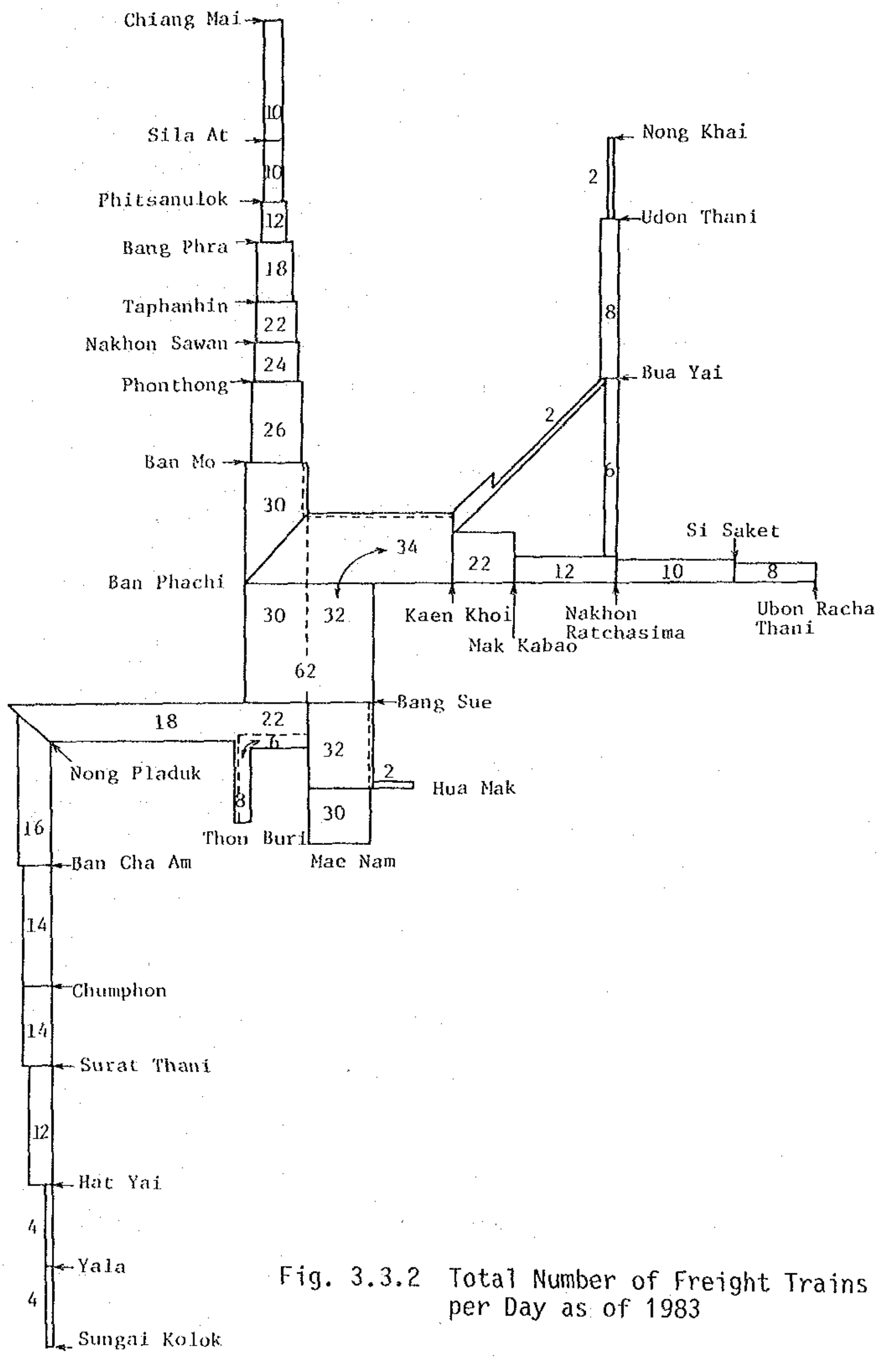


Fig. 3.3.2 Total Number of Freight Trains per Day as of 1983

3.3.2 Present Condition of Rolling Stock

Present condition of rolling stock usage and maintenance is described below.

(1) Condition of rolling stock usage

The number of rolling stocks and car-km in service per day for each type of car are shown in Table 3.3.3.

All types of cars have been improved in efficiency of usage, but improvement of maintenance and utilization reliability will be needed.

Table 3.3.3 Record of Rolling Stock Usage

(as of 1981)

	Diesel locomotive (DL)	Diesel railcar (DRC)	Passenger car (PC)	Freight car (FC)
Number of cars (in service)	212	44 set	980	8,064
Car-km per car in service per day	380	477	662	96
Car-km per car in service per day in JNR (reference)	159	371	406	80

(2) Present condition or rolling stock maintenance

(i) Distribution of rolling stock depot

Nationwide distribution of rolling stock depots and points related to train operation are presented in Fig. 3.3.3.

The scale of each rolling stock depot is shown in Table 3.3.4, which indicates that a majority of rolling stocks are distributed in depots around Bangkok.

(ii) Makkasan Workshop

This workshop is responsible for inspection/repair of all types or rolling stock owned by SRT and has around 3,000 employees. Daily average number of rolling stocks in the workshop for inspection/repair is 210 as shown in Table 3.3.5.

Daily number of rolling stocks in-shop and out-shop is about 12 on the average, as shown in Table 3.3.6.

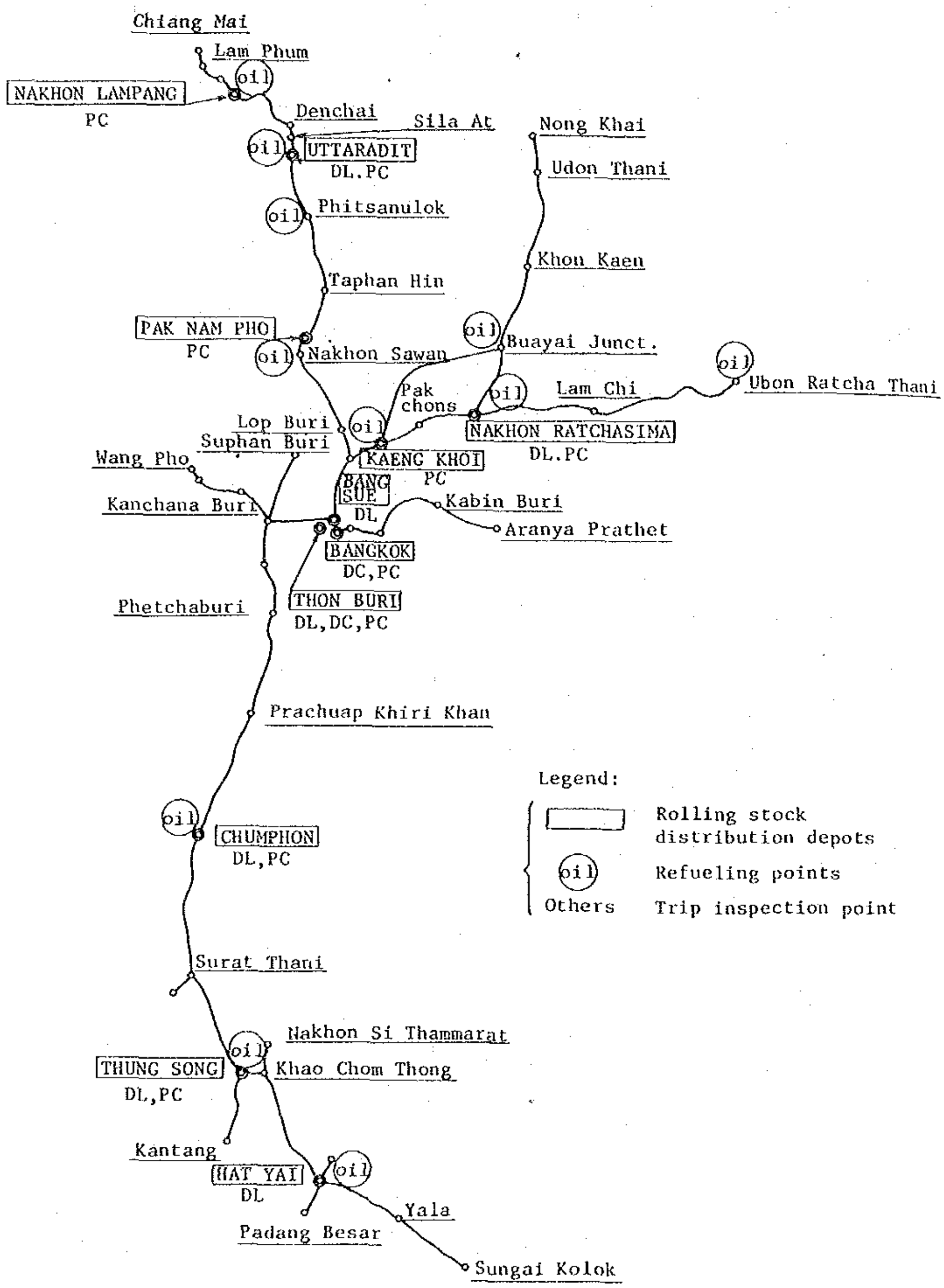


Fig. 3.3.3 Locations of Rolling Stock Depots and Points Related to Train Operation

Table 3.3.4 Present Condition of Rolling Stock Depots

	Name of depot	Number of rolling stocks assigned			Kind of inspection carrried out									
					1 mth.	3 mth.	4 mth.	6 mth.	8 mth.	1 year	20 mth.	2 year	3 year	4 year
		DL	DRC (set)	PC	DL DRC	DL DRC	PC	DL DRC	FC	DL DRC	PC	DL DRC FC	PC	FC
Locomotive depot	Bang Sue	162			○	○		○		○		○		
	Thon Buri	24	4		○	○		○		○		○		
	Nakhon Ratchasima	21			○	○		○		○				
	Uttaradit	20			○	○		○		○				
	Thung Song	13			○	○		○						
	Hat Yai	26		47	○	○	○	○	○					
	Chumphon	2		20	○		○		○					
Car operation and repair depot	Kaeng Khoi			9			○		○			FC ○		
	Pak Nam Pho			27			○		○			FC ○		
	Nakhon Lampang			19			○		○			FC ○		
	Bangkok		58	750	○	○	○	○			○			
	(Mae Klong)		7	6	○	○	○	○	○					
Passenger car and freight car depot	Bang Sue								○			FC ○		
	Thon Buri			93			○		○		○	FC ○		
	Nakhon Ratchasima			50			○		○		○	FC ○		○
	Uttaradit			35			○		○		○	FC ○	○	○
	Thung Song			50			○		○		○	FC ○	○	○
Total		268	69	1,106										

Table 3.3.5 Number of Rolling Stocks Inspected/Repaired per Day at Makkasan Workshop

(Data as August 1, 1983)

		Number of rolling stocks inspected/repaired	Remarks
DL		22	Total 210
DRC		4 power	
PC		77	
FC	Bogie wagon	27	
	4-wheeled wagon	80	

Table 3.3.6 Average Number of Rolling Stocks In-shop and Out-shop per Day (1983)

	DL	DRC	PC	FC	Total
In-shop	0.98	0.05	1.26	4.11	6.40
Out-shop	1.00	0.06	1.25	3.78	6.09

(3) Main features of rolling stock by type

(i) Operating performance of rolling stock

Operating performance of major types of locomotives used by SRT is shown in Table 3.3.7.

Table 3.3.7 Operating Performance of Major Types of Locomotives

		ALSTHOM	GE	KRUPP
Service weight (tons)		82.5	75.0	55.0
Passenger train	Hauling capacity (ton) (on upward gradient of 10‰)	720	600	600
	Balancing speed (km/h) (on upward gradient of 10‰)	45	33	36
Freight train	Hauling capacity (ton) (on upward gradient of 10‰)	1,280	1,200	1,200
	Balancing speed (km/h) (on upward gradient of 10‰)	25	15	15

Note: See Appendix 3.3.7 for load curves of each type of diesel locomotive.

(ii) Maximum speed of rolling stock

At present, maximum speed is 80 km/h for passenger trains and 50 km/h for freight trains.

The maximum allowable speed of rolling stock is classified variously as shown in Table 3.3.8, limiting its usage.

Table 3.3.8 Maximum Allowable Speed by Type of Rolling Stocks

	Maximum allowable speed (km/h)	100	90	80	70	60	50
DL	No. of cars	80	126	30	30	7	10
	Composition	28%	45%	11%	11%	2%	3%
DRC	No. of cars	-	28 set	17 set	4 set	-	-
	Composition	-	57%	35%	8%		
PC	No. of cars	-	844	-	269	-	-
	Composition		76%		24%		
FC (Bogie wagon)	No. of cars	-	-	-	2,445	127	510
	Composition				79%	4%	17%
FC(4-wheeled wagon)	No. of cars	-	-	-	2,110	59	3,900
	Composition				35%	1%	64%

Note: Most rolling stocks with low speed in Table 3.3.8 are old aged. For reference, average age of each type of rolling stock is shown in Table 3.3.9.

Table 3.3.9 Average Age of Each Type of Rolling Stock

	DL	DRC	PC	FC	Remarks
Average age (years)	15.03	11.82	15.64	24.38	
Ratio of rolling stocks over 21 years (%)	19.8	*63.3	38.6	53.1	* over 11 years

3.3.3 Current Condition of Railway Facilities

The present status of railway facilities for the proposed elevated section is summarized as follows.

(1) Horizontal and profile alignment

The proposed elevated section looks nearly straight except for the curved sections of R = 400 m at the junction of the Eastern Line and of R = 600 m on the Mae Nam Line.

In terms of the profile, the track is nearly level along the whole line with the exception of 5 ‰ gradient in three bridge sections on the Northern Line, 1.5 ‰ at the junction of the Eastern Line, and 5 ‰ in two bridge sections and in the Rama IV Bridge section on the Mae Nam Line.

The alignment and profile of the existing track are illustrated in Figs. 3.3.4 and 7.1.9 respectively.

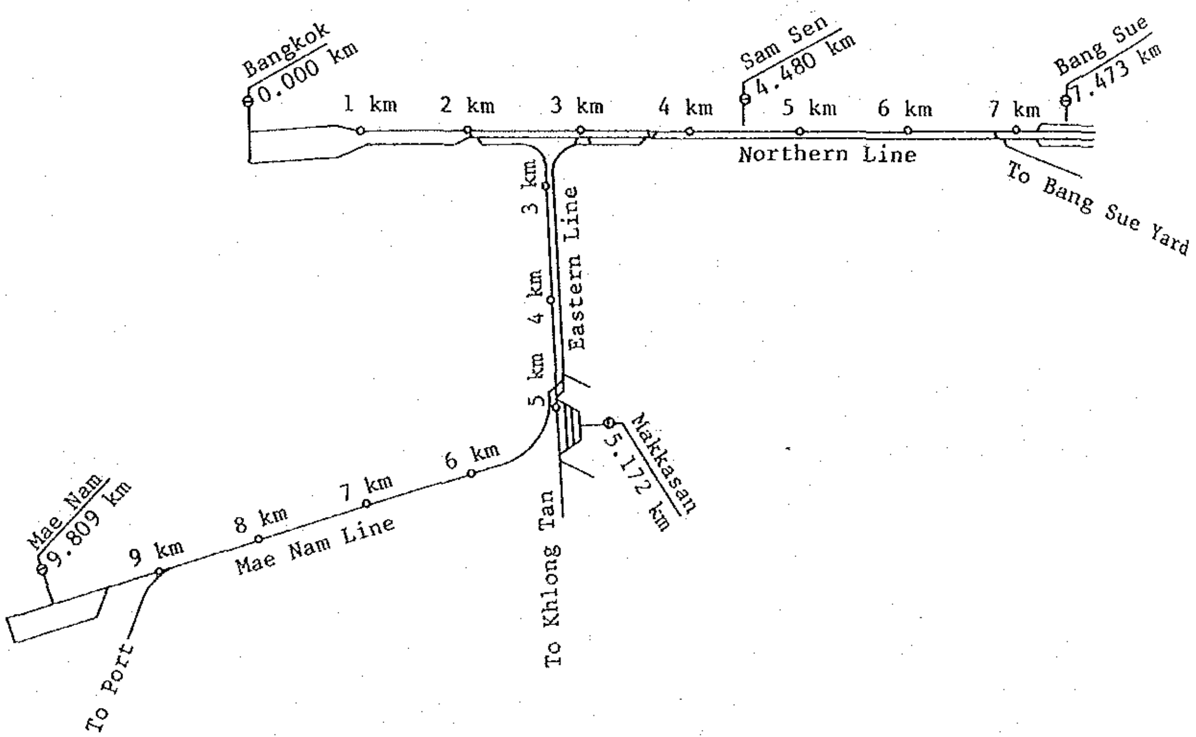


Fig. 3.3.4 Existing Alignment

(2) Track

The track is generally well maintained on all lines because of the use of 70 lb rail/m and timber sleepers. However, in various intersections, the ballast is sinking due to the heavy traffic and many large vehicles. Because of this, the rails are loosening from the ballast surface.

(3) Bridges

Bridges are listed in Table 3.3.10. Two of them are superannuated and, therefore, will require either reinforcement or replacement of the entire span.

Table 3.3.10 Bridge List

Line name	Location	Span (m)	Type	Remarks
Northern Line	$1^k\ 643^m$	$33.5^m \times 1$	T.T.	Superannuated structures
	$4^k\ 216^m$	$30^m \times 1$	T.T.	
	$7^k\ 000^m$	$30^m \times 2$	T.T.	Superannuated structures
Mae Nam Line	$5^k\ 882^m$	$10^m + 15^m + 10^m$	T.P.	
	$7^k\ 492^m$	$10^m \times 1$	T.P.	

Note: T.T. through truss
T.P. through plate girder

(4) Station facilities

The proposed elevated section has six stations. All of them except Sam Sen are unattended stations, and only local trains make stops.

Sam Sen Station is utilized by many passengers because of existing residential areas and public facilities, and so all passenger trains stop at this station. It has with two sheltered side platforms. The station plaza is favorably disposed to the road traffic system.

The unattended stations each have two side platforms made of old timber sleepers. These platforms will require refurbishing because their surfaces are uneven and dangerous.

In addition to these stations, there is another station named Makkasan, which is utilized by many people because of its proximity to the Makkasan Workshop and commercial district. This station has a side platform and an island platform and also includes the connected tracks with the Makkasan Workshop.

(5) Grade crossing facilities

The proposed elevated section has a total of 14 grade crossings, which are broken down into seven on the Northern Line, three on the Eastern Line and four the Mae Nam Line. Table 3.3.11 lists existing facilities at those grade crossings.

Because of the excessive traffic volume at the main grade crossings, it is difficult to stop road traffic for an approaching train. As a result, trains must frequently stop immediately before a grade crossing. This causes chronic delay of train schedule as well as accidents at grade crossings.

Table 3.3.11 List of Grade Crossings

Line Name	No.	Distance (km)	Crossing Road	Width of Road (m)	Operator (persons)	Barrier
Northern Line	1	2,170	Phetburi Rd.	32.3	3	A
	2	2,866	Sriayutthaya Rd.	31.8	3	A
	3	3,750	Rajavithi Rd.	25.4	3	A
	4	4,426	Nakornchaisri Rd.	20.6	3	B
	5	5,074	Setsiri Rd.	9.0	3	B
	6	5,739	Ranong I Rd.	4.5	3	B
	7	6,377	Pradipat Rd.	21.3	3	B
Eastern Line	8	2,645	Rama IV Rd.	34.1	3	A
	9	3,672	Phyathai Rd.	35.0	3	A
	10	4,595	Rajaprarop Rd.	27.5	3	B
Mae Nam Line	11	5,204	Makkasan Rd.	6.5	2	B
	12	5,692	Phetburi Rd.	26.4	3	C
	13	6,509	Sukhumvit Rd.	30.0	3	A
	14	8,728	Rama VI Rd.	41.0	3	A

Notes: A Electrically Operated Railway Barrier
B Manually Operated Lifting Brrier
C Sliding Gate Barrier

(6) Electrical facilities

No SRT lines are electrified, so electrical facilities of the SRT mainly consist of signalling and telecommunication equipment.

The SRT is promoting the installation of color light signals and tokenless block equipment to improve the signalling system. In the Fifth Plan, the color light signals and tokenless block equipment will be installed in every main line.

(i) Signalling

The classification of interlocking system and block system in the Study Area is shown in Fig. 3.3.5.

Signals are two-aspect type and their normal position is red aspect. Color light signals near grade crossings are interlocked with the grade crossing equipment.

Between Bangkok and Bang Sue Station, Yoma Rat Chit-La-Da Junction and Makkasan Station, continuous track circuits are installed.

Automatic grade crossings are controlled by track circuits. Man-operated grade crossings are operated by the telephone from the nearest station.

Color light signals are being constructed along the Southern Line. In the Fifth Plan, color light signals, all relays interlocking and tokenless block equipment will be installed on the Eastern Line.

(ii) Telecommunication

Most telecommunication lines are open wires. In the proposed elevated track section, telecommunication cables are used, too.

The train operation dispatching telephones are handled by 11 control centers which give commands to each line divided into 13 blocks. In this Study Area each station belongs to Bang Sue dispatching center (Northern Line dispatcher, Southern Line dispatcher, and Eastern Line dispatcher). Dispatching telephones connect the center and each station, but they are old. So the SRT is studying the replacement of the dispatching equipment in the Fifth Plan.

The private automatic branch exchange (PABX) is installed in Bangkok, Bang Sue and Makkasan Stations in the Study Area. They are used for convenient business communicacation.

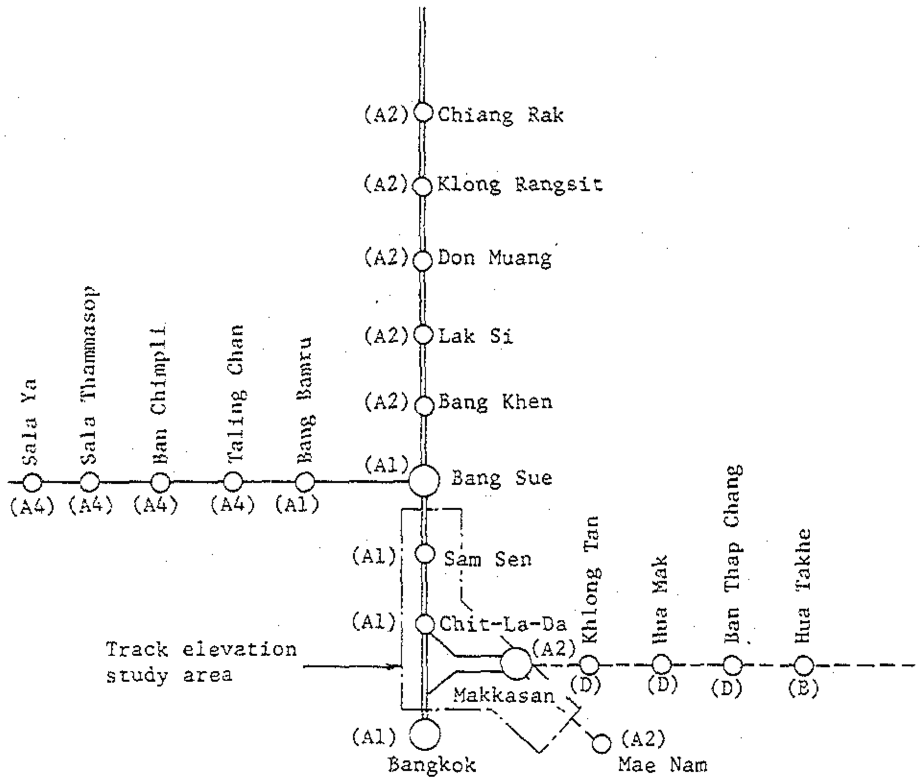


Fig. 3.3.5 Classification of Interlocking Stations and Block System

Classification of Interlocking Stations

Class A		Fully Interlocking
	A.1	All Relay Interlocking
	A.2	Electromechanical Interlocking - with points and color light signals electrically operated from lever frame - with points mechanically but color light signals electrically operated from lever frame
	A.3	Mechanical Interlocking - with warner, home and starter signals
	A.4	Mechanical Interlocking - without warner but with either home and starter signals or with home signals only
Class B		Semi-interlocking Stations with hand-operated and key-locked points with home signals operated from lever frame
Class C		Stations with semaphore signals only
Class D		Noninterlocking Stations with hand-operated and key-locked points but with no signals

Block system

═══	Double-line, tokenless block
───	Single-line, tokenless block
- - - -	Token block

CHAPTER 4 DEMAND FORECAST

CHAPTER 4 DEMAND FORECAST

4.1 Basic Concept

The proposed elevated section includes long-distance passenger departure/arrival in Bangkok and urban passenger traffic along with transit sections for large-volume freight departure/arrival in the Mae Nam port area. Moreover, if the national plan for the Eastern Seaboard is realized, railway freight departure/arrival in Bangkok related to this plan will also pass through this section.

Therefore, the object of this forecast is both passenger and freight traffic demand. The former is divided into inter-zonal and urban passenger traffic demand, and the latter is inter-zonal freight traffic demand.

The demand forecast results will have a great effect on the decision making for the Project's implementation planning. In addition, the forecast target years and cases will be established fully considering all the basic conditions for planning.

The establishment of the forecast cases is explained in detail in 4.2.1. Considering the study period, construction period, project life and the like, the target years in principle are 1984, 1991 and 2003.

Since demand forecasts will be carried out in general on the basis of inter-zonal traffic volume, zoning is essential for demand forecasting. The actual zoning is mentioned in detail in 4.2.2.

The damand forecast methodology of the Study is based on the so-called "four-step deduction." According to this method, first the socio-economic framework which can be thought of as controlling traffic demand is deduced. This framework includes future population, GDP and the like. Second, the generated/concentrated traffic volume by zone is deduced on the basis of the socio-economic framework found in Step One. At this point the generated/concentrated basic unit is found with the present generated/concentrated volume and the present socio-economic framework, and the method for extrapolating this to the future is adopted.

In Step Three the distributed traffic volume, namely the inter-zonal traffic volume (the so-called O.D. traffic volume) is deduced. Fundamentally, this is carried out by applying the Gravity Model whose parameters are deduced on the basis of the present O.D. table. When it is difficult to apply the Gravity Model, the Present Pattern Method can be applied to directly calculate future traffic volume from the current level of traffic flow. Totaling O.D. traffic volume for each zone will yield the generated/concentrated traffic volume by zone. However, since this value differs in general from the value calculated in Step Two, it should be made consistent by applying the growth rate method or the Frator Method to remove this contradiction.

When, from experience, the generated and the concentrated traffic volume by zone are practically the same as the inter-zonal passengers, successive iteration methods such as the average growth rate method and the Frator Method are abbreviated and another simpler method is applied.

In Step Four, traffic volume by mode, in particular railway traffic volume, is deduced by using a modal share model based on the inter-zonal traffic volume found in Step Three. Railway traffic volume is deduced by using the Logit Model or time value model for passengers and the relative time share model or the time value model for freight sufficiently scrutinizing a distribution model in relation to passengers and freight. Whatever type this model may take, it basically includes the modal choice factors (such as required time and rates and charges between zones for passengers and freight by mode).

It goes without saying that at the time of parameter deduction, the most explanatory parameters are found by multi-regression analysis based on data showing current shares.

In principle, demand forecasting in this Study was carried out according to the above "four-step deduction," but in some cases intermediate steps were omitted because of data limitations or the results of regression analysis. What kind of model is constructed according to what concept is described in detail in 4.3 of this report including the forecast results. Furthermore, cross-sectional traffic demand, which is essential for the study of a transport plan, is also estimated along with the demand forecast results.

4.2 Preconditions

4.2.1 Establishing the Forecast Cases

Demand forecast is carried out for the following cases:

- Passenger
  - Inter-zone ——— (1)
  - Urban
    - Natural Trend Type (Case I) ——— (2)
    - High-level Service Type (Case II) ——— (3)
- Freight ——— Inter-zone ——— (4)

"Natural Trend Type" (Case I) is considered to be the case in which the service level of SRT remains merely at the present level just possible to cope with changes on the demand side.

"High-level Service Type" (Case II) is considered to be the case in which SRT would provide high-level services and functions along with other modes coping with changes on the supply side on the condition that full service is given to the railway passenger.

Along with considering the Eastern Seaboard Plan for inter-zonal freight traffic demand forecasting, another premise is the completion of the Northern Link Line as a link in the chain of the Plan.

4.2.2 Zoning

(1) Zoning for inter-zonal passenger/freight demand forecasting

In corresponding to Thailand's administrative divisions by region and province, the country is divided into 19 zones in considering the actual state of the railway network. This is illustrated in Table 4.2.1 and Fig. 4.2.1. Furthermore, the zonal center needed for demand forecasting was regarded as the railway station in the administrative seat of the major province in each zone. Thus, no railway traffic volume is recorded in this Study for zones in which there is no railway.

Table 4.2.1 Zoning

Zone Number	Name of province	Zone number	Name of province
1	Bangkok, Nontaburi, Samut Prakan	13	Ayutthaya, Pathum Thani, Saraburi
2	Mae Hongson, Chiang Mai, Lamphun	14	Nakhon Pathom, Samut Sakhon, Samut Songkhram
3	Chiangrai, Payao, Lampang	15	Nakhon Nayok, Prachinburi, Chachoengsao, Chanthaburi, Trat
4	Phrae, Nan, Uttaradit	16	Chonburi, Rayong
5	Tak, Kampaengphet, Nakhon Sawan, Uthai Thani	17	Phetchaburi, Prachuap Khirikhan, Chumphon
6	Sukhothai, Phitsanulok, Phichit, Phetchabun	18	Ranong, Phangnga, Surat Thani, Phuket, Krabi, Nakhon Srithammarat, Trang
7	Loei, Nongkhai, Udon Thani, Khon Kaen	19	Phattalung, Satun, Songkhla, Pattani, Yala, Narathiwat
8	Sakon Nakhon, Kalasin, Nakhon Phanom, Mahasarakham, Roi Et		
9	Chaiyapum, Nakhon Ratchasima		
10	Buriram, Surin, Yasothon, Sisaket, Ubon Ratchathani		
11	Kanchanaburi, Ratchaburi, Suphanburi		
12	Chainat, Singburi, Angthong, Lopburi		

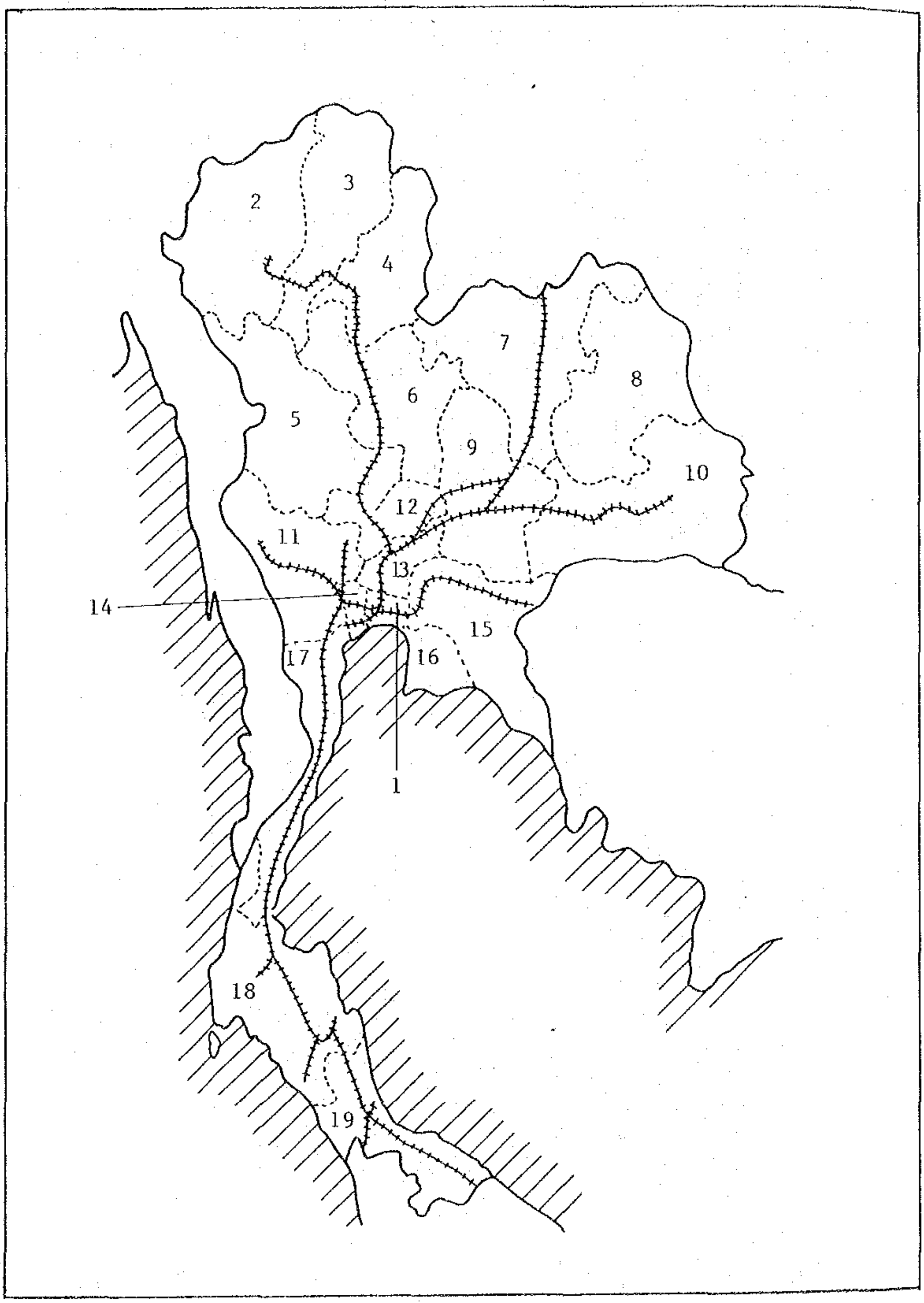


Fig. 4.2.1' Zone Map

(2) Zoning for urban passenger traffic demand forecasting

As stated in 3.2.4, the commuter area of the Study Area is estimated to be within a radius of about 30 km from the center of Bangkok.

Railways included in the above radius are the Northen Line Chiang Rak, the Eastern Line Hua Takhe and the Southern Line Sala Ya, and station zones are created on the assumption that there are station spheres of influence for each station within this radius as shown in Fig. 4.2.2. As a premise for the attempt to offer high-level service in Case II, distance between stations in the proposed elevated section is assumed around 2 km, and 4 km in other sections of the three lines as shown in Fig. 4.2.3.

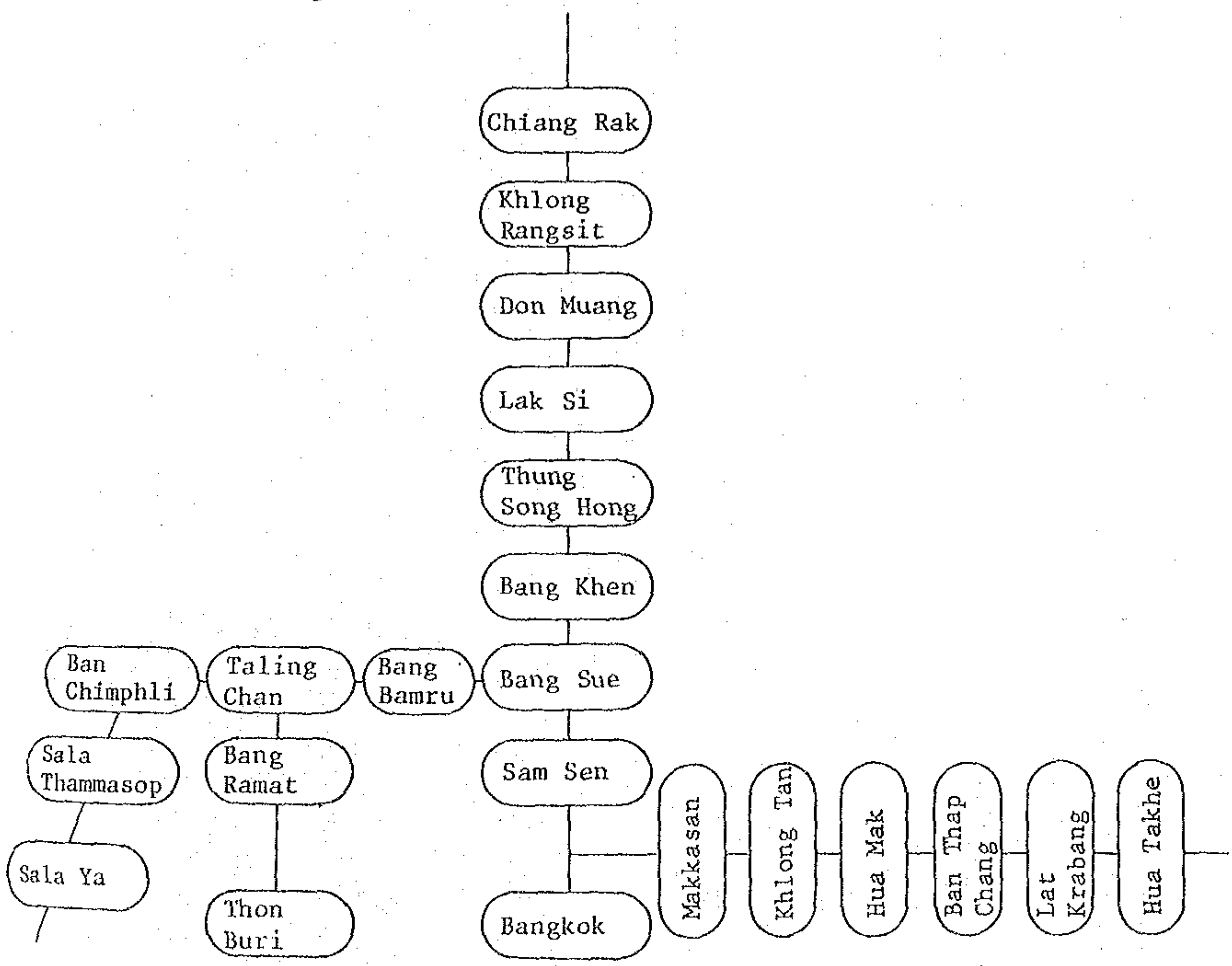


Fig. 4.2.2 Stations in Urban Area

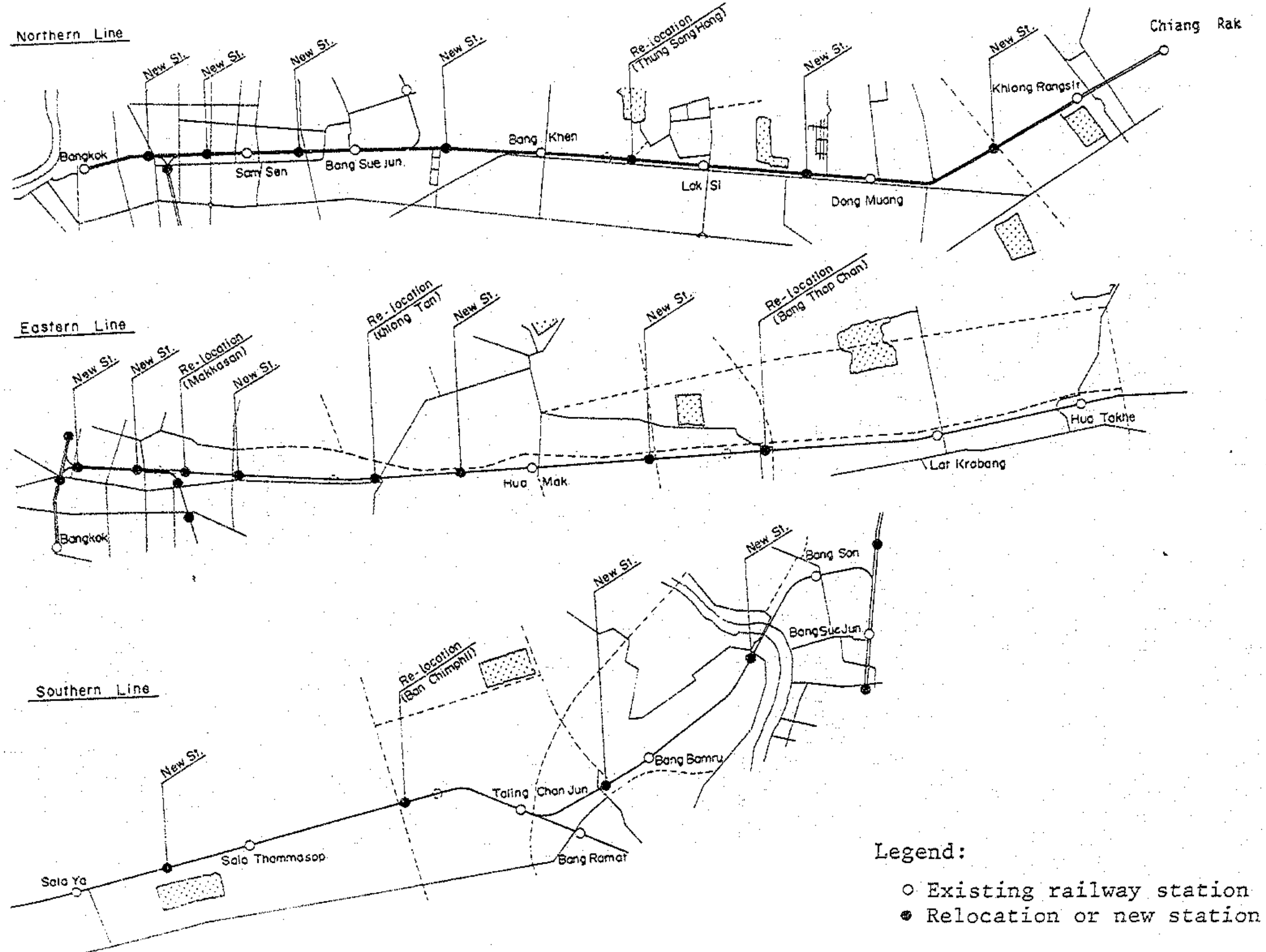


Fig. 4.2.3 Location of New Stations

4.2.3 Future Population and Products by Zone

(1) Population by zone

Future population by zone is estimated by using population growth rates taken from the Fifth Plan and the "Feasibility Study on the Second Stage Expressway Study in the Greater Bangkok Area," Final Report December 1983 based on numerical values totaled in 1982 for each province for zones as defined in Table 4.2.1. The estimated values are shown in Table 4.2.2.

Table 4.2.2 Estimate of Pupulation by Zone

(Unit: 1,000 persons)

Zone \ Year	1982 (Actual)	1984	1991	1998	2003	2013
1	6,470	6,770	7,809	8,616	9,096	10,089
2	1,711	1,764	1,907	2,044	2,137	2,323
3	2,088	2,152	2,327	2,495	2,607	2,835
4	1,288	1,328	1,435	1,539	1,608	1,749
5	2,148	2,214	2,394	2,567	2,683	2,918
6	2,598	2,678	2,895	3,105	3,245	3,528
7	4,127	4,289	4,740	5,122	5,325	5,727
8	4,001	4,158	4,596	4,966	5,162	5,552
9	2,865	2,978	3,290	3,555	3,697	3,976
10	5,484	5,698	6,298	6,806	7,075	7,610
11	1,983	2,010	2,057	2,135	2,221	2,393
12	1,462	1,533	1,753	1,923	1,982	2,096
13	1,452	1,523	1,741	1,910	1,969	2,083
14	1,068	1,120	1,280	1,405	1,448	1,532
15	1,907	2,051	2,591	3,283	3,907	5,504
16	1,131	1,217	1,536	1,947	2,317	3,264
17	1,110	1,153	1,274	1,377	1,434	1,549
18	3,004	3,120	3,447	3,727	3,883	4,193
19	2,700	2,804	3,098	3,350	3,490	3,769
Total	48,597	50,560	56,468	61,872	65,286	72,690

Note: The actual results for 1982 are constructed from data presented by SRT. Population increase rates are from the "Feasibility Study on the Second Stage Expressway System in the Greater Bangkok" Final Report (December 1983, JICA)

(2) Future GDP by zone

The average annual growth rates for the GDP for the past four five-year plans were 7.3% (First), 7.2% (Second), 6.2% (Third) and 7.3% (Fourth), and the average annual growth rate for the present Fifth Plan (1982 to 1986) is expected to be 6.6%. Estimates until 1986 in this Study utilizes the growth rate from the Fifth Plan, and for later years assumptions are made using the results of recent years as well as the Fifth Plan to yield a 6% average annual growth rate for the 1986 to 1996 period and a 5% rate for the 1996 to 2003 period. Resulting estimates are shown in Table 4.2.3.

Table 4.2.3 Estimate of Products by Zone (1972 prices)

(Unit: Million baht)

Zone \ Year	1980 (Actual)	1984	1991	1998	2003	2013
1	117,963	154,333	234,695	346,268	441,935	719,866
2	8,249	10,792	16,412	24,214	30,904	50,339
3	6,564	8,588	13,060	19,268	24,591	40,057
4	5,371	7.027	10,686	15,766	20,122	32,776
5	9,088	11,890	18,081	26,677	34,047	55,459
6	8,919	11,669	17,745	26,181	33,414	54,428
7	11,618	15,200	23,115	34,103	43,526	70,899
8	9,669	12,650	19,237	38,382	36,224	59,005
9	9,854	12,892	19,605	28,925	36,917	60,134
10	11,853	15,508	23,582	34,793	44,406	72,333
11	11,606	15,184	23,091	34,068	43,481	70,825
12	5,875	7,686	11,689	17,245	22,010	35,852
13	12,023	15,730	23,921	35,292	45,043	73,370
14	7,767	10,162	15,453	22,799	29,098	47,398
15	8,959	11,721	17,825	26,298	33,564	54,672
16	11,486	15,027	22,852	33,716	43,031	70,093
17	7,734	10,119	15,387	22,702	28,975	47,197
18	16,511	21,602	32,850	48,466	61,857	100,758
19	11,744	15,365	23,365	34,473	43,998	71,667
Total	292,852	383,145	582,645	859,636	1,097,143	1,787,128

Note: The growth in output for 1980 to 1982 was 7.3% (from the actual results of the Fourth Plan). It is expected to be 6.6% for the Fifth Plan (1982 to 1986), 6% for 1986 to 1996, and 5% for 1996 to 2013 from estimates using past results.

4.2.4 Transport Conditions by Mode

Transport conditions by mode only consider required time for the purpose of demand forecasting. Furthermore, the relative ratios of the current rate levels for each mode are presumed to continue into the future. The average speeds for each means of transportation are estimated as follows as a basis for calculating required time for each mode.

(1)	Trains	Passenger:	Northern Line	50 km/h
			Eastern Line	45 km/h
			Northeastern Line	48 km/h
			Southern Line	49 km/h
		Freight:	All lines	30 km/h
(2)	Automobiles	Buses:	Inter-urban	70 km/h
			Urban	12 km/h
		Trucks:		60 km/h

Note: Current train schedules were referred to for train estimates. The "Feasibility Study on the Second Stage Expressway System in the Greater Bangkok" Final Report (December 1983, JICA) is used for urban buses. Inter-urban bus and truck figures are from SRT data.

Basic data for travel time and calculation formulas other than the above are referred to in the following explanation of the forecasting model by type of traffic demand. Passenger diversion to railway due to improved railway service is assumed to have shifted from buses as seen by actual conditions in Thailand.

4.3 Actual Demand Forecasting

The following three demand forecast models are built to carry out the forecasting of each kind of traffic demand.

(1) Inter-zonal passenger traffic demand forecast model
(2) Urban passenger traffic demand forecast model
(3) Inter-zonal freight traffic demand forecast model

4.3.1 Inter-zonal Passenger Traffic

(1) Basic concept

The total inter-zonal passenger flow is found by using a gravity model which uses each zone's future population and the average distance between each zone as independent variables. Next, the railway share is found by using a railway share model which has each mode's required time as a traffic condition and as its independent variable. Finally, the railway traffic volume between each zone is found by multiplying the above total inter-zonal passenger flow by the above inter-zonal railway share.

This concept is illustrated by the flow chart in Fig. 4.3.1.

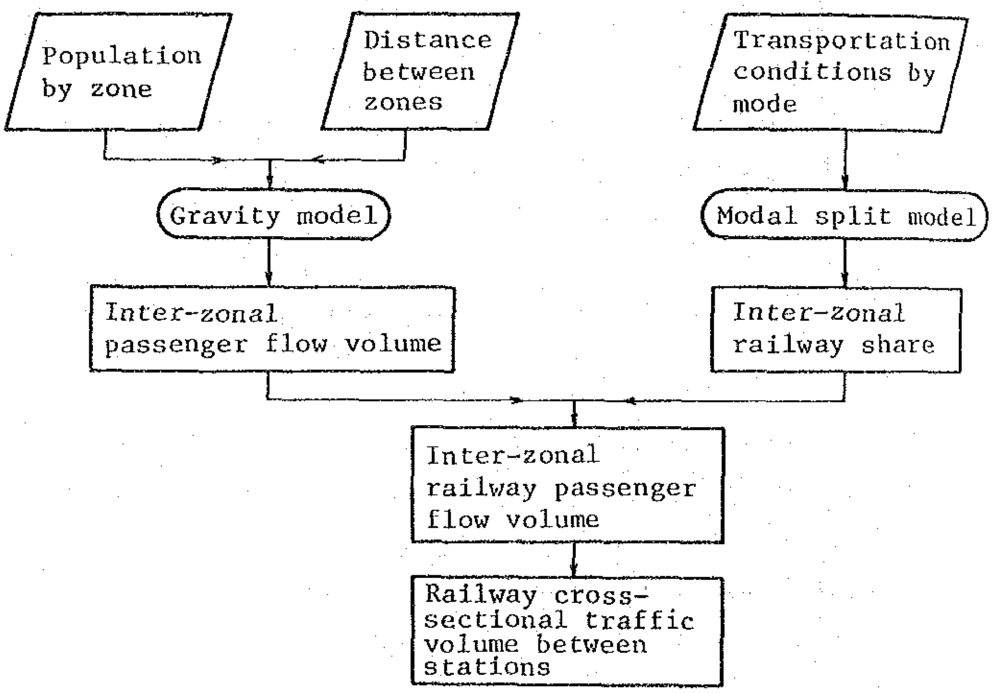


Fig. 4.3.1 Flow Chart of Inter-zonal Passenger Traffic Demand Forecasting

(2) Model type

When an inter-zonal passenger flow model and a railway share model are deduced by regression analysis, the following results can be obtained. Those models use the 1982 populations by zone, distances between zones and rail and bus traffic volumes and required times as independent variables. The results are as follows:

° Gravity Model

$$Tij_{(t)} = 0.0104 \cdot Pi_{(t)}^{1.333} \cdot Pj_{(t)}^{0.8377} / Dij^{1.01742} \quad (r = 0.814)$$

$Tij_{(t)}$(1,000 persons):	Passenger flow volume between i and j zones in year t
$Pi_{(t)}$(1,000 persons):	Population for i zone in year t
$Pj_{(t)}$(1,000 persons):	Population for j zone in year t
Dij (km):	Distance between i and j (average for railway and road)

° Modal Split Model

$$Sij_{(t)}^{R} = 1/[1 + \exp\{F(x_{(t)}, Dij)\}]$$

$$F(x_{(t)}, Dij) = 2.18324 + 0.726933 \cdot x_{(t)} - 7.3855 \cdot 10^{-3}\ Dij$$
$$(r = 0.800)$$

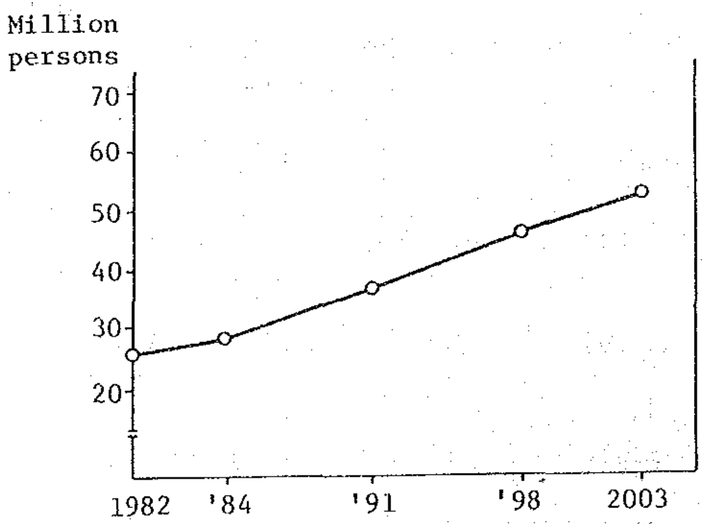
$Sij^{R}_{(t)}$:	Railway share between i and j zones in year t
$x(t)$:	Difference in required time for railway and road between i and j zones in year t
Dij:	Distance between i and j zones (km)

(3) Traffic demand forecast results

As shown in Fig. 4.3.2, passenger traffic volume increases at an average annual rate of 3.5% from 25.6 million passengers in 1982 to 53 million passengers in 2003. This increase rate is greater than the population growth rate (1.4% annual average) and can be considered as being tied to a further strengthening of Greater Bangkok's attraction which activates passenger flow beyond the population growth rate.

Appendixes 4.3.1 (1) to (3) show the inter-zonal passenger O.D. table by year. Figs. 4.3.3 (1) and (2) show the cross-sectional traffic volume of the inter-zonal railway passenger for 1984, 2003 and 1991.

Appendix 4.3.1 (4) shows the inter-zonal passenger traffic demand volume supplementally estimating interim years.



(Unit: 1,000 persons per year)

Year	1982 (Actual)	1984	1991	1998	2003
Volume	25,606	28,017	37,661	46,907	53,105
per annum	4.6%	4.3%	3.2%	2.5%	

Fig. 4.3.2 Inter-zonal Passenger Traffic Volume

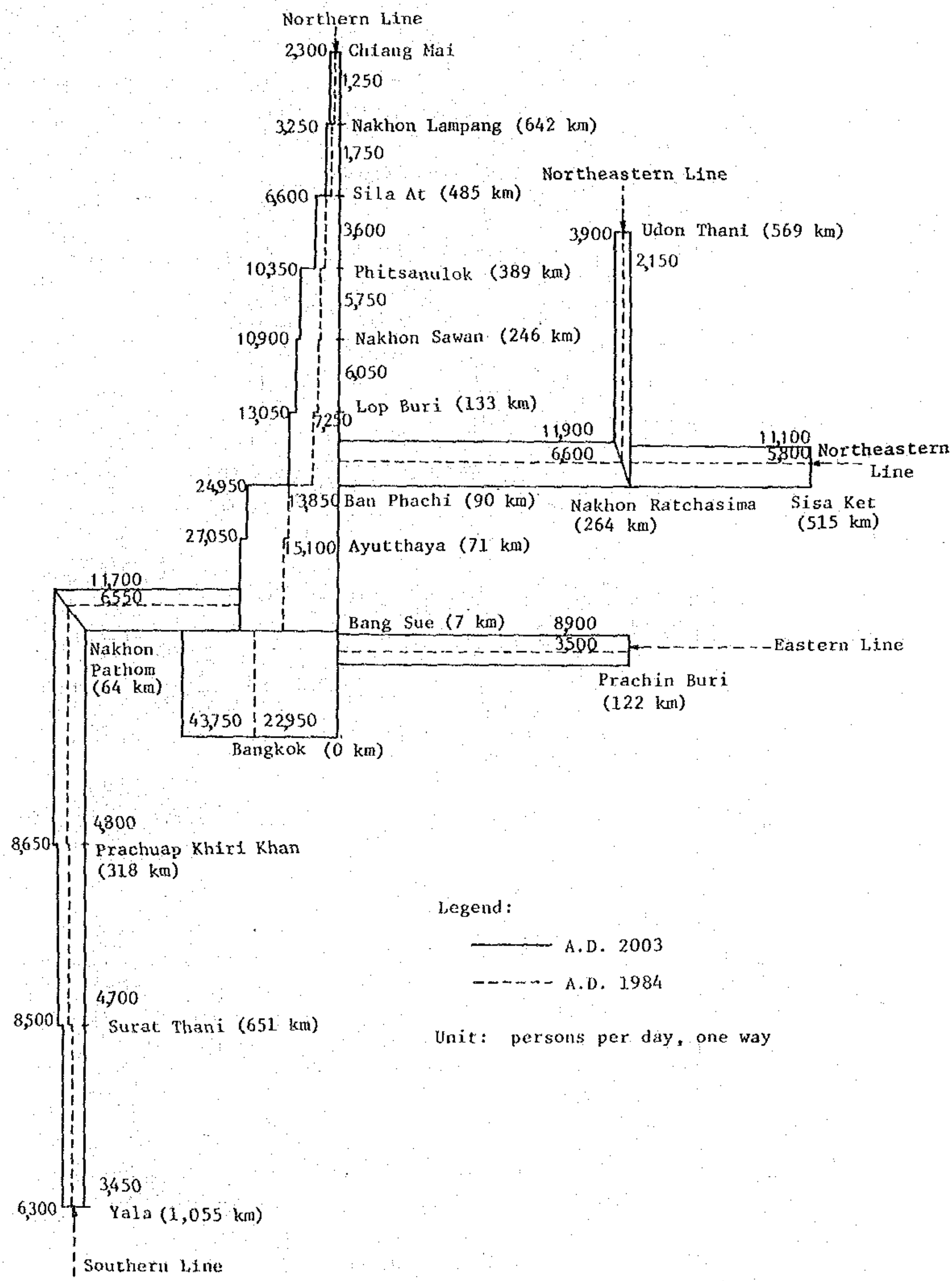


Fig. 4.3.3 (1) Inter-zonal Cross-sectional Passenger Traffic (1984, 2003)

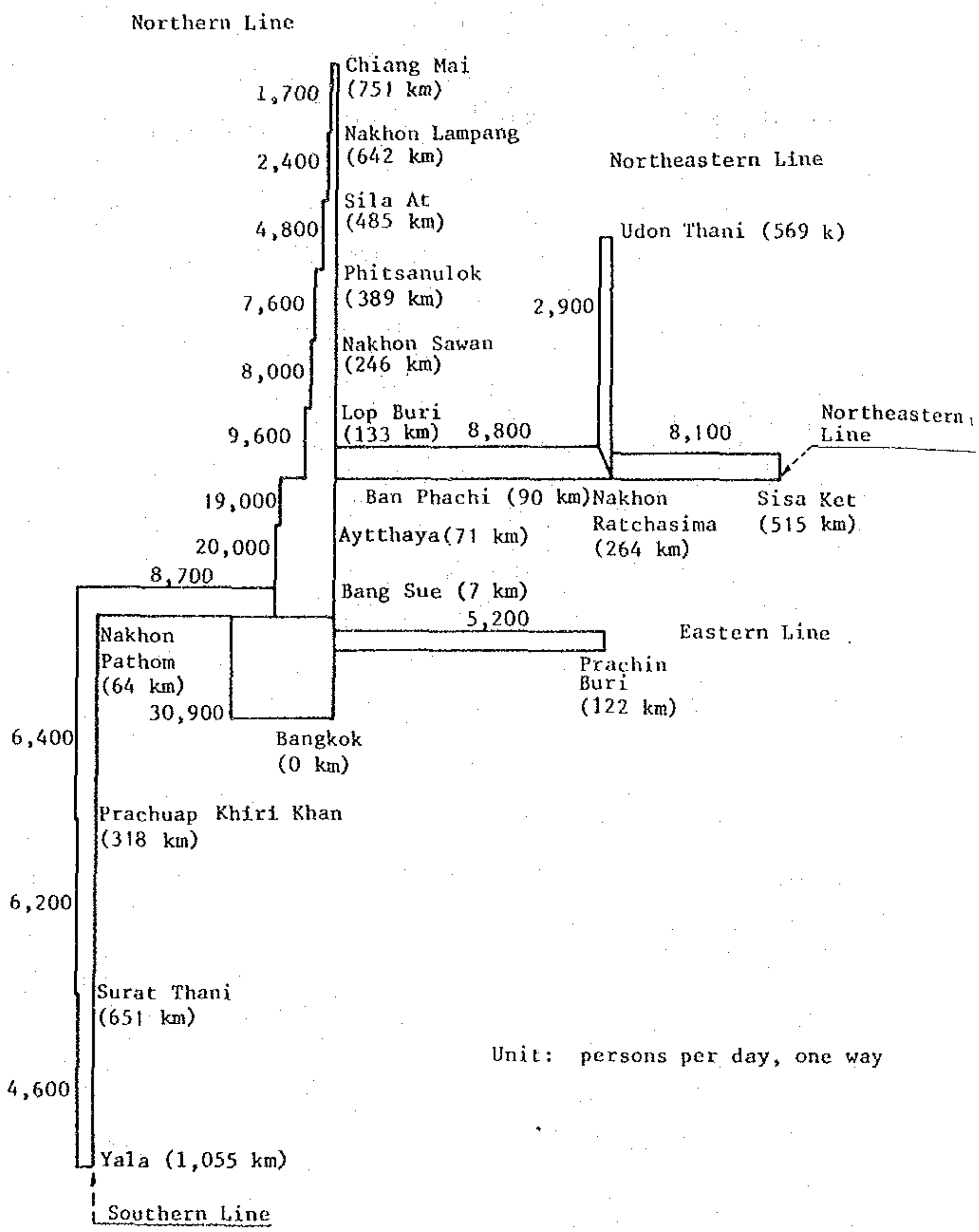


Fig. 4.3.3 (2) Inter-zonal Cross-sectional Passenger Traffic (1991)

4.3.2 Urban Passenger Traffic

(1) Basic concept

Required time is calculated according to the following method as each mode's traffic conditions.

Railway travel time = Running time + 1/2 headway + access and egress time

Bus travel time = Running time + access and egress time

Railway access and egress time is 14.2 min. and that of bus 22.8 min. This is based on the results of a traffic volume survey of the Study Area carried out as part of this Study. Furthermore, bus routes are 30% longer than those of trains in consideration of the complicated bus routes and its speed is 12 km per hour due to traffic congestion in the center of the city.

Demand forecasting is carried out for Case I and Case II separately, attaching particular importance to the role which SRT should play in the future in the Study Area.

The following preconditions are established for Case II which is considered to provide high-level service.

(i) SRT will improve train headway as shown in Table 4.3.1 to offer high-level service.

Table 4.3.1 Headway Improvement in SRT (Case II)

(Unit: Minutes)

	Northern Line	Eastern Line	Southern Line
1984	15	30	30
1991	10	15	15
1998	7.5	10	10
2003	7.5	10	10

(Including trains to Thon Buri on the Southern Line)

(ii) The approach to stations will be made easier as a part of improving transportation service. Therefore access and egress time to stations can be cut by one fourth.

(iii) Greater convenience will be offered to railway passengers by building new stations (about 4 km between stations) in the outside of the proposed elevated section as shown in Fig. 4.2.3.

This Study examines the supposed effects on SRT by the opening of MTS by ETA.

MTS routes being considered in Stage I pass through only part of the city center and do not form a network and, in addition, there will be no competition between them from the standpoint of SRT's station spheres of influence.

Concerning MTS extensions after the year 2,000 running in parallel with parts of the Northen Line, the two stations of Bangkok and Bang Sue combine with the three stations of Ban Khen, Lak Si and Don Muang to form six pairs of stations which can be expected to be affected. The service level of MTS is estimated to be 37 km per hour for scheduled speed and 10 min. for train headway. These values were found at a meeting with ETA. The urban passenger traffic demand volume is found according to the function formula which forecasts demand volume by using the abovementioned traffic conditions for each mode and the population for each station's sphere of influence as input data. This demand forecast method is shown by the flow chart in Fig. 4.3.4.

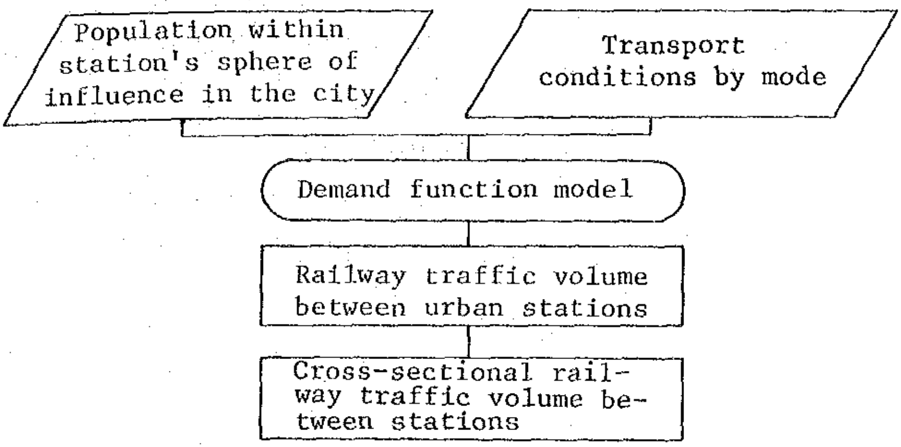


Fig. 4.3.4 Flow Chart of Urban Passenger Traffic Demand Forecasting

(2) Model type

The "Demand Function Model" for calculating urban passenger traffic volume based on the populations of station spheres of influence and each mode's traffic conditions as actual data is found by regression analysis. The results are as follows:

$$Tij^{R}_{(t)} = 0.00675 \cdot (pi \cdot pj)_{(t)}^{0.64136} \cdot Xij^{-3.07896}$$

(r = 0.639)

$$Xij = t^{R}/t^{o}$$

$Tij^{R}_{(t)}$: Railway traffic volume between i and j stations year t

$(pi \cdot pj)_{(t)}$: The product of population of i and j station spheres in year t

t^{R} : Railway travel time

t^{o} : Bus travel time

(3) Traffic demand forecast results

The urban passenger traffic volume results are shown in Table 4.3.2 and Fig. 4.3.5. In addition, supplementary estimates for interim years are shown in Appendix 4.3.2 (6). The urban passenger O.D. tables by year and by case are shown in Appendixes 4.3.2 (1) to (5).

Urban passenger traffic in Bangkok relies heavily on roads. However, roads are deficient in both quality and quantity, and construction is not keeping up with the increase in automobiles. With this kind of background, traffic congestion is becoming even worse.

Table 4.3.2 Urban Passenger Traffic Volume

(Unit: 1,000 persons per year)

Year		1982	1984	1991	1998	2003
Volume (1,000 persons)	Case I	6,836 (100)	7,584 (111)	9,070 (133)	10,175 (149)	10,793 (158)
	Case II			17,329 (253)	21,330 (312)	22,636 (331)

Note: ( ) indicates indices when the traffic in 1982 is 100.

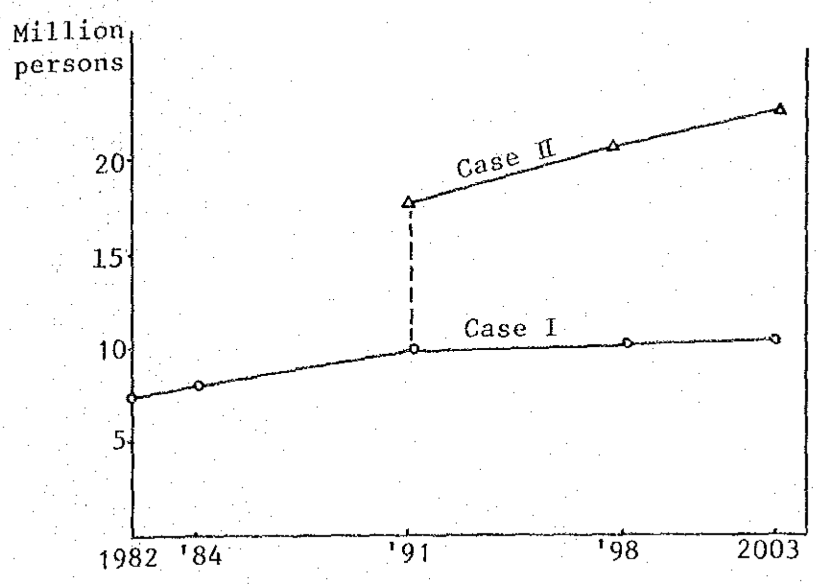


Fig. 4.3.5 Urban Passenger Traffic Volume

The low dependence ratio on railways until now is due to an urban structure which leans towards roads, but it can also be attributed to the insufficient service of SRT in regard to urban transportation. By this estimate, the traffic volume in Case II is twice that of in Case I. This shows that improving SRT transportation service and making trains easier for passengers to use will contribute to urban transportation and alleviate traffic congestion to some extent.

The opening of Mass Transit System by ETA will have absolutely no impact on SRT in Phase I. However, in the event that the extension north of Bang Sue is operated in the future, passenger shift from SRT to MTS is assumed to be 697,000 passengers a year in Case I and 1,257,000 passengers a year in Case II in 2003.

The effect of MTS on SRT's total urban passenger traffic, though, is extremely small. The cross-sectional passsenger traffic volume for stations within the Study Area is shown in Figs. 4.3 6 (1) to (4).

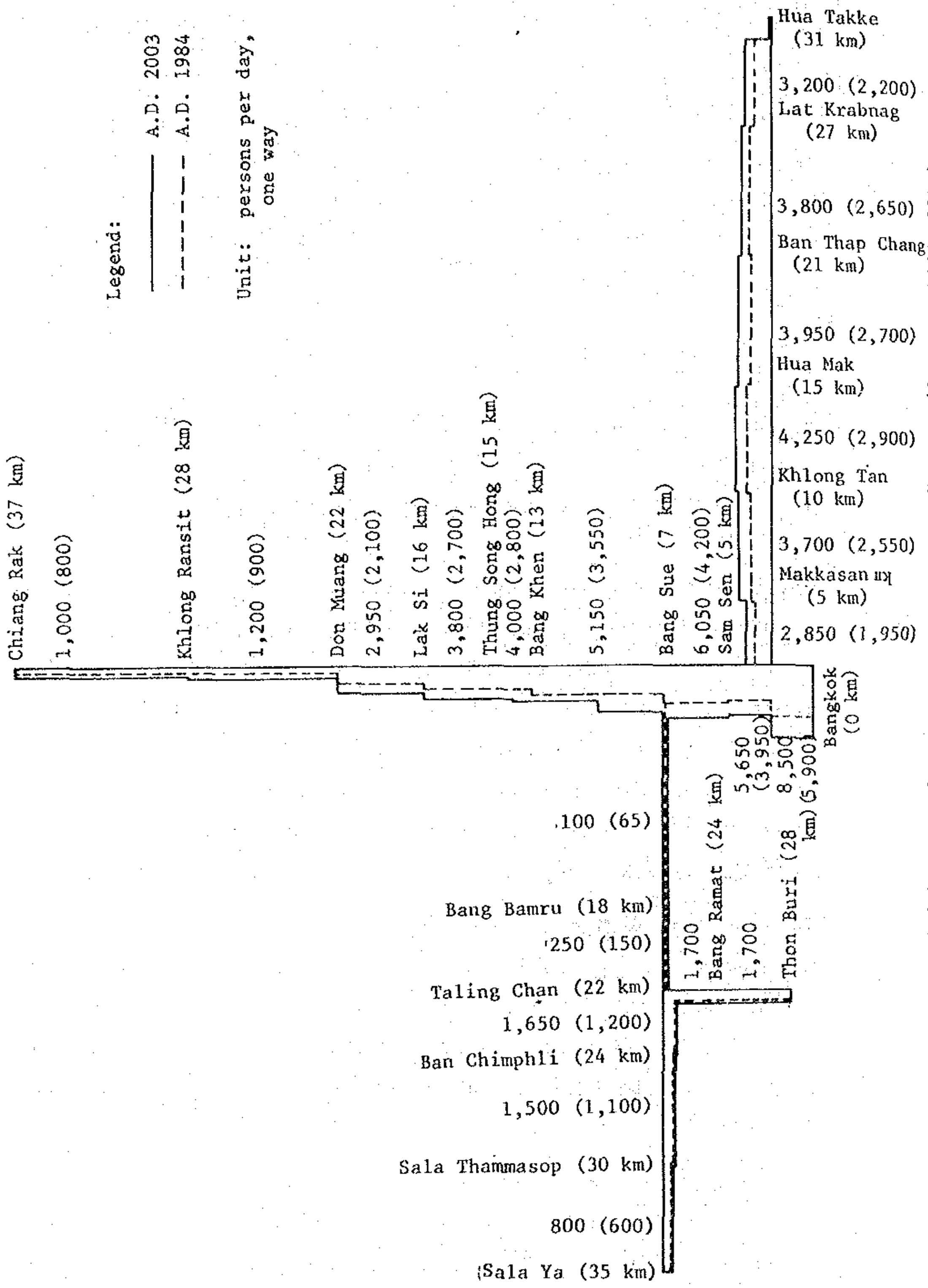


Fig. 4.3.6 (1) Urban Cross-sectional Passenger Traffic (Case I: 1984, 2003)

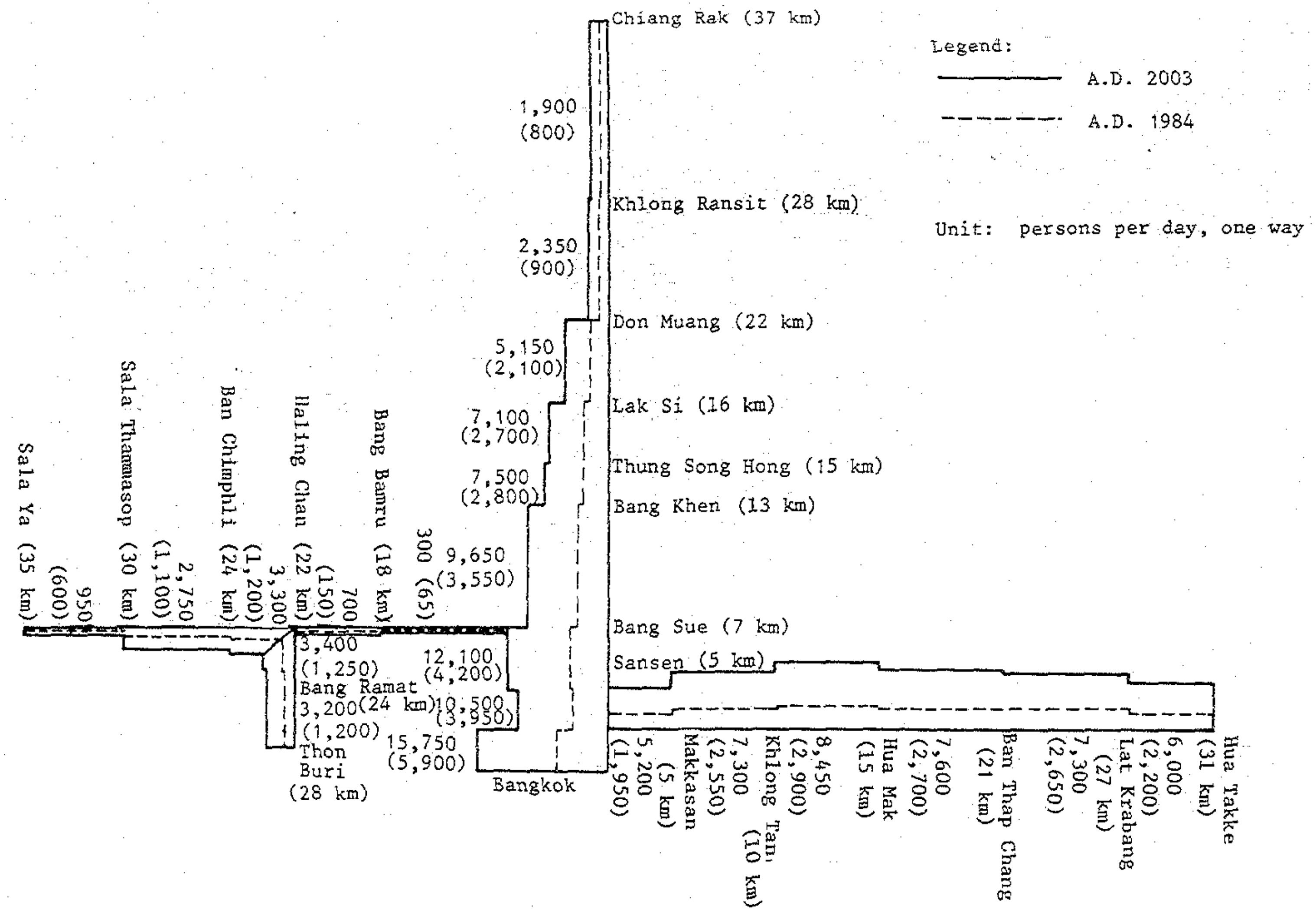


Fig. 4.3.6 (2) Urban Cross-sectional Passenger Traffic (Case II: 1984, 2003)

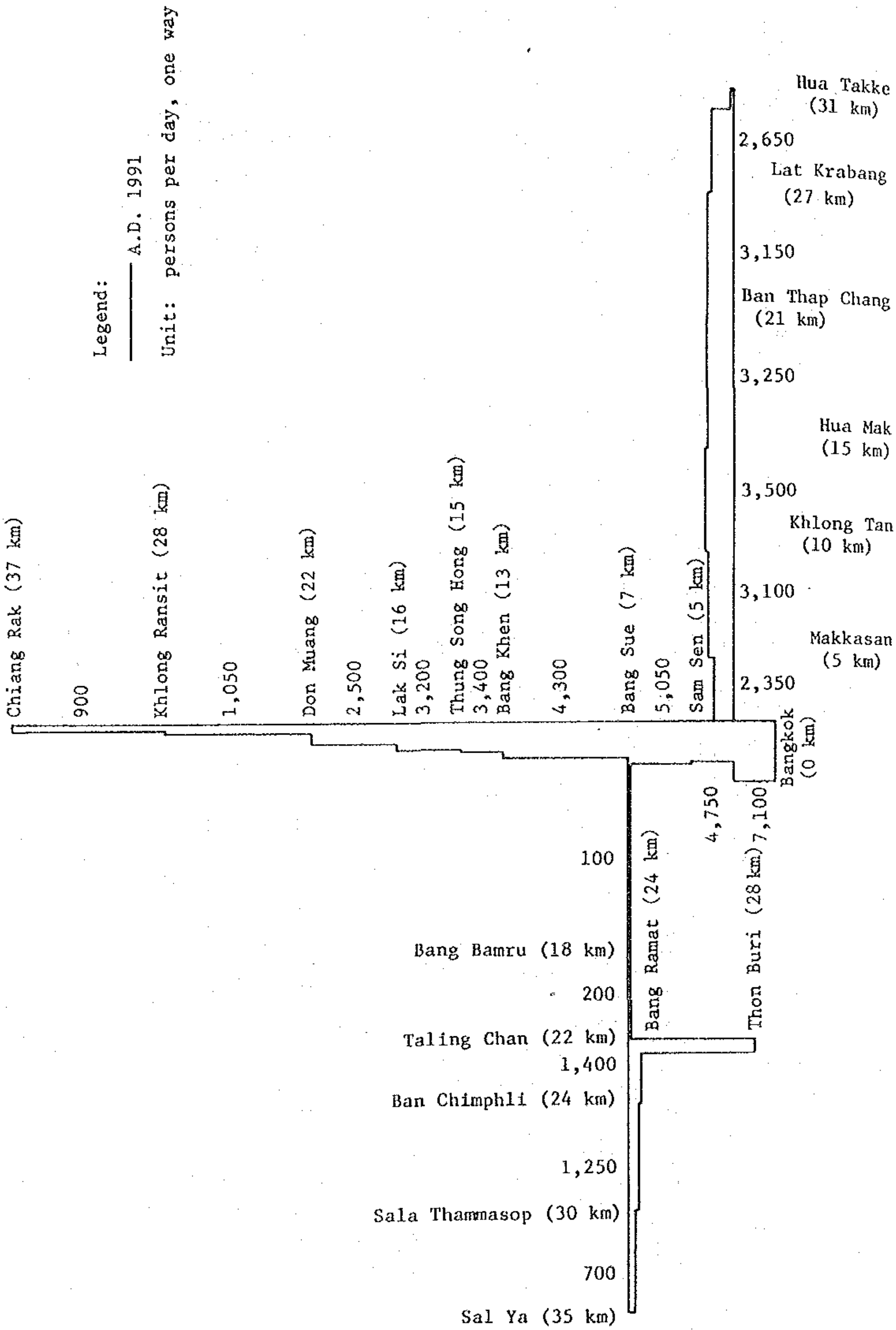


Fig. 4.3.6 (3) Urban Cross-sectional Passenger Traffic (Case I: 1991)

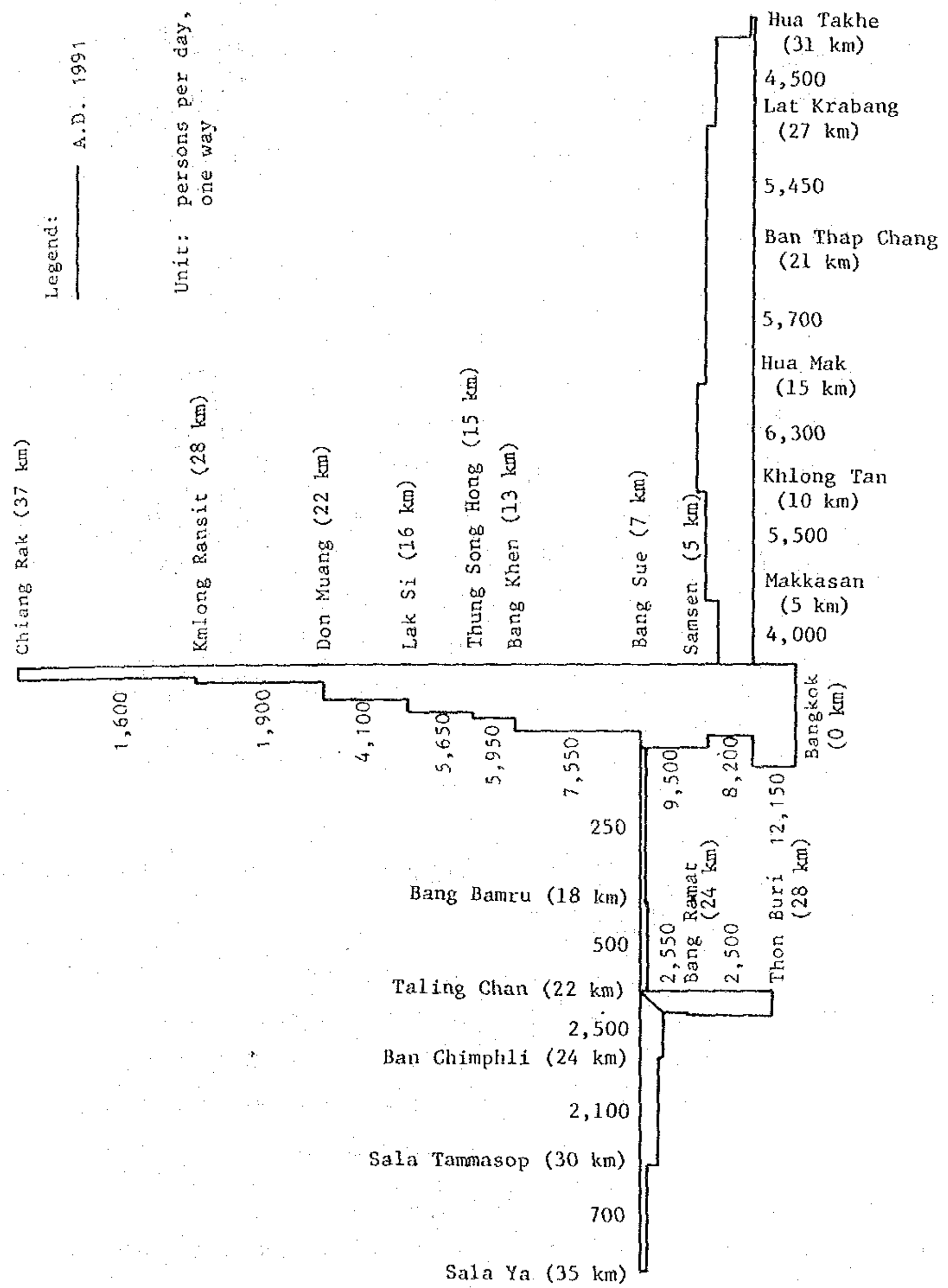


Fig. 4.3.6 (3) Urban Cross-sectional Passenger Traffic (Case I: 1991)

4.3.3 Inter-zonal Freight Traffic

(1) Basic concept

Along with the invigoration of economic activity, more raw materials are shipped to manufacturing areas, and more manufactured goods are shipped to the market.

This is the fundamental relationship between economic activity and freight traffic.

Thus, in this study the future gross domestic freight traffic volume is found in the socio-economic framework of its relationship with the future GDP. In the same way, the future generated/concentrated freight volume by zone is found in its relationship with the future Gross Regional Product (GRP) by zone. The future freight flow volume is found by successive iteration using the above-mentioned inter-zonal generated/concentrated freight volume as a control value and the current inter-zonal freight flow as the pattern for future freight flow. This successive iteration is carried out according to the Frator Method.

The railway share of the future inter-zonal traffic demand is estimated by using the Modal Split Model to measure the railway share with the required times for each mode and the distance between zones as input data.

Finally, the railway inter-zonal traffic volume as the first estimated value is found by multiplying the above railway share by the above inter-zonal freight flow volume. Then, the final value for the future inter-zonal railway freight volume is found in consideration of the Eastern Seaboard-related railway freight volume according to the Thai Government's plan.

The above-mentioned demand forecasting is shown in the Fig. 4.3.7.

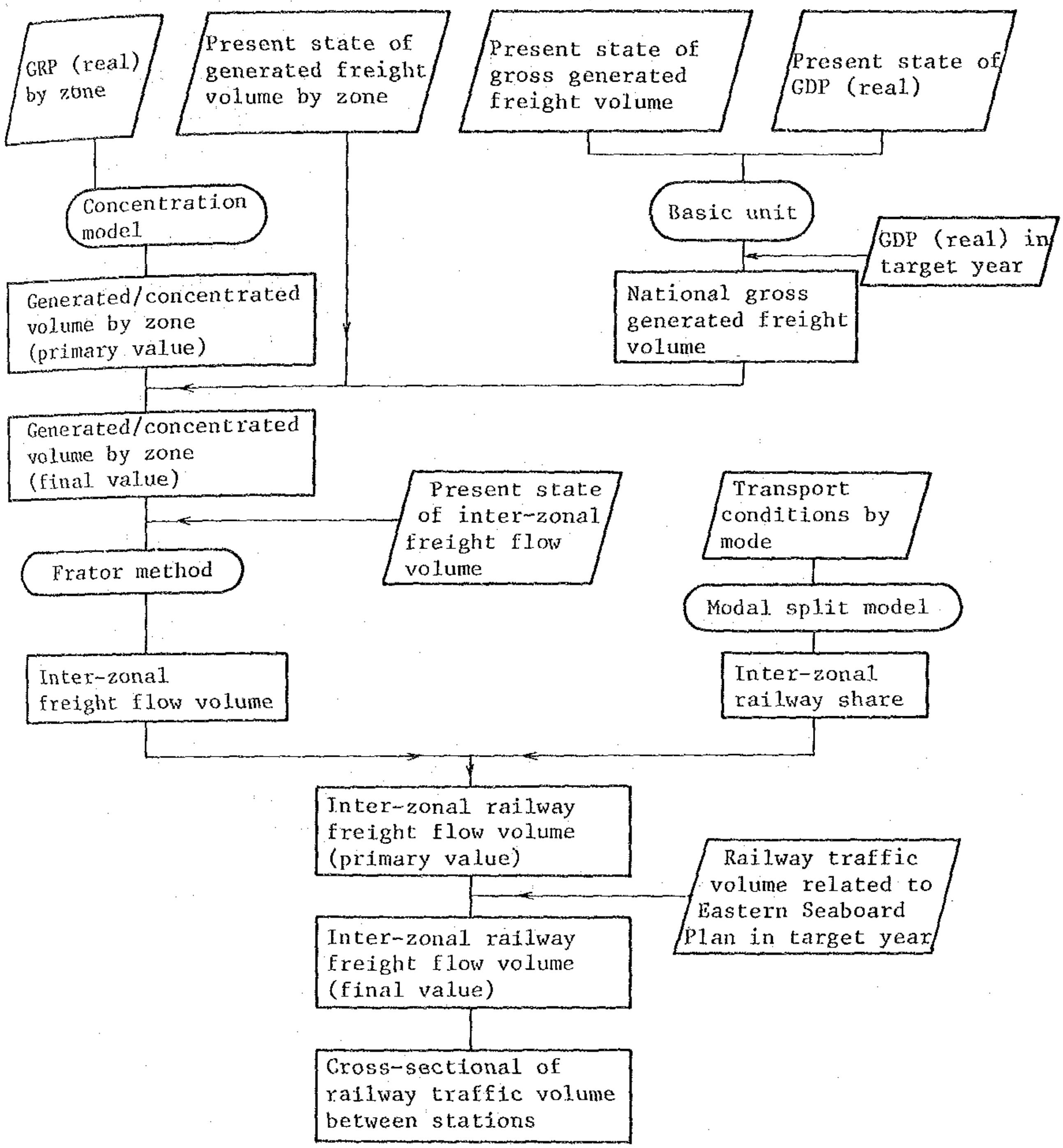


Fig. 4.3.7 Flow Chart of Inter-zonal Freight Traffic Demand Forecasting

(2) Model type

Two models are used here. One is the "Zonal Generated/Concentrated Freight Volume Forecasting Model Formula" which gives the generated/concentrated volume by zone based on each GRP. The other is the "Railway Share Forecasting Model" which gives the railway's share between zones i, j based on the required time for trains and trucks and the distance between zones i, j.

These models are both found by regression analysis using actual data. The models resulting from this analysis are shown below.

◦ Zonal concentrated volume forecasting model

$$T\,j_{(t)} = 0.00522 \cdot GRPj_{(t)}^{1.34052} \quad (r = 0.872)$$

$T\,j_{(t)}$(1,000 tons): Concentrated volume in j zone in year t

GRP $j_{(t)}$(1 million Baht): j zone's GRP in year t

◦ Railway share forecasting model (Modal split model)

$$Sij^{R}_{(t)} = 1/[1 + \exp\{f(x,Dij,d)_{(t)}\}]$$

$$f(x,D_{ij},d)_{(t)} = 4.25101 + 0.46482 \cdot x_{(t)}^{-1.2212} \cdot 10^{-2} \cdot D_{ij} + 1.9245 \cdot d \qquad (r = 0.690)$$

$x_{(t)}$: *Difference in required time for trains and trucks between zones in year t*

D_{ij}: Distance between i and j zones

d: Dummy (0 if generated volume, 1 if concentrated volume)

$S_{ij(t)}^{R}$: Railway share between i and j zones in year t

(3) Traffic demand forecast results

SRT freight traffic has shown only negligible fluctuations until now. However, if the national project for the Eastern Seaboard industrial area goes into operation as planned, a complete change can be expected.

Table 4.3.3 shows railway freight volume to be handled in relation to the Eastern Seaboard Plan.

Table 4.3.3 Freight Traffic Volume by SRT Related to the Eastern Seaboard Plan

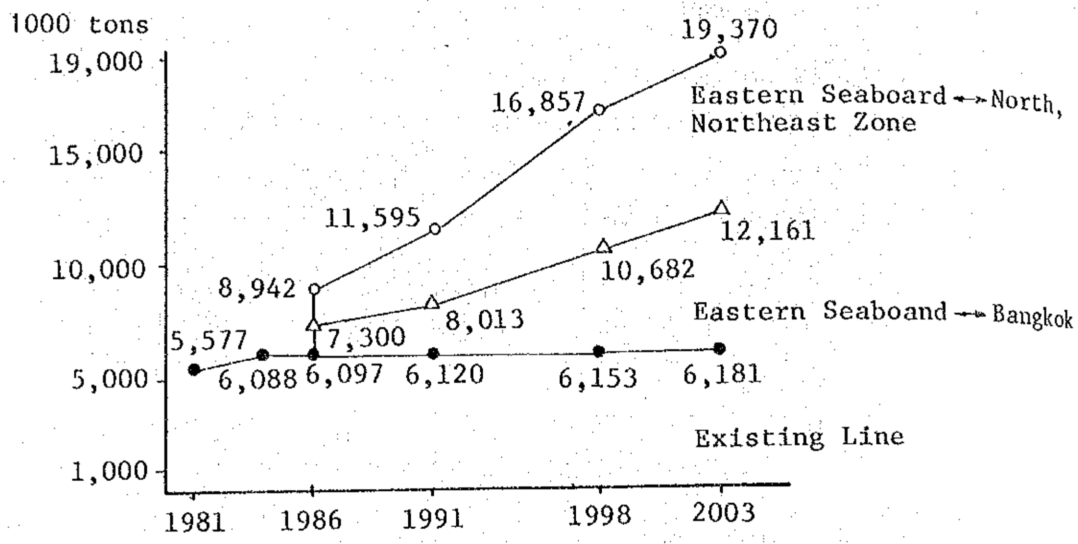
(Unit: 1,000 tons per year)

Direction \ Year	1986	1991	1996	2001
Bangkok	1,180	1,870	4,050	5,350
North, Northeast	1,665	3,605	5,800	6,775
Total	2,845	5,475	9,850	12,125

Fig. 4.3.8 shows the estimated results for the total inter-zonal freight traffic volume including Eastern Seaboard-related railway freight volume.

Appendix 4.3.3 (4) shows the inter-zonal freight traffic volume supplementally estimating interim years.

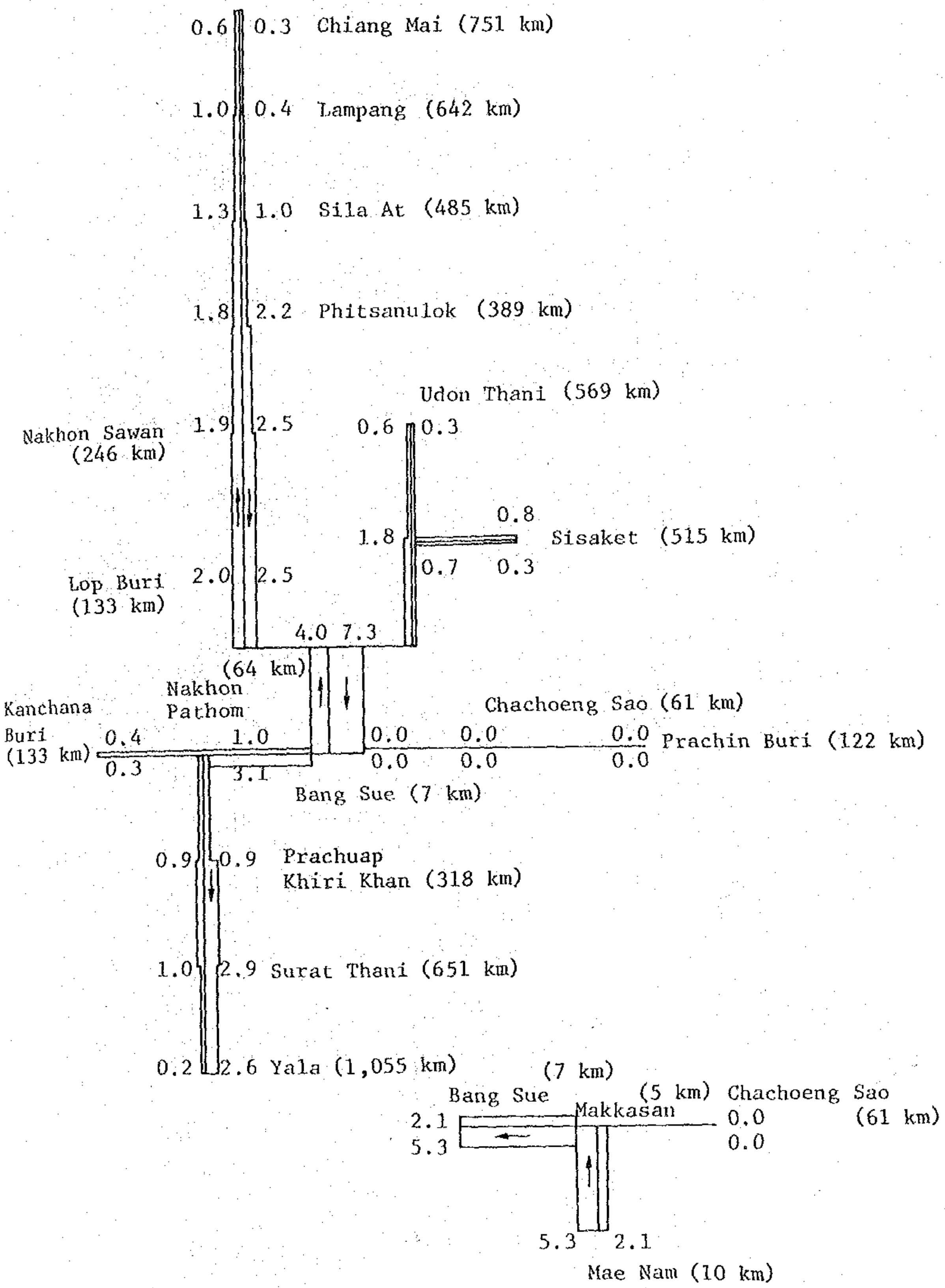
Appendixes 4.3.3 (1) to (3) show the inter-zonal freight O.D. tables. In addition, the cross-sectional traffic volumes are shown in Figs. 4.3.9 to 4.3.11.



(Unit: 1,000 tons per year)

Year	1981	1984	1991	1998	2003
Volume	5,577	6,088	11,595	16,857	19,370
per annum	2.9%	9.6%	5.5%	2.8%	

Fig. 4.3.8 Inter-zonal Freight Traffic Volume



Unit: 1,000 tons per day

Fig. 4.3.9 Inter-zonal Cross-sectional Freight Traffic (1984)

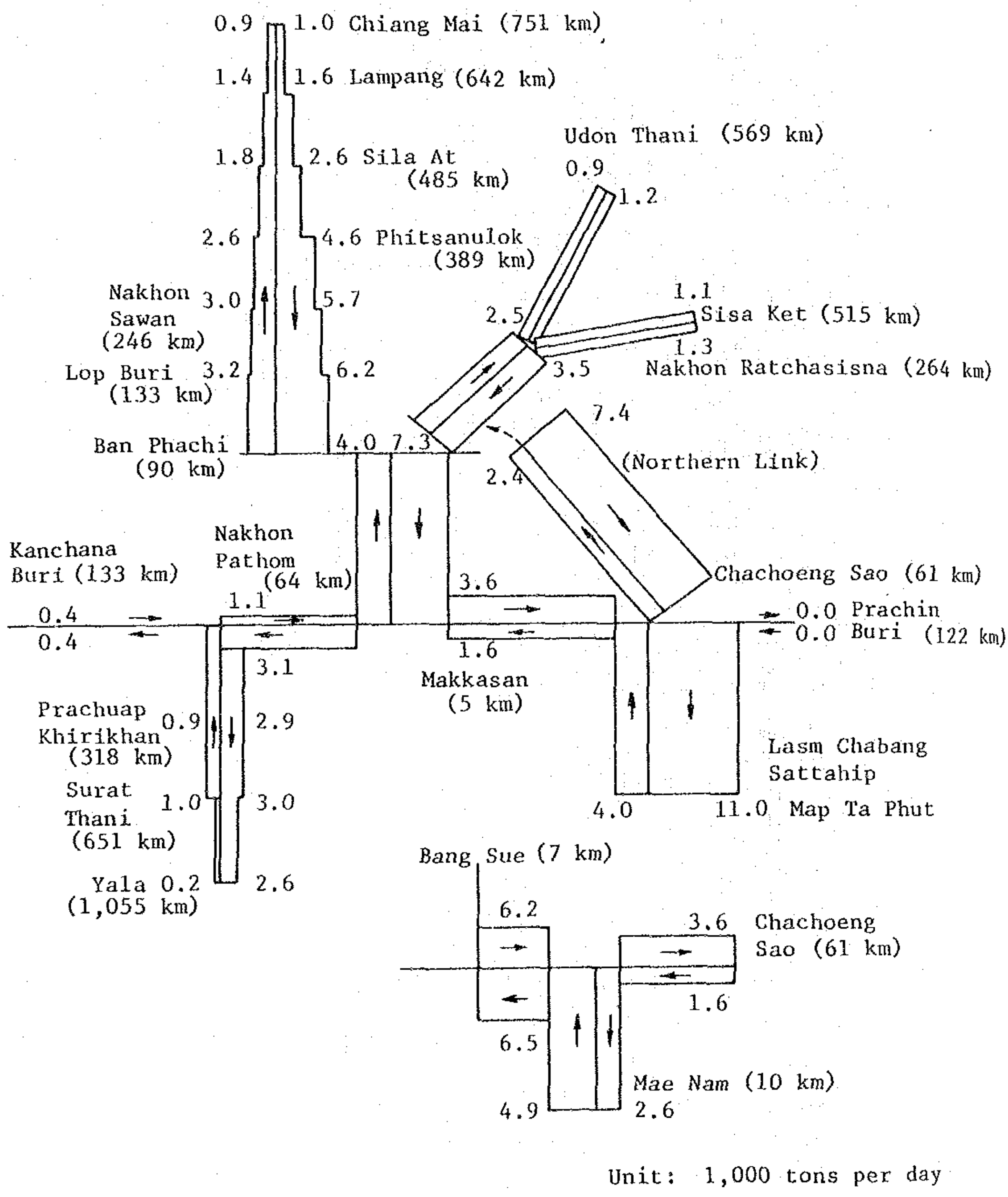
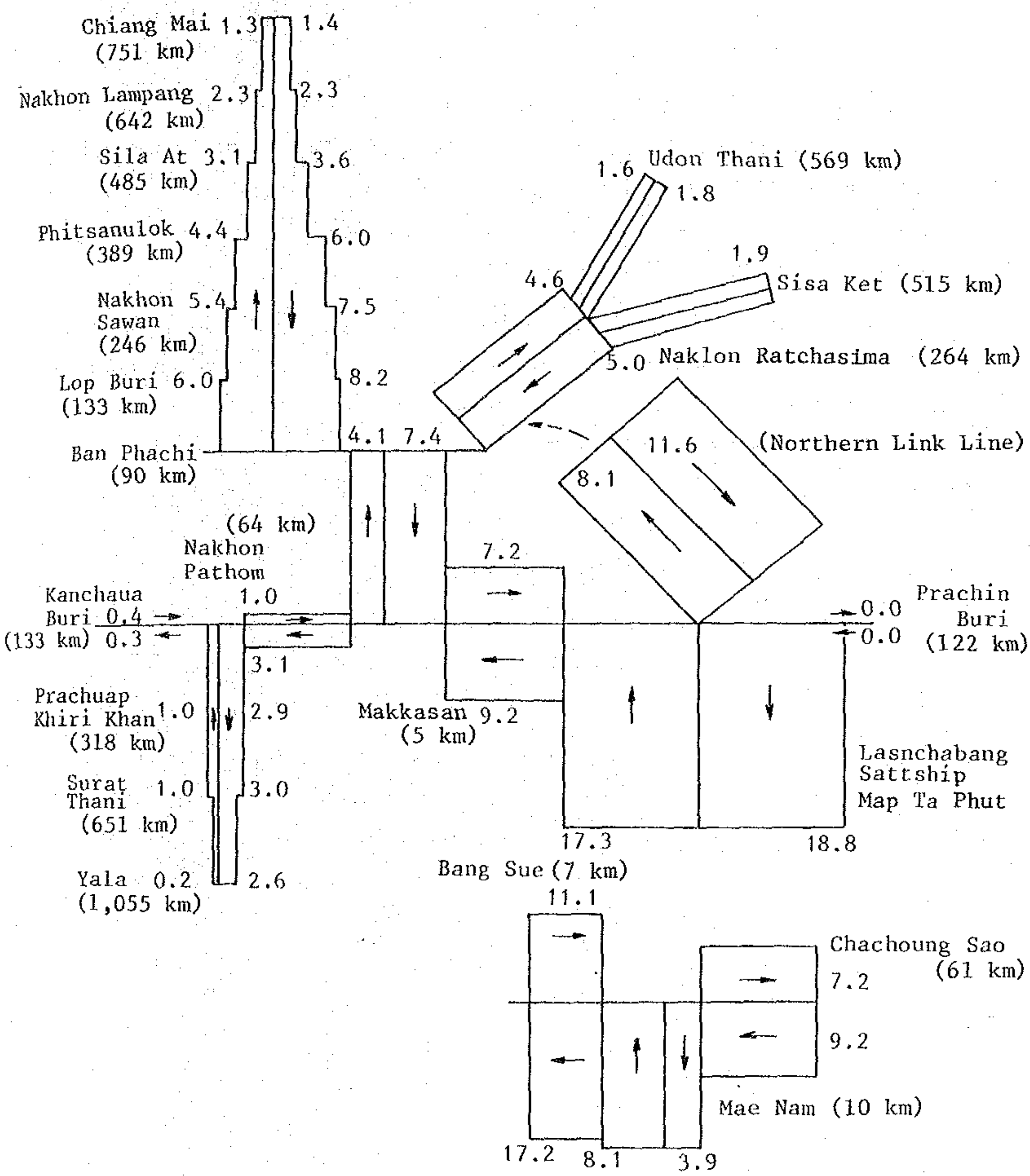


Fig. 4.3.10 Inter-zonal Cross-sectional Freight Traffic (1991)



Unit: 1,000 tons per day

Fig. 4.3.11 Inter-zonal Cross-sectional Freight Traffic (2003)

4.4 An Examination of the Results

The overall results of demand forecasting carried out in this Study are shown in Table 4.4.1.

The utmost respect was paid to the aforementioned national plans and their indices, and considerably clear-cut creations could not be helped for anything outside the scope of the plans. Thus, there are some aspects on which it is difficult to say if a sufficient traffic demand forecast was always possible.

However, according to the socio-economic framework and other preconditions established in this Study, the growth rate for traffic demand into the future shows a satisfactory increase to a noticeable degree for the objects of this forecast (inter-zonal passengers, inter-zonal freight and urban passengers). Above all, urban railway passenger traffic demand shows that more passengers can be attracted by means of transport service improvement.

Moreover, the results of the Study show that the effect by MTS will be extremely insignificant overall, because the competitive sections are quite few.

If SRT improves transportation on its own, it will greatly contribute to urban passenger transportation combining with other transportation means, especially MTS, as a mass transit system. In addition, looking at railway freight traffic demand, there has been no marked fluctuation as of late, but when the Eastern Seaboard Plan is carried out, a rapid increase can be expected.

Table 4.4.1 Summary of Results of Demand Forecast

(1) Passenger traffic demand

(Unit: 1,000 persons)

Year		1982	1991	1998	2003	(2003)/(1982)
Inter-zone		25,606	37,661	46,907	53,105	2.07
Urban	Case I	6,836	9,070	10,175	10,793	1.58
	Case II	6,836	17,329	21,330	22,636	3.31

(2) Freight traffic demand

(Unit: 1,000 tons)

Year		1981	1991	1998	2003	(2003)/(1981)
Existing Lines		5,577	6,120	6,153	6,181	1.11
Eastern Seaboard	Bangkok	-	1,870	4,530	6,008	
	Northern Link Line	-	3,605	6,174	7,181	
Total		5,577	11,595	16,857	19,370	3.47

CHAPTER 5 TRANSPORTATION PLANNING

CHAPTER 5 TRANSPORTATION PLANNING

As mentioned in the previous chapter, a considerable demand, both passenger and freight, is expected in the State Railway of Thailand (SRT).

On the other hand, transport improvement and additional train operation could not be implemented to a significant degree due to the following reasons:

Obstacles by grade crossings between Bangkok and Bang Sue/ Makkasan Station

Limited train handling capacity and Bangkok Station

Limited track capacity on each line in the metropolitan area

Chronic train delays which disturb scheduled operations

Under these circumstances, grade crossings in sections between Bangkok and Bang Sue Station as well as Bangkok and Makkasan Station which are the most serious bottlenecks should be eliminated as the first step toward transport improvement, along with improvement of related facilities.

Transportation planning on proposed elevated section and required facilities for train operation are discussed below.

5.1 Train Operation Planning

5.1.1 Assumptions

Assumptions for determining the required number of trains are as follows:

(1) Motive power tractive systems

SRT is currently implementing modernization of motive power tractive systems by introducing diesel locomotives and diesel railcars, to carry out efficient transportation.

In the final year of this Study (2003), train set-up during the peak hour zone is expected to be 4-minute headway operation, so that there is slight need for further modernization of motive power tractive system (electrification).

Thus, transportation planning is conducted on the basis of the existing motive power tractive system, considering common use of rolling stock and through train operation among lines.

In addition, when a train is set-up with headway less than 4 minutes in the future, electric railcar operation is desirable, and in this case an electrification project should be studied in line with "Techno-economic Feasibility Study for the Electrification of the Bangkok to Chiang Mai Line State Railway of Thailand."

(2) Passenger trains

Based on the demand forecast in Chapter 4, train operation planning was studied separately for long/intermediate-distance passenger trains which deal with inter-zonal passenger traffic and for short-distance passenger trains which deal with urban passenger traffic.

The basic principle for calculating the required number of trains is to keep the present level of service such as loading factor and train frequency.

The actual procedure to calculate the required number of trains is described as follows:

(i) Long/intermediate-distance trains

The number of trains per day required for inter-zonal transport (N_{PL}) is calculated from the following formula:

$$N_{PL} = \frac{\text{Cross-sectional traffic volume (persons per day outbound/inbound total)} \times \left(1 + \text{Seasonal fluctuation in traffic volume}\right)}{\text{Seating capacity (persons per car)} \times \text{Loading factor} \times \text{Average number of cars per train consist}} \quad \text{(trains per day outbound/inbound total)}$$

Where,

(a) Cross-sectional traffic volume

..... Average daily traffic volume between zones (persons per day outbound/inbound total)

The value of Fig. 4.3.3 in Chapter 4 is used.

(b) Seasonal fluctuation in traffic volume 20%

Monthly fluctuation of number of passengers (Appendix 3.3.4) is used. (117% in March and 118% in April)

(c) Seating capacity of a passenger car ..... 76 persons (Average number of seats in third-class cars)

(d) Loading factor 57%

Average number of passengers per passenger car (including van-car, postal-car and restaurant-car) of SRT was 44 persons in 1981.

Note:

$$\frac{\text{Total passenger-km}}{\text{Total passenger car-km}} = \frac{9{,}483 \times 10^6}{213{,}873 \times 10^3} = 44 \text{ persons per car}$$

Thus,

$$\text{Loading factor} = \frac{\text{Average number of passengers per car}}{\text{Seating capacity per car}} = \frac{44}{76} = 0.57$$

(e) Average number of cars per train consist ... 11 cars

The average number of cars per train consist in 1981 is calculated as follows:

Note:

$$\frac{\text{Passenger car-km per year}}{\text{Passenger train-km per year}} = \frac{213{,}873 \times 10^3}{19{,}615 \times 10^3} = 11 \text{ cars}$$

(ii) *Short-distance passenger trains*

The number of trains (N_{PS}) per day required for transportation in the Study Area is calculated from the following formula:

N_{PS} = Required number of trains per hour in peak time 1/2 Effective time zone

The effective time zone is set for 16 hours between 6:00 and 22:00.

The required number of trains per hour in peak time (M) is calculated from the following formula:

$$M = \frac{\text{Cross-sectional traffic volume} \times \text{Rate of concentration per hour during peak time}}{\text{Seating capacity} \times \text{Loading factor} \times \text{Average number of cars per train consist}}$$

(Trains per hour outbound /inbound total)

Where,

(a) Cross-sectional traffic volume

..... Average daily traffic volume in each section (persons per day outbound/inbound total)

The value in Fig. 4.3.6 in Chapter 4 is used.

(b) Rate of concentration per hour during peak time 30%

This is estimated from the ratio of the number of passengers alighting at Bangkok Station during morning rush hour (7:00 to 8:00) to the number of passengers alighting for the day (except for passengers of express and rapid trains). (Appendix 5.1.1.)

(c) Seating capacity of passenger cars ..... 76 persons (Average number of seats in third-class cars)

(d) Loading factor 150%

In SRT, an additional train is needed when the loading factor exceeds 150%.

(e) Average number of cars per train consist ... 6 cars

Six-car make-up is assumed to provide frequent service, based on the average number of cars in commuter trains (Appendix 5.1.1) which arrive at Bangkok Station during morning peak hours (7:00 to 8:00).

(2) Freight trains

Based on the inter-zonal railway freight traffic volume determined in Chapter 4, freight train operation is planned as follows.

The basic principle in establishing freight trains is to keep the present level of service, and thus normal hauling capacity per train is set at the present level.

Therefore, the required number of freight trains per day (N_F) is calculated from the following formula:

$$N_F = \frac{\text{Cross-sectional traffic volume (tons per day outbound/inbound total)} \times \left(1 + \text{Fluctuation in traffic volume}\right)}{\text{Average net ton-km per train-km (tons per train)}} \quad \text{(Trains per day outbound/inbound total)}$$

Where,

(i) Cross sectional traffic volume

..... Average daily traffic volume between zones (tons per day outbound/inbound total)

The value in Figs. 4.3.10 and 11 in Chapter 4 is used.

(ii) Fluctuation in traffic volume 30%

The fluctuation in traffic volume is set at 0.3, based on the ratio of established train-km of freight trains operated as required to one of all freight trains at present.

$$\frac{\text{Established train-km of freight trains operated as required}}{\text{Established train-km of all freight trains}} = \frac{12{,}258 \text{ km/day}}{39{,}319 \text{ km/day}} = 0.3$$

(iii) The average net ton-km per train-km (T) is calculated as follows:

$$T = \text{Freight cars per freight train} \times \text{Net ton-km per loading car-km} \times \text{Loading factor}$$

T is 350 tons when actual 1981 values are used.

$$T = 47 \text{ (cars)} \times 13 \text{ (tons per car)} \times 0.57 = 350 \text{ tons}$$

Note: The loading factor is the ratio of revenue freight car-km to all freight car-km.

$$\frac{\text{Revenue freight car-km per year}}{\text{freight All car-km per year}} = \frac{193{,}587 \times 10^3 \text{ km per year}}{338{,}103 \times 10^3 \text{ km per year}} = 0.57$$

However, for a section (Note) where traffic volume exceeds 15,000 tons per day outbound/inbound total, improvement of transport efficiency is assumed to be feasible, so that average net ton-km per train-km is set at 450 tons (approximately 30% increase compared with 350 tons).

Note: Eastern Line and Northern Link Line in 2003

5.1.2 Required Number of Trains

In accordance with the calculation procedure mentioned above, the required number of trains per day for long/intermediate-distance passenger trains, short-distance passenger trains and freight trains is calculated as follows:

(1) Required number of trains per day

(i) Long/intermediate-distance passenger train

The required number of passenger trains in the proposed elevated section is shown in Table 5.1.1.

Table 5.1.1 Required Number of Trains Departing/Arriving at Bangkok Station

(trains per day)

Line	Distance from Bangkok (km)	1983	1991	2003
Northern Line	Ban Phachi (90 km)	34	54	76
Northeastern Line	Keang Khoi (125 km)	26	44	60
Southern Line	Nong Pladuk (80 km)	18	28	40
Eastern Line	Chachoeng Sao (61 km)	22	28	46
Total		100	154	222

Required number of passenger trains between zones is shown in Fig. 5.1.1.

(ii) Short-distance passenger trains

As mentioned in Chapter 4, the required number of short-distance passenger trains is calculated for two cases (Case I and Case II). Results are presented in Table 5.1.2.

Table 5.1.2 Required Number of Short-distance Passenger Trains Departing/Arriving at Bangkok Station

(Unit: trains per day)

Line	1983	Case I		Case II	
		1991	2003	1991	2003
Northern Line	4	26	32	46	60
Southern Line	0	0	0	4	6
Eastern Line	0	16	20	28	36
(Northern ↔ Eastern Line)	(6)	(8)	(8)	(12)	(14)
Total	4	42	52	78	102

Note: ( ) represents trains operated between Don Muang and Hua Takhe.

The number of short-distance passenger trains in each section, for Case I and Case II, is shown in Fig. 5.1.2.

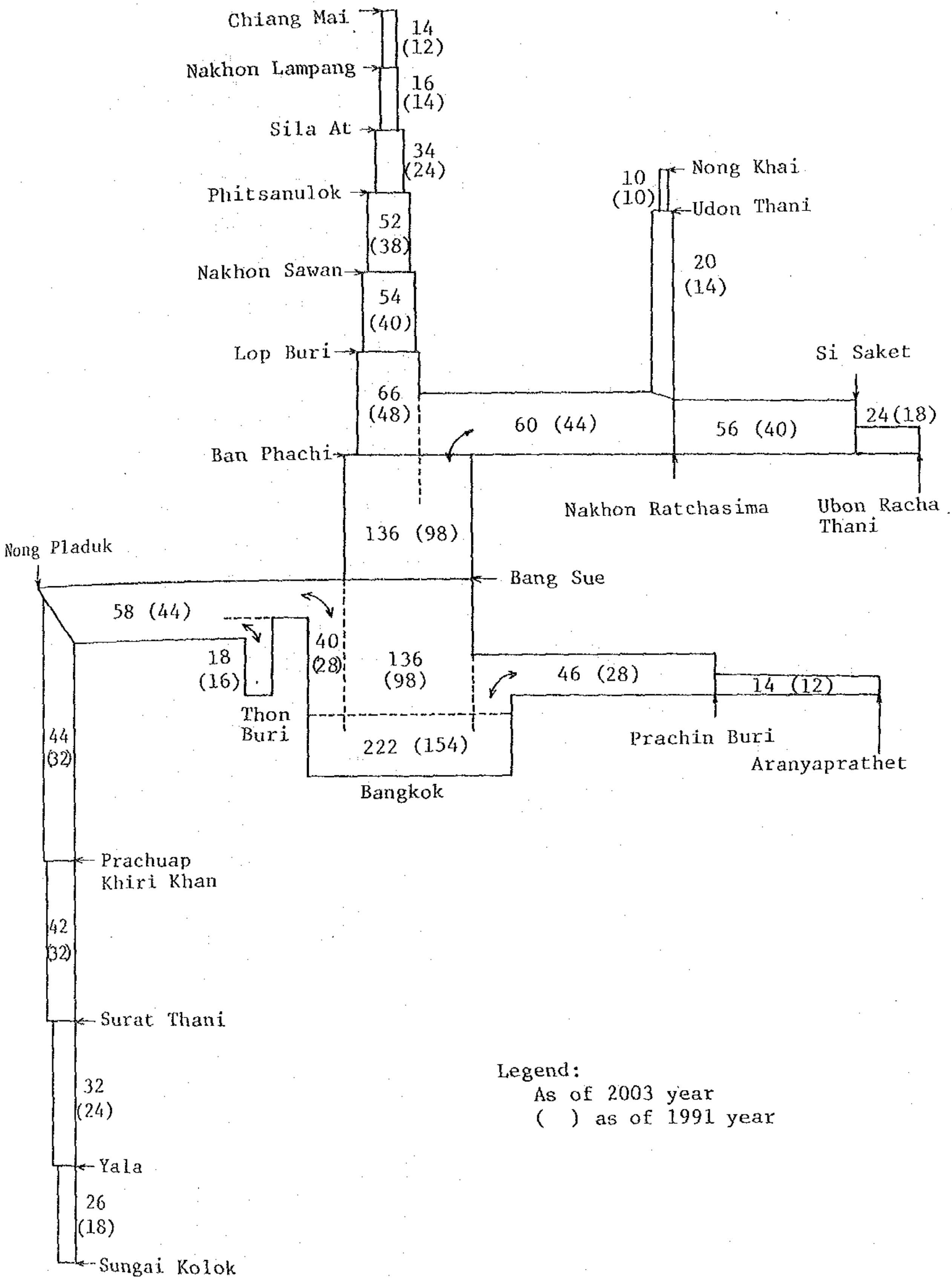


Fig. 5.1.1 Number of Long/Intermediate-distance Passenger Trains

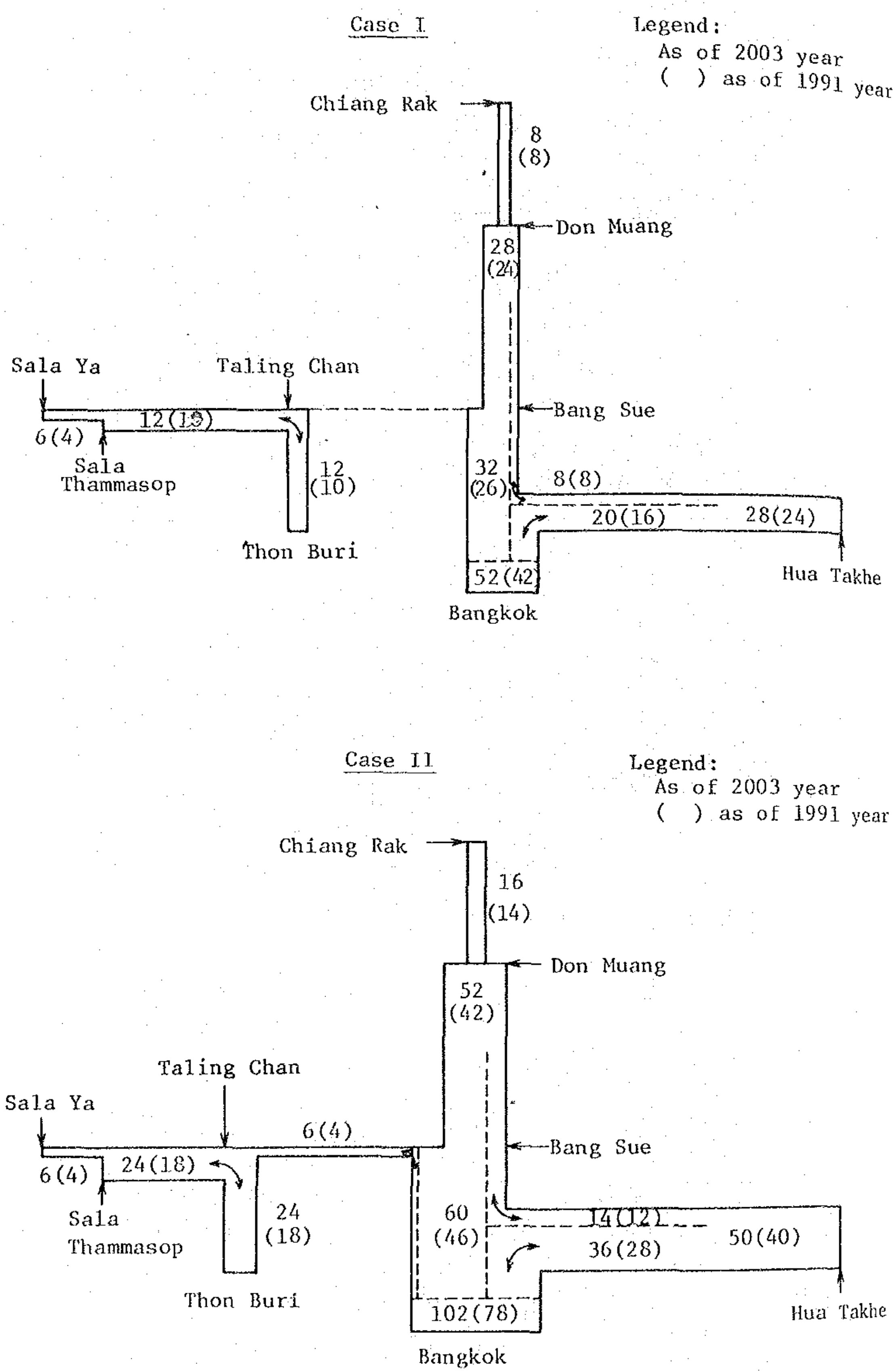


Fig. 5.1.2 Number of Short-distance Passenger Trains

(iii) Freight trains

The required number of freight trains is calculated from the traffic volume in each section. Results are as follows.

The required number of trains in the proposed elevated section is shown in Table 5.1.3.

Table 5.1.3 Required Number of Freight Trains in Proposed Elevated Section

(Unit: trains per day)

Line		Distance from Bangkok (km)	1983	1991	2003	Remarks
Mae Nam Line	Northern	Ban Mo (109 km)	(8) 12	12	16	Through train from Mae Nam
	Northeastern	Kaeng Khoi (125 km)	(4) 6	6	10	Through train from Mae Nam
	Bang Sue	Bang Sue (7 km)	12	12	18	Short-distance train (Bang Sue ↔ Mae Nam)
	Subtotal		(12) 30	30	44	
Eastern Line		Chachoeng Sao (61 km)	2	20	46	Through train from Sattahib
Total			(12) 32	50	90	

Note: ( ) represents the number of as required supplemental trains (included in the required number).

The number of freight trains in each section is shown in Fig. 5.1.3.

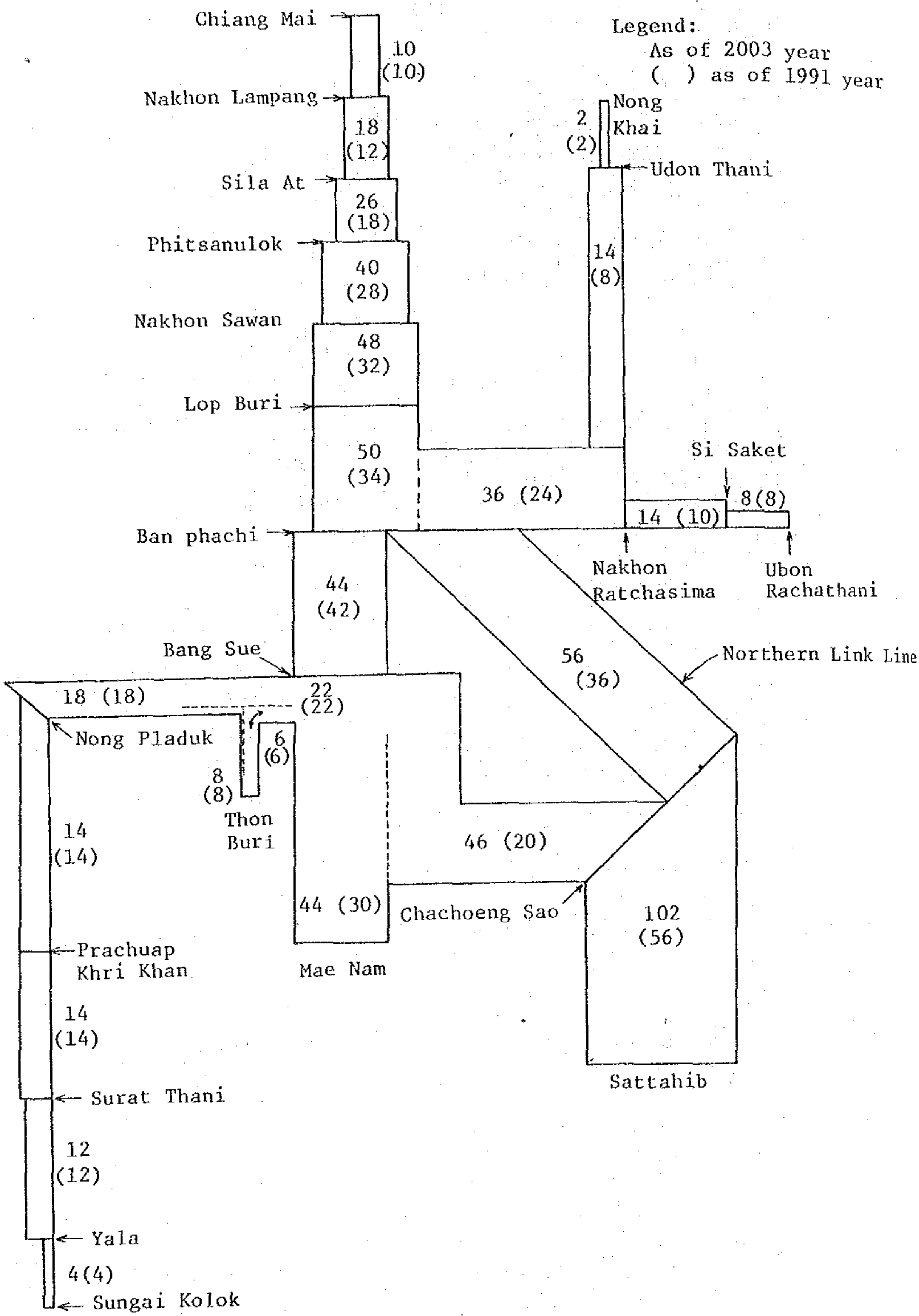


Fig. 5.1.3 Number of Freight Trains

(2) The number of passenger trains per hour during peak time at Bangkok Station

The number of passenger trains per hour during peak time at Bangkok Station, after track elevation, is shown in Table 5.1.4.

Table 5.1.4 The Number of Passenger Trains per Hour during Peak Time at Bangkok Station

(each direction)

Year / Line	1983			1991						2003					
				Case I			Case II			Case I			Case II		
	A	B	Total	A	B	Total	A	B	Total	A	B	Total	A	B	Total
Northern	3	1	4	3	2	5	3	3	6	5	2	7	5	4	9
Southern	0	0	0	1	0	1	1	1	2	1	0	1	1	1	2
Eastern	2	0	2	2	1	3	2	2	4	2	2	4	2	3	5
Total	5	1	6	6	3	9	6	6	12	8	4	12	8	8	16
Headway (min.)			10			7			5			5			4

Notes: A Intermediate/long-distance passenger trains
(Sphere beyoun 30 km from Bangkok Station)

B Short-distance passenger trains
(Sphere within 30 km from Bangkok Station)

(3) Flow of trains in the proposed elevated section

The number of required trains for the proposed elevated section is shown in Fig. 5.1.4 to Fig 5.1.8.

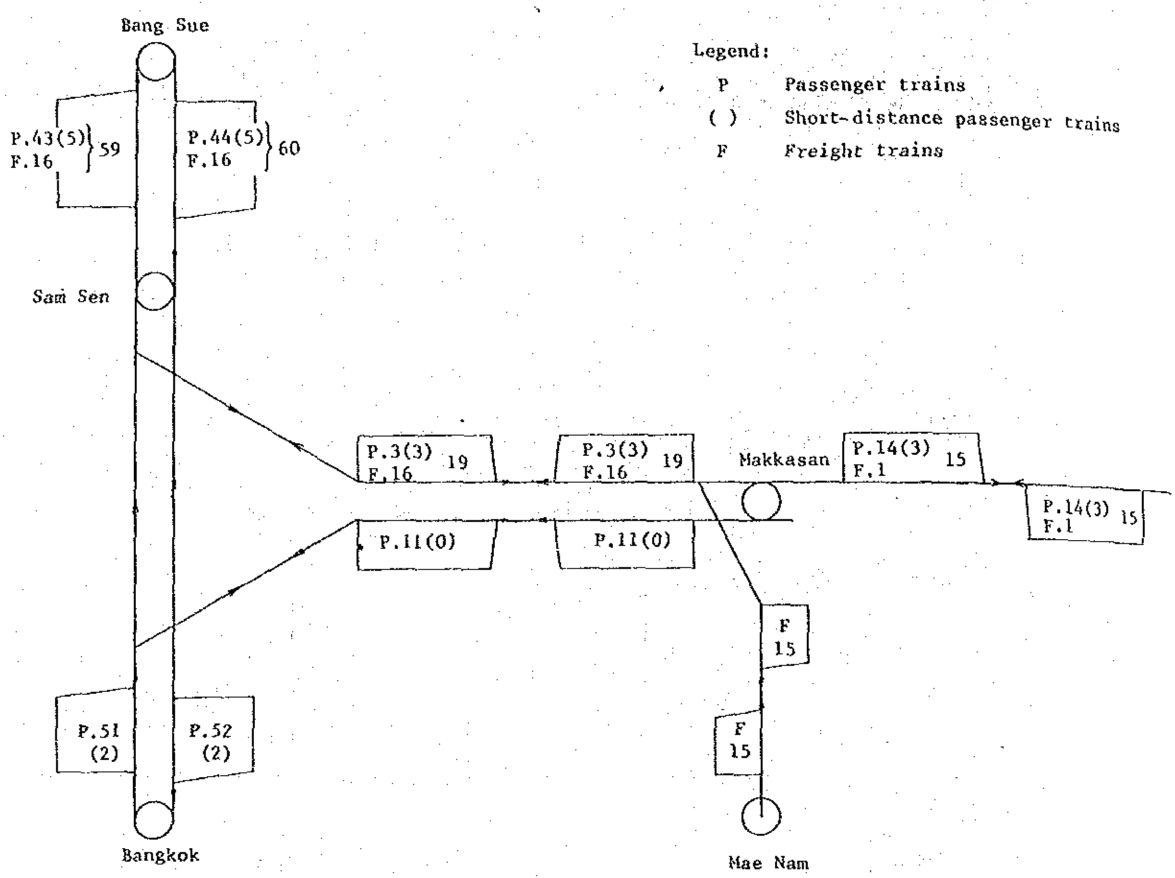


Fig. 5.1.4 Flow of Trains on Elevated Section (as of 1983)

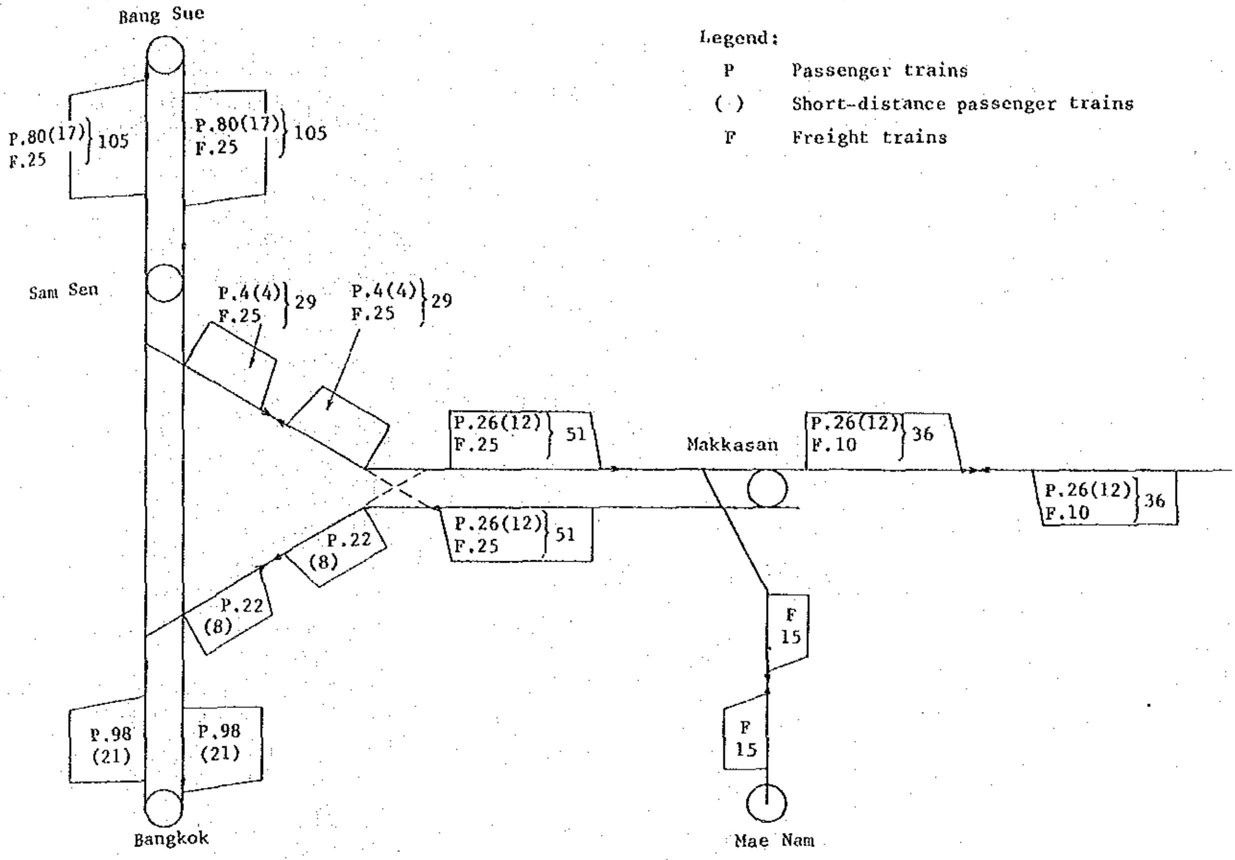


Fig. 5.1.5 Flow of Trains on Elevated Section (1991, Case I)

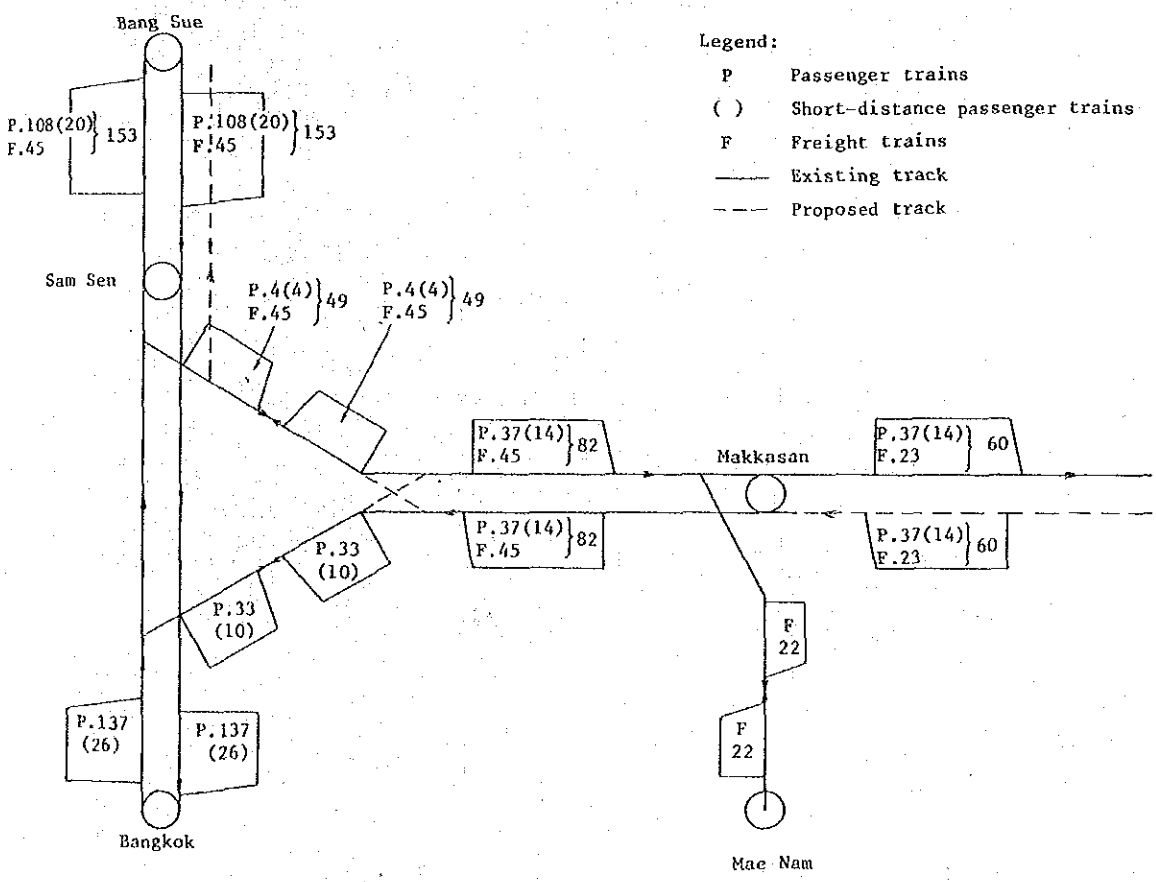


Fig. 5.1.6 Flow of Trains on Elevated Section (2003, Case I)

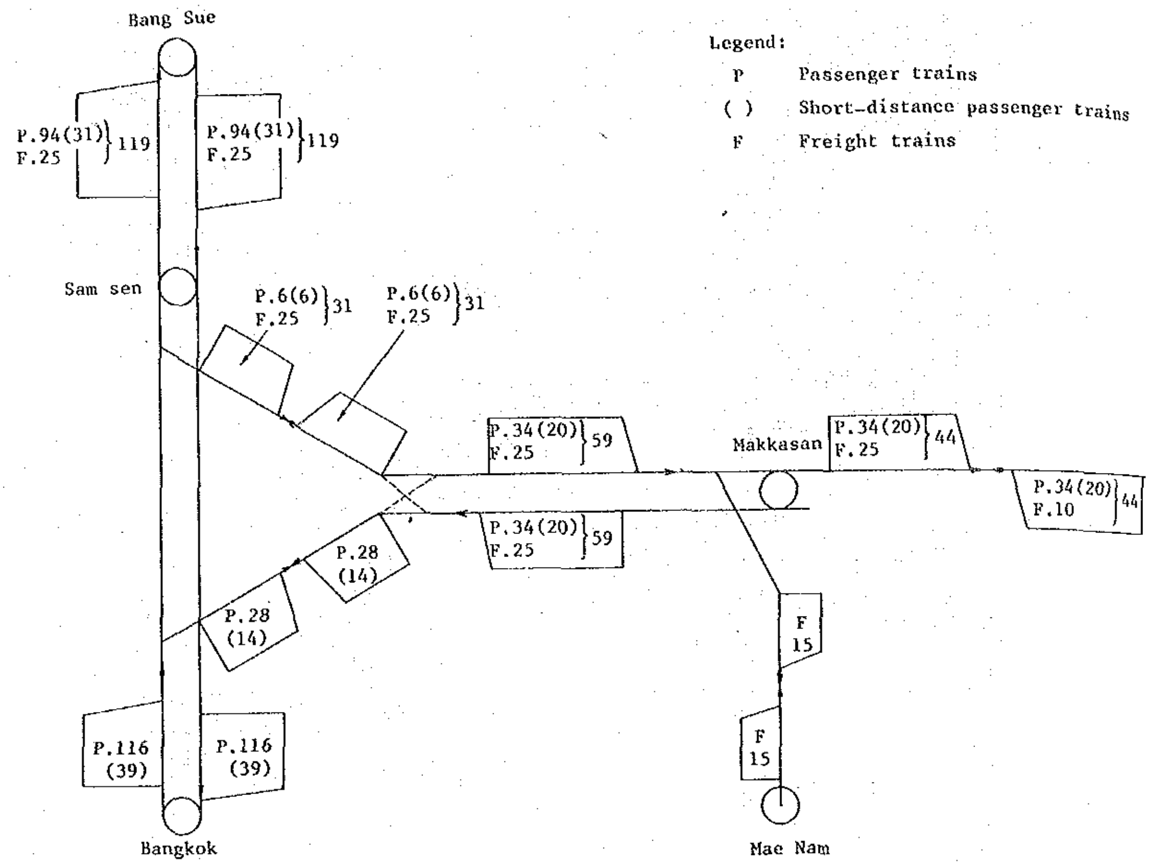


Fig. 5.1.7 Flow of Trains on Elevated Section (1991, Case II)

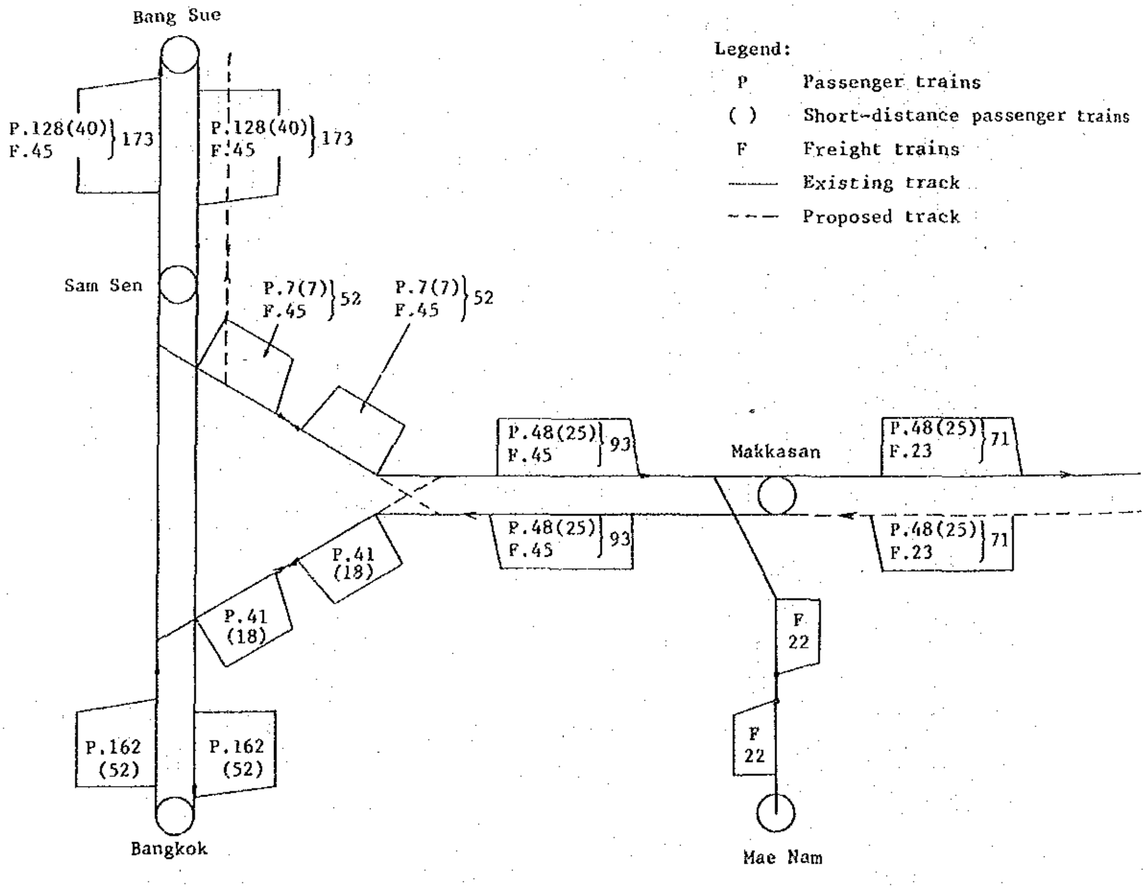


Fig. 5.1.8 Flow of Trains on Elevated Section (2003, Case II)

5.2 Rolling Stock Planning

The number of rolling stocks required to operate trains planned in 5.1.2 is calculated and basic principles of inspection/repair planning for the rolling stock are described.

5.2.1 Calculation Basis

The basic principles of calculating the number of rolling stock are that required passenger and freight train-km are first calculated from the train operation plan in 5.1.2, then passenger and freight car-km is calculated and divided by car-km per car in service per day.

Actual calculation procedure is as follows:

(1) Number of rolling stocks for passenger trains

Passenger trains are classified into passenger car (PC) trains and diesel railcar (DRC) trains under the following principles:

- All short-distance passenger trains are assumed to be DRC trains so as to facilitate high acceleration/deceleration for stopping at each station and to carry out smooth turnback operation at the platform.
- For long/intermediate-distance passenger trains, the ratio of PC trains to DRC trains in sections where DRC trains are currently operated is set at 2:1 by considering the present ratio of these two trains. Long/intermediate passenger trains operated in the Eastern Line are assumed to be DRC trains except for mixed trains, just as they are now.

(i) Required number of diesel locomotives (DL_P) for PC trains

$$DL_P = \frac{\text{PC train-km per day (= locomotive-km per day)}}{\text{Diesel locomotive-km per engine in service per day}} \text{ (cars)}$$

Where,

(a) PC train-km per day is calculated from the number of trains in each section and section length, in accordance with the following formula.

$$\text{PC train-km} = \Sigma(\text{number of PC trains in each section} \times \text{section length}) \text{ (km per day)}$$

(b) Diesel locomotive-km per engine in service per day is estimated from the recent record of use to be 420 km per day.

(ii) Required number of PCs

$$PC = \frac{\text{PC train-km per day} \times \text{Average number of cars per train consist}}{\text{Passenger car-km per car in service per day}} \text{ (cars)}$$

Where,

(a) PC train-km per day is calculated in the same method as previously done:

$$\text{PC train-km} = \Sigma(\text{number of PC trains in each section} \times \text{section length}) \text{ (km per day)}$$

(b) Average number of cars per train consist is 11.

(c) Passenger car-km per car in service per day is estimated from the recent record of use to be 670 km per day.

(iii) Required number of DRCs

$$DRC = \frac{\text{DRC train-km per day between zones} \times \text{Average number of cars per train consist} + \text{Short-distance DRC train-km per day} \times \text{Average number of cars per train consist}}{\text{Diesel railcar-km per car in service per day}} \text{ (cars)}$$

Where,

(a) DRC train-km per day is calculated for long/intermediate-distance and short-distance trains by the following formula:

$$\text{DRC train-km} = \Sigma(\text{number of trains operated in each section} \times \text{section length}) \quad \text{(km per day)}$$

(b) Average number of cars per train consist is assumed to be 11 for long/intermediate-distance trains and 6 for short-distance trains.

(c) Diesel railcar-km per car in service per day is estimated from the recent record of use to be 510 km per day.

(2) Number of rolling stocks for freight train

Basic freight car (FC) train-km (established) is calculated from the following formula:

$$\text{FC train-km (established)} = \Sigma(\text{number of FC trains operated in a section} \times \text{section length}) \quad \text{(km per day)}$$

(i) Required number of diesel locomotives (DL_F) for FC trains

$$DL_F = \frac{\text{FC train-km per day (established)}}{\text{Diesel locomotive-km per engine in service per day}}$$

Diesel locomotive-km per engine in service per day is estimated from the recent record of use to be 420 km per day.

(ii) Required number of FCs

FC train-km (established) was revised by using actual operation rate in 1982.

$$\frac{\text{Actual operation-km per day}}{\text{Train-km (established) per day}} = \frac{19{,}557 \text{ km per day}}{39{,}319 \text{ km per day}} = 0.50$$

Thus,

$$FC = \frac{0.5 \times \begin{array}{l}\text{FC train-km per day}\\ \text{(established)}\end{array} \times \begin{array}{l}\text{Average number of}\\ \text{freight cars per train}\end{array}}{\text{Freight car-km per car in service per day}} \text{ (cars)}$$

- Average number of freight cars per train is assumed to be 47.
- Freight car-km per car in service per day is estimated from the recent record of use to be 100 km per day.

5.2.2 Required Number of Rolling Stocks

In accordance with calculation procedures described in 5.2.1, the required number of rolling stocks in both the whole country and in Bangkok Metropolitan Area (BMA) is calculated and shown in Table 5.2.1.

Table 5.2.1 Required Number of Rolling Stocks

(Unit: Cars)

		1981 (in service)	Case I		Case II	
			1991	2003	1991	2003
Whole Country	DL	212	310	420	310	420
	DRC	(4) 88	(18) 330	(24) 480	(36) 350	(48) 500
	PC	980	1,200	1,600	1,200	1,600
	FC	8,064	13,000	18,000	13,000	18,000
BMA	DL	13	16	21	16	21
	DRC	(4) 22	(18) 71	(24) 103	(36) 89	(48) 127
	PC	38	54	74	54	74
	FC	654	660	908	660	908

Note: ( ) is the number of DRCs for short-distance passenger trains (included in the required number).

5.2.3 Basic Principles of Rolling Stock Inspection and Repair

In light of heavy concentration of rolling stock inspection/repair facilities in BMA and facilities necessary for substantial increase in rolling stocks in the future, rolling stock maintenance should be done under the following principles:

- Rolling stock inspection/repair facilities should be improved and strengthened in rapport with modernization and rationalization of inspection/repair work such as prolongation of inspection cycle.
- Local rolling stock depots should be utilized as much as possible in such work as trip inspection, refuelling and monthly inspection of DLs and DRCs.

- A new rolling stock depot should be constructed to deal with the increase in rolling stocks.
- Makkasan Workshop should be upgraded and expanded in order to deal with the increase in inspection/repair work, such as overall inspection, because of the increase in rolling stocks.
- A new locomotive depot and freight car depot should be constructed in Sattahib Line to deal with the demand.
- Entire train consists of DRCs and PCs should be inspected regularly, for example an entire six-car consist should be inspected at one time.

5.3 Train Operation Facilities

Train operation facilities to deal with required number of trains and rolling stocks are studied separately for the proposed elevated section and unelevated section in the Study Area.

5.3.1 Elevated Section

(1) Number of tracks

Required number of trains in the elevated section by year is as shown in Table 5.3.1.

Table 5.3.1 Number of Trains (Each Direction per Day)

Section \ Case \ Year		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
(1) Bang Sue to Chit-La-Da	Case I	105	109	113	117	121	125	129	133**	137	141	145	149	153
	Case II	119	123	128	132**	137	141	146	150	155	159	164	168	173
(2) Yoma Rat to Bangkok	Case I	98	101	105	108	111	114	118	121	124	127	131	134	137
	Case II	116	120	124	127	131	135	139	143	147	150	154	158	162
(3) Yoma Rat to Makkasan	Case I	51	54	56	59	61	64	66	69	72	74	77	79	82
	Case II	59	62	65	67	70	73	76	79	82	84	87	90	93
(4) Makkasan to Mae Nam	Case I	30	31	32	34	35	36	37	38	39	40	42	43	44
	Case II	30	31	32	34	35	36	37	38	39	40	42	43	44

Note : ** The year with more then 130 trains per day per each direction (track capacity on double-track section) except for sections where only passenger trains are operated.

Accordingly, the number of tracks in each section is planned as follows:

(i) Northern Line

In general, the track capacity in the double-track section, where both passenger and freight trains are operated, is about 130 trains per day per each direction. (Appendix 5.3.1.)

Accordingly, the section between Bang Sue and Chit-La-Da where freight trains with low-speed and poor brake performance are operated is expected to reach the limit of double-track capacity in the year below:

- Case I 1998
- Case II 1994

However, if the third track could be used exclusively for freight train, its track capacity will become around 110 trains per day. (Appendix 5.3.2.) In this case increasing traffic volume can be sufficiently handled in 2003 when the number of freight trains is expected to be 90 trains per day.

Only passenger trains are operated on the section between Chit-La-Da and Bangkok to facilitate 4 minute headway by improving signal system, so that double track will suffice up until 2003.

(ii) Eastern Line

Double-track will suffice for the section between Makkasan and Chit-La-Da/Yoma Rat, until 2003 when the number of trains per day per each direction is expected to be 83 (Case I) or 93 (Case II).

(iii) Mae Nam Line

Single track will suffice in this line until 2003 when the number of trains is expected to be 44 trains per day.

(iv) Obstruction by rail-rail grade-crossing at junction points

Obstruction by rail-rail grade-crossing at junction points in Chit-La-Da, Bang Sue, Yoma Rat and Makkasan is studied (Fig. 5.3.1).

Obstruction ratio at rail-rail grade-crossing at each junction by case and year is shown in Table 5.3.2.

In general, grade-separated crossing of railways is introduced when obstruction ratio at rail-rail grade-crossing becomes 40 to 50% when additional trains are difficult to establish.

Thus, Chit-La-Da with most serious obstruction ratio can be dealt with by efficiently utilizing relief track for temporary measures, and a new exclusive freight line is desirable as soon as possible.

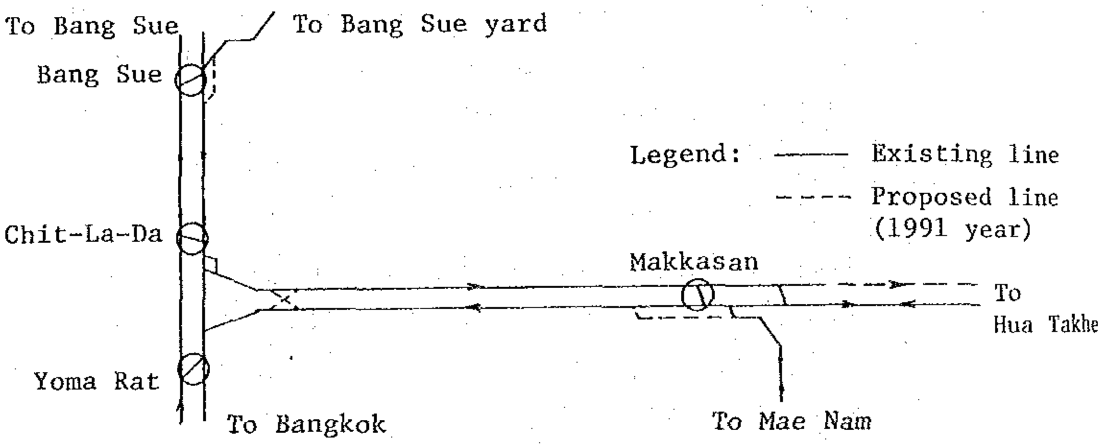


Fig. 5.3.1 Obstruction Points by Rail-rail Grade-crossing at Junction Point

Table 5.3.2 Obstruction Ratio of Rail-rail Grade-crossing

Item	Junction / Year	Chit-La-Da		Bang Sue		Yoma Rat		Makkasan		Remarks
		Case I	Case II	Case I	Case II	Case I	Case II	Case I	Case II	
Total obstructed time (min.) per day	1983	360	360	230	230	240	240	330	330	Rough estimate
	1991	410	450	340	390	330	400	210	230	
	2003	630	690	540	590	470	560	330	350	
Obstruction ratio (%)	1983	25	25	16	16	17	17	23	23	
	1991	28	31	24	26	23	28	15	16	
	2003	44	48	38	41	33	39	23	25	

Note: Obstruction ratio (C) at rail-rail grade-crossing is calculated by the following formula:

$$C = \frac{Na(Ta + Ta') + Nb(Tb + Tb')}{1,440} \times 100 \quad (\%)$$

Where,

Na, Nb — Number of trains on route A and route B

Ta, Tb — Average operating time of route A train and route B train to pass through a section obstructed by rail-rail grade-crossing point

Ta', Tb' — Setting time required for route A and route B (6 seconds when succeeding, and 20 seconds when turnout has to be switched)

(2) Track layout at station

Proposed elevated sections are relatively short; the longest section is about 7 km in the Northern Line. Among them, freight trains are operated in the section between Chit-La-Da and Bang Sue, approximately 4 km.

At the same time, the difference in travelling time among various kinds of trains in the elevated section will not be large, around 2 minutes.

Therefore, track layout at each station will be planned based on the assumption that rapid trains will not pass local trains on the elevated section.

(Track layout at each station in the proposed elevated section is presented in Chapter 7, Fig. 7.1.8.)

(3) Train operation safety facilities

(i) Automatic signal system

An automatic signal system will be installed to reduce headway with track elevating work so as to deal with operation of required trains.

In this case, in the sections where both passenger and freight trains are operated, block division should be done considering brake performance of freight trains.

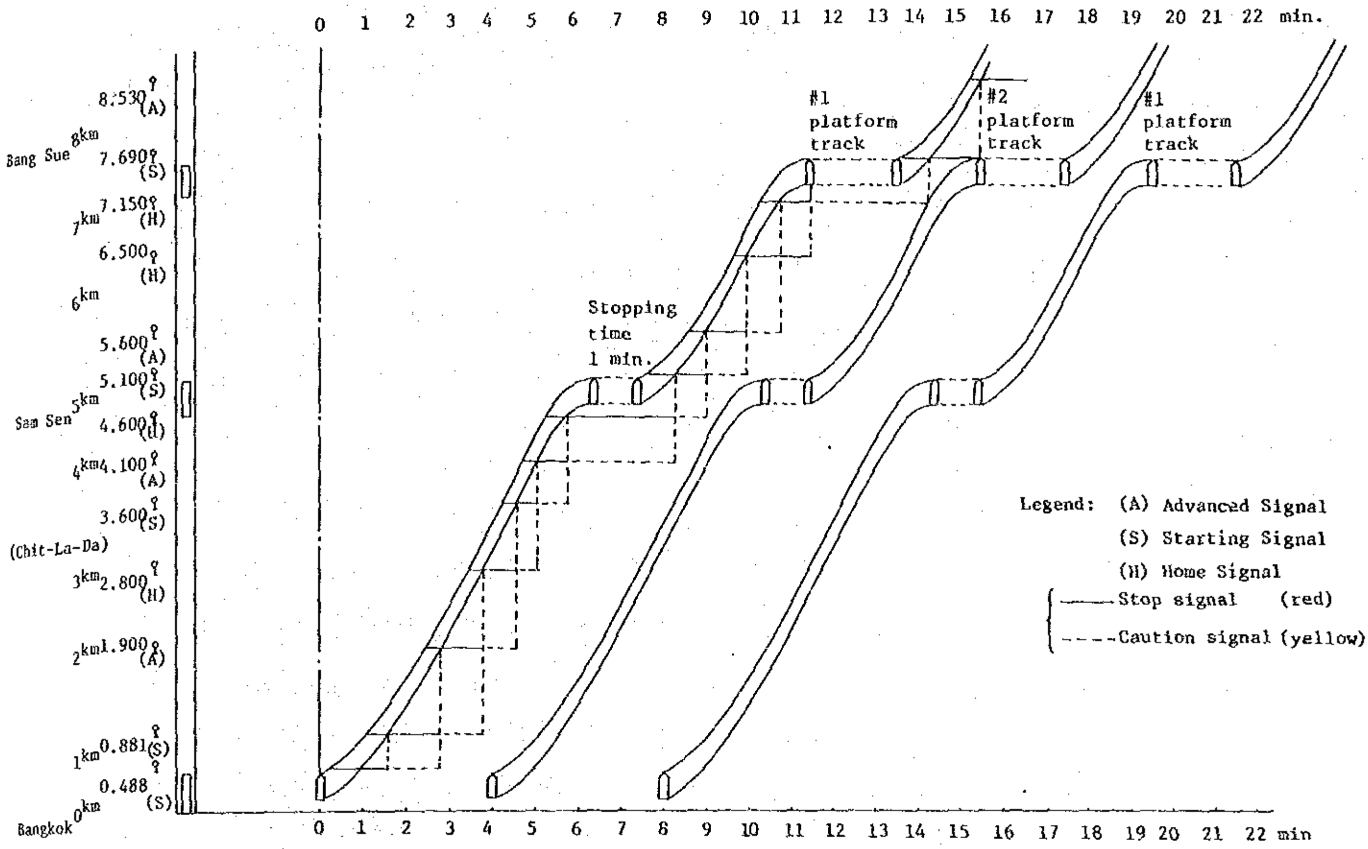
When passenger and freight train are operated on separate tracks, the minimum headway could be reduced to 4 minutes, as shown in Fig. 5.3.2.

(ii) Centralized Traffic Control system (CTC)

At present, it is difficult to adjust train operation in the rail-rail grade-crossing section, such as Chit-La-Da, when train delay occurs. (Appendix 5.3.3)

Since train frequency will further increase in the future, appropriate train operation adjustment should be implemented.

For this purpose, a CTC will be introduced in the proposed elevated section to facilitate route control for train operation in the dispatching center.



Note: For 4 minutes headway operation,

- One block section shoule be set at around 500 m of length and at 3 aspect signalling system should be employed.
- At Bang Sue Station platform sides should be alternated. (one platform - two track is used)

Fig. 5.3.2 Operation Headway (4 minutes)

5.3.2 Unelevated Section in the Study Area

(1) Number of tracks

The required number of trains in the Study Area by year is shown in Table 5.3.3. Accordingly, the number of tracks in each section is planned as follows:

(i) Northern Line (Bang Sue to Don Muang)

The number of trains is 2003 is expected to be 116 trains per day per each direction even in Case II, so that double track available at the present will be sufficient to deal with the traffic volume.

(ii) Eastern Line (Makkasan to Hua Takhe)

Single track available at the present is estimated to reach the limit of its capacity (90 trains per day) in the following years:

Case I 1996
Case II 1992

(iii) Southern Line (Bang Sue to Sala Ya)

(a) In the section between Bang Sue and Taling Chan J.

As the required number of trains is expected to exceed track capacity by 1991, both in Case I and Case II, passing facilities for train meeting/overpassing should be provided between Bang Sue and Bamru.

Note: Present track capacity between Bang Sue and Bang Bamru is 47 trains per day.

Table 5.3.3 Required Number of Trains in Bangkok Metropolitan Area

(per day)

Section	Case \ Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
(1) Bang Sue to Don Muang	Case I**	82	84	86	87	89	91	93	95	97	98	100	102	104
	Case II**	91	93	95	97	99	101	104	106	108	110	112	114	116
(2) Bang Sue to Taling Chan J.	Case I	50	51	52	53	54	55	56	57	58	59	60	61	62
	Case II	54	55	56	57	59	60	61	62	64	65	66	67	68
(3) Taling Chan J. to Sala Thammasop	Case I	72	73	74	76	77	78	80	81	82	84	85	86	88
	Case II	80	82	83	85	87	88	90*	92	93	95	97	98	100
(4) Sala Thommasop to Sala Ya	Case I	66	67	69	70	71	73	74	75	77	78	79	81	82
	Case II	66	67	69	70	71	70	74	75	77	78	79	81	82
(5) Makkasan to Hua Takhe	Case I	72	76	80	84	88	92*	96	100	104	108	112	116	120
	Case II	88	93*	97	102	106	111	115	119	124	128	133	138	142

Note: * is the year when the required number of trains is expected to exceed track capacity of single track (90 trains per day).

** is the number of trains per each direction.

(b) In the section between Taling Chan J. and Sala Thammasop

The required number of trains is expected to exceed track capacity of single track (90 trains per day) in the following years:

Case I 2004

Case II 1997

(2) Improvement of turnback station

Improvement of Bangkok Station yard is essential to strengthen transport capacity of SRT as a whole, and it should be studied individually from a nationwide perspective.

To improve passenger service, only facilities required for operation of additional short-distance passenger trains in the Study Area are described.

(i) Arrival/departure track for turnback operation

Arrival/departure tracks for exclusive use of turnback operation will be provided at Don Muang, Chiang Rak, Sala Thammasop, Sala Ya and Hua Takhe where turnback operation of short-distance passenger trains is planned.

(ii) Storage track for DRC trains

In order to increase transport capacity in the future, it is necessary to reduce rolling stock layover at Bangkok rolling stock depot and to minimize in-depot and out-depot at Bangkok Station.

For this purpose, storage tracks will be provided at DRC train turnback stations, along with daily inspection facilities and refuelling facilities. Chiang Rak and Hua Takhe are considered to be appropriate locations for such facilities.

(iii) Relocation of Makkasan Station and improvement of in-shop/out-shop tracks at the Makkasan Workshop

Makkasan Station will be relocated approximately 300 m east of the present location because of the gradient of the approach to the elevated section. In-shop/out-shop tracks at Makkasan Workshop will also be improved to allow trains to go in and out of the workshop directly.

(iv) Departure/arrival tracks addition at Bang Sue Station

The departure/arrival tracks for both passenger and freight trains will be added due to the increase of additional trains.

(3) Improvement of train operation safety facilities

(i) Northern Line (Bang Sue to Chiang Rak)

An automatic signal system will be introduced for the transport improvement in parallel with by track elevation work.

(ii) Eastern Line (Makkasan to Hua Takhe) and Southern Line

Color light signal and tokenless block installation which are currently planned will be introduced for the time being, then an automatic signal system will be installed when double track is introduced.

CHAPTER 6 SOILS AND ENVIRONMENTAL IMPACT STUDY

CHAPTER 6 SOILS AND ENVIRONMENTAL IMPACT STUDY

6.1 Soils and Hydrological Study

The purpose of the survey was to collect data necessary for the preliminary design.

6.1.1 Soils Study

(1) Soils survey

(i) Review of documents

Representative strata and soils characteristics were initially identified from the following documents:

- Study on Bangkok Soil (The Engineering Institute of Thailand, 1977)
- Feasibility Study on the First Stage Mass Transit System in Bangkok, Nov. 1979
- Feasibility Study on the Nonthaburi and Pathumthani Bridge Construction Project, May 1980
- Feasibility Study on the Second Stage Expressway System in Bangkok, Dec. 1983

(ii) Field work and laboratory test

The soil investigation work in the field and the laboratory testing were performed by a local consulting firm in September and October, 1983. The locations of ten boreholes, each to a depth of 30 to 40 m below ground surface, are shown in Fig. 6.1.1.

The summary of the site investigation work is shown in Table 6.1.1.

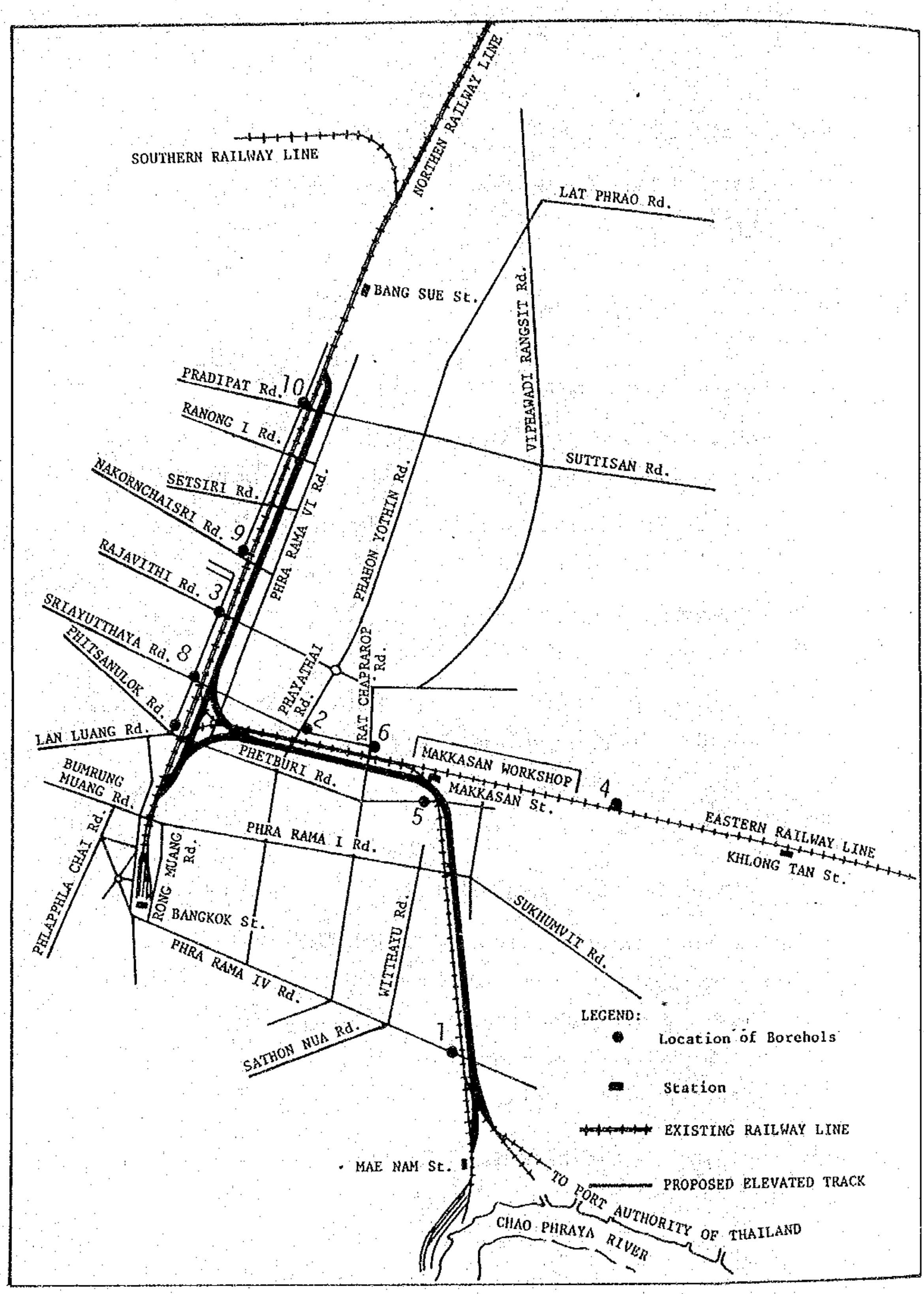


Fig. 6.1.1 Location of Boreholes

Table 6.1.1 Method of Drilling, Sampling, Field and Laboratory Tests, and Quantity

Type of boring, sampling, field and laboratory tests	Method	Depth	Q'ty	Unit
Wash boring	HVORSLEV (1965) by using rotary drilling rig 18 HP, stabilized bore hole by using 4" dia. steel casing in soft clay and bentonite mud in stiff clay and sandy soil	30.0 to 40.0 m below ground surface	322	m
Undisturbed sampling thin wall 75 mm dia.	ASTM D 1587	Only BH 1-3, at selected depth in soft and stiff clay	14	Nos.
Standard penetration test	ASTM D 1586	Every 2.0 m interval	162	Nos.
Natural water content (Lab. test)	ASTM D 2216	All samples in split spoon samplers	160	Nos.
Natural water content (Lab. test)	ASTM D 2216	In association with unconfined compression test	12	Nos.
Specific gravity	ASTM D 854	ditto	12	Nos.
Unit weight	Weight-volume measurement of undisturbed samples	ditto	12	Nos.
Unconfined compression test	ASTM D 2166	On undisturbed samples	12	Nos.
Ground water level measurement	Measurement in bore hole at the beginning of each day and at least 24 hours after completion of bore-hole		10	Nos.

(2) General description of Bangkok soil

The Study Area is underlain by an indeterminate depth of unconsolidated quarternary deposits, in the form of alternate strata of clay, sand and gravel. These deposits were formed by a series of alluvial cycles upon a depression in the present central part of Thailand created by earth crust movements during the Tertiary Age.

The marine and alluvial deposits have formed an exceptionally homogeneous and level plain. The elevation at Chai Nat is +18 meters; that at Ayutthaya, +4 meters; and that of Bangkok, only +1 to +2 meters above mean sea level. A longitudinal section through the basins from north to south is shown in Fig. 6.1.2.

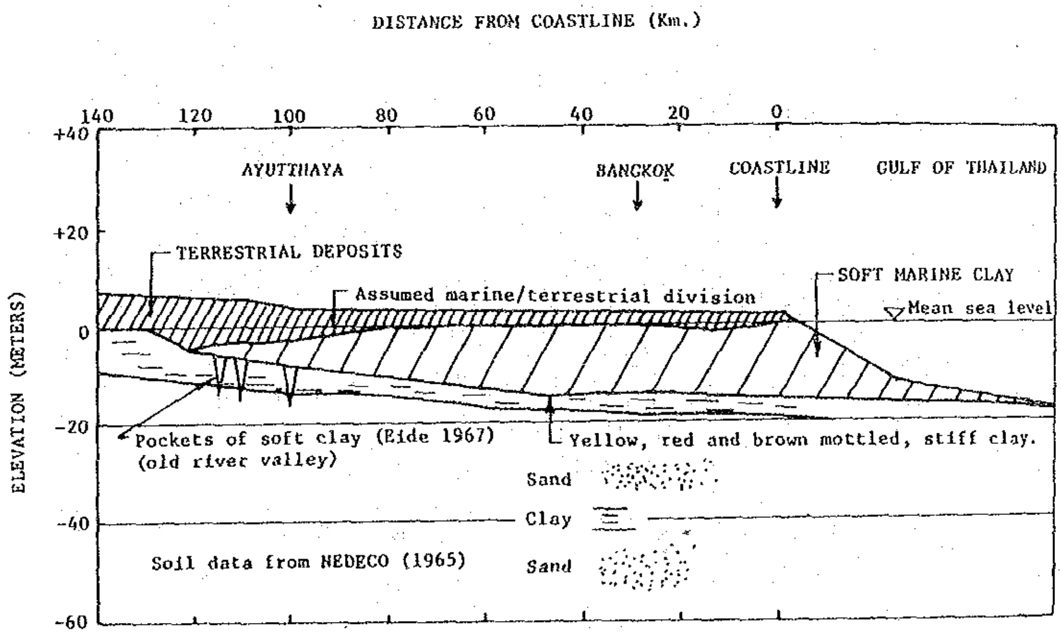


Fig. 6.1.2 Longitudinal Soil Profile

The subsoil stratification in the Study Area is summarized in Table 6.1.2.

Table 6.1.2 Stratification

Strata	Description	Depth below ground surface, m lower boundary	
		Representative range	Representative value
Soft Bangkok clay	Soft to medium silty clay, with slickenside, trace of shell bits, decayed wood and fine sand, dark grey to grey.	13 - 16	14.5
Stiff Bangkok clay	Stiff to very stiff silty clay, with slight slickenside, trace of fine sand and calcareous materials, yellowish brown to grey	20 - 28	20.5
Sand	Medium compact to compact silty fine to coarse sand, yellowish brown to grey	22 - 32	22.5 and deeper
Very stiff clay	Very stiff to hard silty clay, yellowish brown to grey	30 and deeper than 30	deeper than 30

(3) Description of subsoil

The results of field work and laboratory work are described below.

(i) Subsurface soils

Details of subsurface soils along the SRT lines are shown in Fig. 6.1.3. The bearing strata suitable for pile foundations is situated at a depth of between 20 to 30 meters below ground surface.

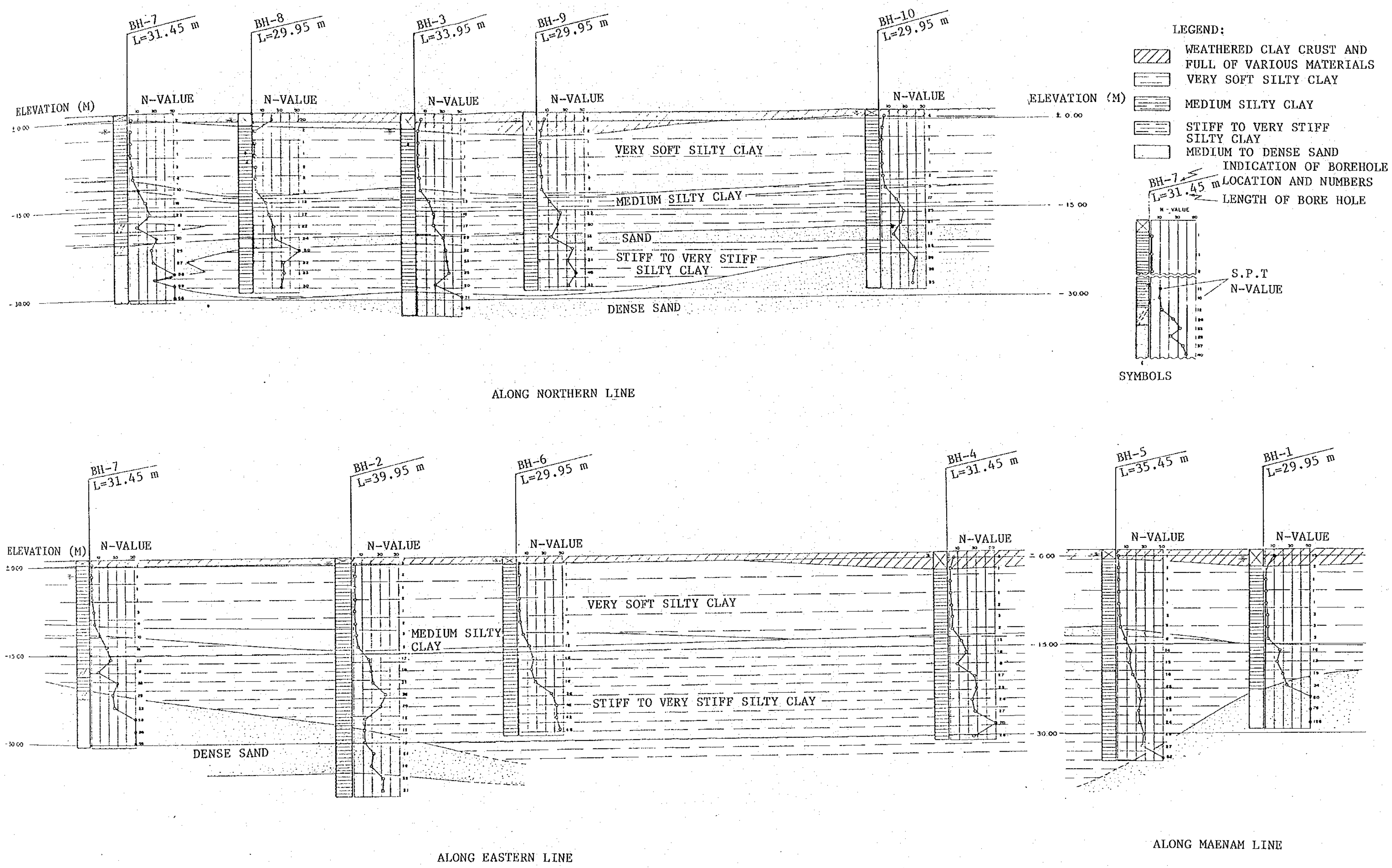


Fig. 6.1.3 Longitudinal Soil Profile

(ii) Index properties

The representative range values of natural water content, specific gravity and unit weight in the various subsoil strata are shown in Table 6.1.3.

(iii) Strength characteristics

The representative range values of the results of unconfined compression and standard penetration tests for each stratum are shown in Table 6.1.4.

Table 6.1.3 Summary of Natural Water Content, Specific Gravity and Unit Weight

Strata	Natural water content	Specific gravity	Unit weight g/cc
	Wn (%)	Gs	γ_t
Soft Bangkok clay	50 - 80	2.65 - 2.71	1.58 - 1.69
Stiff Bangkok clay	22 - 38	2.58 - 2.69	1.89 - 2.04
Sand	17 - 26	-	-
Very stiff clay	20 - 25	2.63 - 2.65	2.05 - 2.07

Table 6.1.4 Summary of Strength Characteristics

Strata	Unconfined compressive strength kg/cm^2	Standard penetration blows/30 cm
Soft Bangkok clay	0.38 - 0.66	1 - 9
Stiff Bangkok clay	1.24 - 1.88	13 - 25
Sand	-	28 - 60
Very stiff clay (not deeper than 40 m)	3.55 - 3.58	21 - 40

(4) Consideration for structural foundations

Structural foundations should be supported by bearing piles, which are driven into the stiff clay or sand strata (standard penetration test value N > 30), situated at a depth of between 20 and 30 meters below ground surface.

A very soft clay strata (N ≒ 1.0) exists from ground surface to a depth of 10 m, so it is necessary to consider horizontal forces in the design for pile foundations.

For the embankment sections, countermeasures against settlements due to consolidation and differential settlement are required.

6.1.2 Hydrological Study

(1) Rainfall

The climatological data in the Study Area is shown in Table 6.1.5.

This information is supplied by Bangkok Metropolis gauging station and is based on observations over the 30-year period 1951 to 1980.

The mean annual rainfall is seen to be close to 1,500 mm with over 50% of the total occurring during the three months August, September and October, when the Southwest monsoon brings a stream of warm, moist air from the Indian Ocean. The level of the ground water table is governed by the close proximity of the sea and the drainage system of the area. Even in the dry season, the water table is unlikely to fall more than 2 m below the ground surface. During the wet season the water table often reaches the ground surface.

Table 6.1.5 Summary of Temperture, Rainfall and Wind Data (1951 to 1980) in the Study Area

Month	Temperature (°C)					Rainfall (mm)			Wind (knots)	
	Mean	Mean max.	Mean min.	Ext. max.	Ext. min.	Mean	Mean rainy days (No.)	Greatest in 24 hrs.	Mean wind speed	Max. wind speed
January	25.6	31.9	20.6	36.0	9.9	10.3	1.7	39.3	3.6	31
February	27.2	32.7	22.8	36.6	14.9	30.7	3.0	73.0	5.1	37
March	28.6	33.8	24.6	39.8	16.5	23.7	3.3	52.8	5.8	48
April	29.6	34.9	25.7	40.0	19.9	63.5	6.2	133.5	5.7	56
May	29.1	34.1	25.4	39.4	21.1	185.3	15.6	124.2	4.6	42
June	28.6	33.0	25.1	37.7	21.7	159.8	16.7	167.3	4.8	43
July	28.1	32.5	24.8	37.8	21.9	170.7	18.3	108.8	4.5	43
August	27.8	32.2	24.7	36.3	21.2	198.2	20.6	97.8	4.6	45
September	27.6	31.9	24.4	36.0	21.3	341.8	21.3	153.7	3.8	44
October	27.5	31.7	24.3	35.3	18.3	221.3	16.7	123.2	3.3	40
November	26.6	31.3	22.8	35.1	14.2	44.0	5.5	81.2	3.5	45
December	25.5	31.3	20.7	35.2	10.5	8.9	1.4	32.0	3.4	31
Annual	27.7	32.6	23.8	40.0	9.9	1,485.2	130.3	167.3	–	–

Note: 1 m/sec = 1.944 knots

(2) Heavy floods in the Study Area

Recent heavy floods in the Study Area occurred in 1975, 1978, 1980 and 1983. Among these, the 1983 flood was the most serious in the past 40 years and was caused by continuous heavy rainfall from the middle of September to the end of November.

The depth of the flood water on some roads in the Study Area was 10 to 30 cm, and the Eastern Railway Line was flooded up to the rail level eastwards from Makkasan station. The major causes of flooding in the Study Area are:

- High-intensity, heavy rainfall
- Increased run-off coefficient due to the rapid urbanization
- Low, flat plain and high tide of the Gulf of Thailand
- Progression of land subsidence due to excessive groundwater withdrawal

(3) Height of finished grade and drainage

The topography of the Study Area is very flat and the altitudes range from 1 m to 2 m above mean sea level. Consequently, the Study Area is subjected to periodic flooding, and a certain finished grade height in the embankment section is required.

The provision of adequate drainage is extremely important for the maintenance and safety of railway and roads. The areas where attention must be directed can be categorized as follows:

- Surface water drainage (rainwater on the pavement surface and embankment slope);
- Adjacent territory drainage (rainwater on the fields, grass land and inhabited areas);
- Water openings for rivers and water way (Khlong) which the railway will have to cross.

6.2 Environmental Survey

An environmental survey for the proposed elevated section was conducted with respect to noise, vibration, environmental spoilage and building height limitations.

The locations selected for the noise and vibration survey are listed in Fig. 6.2.1, and the measurement results are provided in Tables 6.2.1 and 6.2.2. Table 6.2.3 provides measurement data.

Table 6.2.1 Measured Data of Noise and Vibration by Rolling Stock

Measured Point No.	Rolling Stock	Noise (dB)	Vibration (dB)	Running Speed (km/h)
1	DL (ALSTHOM)	89	64	47.4
	"	100	63	39.7
	"	85	59	29.5
	DRC (NEW TYPE)	85	64	42.7
	"	83	64	36.9
2	DL (ALSTHOM)	99	61	47.1
	"	92	59	45.2
	DRC (OLD TYPE)	93	63	55.5
	"	85	60	48.3
3	DL (ALSTHOM)	90	60	31.2
	"	85	59	19.5
	DRC (NEW TYPE)	89	59	33.1
	"	82	57	27.6
4	DL (G.E.)	92	56	40.0
	"	88	56	35.1

* Measured point: 6.25 m from Running Track Center

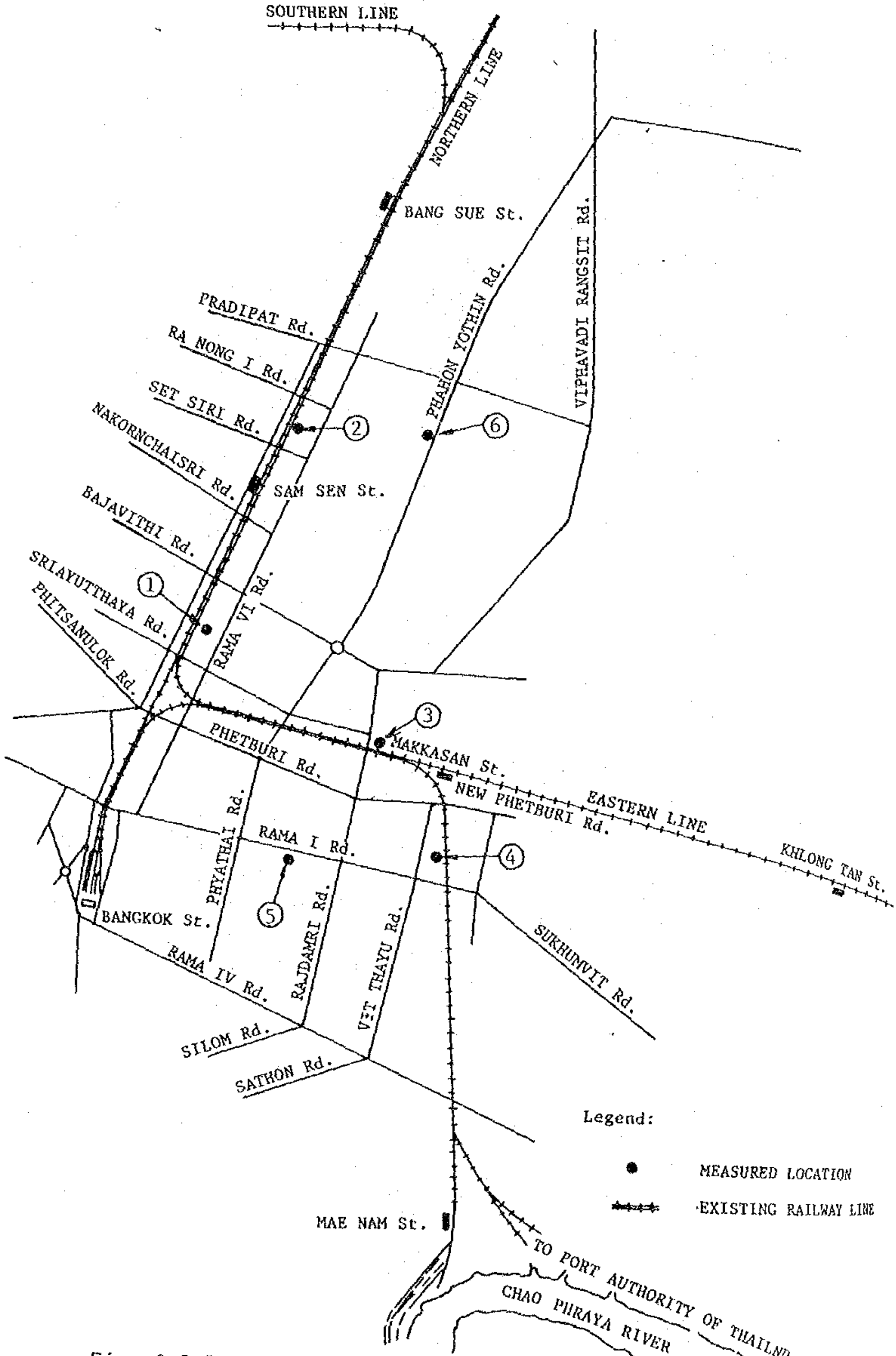


Fig. 6.2.1 Location of Noise and Vibration Survey

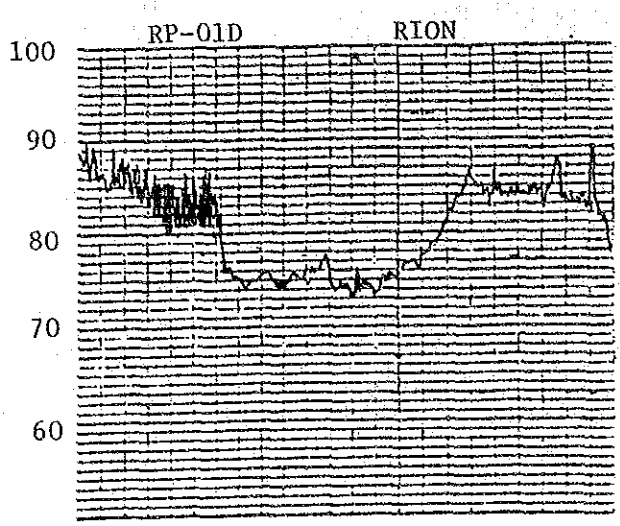
Table 6.2.2 Measured Data of Noise and Vibration by Vehicles

Measured Point No.	Classification	Noise (dB)	Vibration (dB)	Running Speed (km/h)
5	Bus	88	56	About 5 ∿ 15
	Truck	89	54	
	Motorcycle	90	-	
	Tricycle	89	-	
	Sedan	83	-	
6	Bus	87	57	About 30 ∿ 40
	Truck	88	55	
	Motorcycle	83	-	
	Tricycle	87	-	
	Sedan	80	-	

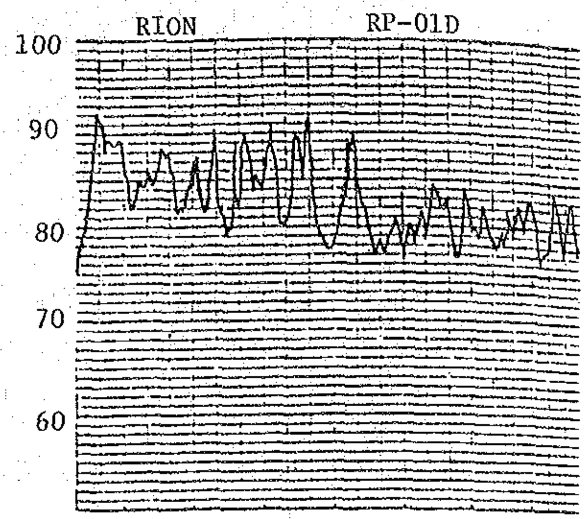
* Measured point: End of footway (roadway side)

Table 6.2.3 Examples of Measured Data

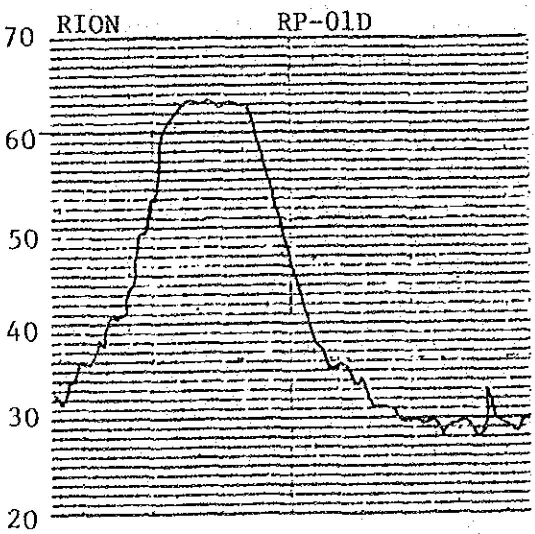
Railway Noise



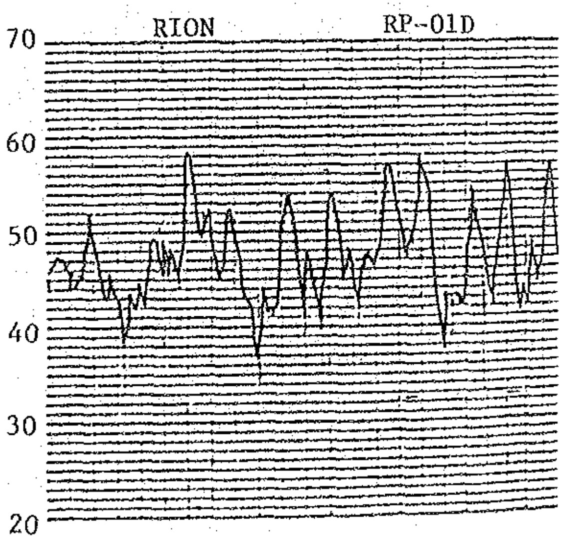
Road Traffic Noise



Railway Vibration



Road Traffic Vibration



6.2.1 Noise

(1) Present noise level

The survey result indicates that the noise level of operating trains is almost equal to that of J.N.R.

The noise level measured at a point 6.25 m from the track center was usually between 85 and 93 dB. Occasionally, however, the noise level rose to 100 dB, probably due to unskilled operation or poor maintenance.

Noise at the comparatively high level of 90 to 100 dB came from diesel locomotives in a power running condition in most instances.

Noise from road traffic is relatively high, exceeding 90 dB regardless of vehicle types. This situation is true of all major existing roads.

Such a high level of noise may be attributable to poor maintenance and rough driving of cars in addition to the number of cars which exceeds road capacity.

This is conspicuously true of specific vehicles such as buses, tricycles and two-wheeled vehicles.

Table 6.2.4 illustrates general noise level patterns in urban areas.

Table 6.2.4 General Noise Level

120	Rivet Gun (1 m)
110	Klaxon of Car
100	Compressor (1 m)
90	Interior of Bus
80	Traffic in Big-city
70	Busy Street
60	Ordinary Conversation
50	Silent Clerical Room
(dB)	

Note: ( ) is distance from the noise source.

(2) Noise assessment

The noise of railway traffic is influenced by diverse factors such as train speed, car type, maintenance and operation, track maintenance, ground quality, and structure form.

The major sources of noise from railways in Thailand are classified into locomotion noises (from the engine, generator and drive unit), friction noise of wheels against rail, noise from rail joints and structural noise. The biggest factor is locomotion noises.

The present railway noise levels are somewhat higher than those of vehicles. Nevertheless, public displeasure is likely to be relatively low because trains pass quickly and the right of way is nearly 20 m on either side of the track.

If the following countermeasures are taken, it is expected that the noise level of railway traffic, after track elevation, can be reduced by 10 dB or so at least, which is equal to or below the present noise level from road vehicles.

Removal of rail joints	A reduction of 4 to 5 dB
Use of rubber pads	A reduction of 3 to 6 dB
Use of concrete sleepers	A reduction of 3 to 5 dB
Erection of noise insulation walls	A reduction of 8 to 10 dB

(3) Noise prevention measures

The following measures will be taken to reduce in connection with the track elevation.

a) Rail length extension and use of PC (Prestressed Concrete) sleepers

Rails will be welded together to extend the length and reduce the number of joints because joints in the tracks are one of the main sources of noise. Furthermore, to enhance the noise-reduction effect, the elastic fastening system will be applied to rails, combined with the use of PC sleepers.

b) Use of rubber pads

Rubber pads will be inserted between rail and sleepers.

c) Erection of noise insulation walls

Noise insulation walls will be provided for the whole length of the viaducts to minimize noise leakage to the outside.

d) Conversion to concrete structures

The structures will be designed mainly for construction using concrete. If steel is used, the bridges should be designed with a ballast-type floor for good noise insulation.

For the future, it is desirable that, together with the aforementioned measures, a buffer zone on both sides of the tracks should be established with trees, paths and parks to further reduce noise. This should be done in coordination with urban development plans.

6.2.2 Vibration

(1) Present vibration levels

As noted in the measurement results, vibrations from trains do not adversely affect the environment of residents living close to the railway. This is because trains are not operated at high speeds ahd the track is well maintained.

(2) Vibration assessment

The vibration level measurements were within the range of 53 to 64 dB near the track. However, the results measured at the end of the right of way were below 50 dB because of the reduction by distance and ditches between the measurement site and the track center.

Table 6.2.5 illustrates human sensations at various vibration levels. As noted in the table, human sensing of vibrations usually begins around 55 dB. Therefore, no problems from vibration are anticipated from the present vibration level.

Table 6.2.5 Feeling with Vibration Level

Vibration Level (dB)	Human Body Feeling
Less than 55	No feeling
55 to 65	Feeling to sensitive persons only.
65 to 75	Slight swing of electric lamp hung from ceiling.
75 to 85	Pretty large swing of electric lamp hung from ceiling.

(3) Vibration prevention measures

The results of the vibration survey indicate that no particular measures are needed against vibrations at present. The condition will become better, if deep piles extending to the stiff bearing strata are used for foundations of viaducts.

6.2.3 Preservation of the View and Height Limitations

(1) Preservation of the view

Special consideration must be given to the area around the Chit-La-Da Palace because of its aesthetic importance; consequently, the Project should be designed to preserve the envi-ronmental harmony. Certain measures may be required of the Palace, for instance, the provision of a buffer zone with trees.

(2) Height limitation

As seen in Fig. 6.2.2, there is a restriction on the height of structures to be constructed near the Palace. This regulation must be strictly observed in planning the track elevation Project.

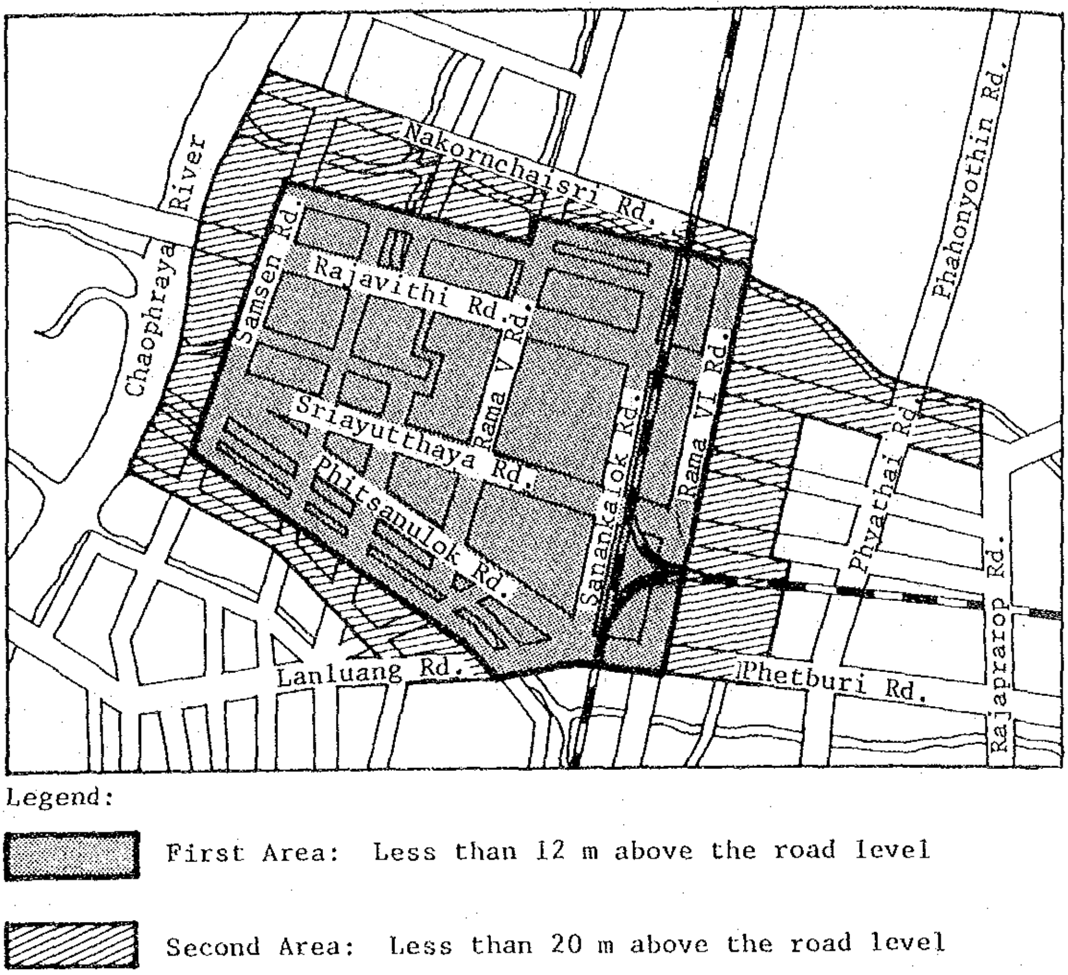


Fig. 6.2.2 Areas with Building Height Restriction

CHAPTER 7 RAILWAY FACILITIES PLAN

CHAPTER 7 RAILWAY FACILITIES PLAN

7.1 Elevated Track Planning

7.1.1 Basic Concept

In planning for the Study Area, various design factors, such as economic advantages, functional efficiency, work execution, environmental protection, utilization of areas under elevated track, related urban facilities and other related plans should be coordinated.

To ensure efficient financial investment, the work will be executed on a step-by-step basis considering trends in traffic demand.

The proposed elevated section covers a length of about 13 km.

7.1.2 Design Standard

(1) Permanent facilities

A roadway diagraph and track clearance are shown in Figs. 7.1.1 and 7.1.2. Other standards are specified in Table 7.1.1.

The embankment height is designed to be less than 3 m as seen in Fig. 7.1.3.

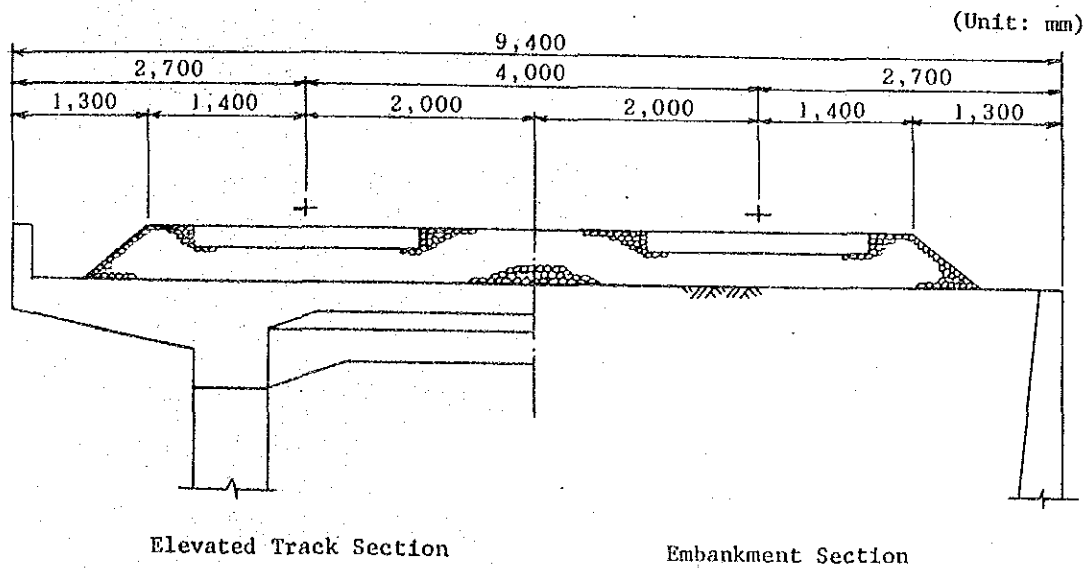


Fig. 7.1.1 Roadway Diagraph

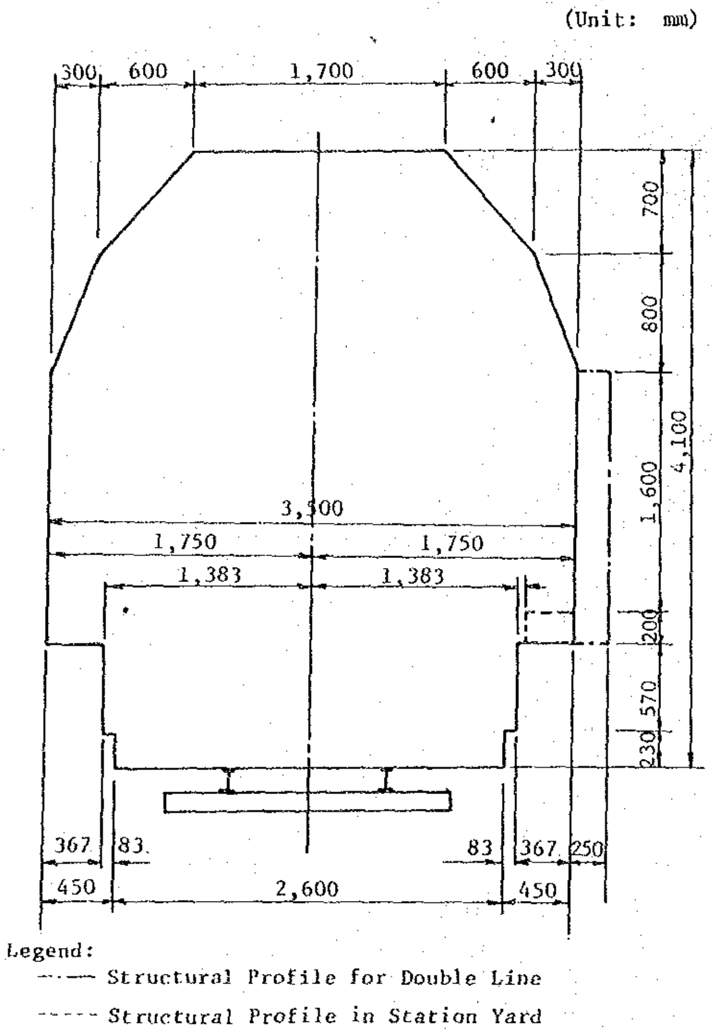


Fig. 7.1.2 Track Clearance (in general)

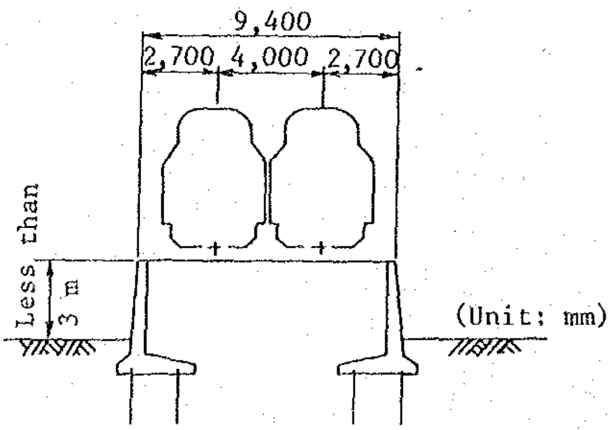


Fig. 7.1.3 Embankment with Retaining Wall

Table 7.1.1 Construction Standard

Items	Terms	Remarks
Maximum design speed	100 km/h	
Minimum curve radius	400 m	
Maximum grade	10 ‰	in general
	13.5 ‰	in special case
	1.1 ‰	in station
Vertical curve	5,000 m	
Distance between track centers	4 m	outside a station yard
	4 m	between the main and side tracks
	4 m	between side track
Width of formation	9.4 m	
Rail	80 1B/yd	
Sleeper	PC Sleeper	
	65 cm	spacing
Minimum depth of ballast below sleeper	25 cm	
Turnout	12 #	in general
Overhead clearance	5.1 m	above rail level
	5.0 m	under railway structure

(2) Design load

The design live load follows the U-20 loading pattern as seen in Fig. 7.1.4. Both load combination and allowable stress will be based on the applicable standards of JNR. No seismic load is considered in the design.

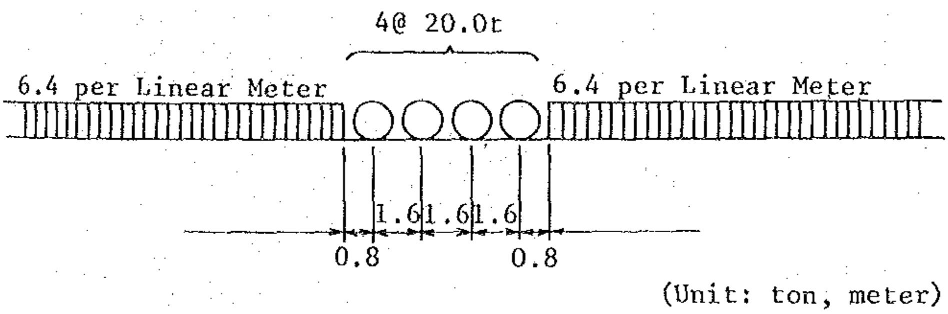


Fig. 7.1.4 U-20 Loading (Loading in Metric Tons)

(3) Bridges

Track clearance for bridge sections is as shown in Fig. 7.1.5. Although the structure will be designed to be of prestressed concrete bridge in principle, steel bridge with ballast may be used where it is difficult to secure the required clearance under a bridge as shown in Table 7.1.1. Bridges over a road will generally be designed with two spans by constructing piers in the median strip of the road.

(Unit: mm)

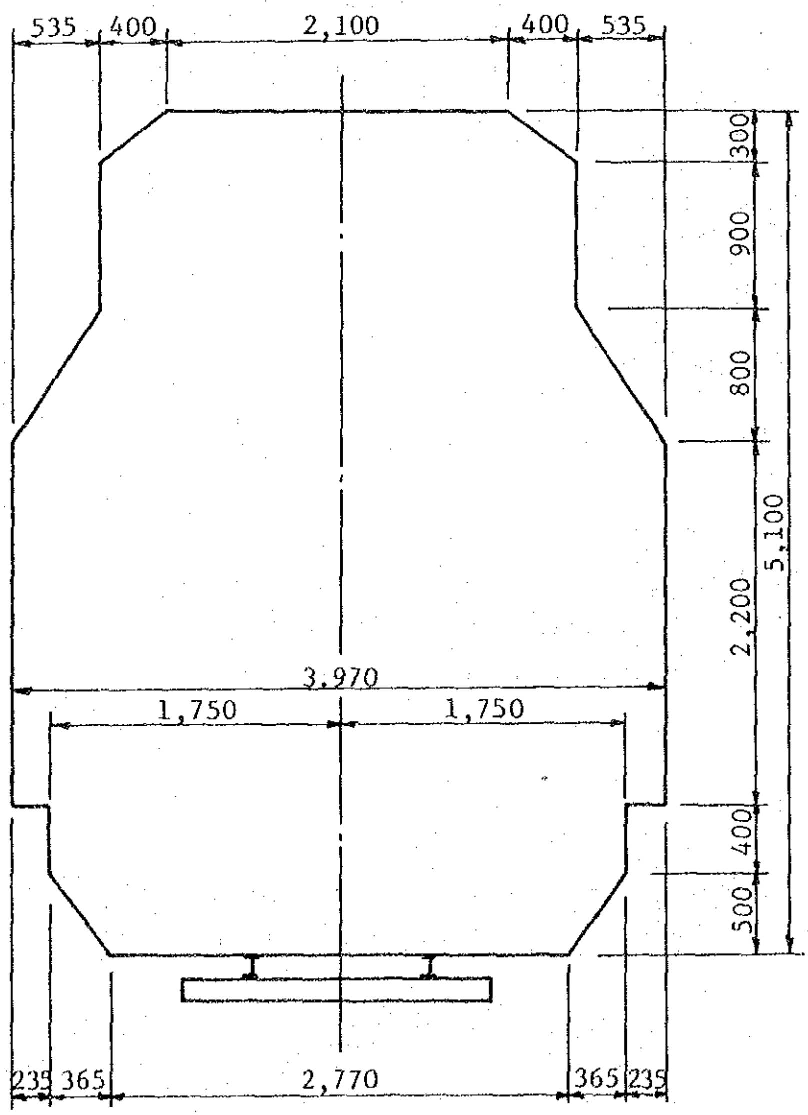


Fig. 7.1.5 Track Clearance for Railway Bridge

(4) Station facilities

Each station of the proposed elevated section will be provided with an office room, a waiting room and a concourse. The platform is designed to have a medium height as shown in Fig. 7.1.6.

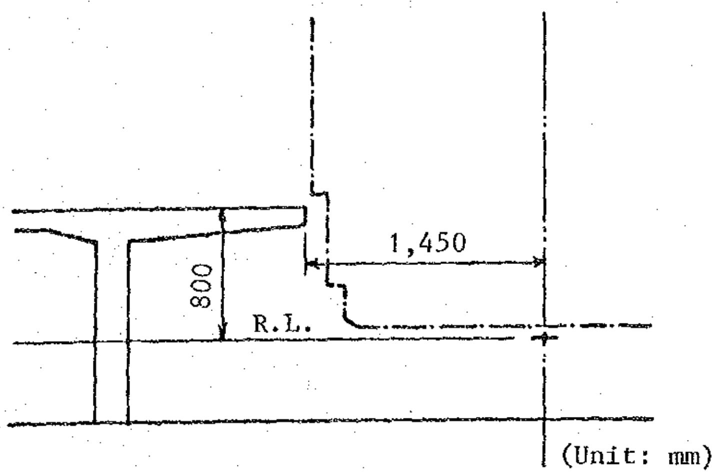


Fig. 7.1.6 Planned Section of Platform

(5) Elevated structure

The elevated track structure must be designed to be lower than the height limitations specified in 6.2.3.

7.1.3 Alignments

(1) The terms of planning

The construction standard as shown in Table 7.1.1 will apply to the designing of the plane and profile alignment.

However, if the application of such standards is restricted by individual site conditions, the standards may be eased to a degree to accommodate site conditions.

Location of the proposed elevated section should be as per Fig. 7.1.1 as shown by SRT.

(2) Plane alignment

The final plane alignment for the proposed elevated section is as shown in Fig. 7.1.8. The greater part of the Northern Line is designed for a 3-track, all of the Eastern Line is double track (except for some 3-track sections) and Mae Nam Line is a single track.

Both the Northern Line and the Eastern Line will be planned on a step-by-step basis in compliance with increasing traffic demand.

(3) Profile alignment

The profile alignment is planned as per Fig. 7.1.9 in accordance with applicable construction standards and the following design concepts.

a) Avoid complex transition and vertical curves
b) Avoid setting of turnouts in steep gradient sections

The gradient for the following road crossings is designed to be more than 10‰ due to the need for a 5 m road clearance:

Eastern Line	Rajaprarop Rd.	10.5‰,
Mae Nam Line	Phetburi Rd.	10.5‰,
Mae Nam Line	Rama IV Rd.	12.0‰.

Near Khlong Sen Seb, 1.6 km north of Bangkok Station, the Up Line gradient is 13.5‰, the Down Line gradient 11.5‰.

These gradients are higher due to right of way limitations and the necessity for proposed line to ride over existing line.

For these sections, the following measures must be taken to secure nominal tractive capacity equal to the present capacity.

a) Basically, KRUPP locomotives are not to be operated on the elevated section. If they are temporarily operated on the elevated section, they must be restricted to a maximum hauling capacity of 900 tons. (Appendix 7.1.1)

b) The signalling system will be formed to ensure that no trains stop in gradient sections.

c) The brake axle ratio for freight trains to be operated on the elevated section must be above 80%.

(4) Establishment of new stations

A new station will be constructed in the elevated section in order to attract a larger number of passengers. The new station will be located close to the existing station now only used for commuting service and will be provided with the necessary facilities.