To estimate the induced trips, the following induced trip model was applied:

$$T_{Iij} = T_{ij} * \{(D_{ij}(0) / D_{ij}(1))^c - 1\} * A$$

where,
T_{Iij} : number of induced trips from Changwat *i* to Changwat *j*
T_{ij} : number of future trips from Changwat *i* to Changwat *j*
$D_{ij}(0)$: minimum travel time distance in minutes from Changwat *i* to Changwat *j* - "without" project case
$D_{ij}(1)$: minimum travel time distance in minutes from Changwat *i* to Changwat *j* - "with project" case
A : adjustment factor = 0.5, as the potential traffic demand will not fully appear with no great effect from other transport modes on road transport
c : parameter estimated by means of the following gravity model:

$$T_{ij} = a (GA_i * GA_j)^b / D_{ij}^c$$

where,
T_{ij} : number of present trips from Changwat *i* to Changwat *j*
GA_i : generated and attracted trips of Changwat *i*
D_{ij} : minimum travel time distance between Changwat *i* and *j* in minutes
a, *b* & *c* : parameters; in which the parameter *c* is used in the induced trip model, with the following values:

Passenger car	: 1.5307	Light bus	: 1.0424
Heavy bus	: 0.7610	Pick-up (passenger)	: 1.5630
Light truck	: 1.6426	Medium truck	: 1.4324
Heavy truck	: 1.0862		

3.2.5 Trips of Generated by Future Development Plans

As trips expected to be generated due to future special development plans related to the project are not included in the normal growth pattern, these trips were estimated for the target years and supplemented to the future OD matrices in order to produce complete future trip distribution and OD tables.

1. Eastern Seaboard Development Program

This development program has been given high priority in the fifth and sixth national development plans to promote balanced regional growth and to boost the economy of the country. It is based on a new infrastructure, industrial estates and international trade activities in the Changwats of Chonburi, Chachoengsao and Rayong with a total area of about 13,215 km² and a population of more than two million inhabitants. Initially, the plan is promoting industrial estates in the two areas of Laem Chabang and Map Ta Phut.

To estimate the development trips of this program, the inter-Changwat trip data developed in the motorway master plan study, which were estimated through trip generation and distribution procedures based on primary data of the Road Development Study in the Central Region (JICA 1989), were used here as supplementary data. The total numbers of total generated and attracted trips till the target year 2010 are presented in Table 3.2-1 for both passenger and commodity vehicles.

TABLE 3.2-1 TRIPS GENERATED BY EASTERN SEABOARD DEVELOPMENT PROGRAM

(Trip/day)

Year	2000	2010	2020
Passenger Vehicles	9,801	17,007	17,007
Commodity Vehicles	12,223	17,497	17,497

2. Southern Seaboard Development Program

The Southern Seaboard is intended to become a regional development core under the sixth national plan. A land-bridge of approximately 180 km of road, rail and pipe lines connecting the Andaman sea at Krabi and the Gulf of Thailand at Khanom will act as the catalyst for the establishment of new economic zones at the terminals. The land-bridge, with deep seaports and industrial states at its terminals, is expected to attract international trade between the east and west as an alternative route.

The Road Development Study in the Southern Region (JICA, 1991) provides trip generation and attraction data between zones in the southern region. Trips from/to Bangkok are assumed, as in the master plan study, to be 20% of the total trips on the land-bridge between Krabi and Khanom. The total number of generated and attracted trips for passenger and commodity vehicles is presented in Table 3.2-2.

TABLE 3.2-2 TRIPS GENERATED BY SOUTHERN SEABOARD DEVELOPMENT PROGRAM

(Trip/day)

Year	2000	2010	2020
Inter-terminal Trips			
Passenger Vehicles	3,722	16,754	16,754
Commodity Vehicles	12	852	852
Trips to/from Bangkok			
Passenger Vehicles	744	3,352	3,352
Commodity Vehicles	2	172	172

3. Hua Hin / Cha Am Tourism Development Plan

Development of the tourism industry in Thailand is one of the main targets in the national plans. The two study routes are expected to serve the tourism activities either in Chiang Mai area or Hua Hin/Cha Am area. As there are no available data on tourism development plans in Chiang Mai area, no development trips are supplemented. The Tourism Development Study on the Hua Hin/Cha Am Beach Area (JICA, 1992) investigated the potential of the area to be a main tourism center and established a plan as a base for the development activities. The plan provides data on future tourist arrivals to the area and the modal share by transport mode. These data were utilized in estimating supplementary trips generated due to tourism development in the area. Total generated trips from the tourism area are presented in Table 3.2-3.

TABLE 3.2-3 TRIPS GENERATED BY HUA HIN/CHA AM TOURISM DEVELOPMENT PLAN

(Trip/day)

Year	2000	2010	2020
Passenger Vehicles	2,322	3,312	3,312

3.2.6 Trips of Other Transport Modes

Comparing with a share of 89.4% for road-freight transport in 1991 as presented in the modal split of the Transport Statistics Data of 1991, MOTC, in which road-passenger data are not available, other modes of transport have in general very small shares without considerable growth in recent years. Railway-freight share of 1991 was 2.3% in terms of tonnage and 5.2% in terms of ton-km. Inland water-ways and coastal shipping had 3.9% and 4.4% for freight in tonnage and 2.6% and 2.9% in ton-km respectively. Data on passengers included in the SRT Master Development Plan (1993) show also small values and decreasing shares for rail-passenger transport from 8.92% in 1985 to 7.50% in 1989 as presented in Table 3.2-4.

TABLE 3.2-4 RAILWAY PASSENGER SHARE IN THAILAND

Year	1985	1986	1987	1988	1989
Railway Share %	8.92	8.65	8.01	8.33	7.50

As the two study routes are running adjacent to the northern and southern railway lines, available passenger and commodity data of the rail transport were analyzed to more-closely investigate the present share in the area of the study routes and, if this share is considerable, to estimate future expected converted traffic flow to the motorways. Data of the northern line were obtained in the form of the number of passengers and freight tonnage by railway station (Statistical Report of Northern Region - 1990), while those of the southern line had the form of number of commuter passengers between stations from Ban Pong to Ratchaburi (SRT Master Development Plan - 1993).

Trips of the northern railway line in 1990 were subject to a trip distribution and allocation procedure to conclude the OD trip matrix and number of passengers between Amphoes in the Changwats traversed by the Lampang - Doi Saket route. Comparing the results with the number of passengers converted from the ADT data of DOH for national highway Rt. 11, the average share was only 3.53%. On the southern line, numbers of commuting passengers in 1991 between Ban Pong and Ratchaburi were expanded, assuming that they present an average share of 10% of total passengers in the central region, and compared with the converted number of passengers from the ADT data of DOH in 1991 for national highway Rt. 4. The share of railway passengers, as presented in Table 3.2-5, was also low at 7.34%. The results show that there is no expected considerable flow will be converted from the railway mode of transport to the two study routes. Appendix 3.2-2 presents the analysis results of road- and rail-passenger transport in Thailand and the two areas traversed by the study routes, as well as the freight transport on the northern line. For future railway projects, the high-speed train routes are currently under planning by the NESDB and the proposed routes for implementation are those for the eastern seabord.

TABLE 3.2-5 RAILWAY PASSENGER SHARE IN STUDY AREA

	Railway Share
Lampang - Doi Saket Area (1990)	3.53 %
Ban Pong - Cha Am Area (1991)	7.34 %

3.2.7 Trip Pattern

The trip pattern presented here is that of the normal OD tables in which induced trips generated due to the implementation of the study routes are not included. Estimated growth rates for generated and attracted trips and the socio-economic parameters of population and GPP for future target years, considering 1993 as the base-year, are plotted in Figure 3.2-1 for the five Changwats traversed by the two study routes and for the whole country. The values used in this estimation are presented in Appendix 3.2-3.

The population growth rate till 2020 for the whole country is only 1.26, which gives an annual increase of less than 1.0%, while the five Changwats have in general lower growth rates. The lowest growth rate in GPP in the area is 4.75 for Lamphun and the highest is 6.70 for Ratchaburi. High growth rates in GPP are reflected into high growth also in the trip generation and attraction in which Thailand has a rate of 8.68. Ratchaburi and Phetchaburi have also relatively high rates of about 8.0. Comparing with the western region, Changwats in the northern region have in general lower growth rates with the lowest rate of 5.53 for Lamphun.

Present and future generated and attracted inter-zonal trips as well as their growth rates for the sub-zones of the five Changwats are included in Appendix 3.2-4. Figure 3.2-2 shows the graphical presentation of these trips for the target year 2000 in which the sub-zones of the Changwat centers are the most trip generators and attractors except for the sub-zone of Ban Pong in Ratchaburi.

Trips which have their origin or destination in one of the three Changwats traversed by the Lampang - Doi Saket route are mostly grouped in regional base and plotted graphically for the three target years in Appendix 3.2-5 separately for the normal traffic and induced traffic. Trips between Lamphun and Chiang Mai and from/to Chiang Rai and BMR are expected to occupy big share and are followed by other Changwats in the northern region. Highest expected induced trips are those between Lampang and Chiang Mai. The trips of the two Changwats traversed by Ban Pong - Cha Am route are plotted in Appendix 3.2-6 and show in general higher values than those of the Lampang - Doi Saket route, specially with BMR and other Changwats in the central region. The induced trips of the route are mostly connected with BMR.

Appendices 3.2-7 and 3.2-8 present the present and future combined OD tables of the inter-zonal trips for the normal traffic and induced traffic separately. In these OD tables, and to simplify these tables, Changwats traversed by each study route are presented on subzonal-base, other Changwats in the same region are on Changwat-base and Changwats of different regions are grouped in regional-base.

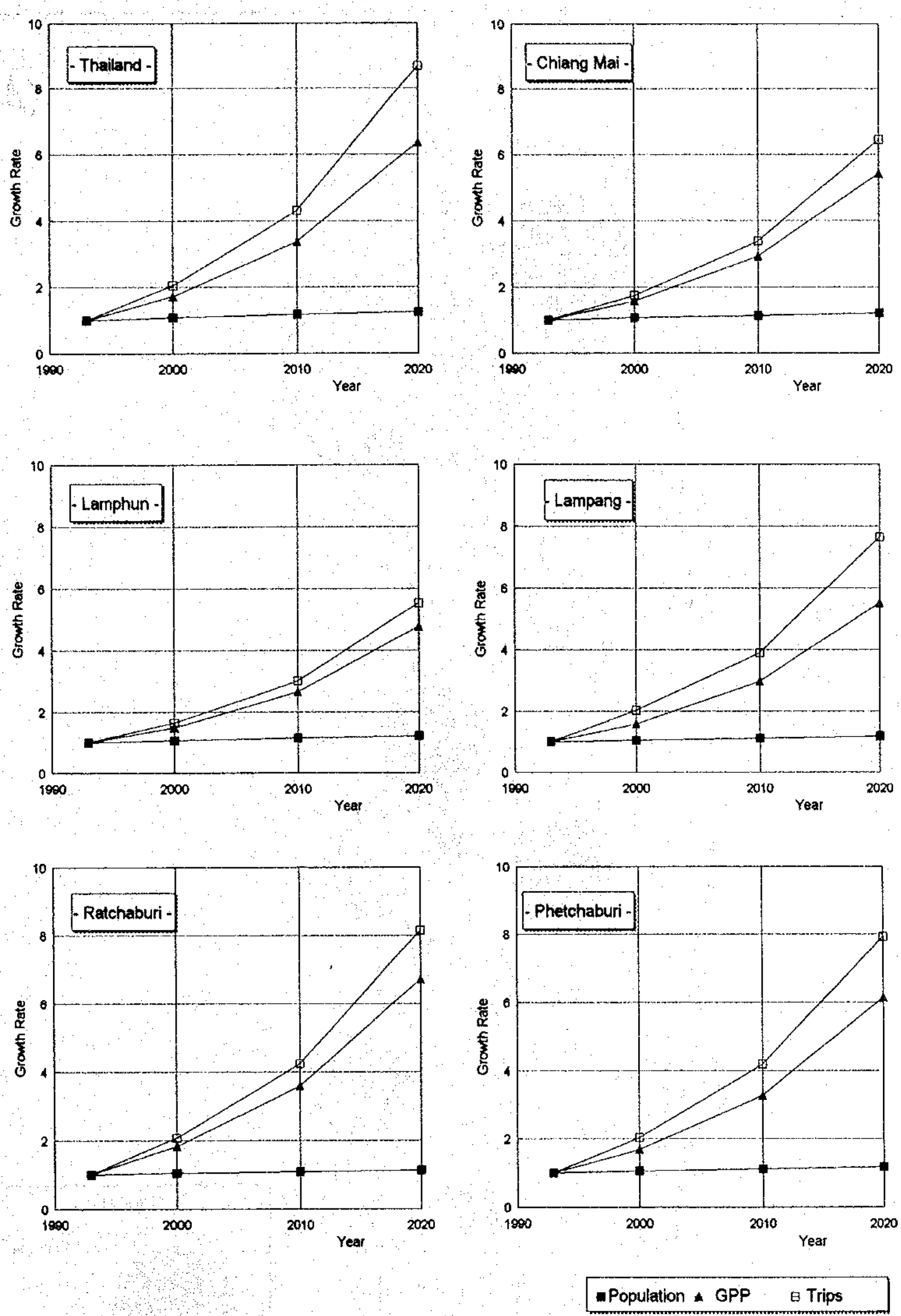
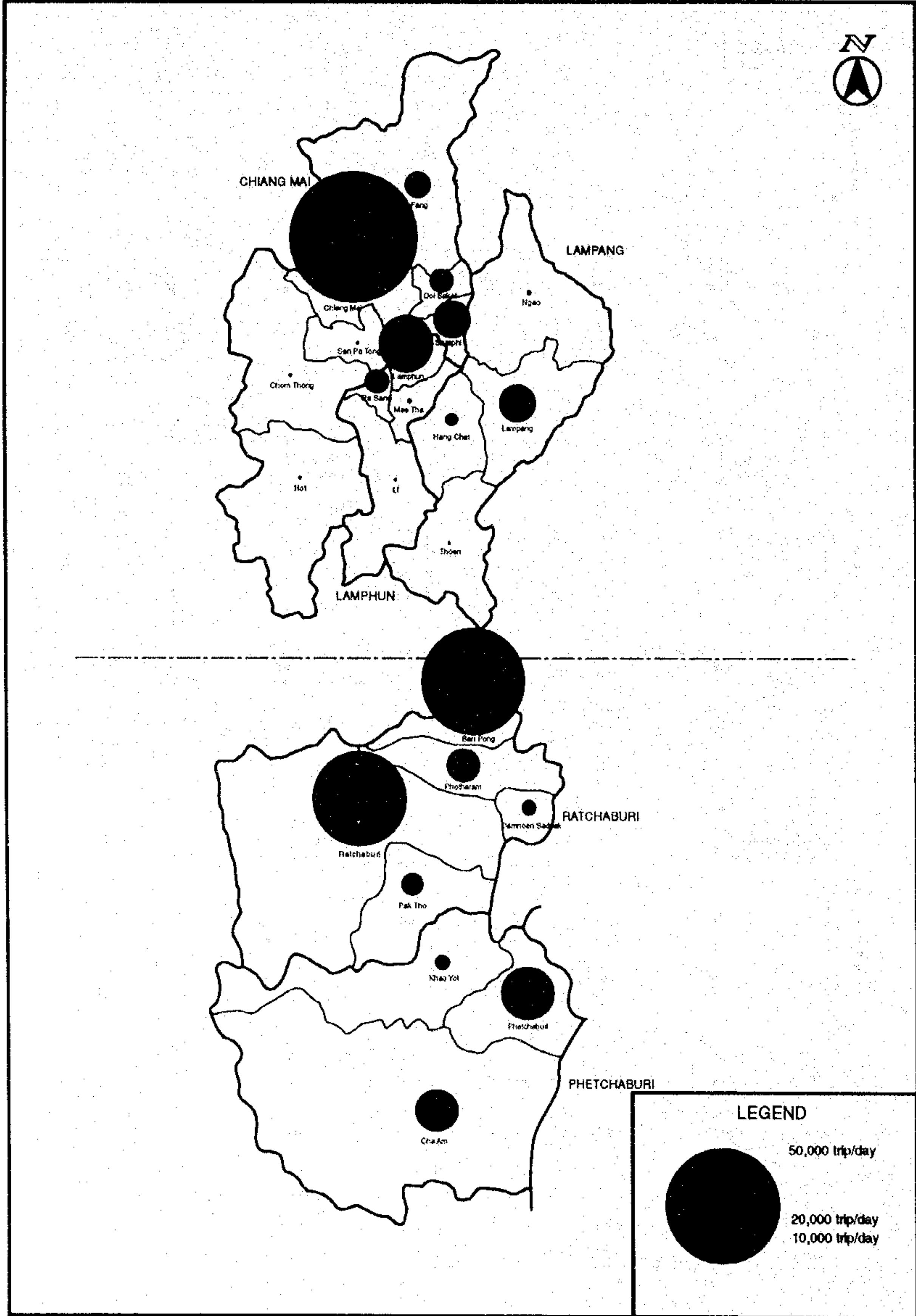


FIGURE 3.2-8 GROWTH IN SOCIO-ECONOMICS AND TRIPS



FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS	FIGURE 3.2-9 INTER-ZONAL TRIP GENERATION AND ATTRACTION - 2000

3.3 ASSIGNED TRAFFIC VOLUMES

Traffic demand was forecasted through the assignment of OD tables, for normal traffic for the case of "without project" and with supplementing the induced trips for the case of "with project", on the road network of each target year. The following sections present the different tasks in the applied procedure and main results.

3.3.1 Assignment Technique

1. Procedure

The applied traffic assignment technique is basically the technique developed in the master plan study using the OD tables for each target year with the corresponding highway and motorway networks and with different toll rates for the motorways. Figure 3.3-1 shows the procedural flow chart of the technique which is based on the capacity restrained assignment as the most straightforward method for large number of zones in the trip matrices. In this assignment technique, link classification and parameters for the road network are presented in Appendix 3.3-1 with the used speed - flow relationship. The program calculates the required travel time for each link according to its travel speed and road conditions and determines the quickest routes between each origin and destination by evaluating the consuming time on links. Next, it assigns the trips between the given origin and destination to these routes starting at the destinations and working back to the origins. As congestion increases till a certain level, alternative routes are introduced to handle the unassigned traffic. Zone-to-zone routing is built, which is the quickest path from each zone to any other, and all trips are assigned to these optimum routes. Since the link-travel time varies with the traffic volume of vehicles using that link, which can be expressed as a degree of link congestion, the OD tables are divided to apply an iteration procedure on five stages. At each iteration, and depending upon the current link loadings, the flows are divided between all the shortest routes generated and a new travel time is computed for the average assigned link flow at each pass. The iteration continues to reestimate the speed on that links considering the assigned traffic on links, and to produce alternative routes so that more accurate allocation can be achieved. The accumulated assigned traffic volume from each OD pair on the links composes the total assigned traffic volumes per direction for the network.

2. Highway and Motorway Networks

For the present highway network, inventory data of DOH was updated to include the newly implemented improvement projects. As for the network of the target years, future plans of DOH were considered by supplementing the present network by new construction and widening projects. That includes mainly the widening of the four main trunk roads Nos. 1, 2, 3 and 4 basically to 4-lane with some sections to 6-lane and 10-lane in addition to many other highways. Future highway network is presented in Appendix 3.3-2.

The motorway network used in the assignment procedure for each of the three target years is presented in Appendix 3.3-3. The network has a total length of about

680 km of motorways under operation by the year 2000, 2,050 km by the year 2010 and with the whole length of 4,347 km by the year 2020. The implementation staging of the motorway network was based on a tentative plan which was prepared in coordination with DOH Counterpart and used in establishing the motorway network for each of the future target years. The tentative implementation plan is presented in Appendix 3.3-4.

3. Toll Rate Structure

The toll rate established in the master plan study was 1.0 Baht/km, which was found to be reasonable when compared with railway fare and applied in the financial analysis and evaluation. In this study, this toll rate of 1.0 Baht/km is basically applied on a constant base for the three target years in addition to the two lower rates of 0.5 and 0.75 Baht/km for the purpose of the project financial evaluation and sensitivity analysis.

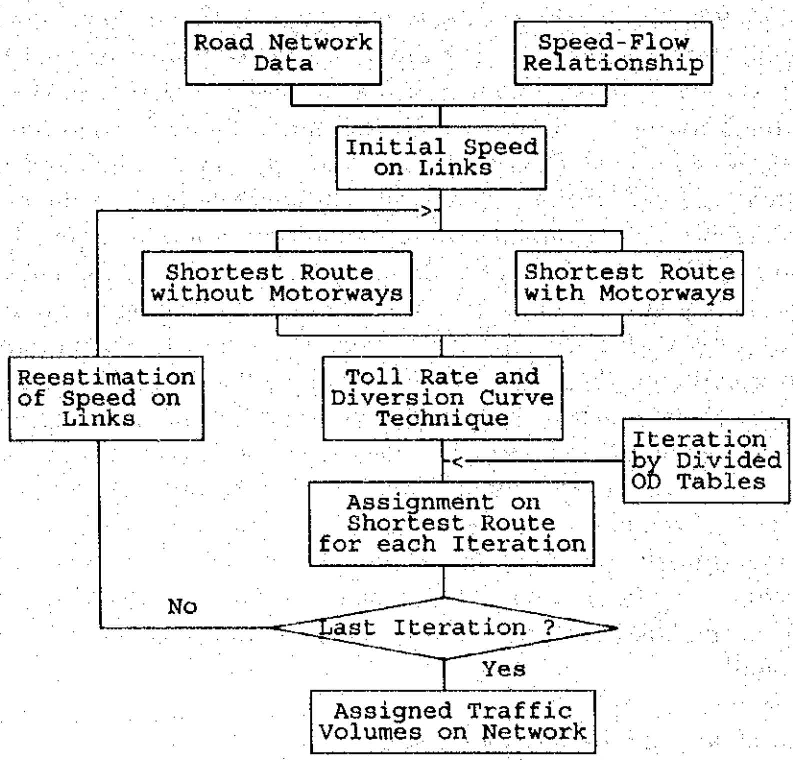


FIGURE 3.3-1 TRAFFIC ASSIGNMENT PROCEDURE

4. Diverted Traffic

To estimate the proportion of traffic volumes diverted to the study routes and toll motorway network the formula used in Japan by the Nihon Doro Kodan (Japan Highway Public Corporation) is applied to develop the diversion curves used in estimating the diverted traffic volumes. This formula is developed specially for toll highways and motorways, and is calibrated and upgraded continuously. In this formula, the diversion rate is determined by the toll-free and the time difference between the two cases of with and without motorways. With a proposed fixed fee of the first year of operation, the diversion curve has the applicability to be shifted for future years. The formula is:

$$P = K / \{1 + (a(C/T*S)^b / T^c)\}$$

where,

P	:	diversion rate
K	:	maximum diversion rate, assumed 0.9
C	:	trip fare in Yen (to be converted to Baht)
T	:	time saving in minutes
S	:	shift factor
a, b, & c	:	parameters, which have the following values:

Vehicle Group	*a*	*b*	*c*
Passenger vehicle	0.616	1.073	1.035
Light commodity vehicle	0.978	1.062	1.088
Heavy commodity vehicle	0.049	1.505	0.542

The diversion rate is estimated from the concluded diversion curve of the first year of operation, and the rates for the following years are obtained by shifting this curve through estimated shift factors (SF). As for the proposed fixed toll rate which will be applied in the future, it is expected that this rate will decrease in actual value in accordance with the increase in the gross domestic product. The formula is developed according the standards in Japan for the base year of 1980, therefore, some adjustments were applied to make it applicable in Thailand for the base year 1993. Before concluding the shift factors of target years, the shift factor of 1993 is adjusted by estimating a conversion ratio of fare burden (CRF) from Baht to Yen. To evaluate the time consumed on links of toll motorways in use for persons, time evaluation value (TEV) is calculated based on the GDP per capita. Calculation procedures are presented in Appendix 3.3-5 and the results are as follows:

Shift Factor	1993:	0.024624
	2000:	0.032157
	2010:	0.058296
	2020:	0.102337

Average time value/person 1993: 0.376 Baht/minute

5. Assignment Validity

To check the validity of the applied assignment procedure, assigned traffic volumes and estimated ADT of 1993 at locations of traffic survey stations were compared and matching rates were concluded. Results are presented in Appendix 3.3-6 in which most of the assigned volumes show good matching rates.

6. Assignment Cases

Traffic volume assignments were carried out mainly for the purpose of estimating the traffic volumes on the study routes for each of the target years by applying the basic toll rate of 1.0 Baht/km. As there are another requirements for different purposes, several cases of assignment were also carried out. To verify the validity of the applied assignment technique traffic volumes were assigned to the 1993 highway network to conclude matching rates between the estimated ADT and assigned traffic volumes. Next, and to get the traffic volumes on the motorways and related national highways in future target years and for economic evaluation purposes, assignments were done for the two cases of "without project" and "with project" for each of the study routes separately. For the financial evaluation, assignment was done also by applying different toll rates. Appendix 3.3-7 presents the different assignment cases applied in the study.

3.3.2 Future Traffic Demand

Future OD tables of vehicle trips for the target years of 2000, 2010 and 2020 are assigned to produce the traffic volumes on the national highways and motorways for each case of assignment. OD tables supplemented by the induced trips are assigned to produce traffic volumes on the study routes for the assignment cases of "with project". Results of the traffic assignment for each of the study routes and related national highways are presented in the following sections.

1. Traffic Volume on Motorways

Flow maps of assigned traffic volumes on the study routes and adjacent national highways for the three future target years are shown in Appendix 3.3-8 for Lampang -Doi Saket route and Appendix 3.3-9 for Ban Pong - Cha Am route. With lower socio-economic growth rates in the northern region, traffic volumes on the Lampang -Doi Saket route are in general lower than those of the Ban Pong - Cha Am route. It should be noticed that traffic generated due to future development projects in the northern region are not supplemented in the forecasting process. The rapid development of tourism industry in Chiang Mai and Chiang Rai area as well as the growth in trade movement with China through Laos and Mynmar and the quadrangle development project are expected to increase the presently forecasted traffic volumes on that route.

2. Characteristics of Traffic Volumes

Different components and characteristics of the traffic volume on each section of both motorways and highways and for each future target year are shown in Figure 3.3-2 for Lampang - Doi Saket route and Figure 3.3-3 for Ban Pong - Cha Am route. In general, shares of heavy vehicles and induced traffic on the study routes as well as the total share of motorways are increasing by time. Future implementation of other connected sections of the motorway network is expected to influence the average trip length on the study routes specially for Chiang Mai - Doi Saket section which will handle longer trips when extended to Chiang Rai.

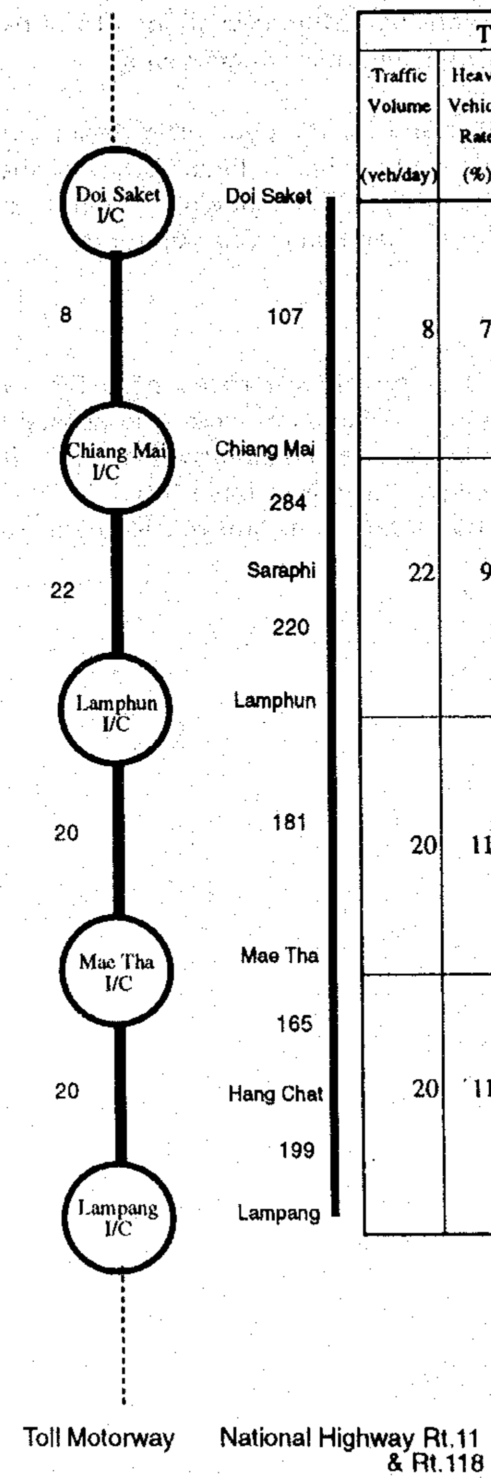
Ban Pong - Cha Am route is expected to handle heavy traffic volumes, with high share of heavy vehicles, in the future which is creating high and critical values of the volume/capacity ratio. Due to the over-saturation of Rt. 35 and Rt. 325, the highest traffic volume is estimated between Pak Tho J/C and I/C as the motorway, with its longer distance, is handling the trips generating between Bangkok and

Samut Songkhram instead of the considerably shorter highways. The two national highways should be widening to handle higher share of future traffic. Breakdown of assigned traffic volumes by vehicle category on the different sections of the two study routes are presented in Appendix 3.3-10 for the future target years.

To select the appropriate type of interchanges and for the geometric design purpose, traffic volume is an important and fundamental criteria. Total traffic volumes assigned at interchanges for the three future target years are shown in Figure 3.3-4 for Lampang - Doi Saket route and Figure 3.3-5 for Ban Pong - Cha Am route.

3. Toll Rate Alteration

For the purposes of financial analysis, the two lower rates of 0.50 and 0.75 Baht/km in addition to the basic toll rate of 1.0 Baht/km, were also applied in the traffic assignment procedure. Resulted traffic volumes on motorway sections for the three target years are presented in passenger car unit in Table 3.3-1 for Lampang - Doi Saket route and Table 3.3-2 for Ban Pong - Cha Am route. Lower toll rates attract in general more traffic.



Toll Motorway					National Highway				Share of Toll Motor-way (%)
Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Induced Traffic Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	
8	7.4	0.4	0.02	42	107	16.4	0.39	50	7
22	9.9	1.6	0.05	357	284	20.9	1.07	156	7
					220	21.0	0.83	238	9
20	11.7	1.8	0.05	450	181	25.5	0.70	324	10
20	11.8	1.8	0.05	457	165	26.2	0.64	355	11
					199	23.2	0.76	300	9

LEGEND

- Study Route
- Other Toll Motorway
- National Highway

Unit : 100 vehicle/day

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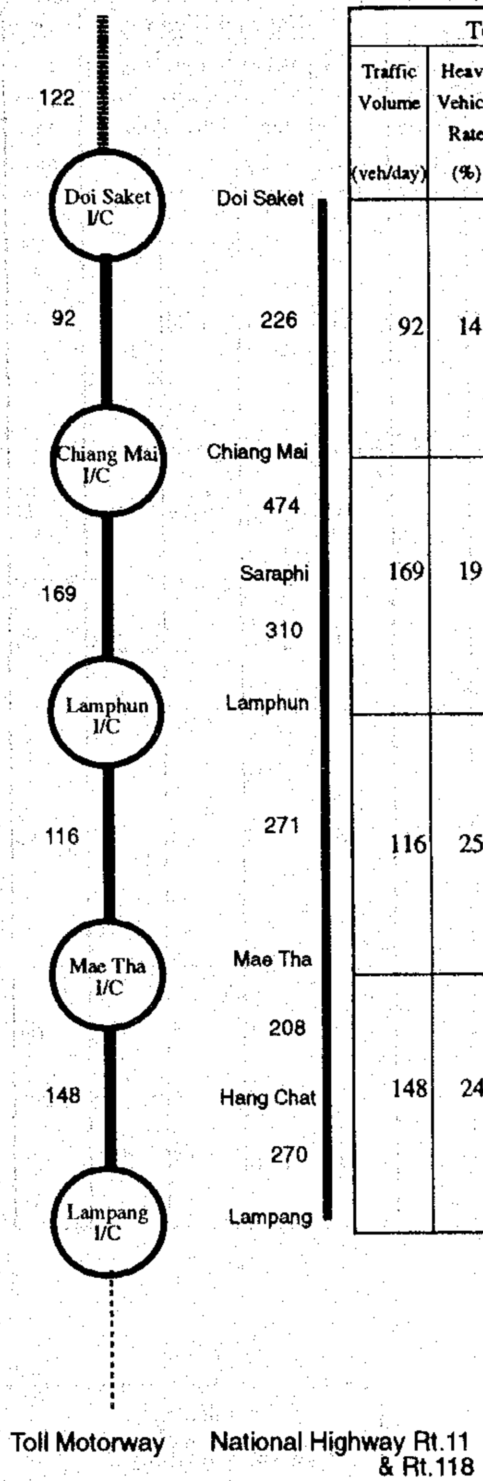
FIGURE 3.3-2 TRAFFIC VOLUME CHARACTERISTICS ON LAMPANG - DOI SAKET ROUTE - 2000 (1/3)



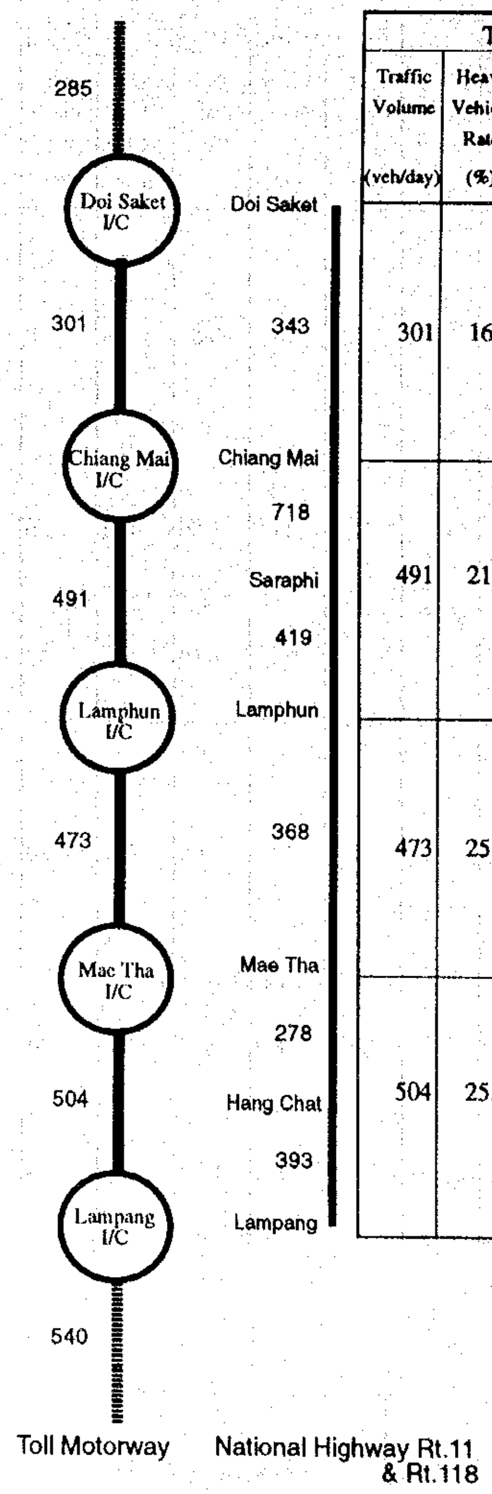
Toll Motorway					National Highway				Share of
Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Induced Traffic Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Toll Motor-way (%)
92	14.0	1.4	0.22	291	226	15.2	0.81	74	29
169	19.0	1.7	0.41	426	474	22.0	1.80	107	26
					310	23.3	1.19	188	35
116	25.5	1.8	0.30	533	271	26.5	1.06	297	30
148	24.3	1.9	0.38	552	208	28.7	0.83	292	42
					270	24.4	1.04	233	35

LEGEND
- Study Route
- Other Toll Motorway
- National Highway

Unit : 100 vehicle/day

FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 3.3-2 TRAFFIC VOLUME CHARACTERISTICS ON LAMPANG - DOI SAKET ROUTE - 2010 (2/3)



Section	Toll Motorway					National Highway				Share of
	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Induced Traffic Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Toll Motor-way (%)
Doi Saket – Chiang Mai	301	16.1	1.6	0.72	269	343	16.1	1.24	70	47
Chiang Mai – Saraphi	491	21.3	2.8	1.23	390	718	23.2	2.76	100	41
Saraphi – Lamphun						419	25.4	1.63	233	54
Lamphun – Mae Tha	473	25.1	3.1	1.22	438	368	30.5	1.49	318	56
Mae Tha – Hang Chat	504	25.2	3.4	1.30	475	278	33.3	1.15	305	64
Hang Chat – Lampang						393	26.6	1.55	227	56

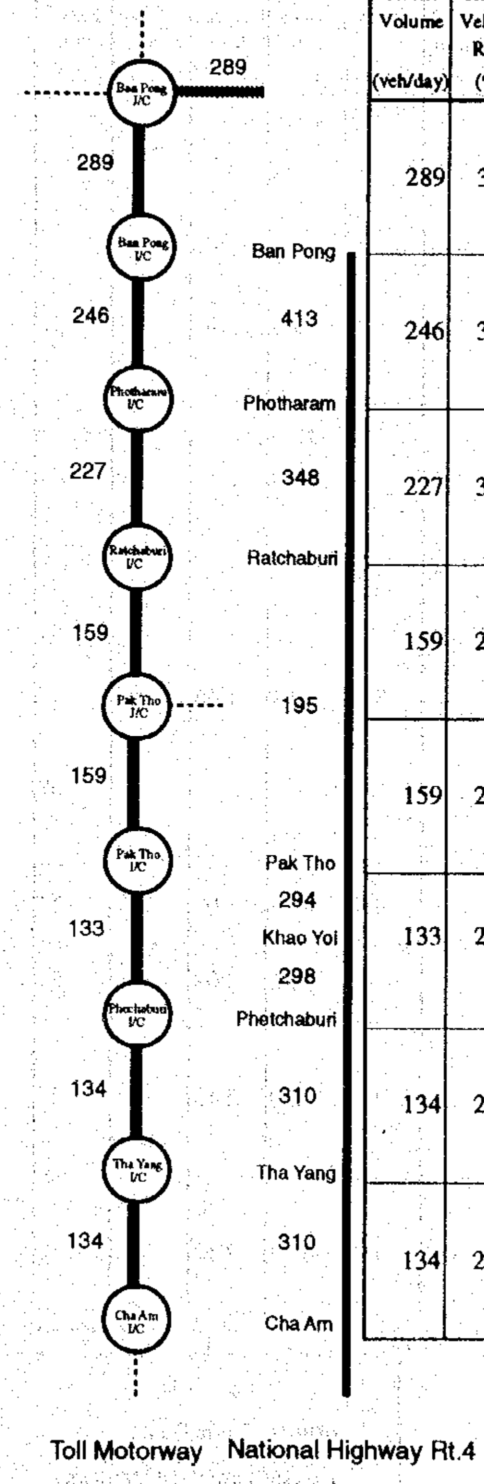
LEGEND

- Study Route
- Other Toll Motorway
- National Highway

Unit : 100 vehicle/day

FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 3.3-2 TRAFFIC VOLUME CHARACTERISTICS ON LAMPANG - DOI SAKET ROUTE - 2020 (3/3)



Toll Motorway					National Highway				Share of Toll Motorway (%)
Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Induced Traffic Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	
289	34.5	1.5	0.80	250					
246	30.4	3.0	0.66	263	413	45.0	1.86	82	37
227	30.1	3.3	0.61	276	348	43.6	1.56	87	39
159	29.9	3.9	0.42	353	195	45.5	0.88	105	45
159	29.9	3.9	0.42	353					45
133	29.8	2.5	0.35	421	294	47.2	1.34	327	31
					298	46.0	1.35	325	31
134	28.6	2.2	0.36	413	310	42.2	1.36	322	30
134	28.6	2.2	0.35	414	310	42.2	1.37	322	30

LEGEND

Study Route

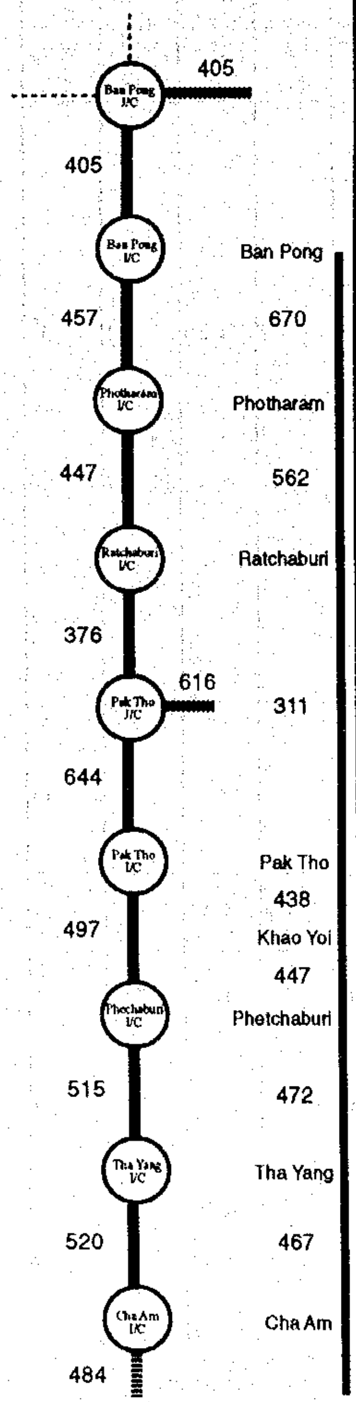
Other Toll Motorway

National Highway

Unit : 100 vehicle/day

FEASIBILITY STUDY
ON
THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 3.3-3 TRAFFIC VOLUME CHARACTERISTICS ON BAN PONG - CHA AM ROUTE - 2000 (1/3)



Toll Motorway					National Highway				Share of Toll Motorway
Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Induced Traffic Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	(%)
405	35.6	2.7	1.14	143					
457	32.1	5.5	1.25	125	670	49.0	3.11	84	41
447	31.9	5.7	1.22	128	562	46.9	2.57	89	44
376	38.3	8.6	1.08	146	311	50.4	1.46	108	55
644	36.1	8.5	1.80	327					67
497	34.6	8.7	1.38	400	438	52.3	2.07	309	53
					447	50.6	2.08	308	53
515	33.0	8.5	1.41	391	472	46.0	2.13	302	52
520	32.9	8.4	1.42	389	467	46.2	2.12	304	53

LEGEND

Study Route

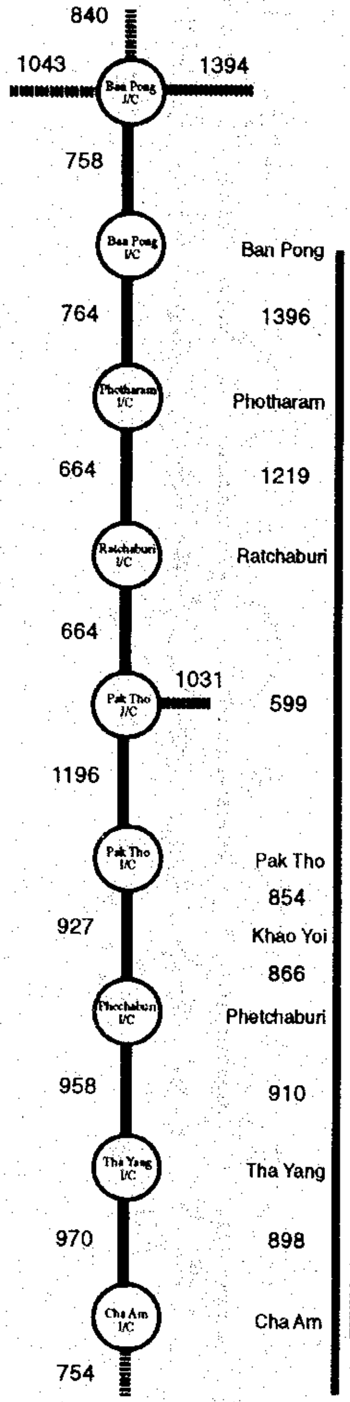
Other Toll Motorway

National Highway

Unit : 100 vehicle/day

FEASIBILITY STUDY
ON
THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 3.3-3 TRAFFIC VOLUME CHARACTERISTICS ON BAN PONG - CHA AM ROUTE - 2010 (2/3)



Toll Motorway National Highway Rt.4

Toll Motorway					National Highway				Share of Toll Motorway (%)
Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Induced Traffic Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	Traffic Volume (veh/day)	Heavy Vehicle Rate (%)	Volume-Capacity Rate	Average Trip Length (km)	
758	37.7	6.0	2.16	156					
764	35.1	8.2	2.14	158	1,396	47.5	6.41	91	35
664	35.5	8.3	1.86	175	1,219	44.4	5.48	94	35
664	41.3	10.9	1.94	185	599	49.9	2.79	119	53
1,196	40.4	9.1	3.46	361					67
927	39.9	8.9	2.67	445	854	51.0	4.00	276	52
					866	49.5	4.01	277	52
958	38.5	8.7	2.73	435	910	44.7	4.08	274	51
970	38.3	8.4	2.76	431	898	45.0	4.04	276	52

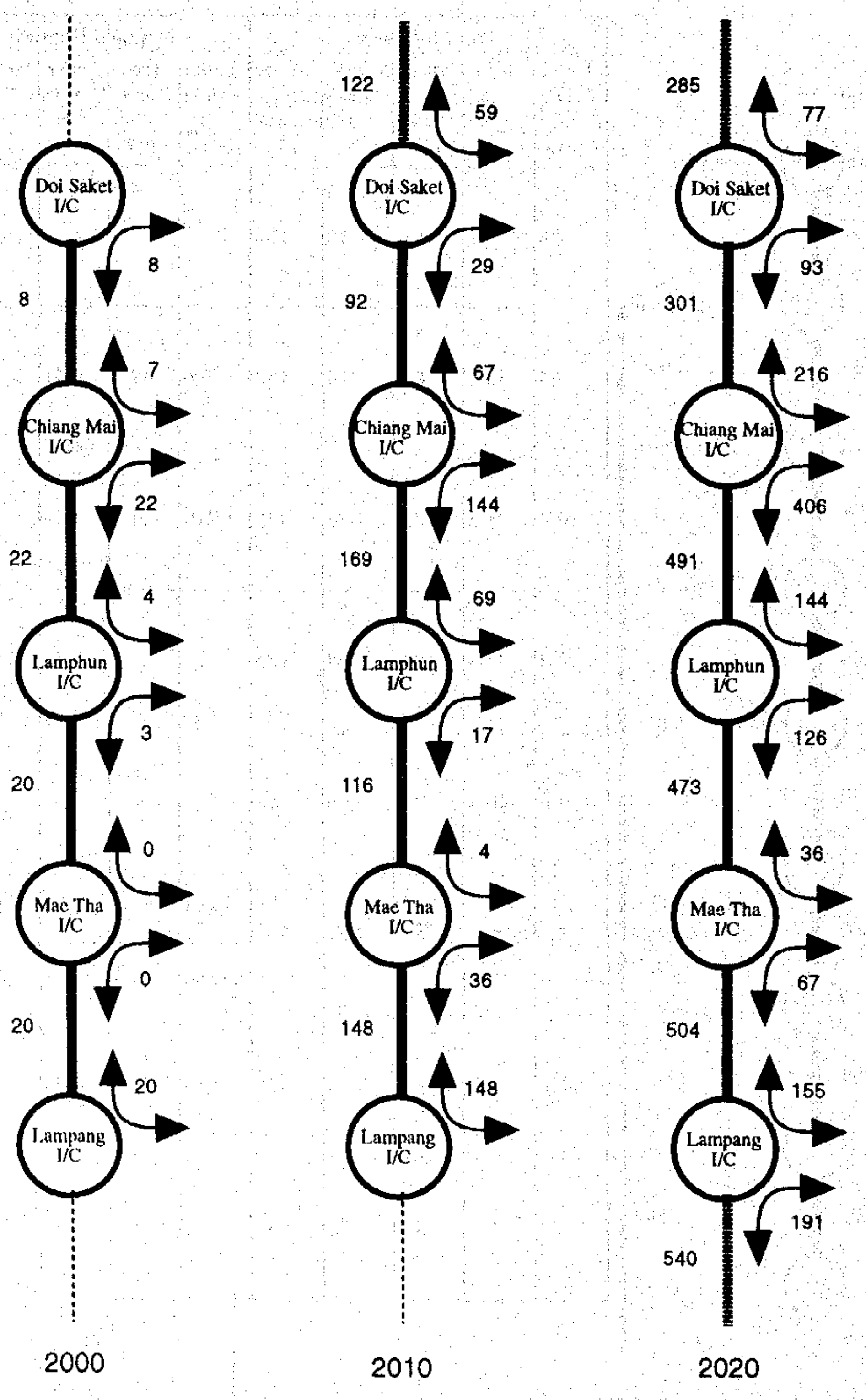
LEGEND

- Study Route
- Other Toll Motorway
- National Highway

Unit : 100 vehicle/day

FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 3.3-3 TRAFFIC VOLUME CHARACTERISTICS ON BAN PONG - CHA AM ROUTE - 2020 (3/3)



LEGEND

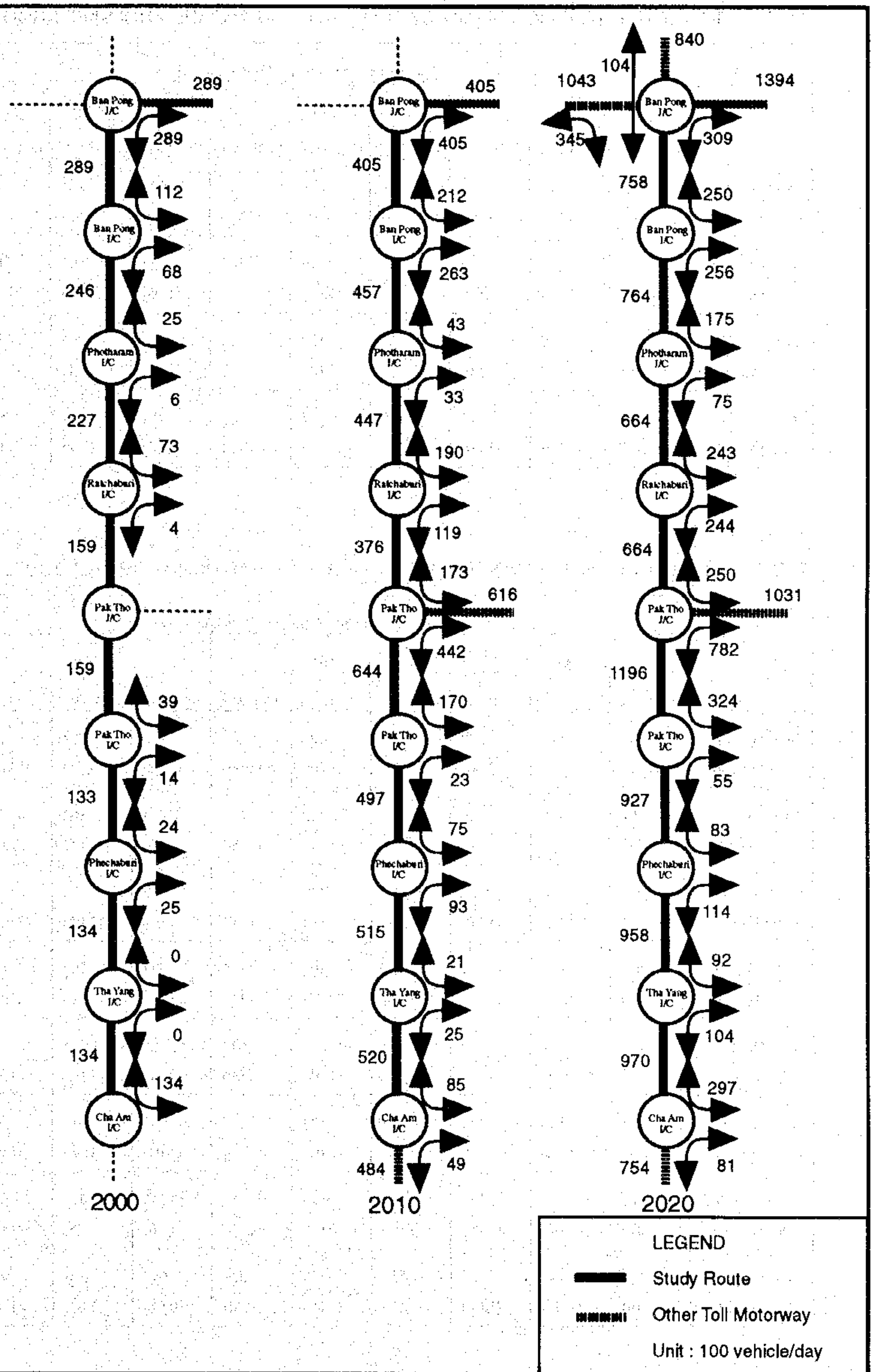
Study Route

Other Toll Motorway

Unit : 100 vehicle/day

FEASIBILITY STUDY
ON
THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 3.3-4 TRAFFIC VOLUMES ON INTERCHANGES OF LAMPANG - DOI SAKET ROUTE



FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS	FIGURE 3.3-5 TRAFFIC VOLUMES ON INTERCHANGES OF BAN PONG - CHA AM ROUTE

TABLE 3.3-1 FUTURE TRAFFIC VOLUME BY TOLL RATE ON LAMPANG - DOI SAKET ROUTE

Section	Assigned Traffic Volume (100 vehicle/day)								
	2000			2010			2020		
	0.5 Baht/km	0.75 Baht/km	1.0 Baht/km	0.5 Baht/km	0.75 Baht/km	1.0 Baht/km	0.5 Baht/km	0.75 Baht/km	1.0 Baht/km
Doi Saket I/C - Chiang Mai I/C	13 (1.63)	10 (1.25)	8 (1.00)	108 (1.17)	99 (1.08)	92 (1.00)	286 (0.95)	285 (0.95)	301 (1.00)
Chiang Mai I/C - Lamphun I/C	37 (1.68)	27 (1.23)	22 (1.00)	197 (1.17)	179 (1.06)	169 (1.00)	514 (1.05)	504 (1.03)	491 (1.00)
Lamphun I/C - Mae Tha I/C	34 (1.70)	25 (1.25)	20 (1.00)	124 (1.07)	120 (1.03)	116 (1.00)	478 (1.01)	476 (1.01)	473 (1.00)
Mae Tha I/C - Lampang I/C	34 (1.70)	25 (1.25)	20 (1.00)	170 (1.15)	157 (1.06)	148 (1.00)	489 (0.97)	514 (1.02)	504 (1.00)

TABLE 3.3-2 FUTURE TRAFFIC VOLUME BY TOLL RATE ON BAN PONG - CHA AM ROUTE

Section	Assigned Traffic Volume (100 vehicle/day)								
	2000			2010			2020		
	0.5 Baht/km	0.75 Baht/km	1.0 Baht/km	0.5 Baht/km	0.75 Baht/km	1.0 Baht/km	0.5 Baht/km	0.75 Baht/km	1.0 Baht/km
Ban Pong J/C - Ban Pong I/C	347 (1.20)	317 (1.10)	289 (1.00)	458 (1.13)	427 (1.05)	405 (1.00)	815 (1.08)	794 (1.05)	758 (1.00)
Ban Pong I/C - Photharam I/C	301 (1.22)	268 (1.09)	246 (1.00)	455 (1.00)	462 (1.01)	457 (1.00)	834 (1.09)	802 (1.05)	764 (1.00)
Photharam I/C - Ratchaburi I/C	277 (1.22)	248 (1.09)	227 (1.00)	457 (1.02)	449 (1.00)	447 (1.00)	712 (1.07)	695 (1.05)	664 (1.00)
Ratchaburi I/C - Pak Tho J/C	193 (1.21)	172 (1.08)	159 (1.00)	387 (1.03)	391 (1.04)	376 (1.00)	737 (1.11)	704 (1.06)	664 (1.00)
Pak Tho J/C - Pak Tho I/C	193 (1.21)	172 (1.08)	159 (1.00)	688 (1.07)	673 (1.05)	644 (1.00)	1,325 (1.11)	1,264 (1.06)	1,196 (1.00)
Pak Tho I/C - Phetchaburi I/C	156 (1.17)	143 (1.08)	133 (1.00)	518 (1.04)	503 (1.01)	497 (1.00)	965 (1.04)	979 (1.06)	927 (1.00)
Phetchaburi I/C - Tha Yang I/C	156 (1.16)	145 (1.08)	134 (1.00)	520 (1.01)	506 (0.98)	515 (1.00)	1,015 (1.06)	1,010 (1.05)	958 (1.00)
Tha Yang I/C - Cha Am I/C	155 (1.16)	144 (1.07)	134 (1.00)	530 (1.02)	538 (1.03)	520 (1.00)	948 (0.98)	996 (1.03)	970 (1.00)

CHAPTER 4

ROUTE SELECTION

CHAPTER 4

ROUTE SELECTION

The optimum routes were selected in the following procedure: (1) establishment of basic policy including identification of control points and decision of way of dealing therewith as well as design requirements, (2) preparation of alternative routes in accordance with the basic policy, (3) comparative evaluation from socio-economic, environmental, traffic and technical aspects, and (4) selection of the optimum route based on the evaluation. This Chapter presents the procedure of route selection.

4.1 BASIC POLICY IN SELECTING ROUTE

4.1.1 Control Points

The control points to be given due consideration in the route selection were identified and the measures to be taken for them were proposed as shown in Table 4.1-1.

TABLE 4.1-1 CONTROL POINTS AND MEASURES

Control Point	Measures	Concerned Route
Natural Condition		
- Mountain range	To select the shortest possible route. To plan tunnel, if necessary.	L - D Rt.
- Wide river	To determine alignment of route to cross the river at as right angle as possible.	Common
- Soft ground	To take no particular measures because soft ground exists only in spot areas.	B - C Rt.
Social Environment		
- Resettlement	To plan route as away from built-up area as possible. To determine route so as to avoid splitting community and to minimize relocation of people.	Common
- School and hospital	To plan route away from these facilities.	Common
- Temple	To be completely avoided.	Common

Control Point	Measures	Concerned Route
Natural Environment		
- National park	To be completely avoided.	L - D Rt.
- Watershed class 1-A	To be strictly avoided, except for tunnel scheme.	L - D Rt.
- Watershed class 1-B	This area requires appropriate soil conservation/protection measures, although a proposed short tunnel will minimize negative environmental impacts.	L - D Rt.
- Wildlife sanctuary	To be strictly, avoided except for tunnel scheme.	L - D Rt.
- Forest reserve	This area is allowed to pass without any measure in principle. However, tunnel is proposed to conserve forest resources.	L - D Rt.
Public Works and Others		
- City planning area	To be basically avoided except for particular cases.	Common
- Special project	To be basically avoided.	B - C Rt.
- Large-scale housing area and industrial estate	To be basically avoided.	Common

Note, L - D Rt. : Lampang - Doi Saket Route
B - C Rt. : Ban Pong - Cha Am Route
Common : Common to both routes

4.1.2 Recommended Level of Service

Freeways are so designed as to accommodate anticipated traffic for the design life (20 years) in expected operational conditions. Operational conditions of freeways are defined using level-of-service concept.

A Policy on Geometric Design of Highways and Streets AASHTO, 1990, (AASHTO Standard) provides a guide for selection of design level of services as shown in Table 4.1-2.

TABLE 4.1-2 GUIDE FOR SELECTION OF DESIGN LEVEL OF SERVICE

Highway Type	Type of Area and Appropriate Level of Service			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C

Note : General operating conditions for level of service

- A; free flow, with low volumes and high speeds
- B; reasonably free flow, but speeds beginning to be restricted by traffic conditions.
- C; in stable flow zone, but most drivers restricted in freedom to select their own speeds.
- D; approaching unstable flow, drivers have little freedom to maneuver.
- E; unstable flow, may be short stoppages.
- F; forced flow.

Level-of-service criteria for basic freeway segments are given in Table 4.1-3 for 70 mph (112 kph) and 60 mph (96 kph) design speed elements.

TABLE 4.1-3 LEVEL OF SERVICE FOR BASIC FREEWAY SECTION

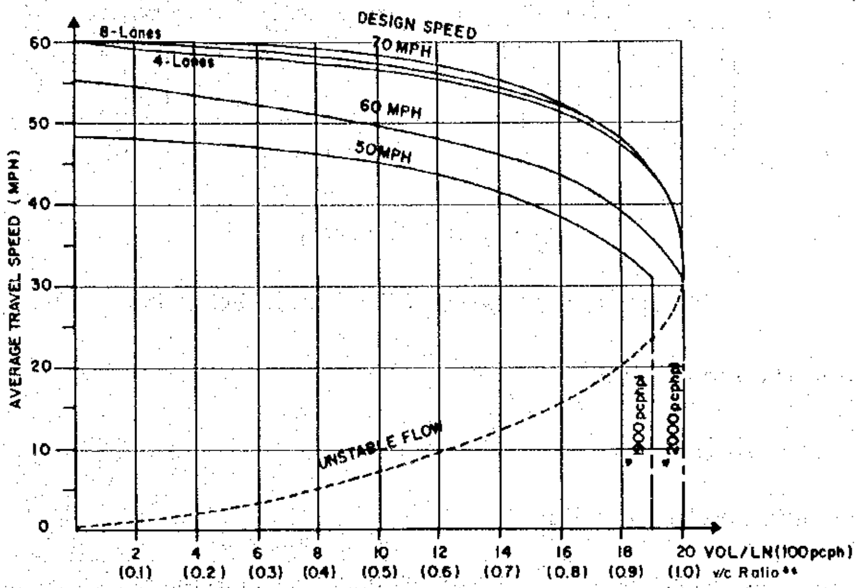
LOS	Density (pc/mi/ln)	70 MPH Speed[b] (MPH)	70 MPH V/C	70 MPH MSF[a] (pcphpl)	60 MPH Speed[b] (MPH)	60 MPH V/C	60 MPH MSF[a] (pcphpl)
A	≤12	≥60	0.35	700	-	-	-
B	≤20	≥57	0.54	1,100	≥50	0.49	1,000
C	≤30	≥54	0.77	1,550	≥47	0.69	1,400
D	≤42	≥46	0.93	1,850	≥42	0.84	1,700
E	≤67	≥30	1.00	2,000	≥30	1.00	2,000
F	>67	<30	c	c	<30	c	c

[a] Maximum service flow rate per lane under ideal conditions.
[b] Average travel speed.
[c] Highly variable, unstable.

Typical flow characteristics under ideal conditions are illustrated in Figure 4.1-1, which depicts the relationships between average travel speed and rate of flow.

The ideal conditions mean;

- .Twelve-foot minimum lane width (3.6 m)
- .Six-foot minimum lateral clearance (1.8 m)
- .All passenger cars in the traffic stream
- .Weekday or commuter traffic in urban areas or regular users in other areas



* capacity
** v/c ratio based on 2000 pcphpl valid only for 60 and 70-MPH design speeds

FIGURE 4.1-1 SPEED-FLOW RELATIONSHIPS UNDER IDEAL CONDITIONS

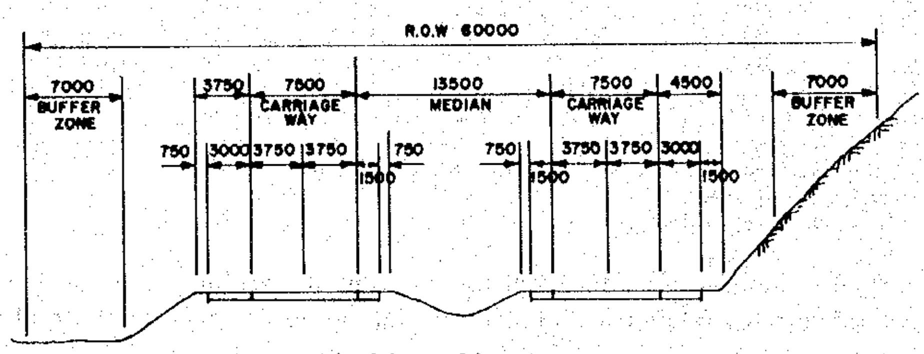
4.1.3 Design Requirement

Design speed and major geometric elements were established as shown in Table 4.1-4.

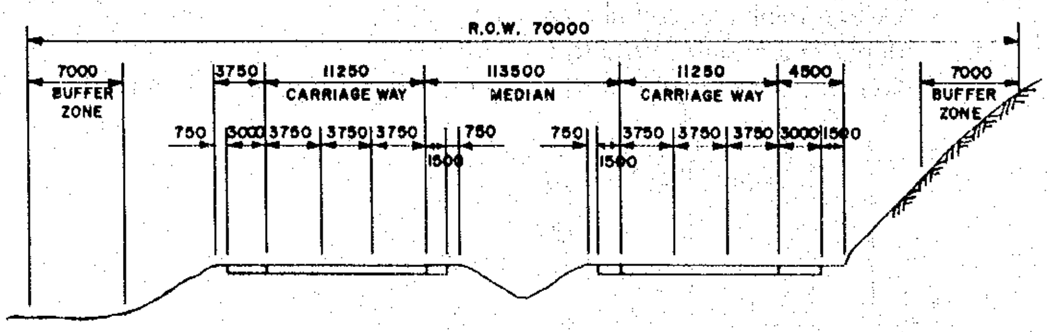
TABLE 4.1-4 DESIGN SPEED AND MAJOR GEOMETRIC ELEMENTS

Classification	Design Speed (km/hr)	Horizontal		Vertical	
		Curve (m)	Length (m)	Grade (%)	Length (m)
Rural Flat/Rolling	120	1000	200	2	100
Rural Mountainous	100	700	170	3	85
Urban/Suburban	100	700	170	3	85

Standard cross section was assumed as shown in Figure 4.1-2.



a) 4-Lane Motorway



b) 6-Lane Motorway

FIGURE 4.1-2 STANDARD CROSS SECTION

4.1.4 Required Number of Lanes

1. Service Flow Rate

1) Maximum Service Flow Rate

Maximum service flow rate (MSF) under ideal conditions shown in Table 4.1-3 are computed from the volume to capacity rations (V/C) as follows:

$MSF_i = C_j \times (V/C)_i$

Where:

MSF_i = Maximum service flow rate per lane for LOS_i under ideal conditions, in pcphpl;
$(V/C)_i$ = maximum volume-to-capacity ratio associated with LOS_i;
C_j = capacity under ideal conditions for freeway element of design speed j: 2,000 pcphpl for 60-mph and 70-mph freeway elements, the value of C_j is synonymous with the maximum service flow rate for LOS E.

2) Service Flow Rate

These values represent ideal conditions of 12-ft lanes (3.6 m), adequate lateral clearances, and all passenger cars in the traffic stream. Therefore, the maximum service flow rates of Table 4.1-3 must be adjusted to reflect any prevailing conditions that are other than ideal, and to reflect the total number of lanes in one direction on the freeway. This is accomplished by using several correction factors, as follows :

$SF_i = MSF_i \times N \times f_w \times f_{hv} \times f_p$ or
$SF_i = C_j \times (V/C)_j \times N \times f_w \times f_{hv} \times f_p$

where:

SF_i = Service flow rate for LOS_i under prevailing roadway and traffic conditions for N lanes in one direction, in vph;
N = number of lanes in one direction of the freeway;
f_w = factor to adjust for the effects of restricted lane widths and/or lateral clearances;
f_{hv} = factor to adjust for the effect of heavy vehicles (trucks, buses, and recreational vehicles) in the traffic stream; and
f_p = factor to adjust for the effect of driver population.

3) Service Flow Rate of Motorway under Consideration

Given conditions;
- lane width = 3.75 m (12.3 ft)
- distance from traveled pavement = 1.75 m (5.74 ft)

- adjustment factor for restricted lane width and lateral clearance
  $f_w = 1.00$
- Lampang-Doi Saket Route
  Typical Truck 10% ET = 3
  Heavy Truck 5% ET = 6
  Bus 10% EB = 1.6
  Grade 2% ,0.6 km ;upgrade
  $f_{hv} = 1/[1 + 0.10\,(3-1) + 0.05\,(6-1) + 0.1\,(1.6 - 1)] = 0.662$

- Banpong-Cha Am Route
  - Typical Truck 15% ET = 2
  - Heavy Truck 15% ET = 3
  - Bus 10% EB = 1.6
  - Grade 1% 0.6 km, upgrade
  - f_{hv} = 1/ [1 + 0.15 (2-1) + 0.15 (3-1) + 0.1 (1.6 - 1)] = 0.662
- Adjustment for Driver Population
  - weekday or commuter fp = 1.0
- Capacity 120 km/h and 100 km/h; C_j = 2000 pcphpl.
- V/C 0.54 for LOS B, 0.77 for LOS C
  0.93 for LOS D, 1.00 for LOS E

SFL = 2000 x 0.54 x 1 x 1.00 x 0.662 x 1.0 = 715 vph per lane (LOS B)
= 2000 x 0.77 x 1 x 1.00 x 0.662 x 1.0 = 1019 vph per lane (LOS C)
= 2000 x 0.93 x 1 x 1.00 x 0.662 x 1.0 = 1231 vph per lane (LOS D)
= 2000 x 1.00 x 1 x 1.00 x 0.662 x 1.0 = 1324 vph per lane (LOS E)

2. Required Number of Lanes

Required number of lanes can be calculated as follow:

N = Design Traffic Volume/SFL (per direction)
Design Traffic Volume = AADT x K x P (per direction)

where; N ; Required number of lanes per direction
AADT; Forecast average annual daily traffic
K ; Direction share 0.55
P ; Peak hour ratio 0.08
SFL ; Service Flow Rate per lane, 715 (B), 1019 (C)
1231 (D), 1324 (E)

Target Level of Service

To decide appropriate number of lanes, 3 options are exercised as shown in Table 4.1-5. It shall be noted that road networks for both routes, Lampang-Doi Saket route and Ban Pong-Cha Am route, will be drastically changed in 2010 and 2020. It may, therefore, be acceptable that target level of service be reduced in 2020.

TABLE 4.1-5 TARGET LEVEL OF SERVICE

Route	Option 1 AASHTO	Option 2 AASHTO	Option 3 Japan
Lampang-Doi Saket	(Rural Rolling) 2010 - LOS `B' 2020 - LOS `C'	(Rural Mountainous) 2010 - LOS `C' 2020 - LOS `D'	(Mountainous) 9,000 veh./lane /day
Ban Pong-Cha Am	(Rural Level) 2010 - LOS `B' 2020 - LOS `C'	(Suburban) 2010 - LOS `C' 2020 - LOS `D"	(Flat) 12,000 veh./lane /day

Appendix 4.1-1 shows the results of Option 1, 2 and 3, and Table 4.1-6 summerizes the analysis results.

TABLE 4.1-6 SUMMARY OF REQUIRED NUMBER OF LANE

Per Direction

	AADT		Option1(AASHTO)		Option2(AASHTO)		Option3(Japan)		Required
Section	2010	2020	2010(B)	2020(C)	2010(C)	2020(D)	2010	2020	Number of lane
Lampang - Doi Saket Route									
Doi Saket-Chiang Mai	9,200	30,100	0.6	1.3	0.4	1.1	0.5	1.7	2
Chiang Mai-Mae Tha	16,300	49,100	1.0	2.1	0.7	1.8	0.9	2.7	3
Mae Tha-Lampang	14,800	50,400	0.9	2.2	0.7	1.8	0.8	2.8	3
Ban Pong - Cha Am Route									
Ban Pong-Pak Tho J/C	45,700	76,400	2.8	3.3	1.9	2.7	1.9	3.2	3
Pak Tho J/C-Pak Tho I/C	64,400	119,600	3.9	5.6	2.8	4.3	2.7	5.0	5
Pak Tho I/C-Cha Am I/C	52,000	97,000	3.2	4.2	2.2	3.5	2.2	4.0	4

The actual number of lanes is discussed taking into consideration the operational condition, continuity of sections, length of sections and stage construction, among others. Stage construction would be considered to efficiently utilize the initial investment and cope with future development and traffic demand forecast.

Proposed number of lanes is as follows:

- Lampang - Doi Saket Route ----- 4 lanes
- Ban Pong - Cha Am Route ------- 6 lanes (first stage)
  2 lanes widening (second stage in 2020)

In preliminary design, 4 lanes and 6 lanes are adopted along Lampang - Doi Saket Route and Ban Pong - Cha Am Route respectively, in consideration of the possibility of planning the second toll motorway in future instead of widening of Ban Pong - Cha Am Route.

4.2 PREPARATION OF ALTERNATIVE ROUTES AND THEIR EVALUATION

4.2.1 Lampang - Doi Saket Route

Five alternative routes are proposed as shown in Figure 4.2-1. Figure 4.2-2 shows schematically component links of each route, viz.:

- Alternative Route 1 (AR-1): Links of A1 and A2
- Alternative Route 2 (AR-2): Links of A1, B1, B5 and B3
- Alternative Route 3 (AR-3): Links of A1, B1, B5 and B4
- Alternative Route 4 (AR-4): Links of A1, B2, B5 and B3
- Alternative Route 5 (AR-5): Links of A1, B2, B5 and B4

A1 and A2 are the links selected in the master plan study, B1 is the link along existing Rt. 11 to make tunnel length shorter, B2 is the link through mountainous area to pass forest reserves with a tunnel, B3 is the link close to city center and B4 is the link through paddy field to avoid urbanized area.

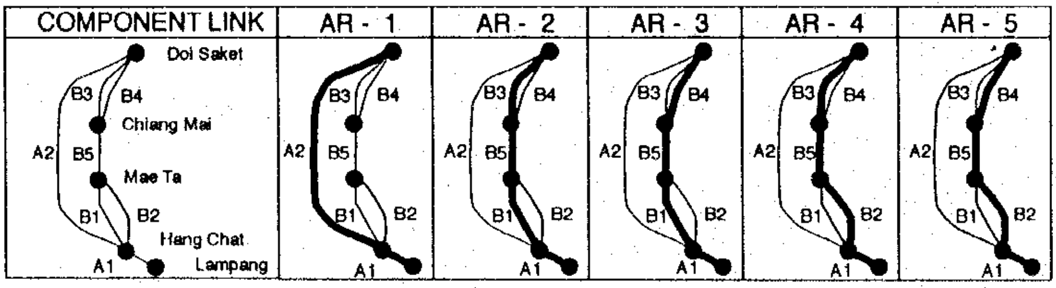


FIGURE 4.2-2 LINKS OF LAMPANG - DOI SAKET ALTERNATIVE ROUTES

1. Characteristics of alternative routes

Characteristics of the alternative routes are described below (refer to Appendix 4.2-1 for results of design of each route):

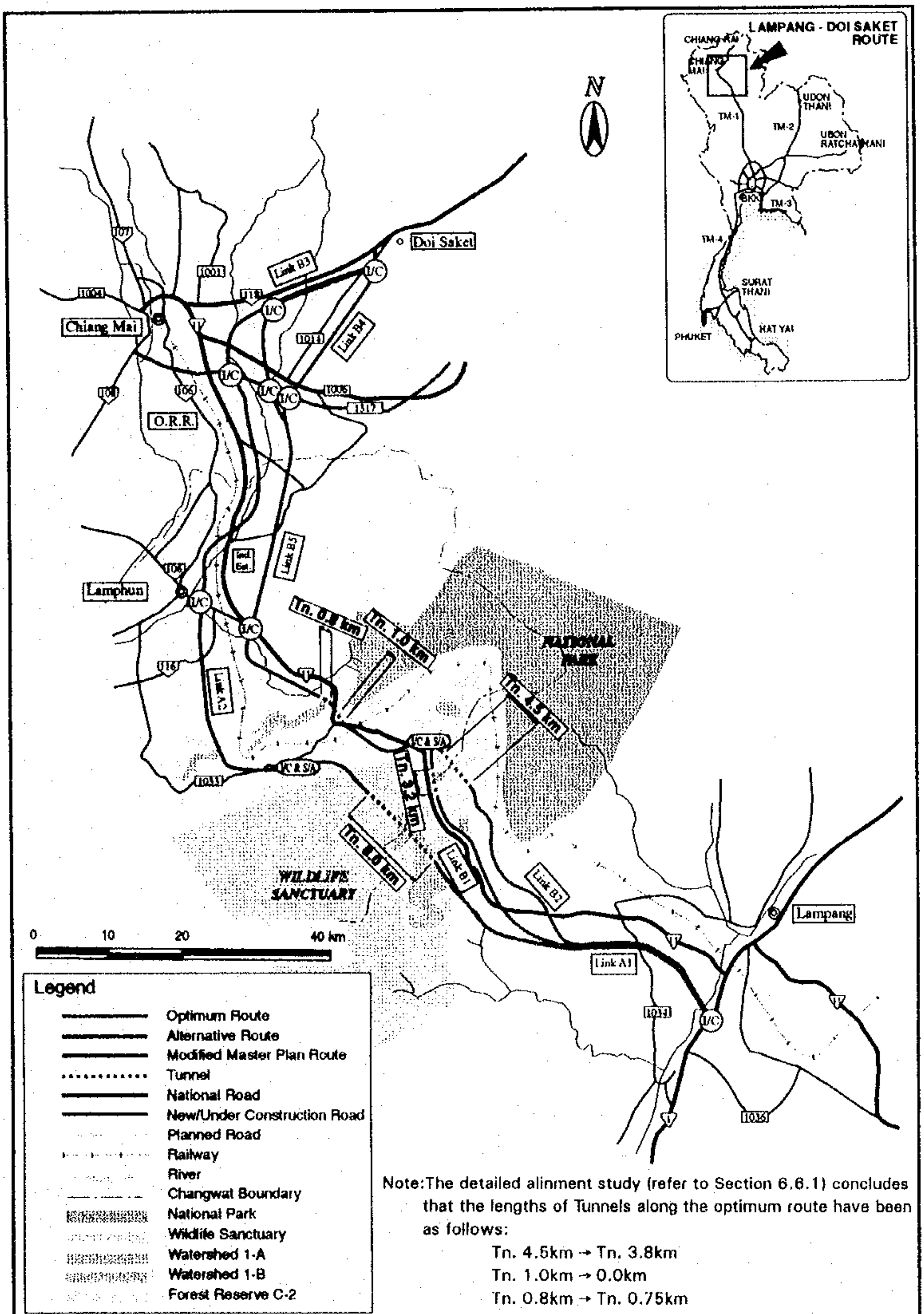
1) AR-1 (Links A1 and A2)

The advantage of this route is the good accessibility of the interchange; that is, interchanges for Lamphun and Chiang Mai are planned closer to their city centers compared with the other routes. There are many disadvantages, as follows:

- It crosses the wildlife sanctuary and watershed class 1-A which are stipulated to be strictly conserved.

- It passes through residential and commercial areas designated under city planning in Lamphun and Chiang Mai.

- It requires the largest construction cost among the alternative routes because it has the longest route length, the longest tunnel designed as a measure to cross the wildlife sanctuary and the watershed class 1-A in the mountainous section, and the longest viaduct planned to pass through relatively urbanized areas in the vicinity of Lamphun and Chiang Mai.



Note:The detailed alinment study (refer to Section 6.6.1) concludes that the lengths of Tunnels along the optimum route have been as follows:

Tn. 4.5km → Tn. 3.8km
Tn. 1.0km → 0.0km
Tn. 0.8km → Tn. 0.75km

FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS	FIGURE 4.2-1 ALTERNATIVES OF LAMPAMG - DOI SAKET ROUTE

2) AR-2 (Links A1, B1, B5 and B3)

This route is better than AR-1 for conservation of the natural environment since it is drawn to avoid the wildlife sanctuary and the watershed class 1-A. However, it is worse than AR-4 and AR-5, because it runs very closely along the wildlife sanctuary.

For Lamphun, the route avoids the city planning area, but for Chiang Mai, it passes through the city planning area, although shifted to the outside compared with AR-1. Other characteristics such as accessibility of the interchanges and the construction cost are average.

3) AR-3 (Links A1, B1, B5 and B4)

This is a route in which only Link B3 in AR-2 changes to Link B4.

Link B4 is planned to completely avoid the city planning area, different from Link B3, resulting in the interchange becoming rather far from the city center.

The construction cost is the lowest because Links B1 and B4 are cheaper than other competitive links.

4) AR-4 (Links A1, B2, B5 and B3)

This is a route in which only Link B1 in AR-2 changes to Link B2.

Link B1 is the best route for conservation of the natural environment because the route passes far from the wildlife sanctuary and the watershed class 1-A. The other characteristics are the same as AR-1.

5) AR-5 (Links A1, B2, B5 and B4)

This is a route in which only Link B3 in AR-4 changes to Link B4.

Therefore, this is the best route in the mountainous section and avoids the city planning area in the vicinity of Chiang Mai.

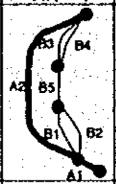
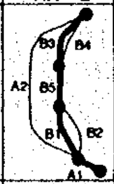
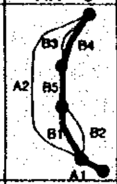
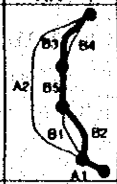
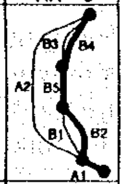
The construction cost is the second lowest among the five alternative routes.

2. Rating

Rating items and results are shown in Table 4.2-1, in which the higher figures show a higher evaluation. The criteria and details of the rating are presented in Appendix 4.2-2.

AR-5 is assessed as the most appropriate route, followed by AR-3, AR-4 and AR-2. AR-1 shows a quite low figure compared with the other alternative routes.

TABLE 4.2-1 RATING RESULTS OF LAMPANG - DOI SAKET ROUTE

Alternative Route		AR - 1	AR - 2	AR - 3	AR - 4	AR - 5
Composition of Alternative Route						
I. SOCIO - ECONOMIC ASPECT	I.1 Adaptability for City Planning	2	3	3	3	3
	I.2 Split of Community	1	2	3	2	3
	I.3 Development Impact	1	3	2	3	2
II. ENVIROMENTAL ASPECT	II.1 Wildlife Sanctuary	1	2	2	3	3
	II.2 Watershed Class 1A	1	2	2	3	3
	II.3 Forest Reserve	1	2	2	3	3
	II.4 Pollution	1	2	3	2	3
III. TRAFFIC ASPECT	III.1 Interchange Location	3	1	2	1	2
	III.2 Expected Traffic Volume	3	1	2	1	2
	III.3 Connection with Highway Network	2	3	2	3	2
IV. TECHNICAL ASPECT	IV.1 Alinement	2	2	2	3	3
	IV.2 Difficulty of Construction	1	2	3	2	3
	IV.3 Construction Cost	1	2	3	2	3
	IV.4 Maintenance Cost	1	3	3	2	3
RATE		21	30	34	33	38

3 : Good / Low negative impact on environment
2 : Fair / Moderate negative impact on environment
1 : Bad / High negative impact on environment

3. Conclusion

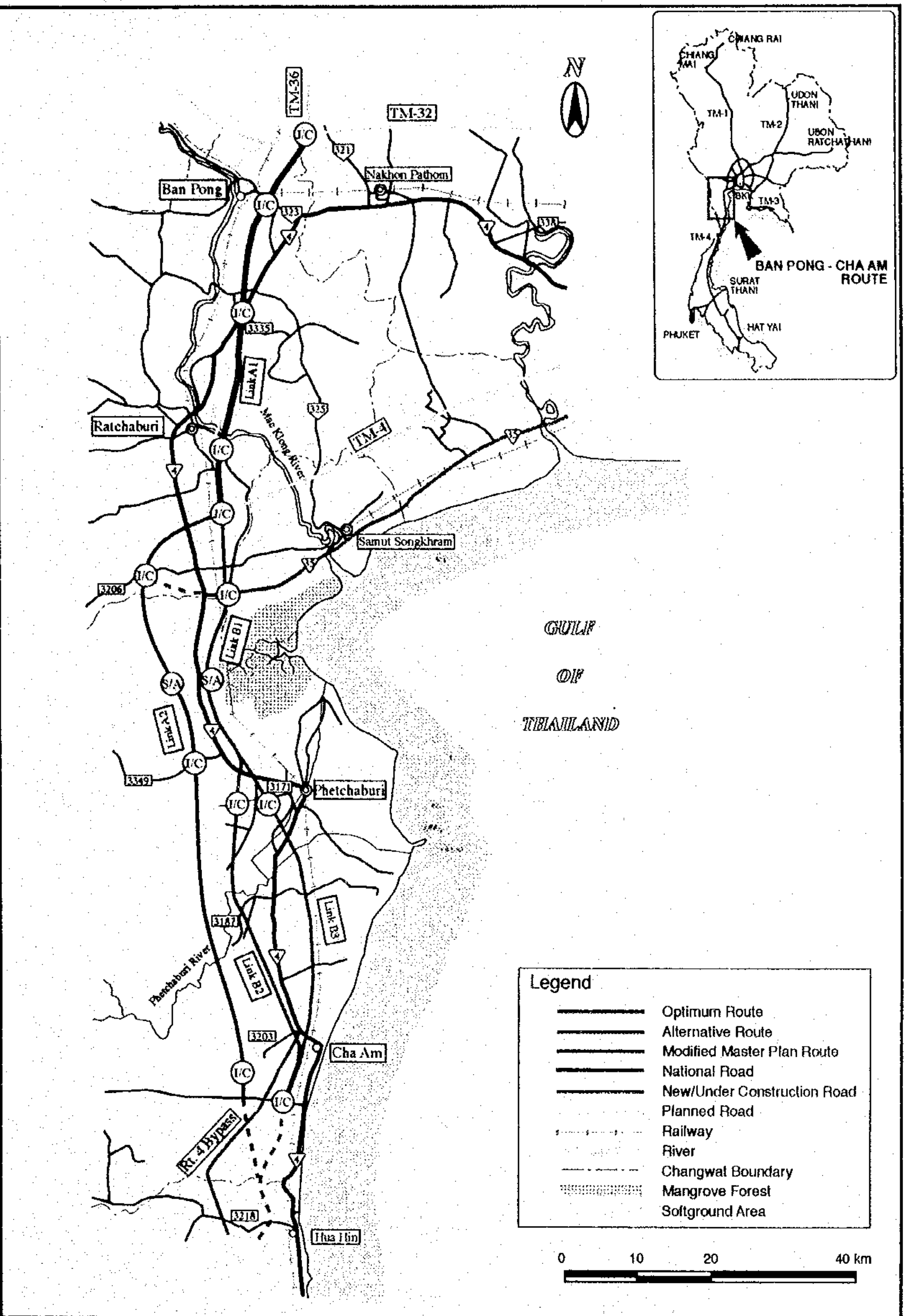
AR-5 is selected as the optimum route because it does, i) completely avoid the wildlife sanctuary and the watershed class 1-A, ii) minimize the negative environmental impact, iii) avoid city planning areas and relatively urbanized areas as much as possible and iv) avoid the Chian Mai Outer Ring Road which will be implemented in the near future.

4.2.2 Ban Pong - Cha Am Route

Three alternative routes are proposed as shown in Figure 4.2-3. Figure 4.2-4 shows schematically component links of each route, viz.:

- Alternative Route 1 (AR-1): Links of A1 and A2
- Alternative Route 2 (AR-2): Links of A1, B1 and B2
- Alternative Route 3 (AR-3): Links of A1, B1 and B3

A1 and A2 are the links selected in the master plan study, B1 is the link through paddy field, B2 is the link through suburban and B3 is the link close to city centers.



FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS	FIGURE 4.2-3 ALTERNATIVES OF BNAG PONG - CHA AM

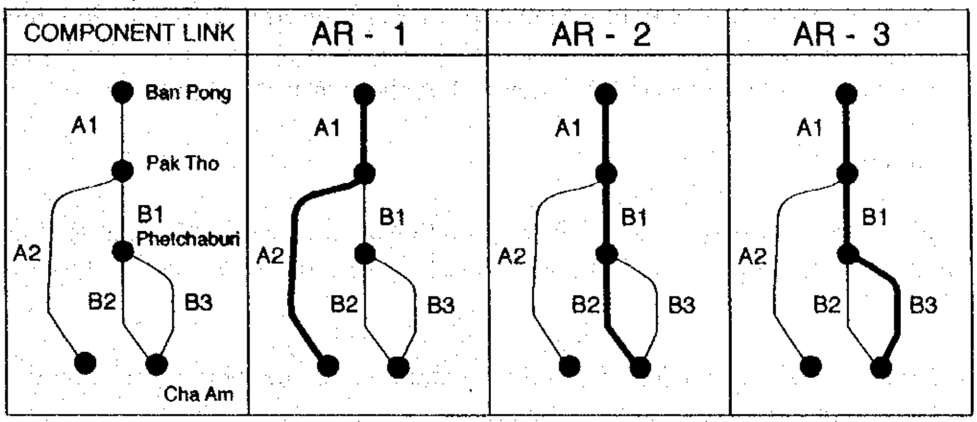


FIGURE 4.2-4 LINKS OF BAN PONG - CHA AM ALTERNATIVE ROUTES

1. Characteristics of alternative routes

Characteristics of the alternative routes are described below (refer to Appendix 4.2-3 for results of design of each route):

1) AR-1 (Links A1 and A2): 126.0 km

As Link A1 is common for all alternative routes, the characteristics of this route are presented under Link A2.

As described above, since Link A2 runs on the west side far from Rt. 35, Phetchaburi city and Cha Am city, its accessibility is the worst among the three alternative routes. In particular, for the interchange with Rt. 35, a considerable length of extension of Rt. 35 is required.

The location of the Cha Am Interchange is planned near the Hup Ka Pong King's Project. There is the concern air, noise and vibration pollution brought about by this motorway would affect this project.
The construction cost is that average among the alternative routes.

2) AR-2 (Links A1, B1 and B2): 126.0 km

As Links A1 and B1 are common for AR-3. The locations of interchanges for Rt. 35 and Cha Am are the same as AR-3. However, the Phetchaburi Interchange is rather far from the city center compared with AR-3.
The construction cost is the lowest.

3) AR-3 (Links A1, B1 and B3): 126.5 km

There is not much difference between this route and AR-2.

As mentioned in 2), the Phetchaburi Interchange was planned closer to the city center than AR-3.

AR-2 crosses Rt. 4 one time; however, this route crosses Rt. 4 for 2 times.

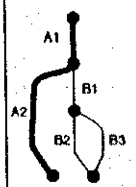
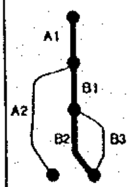
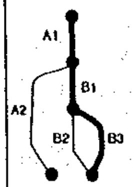
The construction cost is the highest, but the margin is narrow.

2. Rating

Rating items and results are shown in Table 4.2-2, in which the higher figures show a higher evaluation. The criteria and details of the rating are presented in Appendix 4.2-4.

According to the rated figures, A-2 is evaluated as the best route, followed by AR-3. AR-1 is much inferior to the others.

TABLE 4.2-2 RATING RESULTS OF BAN PONG - CHA AM ROUTE

Alternative Route		AR - 1	AR - 2	AR - 3
Composition of Alternative Route				
I. SOCIO - ECONOMIC ASPECT	I.1 Adaptability for City Planning	2	3	3
	I.2 Split of Community	1	3	2
	I.3 Development Impact	3	2	2
	I.4 Specific Project	1	3	3
II. ENVIROMENTAL ASPECT	II.1 Pollution	1	3	3
	II.2 Soft Ground	3	2	2
III. TRAFFIC ASPECT	III.1 Interchange Location	1	2	3
	III.2 Expected Trffic Volume	1	2	3
	III.3 Connection with Highway Network	1	3	3
IV. TECHNICAL ASPECT	IV.1 Alinement	3	3	3
	IV.2 Difficulty of Construction	3	3	2
	IV.3 Construction Cost	2	3	1
	IV.4 Maintenance Cost	1	3	2
RATE		23	35	32

3 : Good / Low negative impact on environment
2 : Fair / Moderate negative impact on environment
1 : Bad / High negative impact on environment

3. Conclusion

AR-2 is selected as the optimum route because it has higher rate than the others, while AR-1 has very poor accessibility and negative environmental impact on the Hup Ka King's Project.

CHAPTER 5

EVALUATION OF SELECTED ROUTES

CHAPTER 5

EVALUATION OF SELECTED ROUTES

The principle considerations in designing motorways are accessibility and mobility. Accessibility is a fixed requirement of the defined area. Mobility is provided at varying levels of service. The dual role that motorways play conflicts each other and necessitates the difference and gradations in planning and designing.

Mobility can incorporate several qualitative elements, such as riding comfort and absence of speed changes, but the most basic factor is operating speed or trip travel time. The important elements of proposed motorway which influence operational conditions are discussed Section 5.2.

The access to urbanized/industrialized centers with acceptable level of services, is one of major functions of motorway, which will be discussed in Section 5.3, although the road access functions may be disregarded at some extent. With this regard, the accessibility of proposed motorways are evaluated in terms of population and route distances in the areas directly influenced. The direct influence area are defined as those Amphoe, center of which are connected to interchanges with reasonable access roads of about 30 Km in length. The Toll Highway Development Study in the Kingdom of Thailand, JICA 1991 (Master Plan Study) defines area-coverage as those which may be able to connect the nearest interchanges within 60 minutes by car.

5.1 CHARACTERISTICS OF SELECTED ROUTES

Table 5.1-1 and 5.1-2 summarize the characteristics of the selected routes, Lampang - Doi Saket Route and Ban Pong - Cha Am Route. Drawings of DWG. NO LD 1-1 and DWG. NO BC 1-1 in 'VOLUME IV DRAWINGS' graphically present the topographical conditions of the proposed routes, Lampang-Doi Saket Route and Ban Pong-Cha Am route, respectively, with some important control elements such as forest reserve areas, city planning areas, etc.

Lampang - Doi Saket Route generally runs rural level and mountainous areas, connecting directly or indirectly three centers of Changwat and 13 Amphoe in three Changwat, namely Lampang, Lamphun and Chiang Mai. These Amphoe except Mae Tha are classified as "urbanized areas" (population of 50,000 and over) in accordance with the definition of urban and rural area by AASHTO Design Standards.

Ban Pong - Cha Am Route directly traverses only two Changwat, Ratchaburi and Phetchaburi, where terrain are classified as rural level or suburban area. Also the route has a close connection with some Amphoe in four Changwat, namely Kanchanaburi, Nakhon Pathom, Samut Songkhram and Prachuap Khiri Khan. The route connects four Changwat centers and 18 Amphoes, which are categorized as "urbanized area" with population of over 50,000 except a few Amphoe.

TABLE 5.1-1 CHARACTERISTICS OF SELECTED ROUTE ; LAMPANG-DOI SAKEKT ROUTE

Section		Lampang-Hang Chat	Hang Chat-Mae Tha	Mae The-Lamphun-Chiang Mai	Chiang Mai-Doi Saket
Route		The route starts at intersection with Rt.1 at southwest of Lampang avoiding its City Planning Area, runs northwestward along southside of Rt. 11, and ends at south of Hang Chat. Length 14.5 Km.	The route runs northwestward,parallel with Rt 11, passing through Forest Resource Areas (C-2), and ends at Mae Tha, crossing with Rt 11. Length 27.5 Km.	The route runs northwestward passing east-side of Lamphun City Planning Area crossing with Rt 11, turns northward and ends at eastside of Chiang-Mai crossing with 1006 Bypass. Length 39.6 Km.	The route runs northeastward along Rt. 104 passing outskirt of Chiang-Mai City Planing Area (11.5 Km far) and ends in a vicinity of Doi Saket connecting with Rt. 118. Length 16.6 Km.
Terrain		Almost flat, covered with paddy field Rural level area.	Almost mountainous area, 5 Km of Forest Resource Areas (C-2) and 3 locations of watershed (1-A). There is King's Project Dam near Mae Tha. Rural mountainous area.	Almost Rolling with upland crop fields near Mae Tha and flat with paddy field in remaining section. There exist, near Mae Tha, watershed (1-B) and Forest Resource (C-2) at east-side, and watershed (1-B) and Forest Resource (C-2). Urban/Suburban area	Flat Covered with paddy field Rural level/suburban area
Major Structures	Tunnels(m)	---	3,800	750	---
	Bridges(m)	255	190	466	215
	Viaduct(m)	1,520	6,925	2,870	2,050
	Overbridge(No)	10	7	8	8
Motorway Facility	Interchanges	-with Rt.1 at Lampang (7.5 Km. South-West)	-with Rt 11 at Mae Tha (4.5 Km. East	-with Rt 11 at Lamphun (9.0 Km South-east)	-with Rt.1006 Bypass at Chiang-Mai (11.5 Km. southeast) -with Rt 118 at Doi Sa Ket (1.5 Km. south
	Junctions	---	---	---	---
	Service Areas	---	-Near Mae Tha, combined with Interchange	---	---
Roughly Estimated Construction Cost		2,062 M Baht	12,859 M Baht	6,407 M Baht	2,693 M Baht
Expecter Traffic Volume		- 2,000 (Y2000) -14,800 (Y2010, connected to Chang-Rai) -50,400 (Y2020, Toll Motorway System Completed)	- 2,000 -14,800 -50,400	- 2,200 -16,900 -48,100	- 800 -9,200 -30,100
Environment	Temples and Schools* (No)	9	0	10	7
	Urbanized Areas (M)	1.5 KM	0.4 KM	0 KM	0.7 KM
	Wildlife Sanctnary (M)	N/A	N/A	N/A	N/A
	Watershade (1-A) (M)	N/A	N/A	N/A	N/A
	Forest Resource Areas (M)	N/A	5.5 KM	1.0 KM	N/A

Note: * Temples and Schools within 500 m. corridor.

TABLE 5.1-2 CHARACTERISTICS OF SELECTED ROUTE: BAN PONG - CHA AM ROUTE

Section		Ban Pong - Ratchaburi - Pak Tho	Pak Tho - Phetchaburi	Phetchaburi - Cha-Am
Route		The route starts at the cross point of TM-32 and TM-36, (both proposed motorways) at northern side of Ban Pong, avoiding its City Planning Area, runs southward crossing Rt.4 avoiding Ratchaburi City Planning Area, and ends at intersection with TM-4. The route is almost parallel with Rt.4. Length 51.0 Km.	The route runs southward crossing with Rt.35,, parallel with Rt.4, avoiding mangrove forest of Khao Yai and Phethaburi City Planning Area, and ends at the cross point with Rt.4, westside of Phetchaburi. Length 36.5 Km.	The route runs southward along westside of Rt.4, passing through Cha Am City Planning Area and ends at cross e point with Sun Rise Valley Road, about 9.0 Km southside of Cha Am, Length 46.3 Km.
Terrain		Alluvium plane covered with paddy fields Rural Level/Suburban area	Alluvium plane covered with paddy fields. Rural level/Suburban area	Alluvia plane covered with paddy fields Rural level/Suburban area
Major Structures	Tunnel (m)	--	--	--
	Bridges(m)	542	253	169
	Viaducts(m)	9,673	2,900	2,012
	Overbridge(No)	17	12	10
Motorway Facilities	Interchanges	- with Rt. 323 at Ban Pong (3.0 Km.east) - with Rt. 4 at Photharam (3.5 Km.east) - with Proposed Ratchaburi Outer Ring at Ratchaburi (4.0 Km Southeast)	- with Rt.35 at Pak Tho (3.5 Km.	- with Rt.3191 at Phetchaburi (7.5 Km. west) - with Rt.3175 at Tha Yang (3.5 Km. west) - with Sun Rise Valley Road near Cha Am (9.0 Km. South)
	Junctions	- with Proposed TM-32 near Ban Pong (8.5 Km. Northeast), Beginning of Route.	- with proposed TM-4	---
	Service Areas	---	- Between Pak Tho and Petchaburi, west-side of mangrove forest	---
Roughly Estimated-Construction Cost		13,802 M Baht	6,639 M Baht	4,563 M Baht
Expected Traffic Volume		- 28,900 (Y2000, connected to OBRR) - 64,400 (Y2010, connectdd to TM-4 and extended to Chumphon) -119,600 (Y2020, Toll Motorway System completed)	- 15,900 - 49,700 - 92,700	- 13,400 - 52,000 - 97,000
Environ-ment	Temples and Schools* (No)	9	4	3
	Urbanized Areas (M)	1.8 KM	0.5 KM	0.5 KM
	Wildlife Sancturary (M)	N/A	N/A	N/A
	Watershed (1-A) (M)	N/A	N/A	N/A
	Forest Resource Areas (M)	N/A	N/A	N/A

Note : * Temples and Schools within 500 m. corridor.

5.2 MOBILITY OF MOTORWAY

Table 5.2-1 presents the outputs of the operational analysis on proposed motorway and summarized as follows.

- Lampang - Doi Saket Route

In 2010, level of service (LOS) is A, maximum V/C ratio 0.28, free flow with a estimated speed of 96 km per hour.

In 2020, LOS will be reduced to D, V/C ratio 0.84. high density but stable flow with a speed of 85 km per hour.

- Ban Pong - Cha Am Route

Along this route, a heaviest traffic will be observed in the section between Pak Tho Junction and Pak Tho Interchange (about 10.2 km).

In 2010, LOS of this section is C, V/C ratio 0.71, stable flow with a speed of 86 km per hour.

In 2020, LOS will be deteriorated to F, V/C ratio 1.32, forced or breakdown flow. LOS of the section between Pak Tho Interchange and Cha Am Interchange will be E, relatively uniform speed but near the capacity level.

TABLE 5.2-1 OPERATIONAL CONDITION OF MOTORWAY

V/C = Design Traffic Volume / Capacity
Capacity = 2000 x 1.00 x 0.662 x 1.0 x N = 1324 x N
N = Number of Lanes

Section	AADT		Design Traffic Volume		Number of Lanes		V/C Ratio		Ave. Travel Speed(km/h)		Level of Service	
	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020
Lampang - Doi Saket Route												
Doi Saket-Chiang Mai	9,200	30,100	405	1324	2	2	0.15	0.50	96	94	A	B
Chiang Mai-Mae Tha	16,300	49,100	744	2160	2	2	0.28	0.82	96	85	A	D
Mae Tha-Lampang	14,800	50,400	651	2218	2	2	0.25	0.84	96	85	A	D
Ban Pong - Cha Am Route												
Ban Pong-Pak Tho J/C	45,700	76,400	2011	3362	3	3	0.51	0.85	94	85	B	D
Pak Tho J/C-Pak Tho I/C	64,400	119,600	2834	5262	3	3	0.71	1.32	86	48	C	F
Pak Tho I/C-Cha Am	52,000	97,000	2288	4268	3	3	0.57	1.07	93	51	C	E

Although 4-lanes in 2010 and 6-lanes in 2020 for Ban Pong Junction - Pak Tho Junction section may be acceptable in terms of level of services, 6-lanes in 2010 and 8-lanes in 2020 or the second toll motorway will be recommended for the corridor between Pak Tho Junction and Cha Am Interchange. In this study, 6 lanes motorway is designed all the way from Ban Pong to Cha Am in consideration of the possibility of planning the second motorway as described in section 4.1.

The proposed number of lanes are considered acceptable comparing with capacity and operational conditions of existing facilities such as Meishin/Tomei Expressway, Japan. As a reference, Table 5.2-3 shows the survey results on congestion along Meishin/Tomei Expressway, Japan in 1986, which are summarized as shown in Table 5.2-2.

TABLE 5.2-2 SUMMARY OF CONGESTIONS ALONG MEISHIN/TOMEI EXPRESSWAY

(in 1986)

Congestion Degree (C/V)	Traffic Volume per lane per day	Frequency of congestion (Time/day)	Hours of Congestion (Hours/Time)
1.5	16,200	0.67	2.2
1.3	13,400	0.04	2.3
1.0	12,200	0.04	2.1

TABLE 5.2-3 CONGESTIONS ALONG MEISHIN/TOMEI EXPRESSWAY

(in 1986)

Daily Traffic Volume V/Both Directions	No. of Lane (Both Directions)	Congestion (DTV/capacity) Congestion Degree	Frequency (Times)	Hours (Hours)	Average
52,079	4	1.63	180	519	C/V = 1.5
68,229	4	1.42	5	4	T.V = 16,200
59,101	4	1.64	160	211	(per lane)
72,757	4	1.65	850	1835	T = 0.67
72,286	4	1.51	20	113	(times/day)
					H = 2.2
64,890	4	1.57	243	536	(hrs./time)
49,581	4	1.38	20	52	
48,418	4	1.34	20	61	C/V = 1.3
47,327	4	1.31	20	27	T.V = 13,400
62,789	4	1.31	5	7	T = 0.04
61,317	4	1.28	10	28	H = 2.3
53,886	4	1.32	15	35	
48,254	4	1.01	50	99	
50,377	4	1.05	5	10	C/V = 1.0
46,265	4	0.96	5	5	T.V = 12,200
48,345	4	1.01	5	10	T = 0.04
50,550	4	1.05	5	23	H = 2.1
48,758	4	1.02	14	29	

5.3 ACCESSIBILITY OF MOTORWAY

5.3.1 Lampang - Doi Saket Route

Presented in Table 5.3-2 are population along routes and distances from Amphoe center to nearby interchanges in the direct influence areas. Table 5.3-1 summarizes the accessibility of proposed motorway. The direct influence area for Lampang - Doi Saket Route is graphically demonstrated in Figure 5.3-1.

TABLE 5.3-1 ACCESSIBILITY OF MOTORWAY ALONG LAMPANG - DOI SAKET ROUTE

population in 1992

Changwat	Whole		Direct Influenced Areas		
	No of Amphoe	Population	No of Amphoe	Population	Average Distance to Interchange
Chiang Mai	22	1,530,900	8	774,100	17.4 km
Lamphun	7	398,000	4	274,100	15.0 km
Lampang	13	776,200	4	413,300	18.0 km
Total	42	2,705,100	16	1,461,500	ave.16.8 km

According to Table 5.3-1, 16 Amphoe among 42 Amphoe in three Changwat will have accesses to interchanges, where residents of 1.46 millions or 54 % among total population of 2.7 millions may be able to arrive at the nearest interchanges with average distance of 16.8 Km.

TABLE 5.3-2 ACCESS BETWEEN AMPHOE AND INTERCHANGES ALONG LAMPANG - DOI SAKET ROUTE

population in 1992

Changwat	Amphoe	Population	Route and Distance to Interchange	
Chiang Mai	Muang Chiang Mai	242,400	Rt.1317	13 km *
	Doi Saket	62,400	Access Road	3 km *
	Hang Dong	62,300	Rt.108	28 km
	Mae Rim	75,100	Rt.107, Rt.1317	31 km
	San Kamphaeng	73,200	Access Road,Rt.1317	7 km
	San Pa Tong	81,200	Rt.1013,Rt.11	26 km
	San Sai	81,800	Rt.1019	23 km
	Saraphi	75,700	Rt.11,Rt.1317	8 km
	Sub Total	774,100		139 km
Lamphun	Muang Lamphun	132,300	Rt.11	7 km *
	Mae Tha	40,000	Rt.11	5 km *
	Pa Sang	83,600	Rt.106,Rt.11	20 km
	K.A. Ban Thi	18,200	Local Road,Rt.1317	28 km
	Sub Total	274,100		60 km

Changwat	Amphoe	Population	Route and Distance to Interchange	
Lampang	Muang Lampang	219,800	Rt.1	9 km *
	Hang Chat	53,900	Rt.11	20 km
	Ko Kha	69,400	Rt.1	10 km
	Mae Tha	70,200	Local Road,Rt.1	33 km
	Sub Total	413,300		72 km
Total		1,461,500		

Note; * Location of interchange

5.3.2 Ban Pong - Cha Am Route

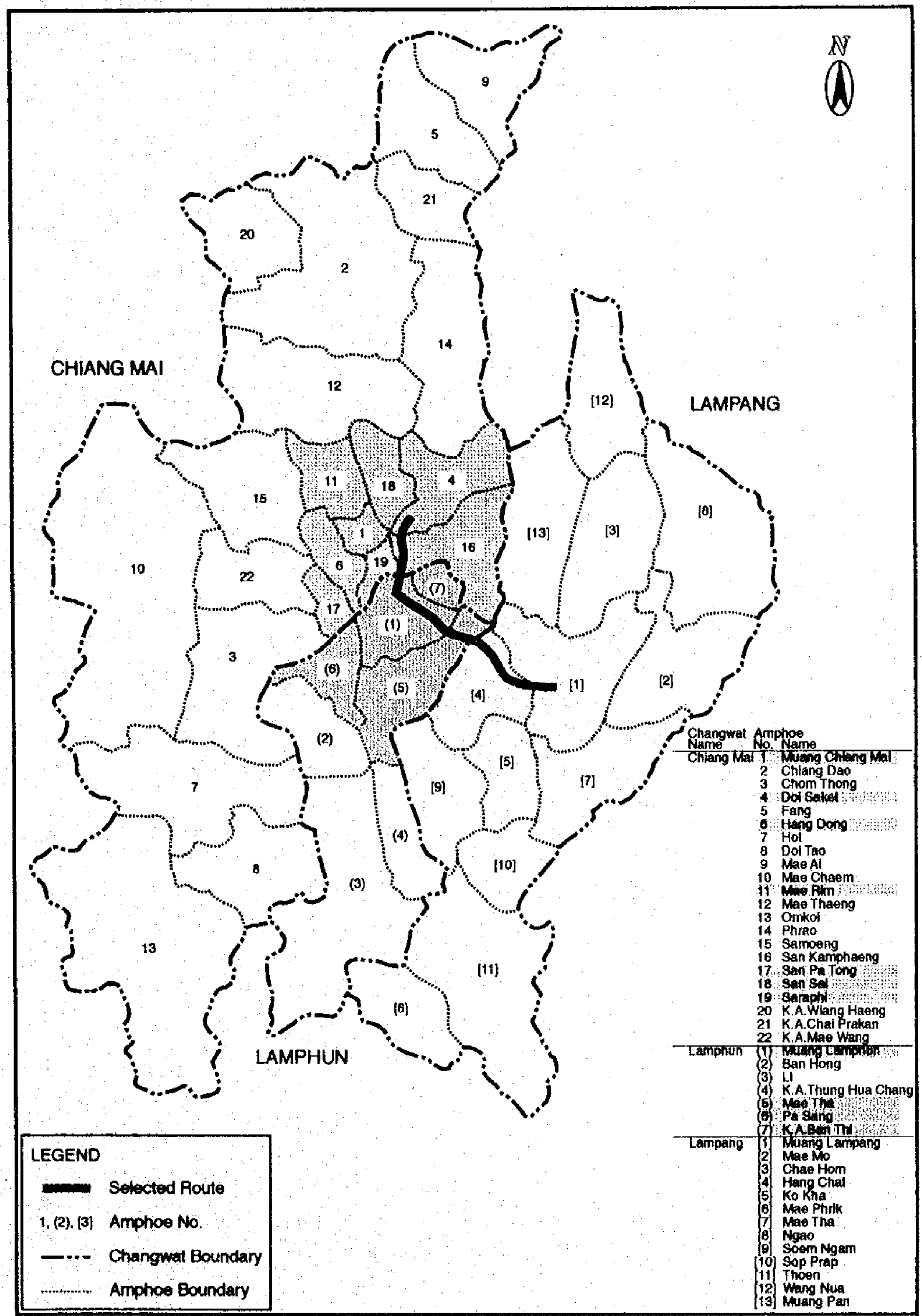
The population of Amphoe in the direct influence areas and access between Amphoe and interchanges are shown on Table 5.3-4. Table 5.3-3 summarizes the accessibility of proposed motorway. The direct influence area for the Route is graphically presented in Figure 5.3-2.

TABLE 5.3-3 ACCESSIBILITY OF MOTORWAY
ALONG BAN PONG - CHA AM ROUTE

population in 1992

Changwat	Whole		Direct Influence Area		
	No of Amphoe	Population	No of Amphoe	Population	Average Distance to Interchange
Kanchanaburi	6	724,000	2	229,200	26.0 km
Nakhon Pathom	5	671,000	2	320,400	36.0 km
Samut Songkhram	3	207,000	3	206,500	23.7 km
Ratchaburi	9	777,200	8	728,900	12.7 km
Phetchaburi	8	438,600	7	417,300	14.6 km
Prachup Khirikhan	2	451,000	1	63,600	17.0 km
Total	33	3,268,800	23	1,965,900	21.7 km

Table 5.3-3 shows that 23 Amphoe Centers in 6 Changwats will be connected with average distance of 21.7 Km and beneficiaries from the Project will be 2.0 millions or 60 % of total population of 3.3 millions in the direct influence area of 6 Changwats.



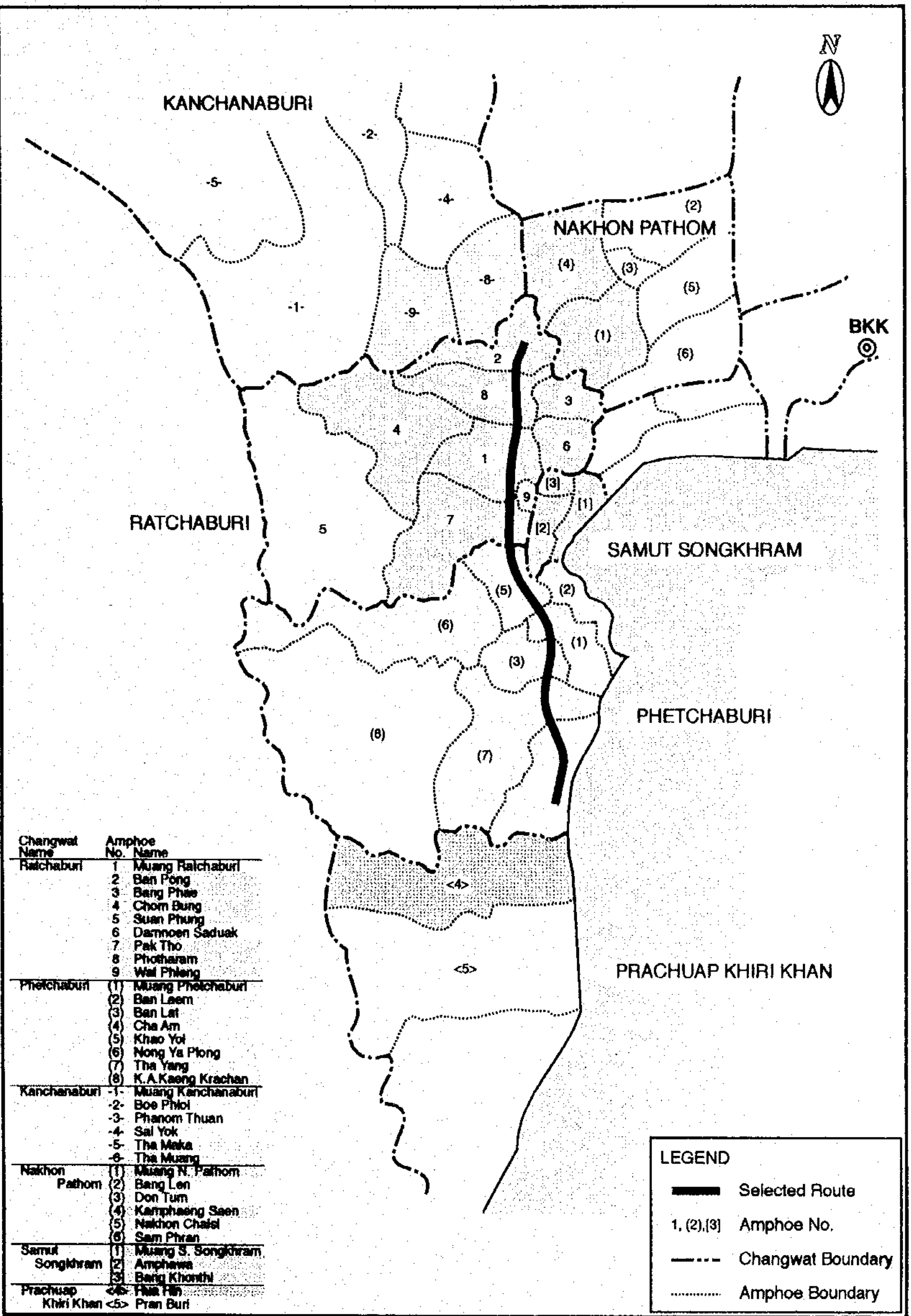
FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS	FIGURE 5.3-1 ACCESS TO AMPHOE ALONG LAMPANG - DOI SAKET ROUTE

TABLE 5.3-4 ACCESS BETWEEN AMPHOE AND INTERCHANGES ALONG BAN PONG - CHA AM ROUTE

population in 1992

Changwat	Amphoe	Population	Route and Distance to Interchange	
Kanchanaburi	Tha Muang	101,200	Rt.323	30 Km
	Tha Maka	128,000	Rt.323	22 Km
	Sub Total	229,200		52 Km
Nakhon Pathom	M.N Pathom	206,000	Rt.4, Rt.323	22 Km
	Kamphaeng Saen	114,400	Rt.321, Rt.4	50 km
	Sub Total	320,400		72 Km
Samut Songkhram	M.S Songkhram	104,500	Rt.35	23 Km
	Ampawa	63,000	Rt.35	18 Km
	Bang Khonthi	38,300	Rt.325, Rt.35	30 Km
	Sub Total	206,500		71 Km
Ratchaburi	Muang Ratchaburi	181,900	City Roads	5.0 Km *
	Ban Pong	153,600	City Roads	3.5 Km *
	Bang Phae	43,100	Rt.325 Rt.4	9.0 Km
	Chom Bung	56,700	Rt.3087	36 Km
	Damnoen Sadrak	101,500	Rt 323	27 Km
	Pak Tho	60,100	Rt.4	6 Km *
	Photharam	120,500	City Road	5 Km *
	Wat Phieng	11,500	Local Road	10 Km
	Sub Total	728,900		101.5 Km
Pheychaburi	Muang Phetchaburi	116,400	Rt.4	10 Km *
	Ban Laen	58,100	Rt.3178, Rt.4	24 Km
	Ban Lat	49,600	Local Road	15 Km
	Cha Am	58,400	Rt.4	10 Km *
	Kha Yoi	37,200	Rt.4	14 Km
	Nong Ya Plong	11,500	Local Road, Rt.4	26 Km
	Tha Yong	86,100	Rt.3175	3.5 Km *
	Sub Total	417,300		102.5 Km
Prachup Krikhan	Hua Hin	63,600	Rt 4	17 Km
	Sub Total	63,600		17 Km
Total		1,965,900		130 Km

Note; * Location of interchange



Changwat Name	Amphoe No.	Name
Ratchaburi	1	Muang Ratchaburi
	2	Ban Pong
	3	Bang Phae
	4	Chom Bung
	5	Suan Phung
	6	Damnoen Saduak
	7	Pak Tho
	8	Photharam
	9	Wat Phleng
Phetchaburi	(1)	Muang Phetchaburi
	(2)	Ban Laem
	(3)	Ban Lat
	(4)	Cha Am
	(5)	Khao Yoi
	(6)	Nong Ya Plong
	(7)	Tha Yang
	(8)	K.A.Kaeng Krachan
Kanchanaburi	-1-	Muang Kanchanaburi
	-2-	Boe Phloi
	-3-	Phanom Thuan
	-4-	Sai Yok
	-5-	Tha Maka
	-6-	Tha Muang
Nakhon Pathom	(1)	Muang N. Pathom
	(2)	Bang Len
	(3)	Don Tum
	(4)	Kamphaeng Saen
	(5)	Nakhon Chaisi
	(6)	Sam Phran
Samut Songkhram	[1]	Muang S. Songkhram
	[2]	Amphawa
	[3]	Bang Khonthi
Prachuap Khiri Khan	<4>	Hua Hin
	<5>	Pran Buri

FEASIBILITY STUDY
ON
THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 5.3-2
ACCESS TO AMPHOE
ALONG BAN PONG - CHA AM ROUTE

CHAPTER 6

PRELIMINARY DESIGN

CHAPTER 6

PRELIMINARY DESIGN

The preliminary design of the selected routes is conducted based on the results of topographic and geological surveys carried out by the local consultants registered in Thailand under the JICA Study Team supervision. The preliminary design covers all geometric elements, structures and facilities of the toll motorway and provides the data necessary for cost estimation. Design standards are established based on the current standards used in Thailand for the items which are acceptable for motorway design and supplemented by AASHTO or Japanese standards for the other items. The design standards are compiled in MOTORWAY DESIGN STANDARD.

6.1 TOPOGRAPHIC AND GEOLOGICAL SURVEYS

6.1.1 Topographic Surveys

For the purpose of the alinement study and the preliminary engineering study of the motorway corridors selected for a feasibility study, the following topographic surveys are conducted on the areas shown in Figure 6.1-1:

- Photogrammetric Mapping along Km.19 to Km.52 of Lampang - Doi Saket Route
- Photo-mosaics along corridors of Lampang - Doi Sket Route and Ban Pong - Cha Am Route
- Ground surveys; including profile leveling survey, spot elevation survey at I/C and J/C sites and river cross section survey, along corridors of Lampang - Doi Saket Route and Ban Pong - Cha Am Route

1. Photogrammetric Mapping

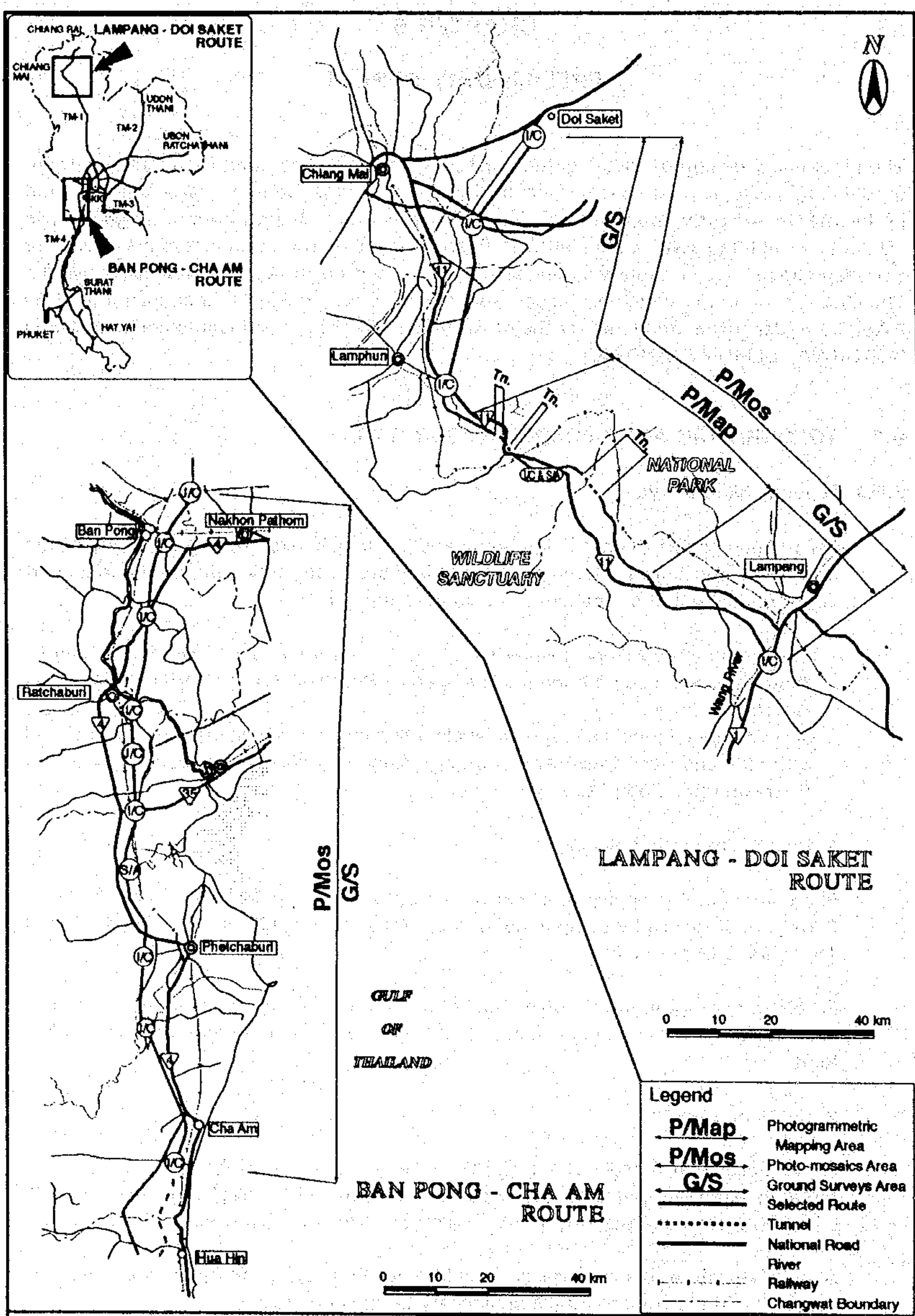
Photogrammetric mapping at a scale of 1 : 5,000 covering 100 km^2 areas (33 km x 3 km) are prepared by using aerial photographs (1 : 15,000 scale) taken by Royal Thai Survey Department.

Prepared photogrammetric map should be used for the alinement study in preliminary design of mountainous section including tunnels along Lampang - Doi Saket Route.

2. Photo-mosaics

Photo-mosaics at a scale of 1 : 5,000 covering the width of about 2 km along the tentative optimum routes are prepared by using aerial photographs (1 : 40,000 or 1 : 15,000 scale) taken by Royal Thai Survey Department in 1988 and 1989.

A set of results of photo-mosaics should be used for reviewing the control points of corridors and superimposing the preliminary design outcomes on it.



FEASIBILITY STUDY ON THE INTER-CITY TOLL MOTORWAY PROJECTS	FIGURE 6.1-1 LOCATION MAP OF TOPOGRAPHIC SURVEYS

3. Ground Surveys

Ground surveys including route survey and spot elevation survey are conducted along the corridors of Lampang - Doi Saket Route and Ban Pong - Cha Am Route as summarized in Table 6.1-1.

TABLE 6.1-1 SUMMARY OF GROUND SURVEYS

(1) Lampang - Doi Saket Route	
Route Surveys	
Lampang I/C - Km.19	19 km
Km.52 - Doi Saket I/C	45 km
Access Road for Doi Saket I/C	2 km
Spot Elevation Surveys	
Lamphun I/C	240,000 m^2
Chiang Mai I/C	240,000 m^2
(2) Ban Pong - Cha Am Route	
Route Surveys	
Ban Pong I/C - Cha Am I/C	132 km
Access Road for Rachaburi I/C	1 km
Access Road for Phetchaburi I/C	2 km
Spot Elevation Surveys	
Ban Pong J/C	490,000 m^2
Ban Pong I/C	240,000 m^2
Photharam I/C	240,000 m^2
Rachaburi I/C	240,000 m^2
Pak Tho I/C	240,000 m^2
Khao Yoi S/A	200,000 m^2
Phetchaburi I/C	240,000 m^2

The followings are the sets of survey results which should fully support to study the preliminary design:

Route Surveys;	Profile Plan (H=1:5,000, V=1:200)
	Cross Section (1:500)
Spot Elevation Surveys;	Topographic Map (1:2,500)
	Cross Section (1:500)

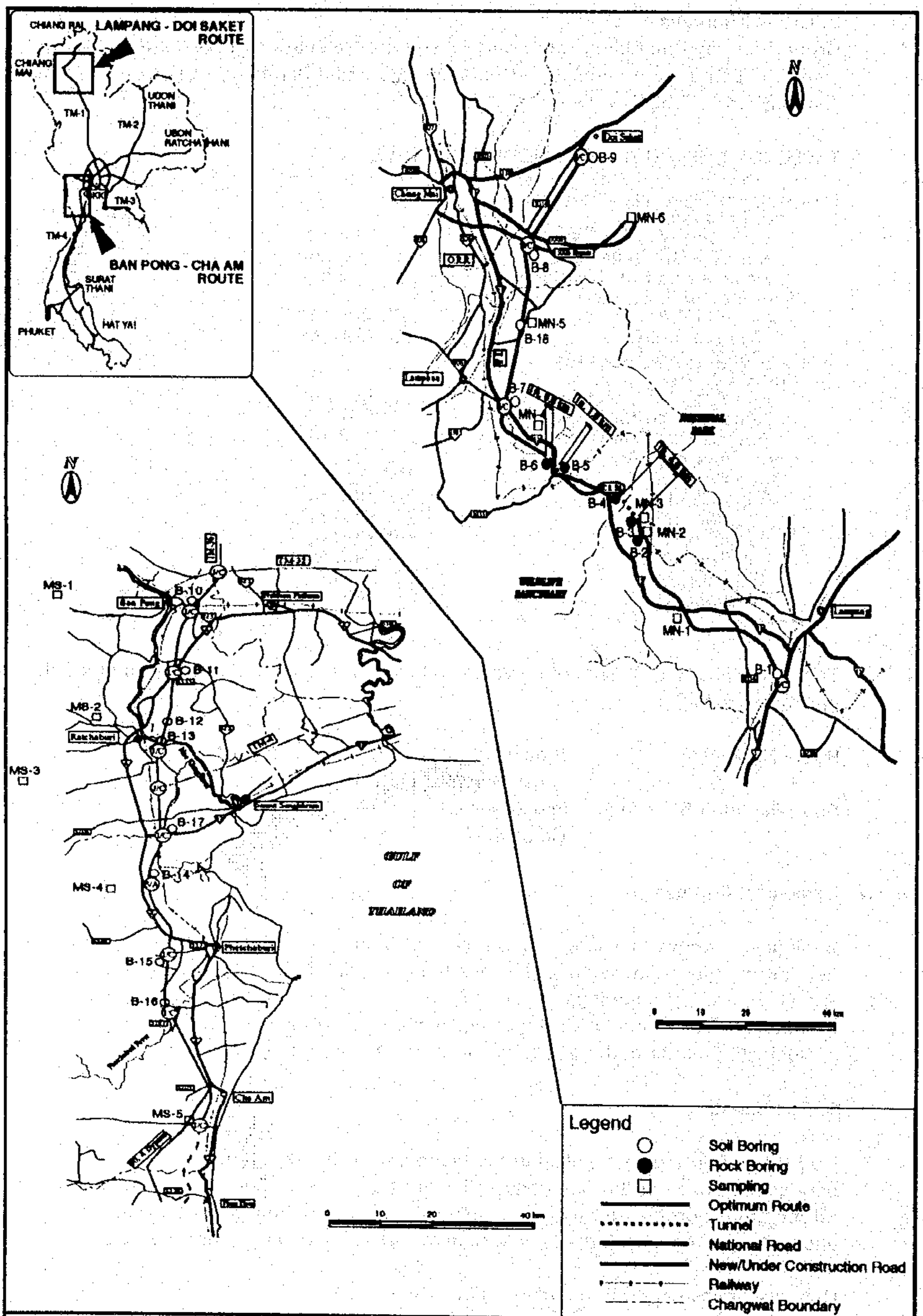
6.1.2 Geological Surveys

Geological surveys including soil boring, rock boring and material sampling are carried out in order to investigate the foundation condition of embankment, excavation and structures, the geological condition of proposed tunnels and the soil condition of material. The locations of all geological surveys are mapped in Figure 6.1-2, and geological profile of both routes are shown in Appendix 6.1-1 and 6.1-2.

1. Soil Boring

Five (5) soil borings are drilled in the Lampang - Doi Saket Route and eight (8) soil borings are drilled in the Ban Pong - Cha Am Route. Laboratory test items are natural moisture content, particle size analysis, atterberg limits, soil particle density, unconfined compression test, consolidation test and triaxial compression test.

Quantity of soil boring is summarized in Table 6.1-2.



FEASIBILITY STUDY
ON
THE INTER-CITY TOLL MOTORWAY PROJECTS

FIGURE 6.1-2
LOCATION MAP OF BORING AND MATERIALS INVESTIGATION

TABLE 6.1-2 QUANTITY OF SOIL BORING

Number of Soil Boring	Number	Depth (m)	SPT (No.)	Undisturbed Samples (No.)
B-1	1	24.15	24	0
B-7	1	5.94	6	0
B-8	1	16.15	16	0
B-9	1	10.00	10	0
B-10	1	18.15	16	3
B-11	1	14.15	12	3
B-12	1	15.15	11	6
B-13	1	20.15	19	3
B-14	1	6.75	5	2
B-15	1	20.15	18	2
B-16	1	15.15	15	0
B-17	1	17.15	14	4
B-18	1	7.60	8	2
TOTAL	13	190.64	174	25

Note: SPT: Standard Penetration Test
B-1 to B-9 and B-18 : Lampang - Doi Saket Route
B-10 to B-17 : Ban Pong - Cha Am Route

2. Rock Boring

Five (5) rock borings and laboratory tests including pulse velocity test and unconfined compression test are carried out in order to investigate the foundation condition of road excavation section and the geological conditions of proposed tunnels in the northern route between Lampang and Doi Saket. Quantity of rock boring is summarized in Table 6.1-3.

TABLE 6.1-3 QUANTITY OF ROCK BORING

Number of Rock Boring	Number	Length of Weathered Rock (m)	Length of Rock (m)	Depth (m)
B-2	1	30.0	0.0	30
B-3	1	30.0	0.0	30
B-4	1	8.5	21.5	30
B-5	1	13.5	16.5	30
B-6	1	30.0	0.0	30
TOTAL	5	112.0	38.0	150

Note: B-2 to B-6 : Lampang - Doi Saket Route

3. Material Sampling

The promised places and usable volumes of the borrow areas and the road excavations planned as material sources for embankment are investigated. Five (5) soil material samples are collected in the vicinity of the route between Lampang and Doi Saket. Four (4) soil material samples are taken from the borrow areas and two (2) soil material samples are taken from the road excavation sections. These material samples are tested in laboratory with natural moisture content, particle size analysis, atterberg limits, soil particle density, compaction test, laboratory CBR test and triaxial compression test.

6.2 DESIGN STANDARD

6.2.1 Geometric Design

It provides high service to motorists on motorways that higher design speed is selected for motorways than for ordinary highways with maximum 110 km/h. On the other hand, design speeds for motorways in developed countries except Japan intend to be decreasing due to high construction costs and high rate of accident arising.

Table 6.2-1 shows that design speeds in Europe countries and USA has trended toward being decreasing its values and Japan is planning to construct the 2 nd Meishin/Tomei Expressway with maximum design speed of 140 km/h instead of 120 km/h for existing expressways.

Regulatory speed is limited within design speed in Japan while regulatory or desirable speed in Europe is 10 km/h higher than design speed based on statistical considerations on actual running speed as say '85 percentile running speed, V_{85}'.

TABLE 6.2-1 DESIGN SPEEDS IN VARIOUS COUNTRIES unit:km/h

		Design Speed(V_e)	Regulatory Speed
JAPAN	Existing	120	100
	2nd Meishin/Tomei	140	Under Discussion
USA	1965	128	
	1984	112	90
	1987	112	105
GERMANY	1973	140	
	1984	120	130 *
FRANCE	1971	140	
	1985	120	130

Note:* A vehicle on motorway is allowed to drive at speed of 130 km/h which is equal to V_{85}.
Where: $V_{85} = V_e + 10$ km/h at V_e ∟&!!∟.100 km/h,
$V_{85} = V_e + 20$ km/h at $V_e < 100$ km/h.

Considering the above, design speed which controls other geometric design elements is selected as follows:

Rural, Flat	120 km/h
Rural, Rolling	120 km/h
Rural, Mountainous	100 km/h
Urban and Suburban	100 km/h

The other elements of geometric design standard for main line of motorway are presented in MOTORWAY DESIGN STANDARD. The major elements of design which will govern the preliminary design including construction planning and cost estimation are summarized in Table 6.2-2.

TABLE 6.2-2 GEOMETRIC DESIGN STANDARD

Description		Unit	Design Speed 120 km/h	100km/h	Remarks
Lane Width	Outer Lane	m	3.75	3.75	
	Center Lane	m	3.75	3.75	
	Inner Lane	m	3.75	3.75	
Median Width		m	13.50	13.50	
Shoulder Width	Outer Shoulder	m	3.00	3.00	
	Inner Shoulder	m	1.50	1.50	
Vertical Clearance		m	5.00	5.00	
Stopping Sight Distance		m	290(210)	210(160)	
Minimum Radius of Curve		m	1,000(710)	700(460)	
Minimum Curve Length		m	1,400/θ (200)	1,200/θ (170)	θ:intersecting angle in degree
Minimum Transition curve length		m	100	85	
Minimum Radius of Curve for Omission of Transition Curve		m	4,000	3,000	
Maximum Grade		%	2(4)	3(5)	
Minimum Radius of Vertical Curve					
	Crest Curve	m	21,000(11,000)	11,000(6,500)	
	Sag Curve	m	6,000(4,000)	4,500(3,000)	
Minimum Length of Vertical Curve		m	100	85	
Slope of Normal Crown		%	2.5	2.5	
Combined Gradient		%	10.0	10.0	

Note: The figure in ( ) shows allowable minimum or maximum value to be used only when necessary for the topographic or other special reasons.

6.2.2 Structural Design

The design of all structures shall meet the requirements which generally are practiced by the DOH and be in accordance with the Standard Drawings for Highway Construction prepared by DOH. Where no provisions are made by these practices or standards, the provisions of "Standard Specifications for Highway Bridges, AASHTO 1991" (AASHTO Spec.) shall be followed.

1. Design Loading

Bridges and box culverts shall be designed for a live load of HS20-44. All other structures or their components shall be designed in accordance with the live loads or equivalent loads specified in the AASHTO Spec. unless the design computation proves that less superimposed load is justified.

For other loadings not mentioned here, they shall conform to those specified in the AASHTO Spec.

2. Allowable Design Stresses

Allowable stresses shall be in accordance with the Service Load Design in the AASHTO Spec.

6.2.3 Pavement Design

Design for cement concrete pavement and asphalt concrete pavement shall be undertaken in accordance with "Road Note No.29, 3rd Edition 1970" and "Asphalt Institute MS-1, 1970", respectively.

6.2.4 Drainage Design

Drainage facilities are designed based on the calculated discharge by appropriate formulas corresponding to the extent of the catchment area in accordance with AASHTO Highway Drainage Guidelines 1987.

The pipe culverts with standard diameters of 100 cm and 150 cm are assumed to be disposed at intervals of the distances shown in Table 6.2-2.

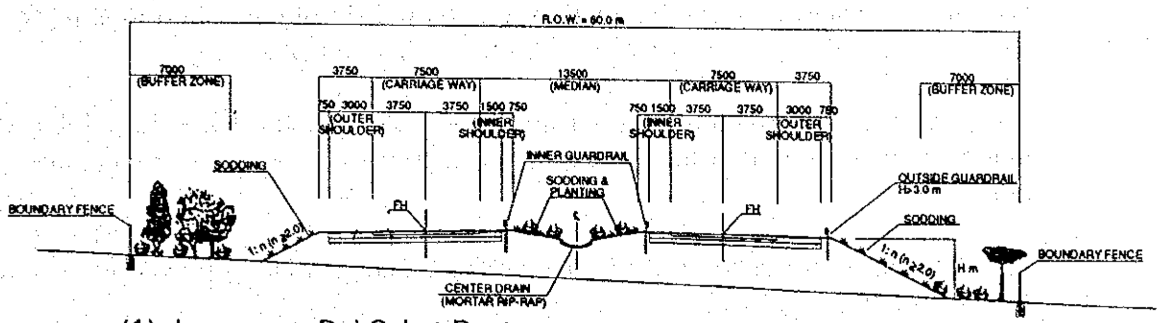
TABLE 6.2-3 ASSUMED INTERVALS OF PIPE CULVERTS IN FLAT AREA

Section	Standard Interval
Paddy or Flood section	200 m
Other section	500 m

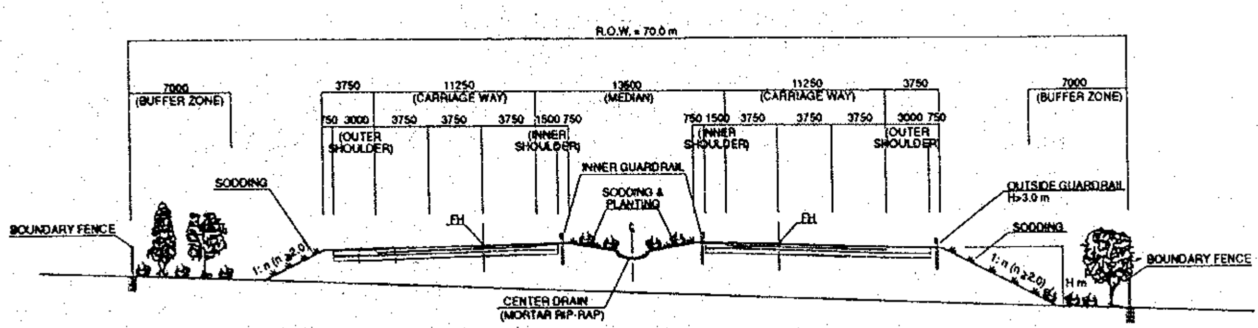
6.3 GEOMETRIC DESIGN

6.3.1 Cross Section

Standard cross sections are shown in Figure 6.3-1.



(1) Lampang - Doi Saket Route



(2) Ban Pong - Cha Am Route

FIGURE 6.3-1 STANDARD CROSS SECTIONS

Major cross section elements are as follows;

Carriageway : 2 and 3 lanes per direction are provided for Lampang - Doi Saket Route and Ban Pong - Cha Am Route, respectively. Surface is paved with cement concrete having a cross slope of 2.5% in normal section.

Shoulder : Shoulders are provided on both sides of carriageway in each direction. Inside shoulder provides lateral clearance for smooth passage of vehicles and lateral support of subbase, base and surface courses, while outside shoulder provides a space for stop of disabled vehicles and other emergency uses as well as lateral clearance and lateral support. Cross slope of shoulders is the same as that of carriageway.

Median : Depressed median of 13.50 m in width is provided for efficient drainage.

Traffic Barrier : Guardrails are installed outside shoulders as roadside and median barriers.

Buffer Zone : Buffer zones are provided on both sides of the road for the purpose of preservation of roadside environment such as mitigation of noise and air pollution.

6.3.2 Horizontal and Vertical Alinement

Geometric design is made following the selected route described in Chapter 4 in accordance with design standards set forth in Section 6.2-1.

The features of horizontal and vertical alinement are summarized in Table 6.3-1 which shows the composition of segments with various ranges of radius and gradient.

The detailed discussions on the alinement of tunnel section is presented in Section 6.6 "DESIGN OF TUNNEL".

TABLE 6.3-1 CHARACTERISTICS OF ALINEMENT
Horizontal Alinement: Length by Ranges of Radius

Radius R(m)	5000≤R	4000≤R <5000	3000≤R <4000	2000≤R <3000	1000≤R <2000
Lampang - Doi Saket Route					
Length (km)	73.0	4.8	2.4	9.3	9.2
(%)	74.0	4.9	2.4	9.4	9.3
Ban Pong - Cha Am Route					
Length (km)	133.7	0.0	0.0	0.0	0.0
(%)	100.0	0.0	0.0	0.0	0.0

Vertical Alinement: Length by Ranges of Gradient

Gradient i(%)	-5.0≤i <-4.0	-4.0≤i <-3.0	-3.0≤i <-2.0	-2.0≤i <-1.0	-1.0≤i <0.0	0.0≤i <1.0	1.0≤i <2.0	2.0≤i <3.0
Lampang - Doi Saket Route								
Length (km)	0.8	0.0	10.4	15.0	79.8	67.3	13.0	11.2
(%)	0.4	0.0	5.2	7.6	40.4	34.1	6.6	5.7
Ban Pong - Cha Am Route								
Length (km)	0.0	0.0	0.0	2.7	152.8	109.2	2.7	0.0
(%)	0.0	0.0	0.0	1.0	57.2	40.8	1.6	0.0

6.4 STRUCTURAL DESIGN

6.4.1 Bridge

Brides are designed where the main line of motorway crosses over rivers, large cannels with side-path, railways and the national highways with number of one or two figure(s).

The bridges are classified, according to their types of superstructure, substructure and foundation, as shown in Figure 6.4-1, so that a bridge can be characterized by the combination of superstructure, substructure and foundation types. For example, B-4 for superstructure, D for substructure and C-3 for foundation indicates a PC-Box girder bridge supported by wall type substructure with ϕ 1.5 m RC Pile foundation.

Superstructure			Subsutructure			Foundation		
Type	Shape	Available Span(m)	Type	Shape	Description	Type	Shape	Description
RC. A		L ≦ 15	A	Pile Bent	DOH Standard	A		Spread Foudation
PC. B-1	1000	15 < L ≦ 25	B		Wall Applicable to Viaduct	B		Precast □ - 400 RC Pile
PC. B-2	1200	25 < L < 30	C		Culum Applicable to River Cossings	C-1		Cast In Place RC. Pile ∅1.0m
PC. B-3	1300	30 ≦ L ≦ 35	D		Wall Applicable to River Cossings	C-2		Cast In Place RC. Pile ∅1.2m
PC. B-4	2000	35 < L ≦ 50	E		Double Column Applicable to the Southern Route	C-3		Cast In Place RC. Pile ∅ 1.5m
M.C		50 < L < 100	F		H - Section Wall Applicable to the High Pier H ≧ 25	D		Open Well Applicable to Mountain area
						E		RC. Pile, ∅ 3.0m (Chicago Board Method)

FIGURE 6.4-1 BRIDGE CLASSIFICATION

Typical general views and all information of bridges, i.e. location, length, type, etc., of both Lampang - Doi Saket Route and Ban Pong - Cha Am Route are given in the following drawings in the DRAWINGS:

TABLE 6.4-1 DRAWING LIST OF BRIDGE

Drawing No.	Title and Contents
<u>Lampang - Doi Saket Route</u>	
LD 4-2	LIST OF BRIDGES AND VIADUCTS
<u>Ban Pong - Cha Am Route</u>	
BC 4-2	LIST OF BRIDGES AND VIADUCTS
BC 4-4	GENERAL VIEW MAEKHLONG RIVER BRIDGE

Note: Bridge locations are also found in the drawings of "PLAN AND PROFILE".

6.4.2 Overbridge

Overbridges are designed where side-paths of small cannel, national highways with number of three or four figures and other minor highways cross over the main line of motorway.

Typical general views and all information of overbridges, i.e. location, length, number of spans, etc., of both Lampang - Doi Saket Route and Ban Pong - Cha Am Route are given in the following drawings in the "DRAWINGS":

TABLE 6.4-2 DRAWING LIST OF OVERBRIDGE

Drawing No.		Title and Contents
<u>Lampang - Doi Saket Route</u>		
LD 4-3	LIST OF OVERBRIDGES AND BOX CULVERTS	
LD 4-5	GENERAL VIEW	OVERBRIDGE AT STA.10+830
<u>Ban Pong - Cha Am Route</u>		
BC 4-3	LIST OF OVERBRIDGES AND BOX CULVERTS	

Note: Overbridge locations are also found in the drawings of "PLAN AND PROFILE".

6.4.3 Viaduct

Viaducts are designed in urban areas and tunnel approach sections over deep valley, where needed due to environmental consideration.

Classification of viaduct has been discussed in Figure 6.4-1 of Section 6.4.1. For example, MC for superstructure, F for substructure and D for foundation indicates a steel truss structure supported by H-section wall pier with open well foundation.

The steel truss structure is introduced for the viaduct in the approaching section of the tunnel through the following comparative study:

<u>Comparative Study on Viaduct with High Pier</u>

The piers for the viaduct structure in approaching section of the tunnel shall be very high structures with about 50 m height because of deep valley at the sites. Two types of superstructure are proposed for comparative study, one is steel truss girder and the other is concrete box girder. Appendices 6.4-1 and 6.4-2 show supplemental engineering data for this sub-section.

A 430 m viaduct section between Sta.31+180 and Sta.31+610 in Lampang - Doi Saket Route is selected for comparative study and its spans are:

- for steel truss girder 2x80 + 90 + 3x60 = 430
- for concrete box girder 5x50 + 4x45 = 430

The followings are study objectives from construction aspect and design aspect:

- construction aspect
  . to select suitable construction method
  . to select suitable construction machine
  . to reduce excavation volume
- design aspect
  . to reduce weight of superstructure
  . to select economical girder height
  . to select suitable substructure
  . to select suitable foundation

The study results are summarized in Table 6.4-3.

TABLE 6.4-3 SUMMERY OF COMPARATIVE STUDY ON VIADUCT SUPERSTRUCTURE

Item	Steel Truss Girder	Concrete box Girder	Remarks
Superstructure's Weight	A	B	Truss; W=1100kg/m² Box; W=1900kg/m²
Substructure's Height	A	B	
Erection	A	B	Truss; Traveling Crane Box; Cantilever Crane
Fabrication	B	A	Truss; Factory Box; Site
Structural Excavation	A	A	
Stock Yard	A	B	Environment
Construction Cost	A	A	
Maintenance	B	A	
Total	6A, 2B	4A, 4B	

Note: "A" is better than "B".

Typical general views and all information of viaducts, i.e. location, length, type, etc., of both Lampang - Doi Saket Route and Ban Pong - Cha Am Route are given in the following drawings in the "DRAWINGS":

TABLE 6.4-4 DRAWING LIST OF VIADUCT

Drawing No.	Title and Contents	
Lampang - Doi Saket Route		
LD 4-2	LIST OF BRIDGES AND VIADUCTS	
LD 4-4	GENERAL VIEW	VIADUCT AT STA.50+770 TO STA.51+700
Ban Pong - Cha Am Route		
BC 4-2	LIST OF BRIDGES AND VIADUCTS	
BC 4-5	GENERAL VIEW	VIADUCT AT STA.6+750 TO STA.9+400

Note: Viaduct locations are also found in the drawings of "PLAN AND PROFILE".

6.4.4 Culvert

Box-culverts are introduced at places where the main line crosses streams having 1.0 to 3.0 m width and 1.0 to 1.5 m depth. For smaller streams, pipe-culverts are assumed to be installed at intervals shown in Table 6.2-2.

Cross sections of box- and pipe-culverts shall be in accordance with DOH Standards, "STANDARD DRAWINGS FOR HIGHWAY CONSTRUCTION, APRIL 1991".

All information of box-culverts, i.e. location, length, classes, etc., of both Lampang - Doi Saket Route and Ban Pong - Cha Am Route are given in the following drawings in the "DRAWINGS":

TABLE 6.4-5 DRAWING LIST OF CULVERT

Drawing No.	Title and Contents
Lampang - Doi Saket Route	
LD 4-3	LIST OF OVERBRIDGES AND BOX CULVERTS
Ban Pong - Cha Am Route	
BC 4-3	LIST OF OVERBRIDGES AND BOX CULVERTS

Note: Box-culvert locations are also found in the drawings of "PLAN AND PROFILE".

6.5 EARTHWORK AND PAVEMENT DESIGN

6.5.1 Earthwork Design

1. Embankment and Cut Sections

An 1.5 meters height of embankment above the ground level shall be the minimum requirement so that the lower level of base course in the pavement structure shall be higher than the high ground water level of 75 cm G.L.

The height of embankment shall not exceed 20 meters above the ground level in consideration of aesthetic view and land acquisition cost. In case where embankment height is over 20 meters as found in the mountainous area on Lampang - Doi Saket Route, viaducts are proposed as shown in Section 6.4.3.

Based on the experiences of highway construction work in Thailand, embankment and cut slopes are determined to be 1:2 and 1:1 respectively.

The appropriate compaction and/or soil improvement work to obtain more than 4.0 of CBR at subgrade shall be required in all earth work sections so that the future repairing work will be minimized. The detailed discussions on soil improvement work and pavement design are found in later sections.

2. Soil Improvement Work

From the result of the geological survey, it is found that there is no such a serious soft ground in Ratchaburi area of Ban Pong - Cha Am Route as shown in 1/50,000 maps.

According to the calculation based on the data of soil tests, 10 cm to 45 cm settlement will be expected for the embankment with height ranging from 1.5 m to 7.5 m, as shown in Appendix 6.5-1 in detail. Generally this range of consolidation settlement will not be so serious problems for operating and maintaining the motorways. However the following soil improvement work are introduced in the sections between Sta.25+000 and Sta.86+750 of Ban Pong - Cha Am Route:

1) Cement Stabilization; 2 m of top soil will be stabilized by mixing cement over the width between both toes of embankment, as shown in the drawing, DRW NO. BC 3-1 TYPICAL CROSS SECTION (1) EMBANKMENT SECTION IN SOFT-GROUND AREA of the DRAWINGS.

2) Control of Filling Speed; Construction speed for filling will be controlled in accordance with the daily observation data of settlement by settlement plates to be installed at every 500 m along the sections between Sta.25+000 and Sta.86+750.

3) Bearing Unit; A bearing unit with concrete piles will be constructed just behind the abutment, as shown in the drawing, DRW NO. BC 4-4 GENERAL VIEW MAE KHLONG RIVER BRIDGE of the DRAWINGS.

6.5.2 Pavement Design

The general characteristics of asphalt pavement and concrete pavement are shown in Table 6.5-1. The major considerations in selecting the pavement type for Lampang - Doi Saket Route and Ban Pong - Cha Am Route are discussed below:

TABLE 6.5-1 GENERAL CHARACTERISTICS OF ASPHALT AND CONCRETE PAVEMENT

Description	Asphalt Pavement	Concrete Pavement
Design Life	:10 yrs. :Service period will be extended by overlay.	:20yrs. :Service period will be extended by overlay.
Resistance against deformation and wear	:Tends to deform in a form of rutting.	:Deformation is unlikely. :Wear resistance is extremely high.
Noise and Vibration	:Less noise and vibration.	:More noise and vibration due to joints and rough surface.
Brightness	:Surface reflection is week.	:More bright.
Surface Smoothness	:More smooth.	:Less smooth.
Construction	:Less constraints for construction execution.	:Some constraints are expected for continuous and effective construction since equipment fleet is generally large.
Maintenance	:Frequent maintenance is required. :Maintenance method is relatively easy.	:Heavy repair is required.
Cost	:Lower initial construction cost. :More frequent repairs and maintenance required.	:Higher initial construction cost. :Less frequent repairs and maintenance required.

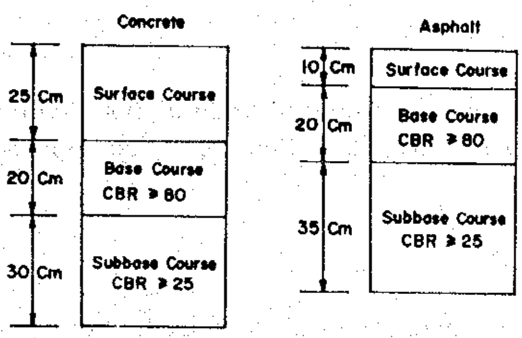
1. Time Constraint

For a total of 20 - 30 years performance period of pavement, multi-stage construction, i.e. initial construction for 10-year design life with periodic overlays to extend the performance period, is usually adopted in case of asphalt pavement, while single-stage construction is normally adopted in case of concrete pavement.

2. Construction Economy

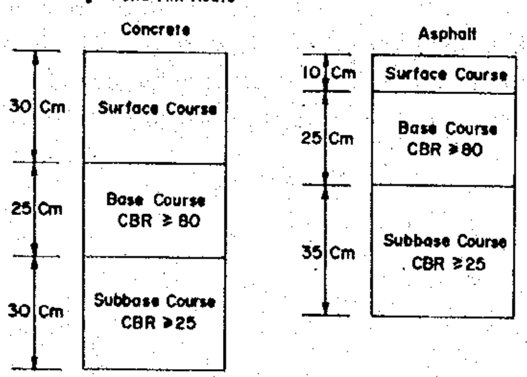
The initial investment cost of concrete pavement is higher than that of asphalt pavement by about 10 % due to the difference of design life of initial pavement (Figure 6.5-1 shows pavement structures for comparison purpose). On the other hands, asphalt pavement requires future overlay and higher annual maintenance cost than concrete pavement. In terms of the discounted total investment cost consisting of initial construction cost and maintenance cost, concrete pavement is more economical.

Lampang - Doi Saket Route



	Concrete	Asphalt
Initial Cost (Bt/m²)	900	737
Overlay Cost (Bt/m²)	936	1920
Total (Bt/m²)	1836	2657

Ban Pong - Cha Am Route



	Concrete	Asphalt
Initial Cost (Bt/m²)	1027	754
Overlay Cost (Bt/m²)	936	1920
Total (Bt/m²)	1963	2674

Note: For concrete; Overlay of 5 cm asphalt concrete will be constructed after 12 years of initial construction.

For asphalt; Overlay of 5 cm asphalt concrete will be constructed after 4 years of initial construction.

FIGURE 6.5-1 PAVEMENT STRUCTURES FOR COMPARATIVE PURPOSE

3. Adoptability in Soft Ground Area

Generally, concrete pavement is not suitable to be adopted in soft ground areas, because structural failure is apt to occur due to uneven settlement of embankment. As discussed in Section 6.5.1, on the other hand, several soil improvement works are proposed along the section between Sta.25+000 and Sta.86+750 of Ban Pong - Cha Am Route where 10 cm to 45 cm consolidation settlement will be expected for three to six years (90% consolidation). In fact, introduction of cement stabilization will result in consolidation settlement reducing to 6.0 cm - 27.0 cm and 90 % consolidation period shortening to one to two years. Therefore, it is concluded that concrete pavement can be adopted even in the section between Sta.25+000 and Sta.86+750 of Ban Pong - Cha Am Route.

4. Local Material Availability and Utilization

More than 90 % of bituminous material for the construction of pavement is imported, while portland cement for concrete pavement slab is manufactured at full scale of demand in Thailand.

In view of the above, concrete pavement is adopted to both Lampang - Doi Saket Route and Ban Pong - Cha Am Route.

6.6 DESIGN OF TUNNEL

6.6.1 Alinement Study of Tunnel

This section discuses detailed for the precise alinement of three portions with possibility of tunnel along the optimum Lampang - Doi Saket Route as selected in Section 4.2.1.

1. No. 1 Tunnel

It is proposed that the tunnel entrance and exit portals shall be located at elevations of between 500 and 550 m depending on the geometry of the tunnel approaches. The optimum tunnel engineering technique is to orientate the approaches as near as practical to 90 degrees to the mountain slope direction. To conform as closely as possible to this requirement three alternative routes have been selected as illustrated in Figure 6.6-1. The comparative details of these routes are tabulated in Table 6.6-1.

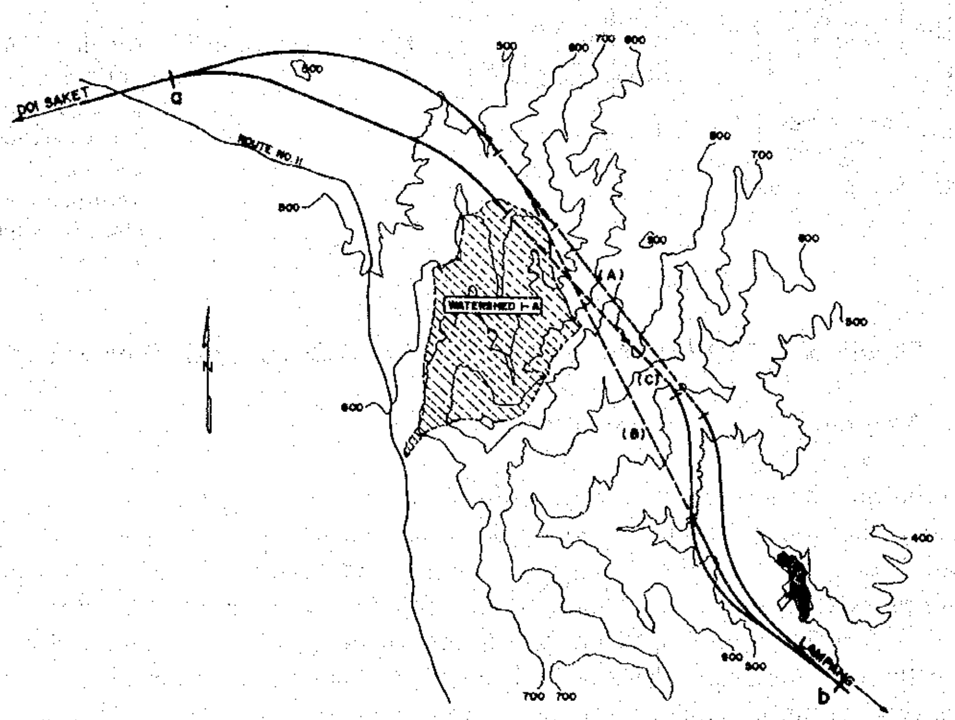


FIGURE 6.6-1 THREE ALTERNATIVE ROUTES OF TUNNEL NO. 1

The following discussion is a brief summary of the main characteristics of the three alternative routes for Tunnel No.1.

1) Route A

- Both alternative approach sections have favorable alignments.
- The tunnel length is about 3,800 m.
- Evacuation passages need to provided.
- A transition curve is introduced near the south portal.

2) Route B

- Both alternative approach sections have very favorable alignments.
- The cut slopes for the approach sections do not exceed 35 m. and are the lowest amongst the three route alternatives.
- The length of tunnel is 4,650 m.
- An evacuation passage and a vertical shaft needs to be provided.

3) Route C

- The length of tunnel is 2,900 m.
- The portal ground conditions are favorable for construction.
- Both approach sections have poor alignments.
- The north portal is located in Watershed 1-A area.

TABLE 6.6-1 COMPARISON OF THREE ROUTES FOR TUNNEL NO. 1

	Route A	Route B	Route C
(1) Tunnel			
•Tunnel length (m)	3,800	4,650	2,900
•Tunnel elevation (m)	500	500	550
•Ventilation system	2-Dust collection chamber	Exaust/intake vertical shaft	1-Dust collection chamber
(2) Approach			
•Total length incl. tunnel (m)	11,200	11,100	10,900
•Length in Forest Reserve C-2 (m)	1,700	800	2,600
•Max. grade & its length (%/m)	3.0/3,800	3.0/3,600	3.0/5,200
•Bridge/viaduct length (m)	1,700	1,200	1,000
•Cut slope height (m)	60	35	60
(3) Rough estimated cost (MB)	9,000	10,000	6,000
(4) Notes			Affects Watershed 1-A (970m)

Of the above alternatives Route A with 3,800 m. of tunnel is favored and has been adopted for preliminary design. Route B has a higher construction cost and Route C affects an environmentally sensitive area (Watershed 1-A). The plan and profile of Route A for Tunnel No.1 are shown in DWG NO. LD. 5-1 contained in the DRAWINGS.

The No.1 tunnel area contains mountain ranging from an elevation of 500 m. to 900 m. and trending SE-NW. Narrow ridges and parallel gullies trend in N-S and E-W directions. The vegetation cover on the mountains range from 25% to 75% forest canopy.

The topography of the Lampang side portal consists of steep mountainous slopes ranging in altitude from 550 m.up to the crest lines at around 900 m. They generally have gradients over 30 deg. to 40 deg. along the sides slopes of the Nam Mae Tan Noi creek. The terrain below 550 m. is more gentle with slope angles less than 15 deg.

The trend of the slopes around the Lampang side portal is N-S. The vegetation around the portal is limited to low trees, shrubs and grasses.

The area around the Doi Saket side portal contains steep slopes ranging from 40° to 45°. They have been eroded by the Haui Sa Khao gully that has a S-N trend. The slopes are continuous from an elevation of about 500 m. up to the crest lines.

The results of investigations into the geological conditions are summarized below:

The high mountainous areas are underlain by massive Mesozoic coarse grained granite and its weathering products. Tectonic structural features such as faults and shear zones have not been observed in the area. The ground conditions in the Lampang side portal were investigated with a 30 m. deep borehole. This hole did not encounter fresh granite and consisted of granitic saprolite (residual soil) and highly weathered granite. The investigation borehole on the Doi Saket side portal area encountered residual soil to a depth of 3.5 m. and highly weathered granite from 3.5 m. to 8.3 m. The balance of the hole was in slightly weathered coarse grained granite. Unconfined compressive strength tests carried out on the unfractured granite core samples indicated strengths varying from 55.5 MPa to 73.4 MPa. When the fresh intact rock is encountered in the tunnel it should have strengths approximately twice these values. The material is considered highly favorable for tunneling. The deeply weathered granite on the Lampang side will require care in the design of portal slopes to ensure stability and to avoid deep gully erosion.

2. No. 2 Tunnel Section

For comparison purposes, two routes have been proposed for Tunnel No.2 as illustrated in Figure 6.6-2. The first alternative, Route A, traverses Forest Reserve C-2 and has about 800 m. of tunnel. The second alternative, Route B, has a total length of 10 km and no tunnel. It passes around the foot of the hills that contain the Forest Reserve C-2. The basic characteristics of the two alternatives are summarized in Table 6.6-2.

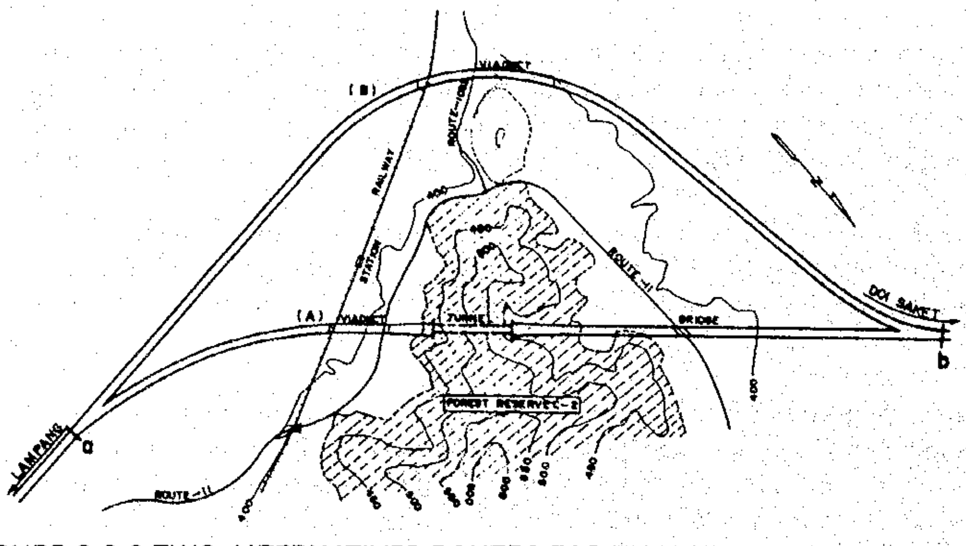


FIGURE 6.6-2 TWO ALTERNATIVES ROUTES FOR THE TUNNEL NO. 2 SECTION

TABLE 6.6-2 COMPARISON OF TWO ROUTES FOR TUNNEL NO. 2 SECTION

	Route A	Route B
(1) Tunnel		
•Tunnel length (m)	800	0
•Tunnel elevation (m)	430	420
(2) Alignment		
•Total length (m)	8,000	9,300
•Length in Forest Reserve C-2 (m)	700	0
•Max. grade & its length (%/m)	2.5/2,700	2.5/1,200
•Min. curve radius & its length (m/m)	----	1,500/2,400
•Bridge/viaduct length (m)	400	900
•Length in urbanized area (m)	300	900
•No. of houses to be removed (no)	12	14
(3) Rough estimated cost (MB)	2,750	2,000

Alternative Route B has been adopted for preliminary design purposes for the following reasons:

1) Construction cost of Route B is about 70 % compared to Route A which contains 800 m. of tunnel.

2) The portals of the tunnel in Route A affect the environmentally sensitive Forest Reserve C-2 area.

3) The numbers of affected houses are about the same.

4) Preliminary cost benefit analysis (refer Appendix 6.6-1) indicate that Route B, with a total length of 9.3 km, is better than Route A with a total length of 8 km.

5) Highly weathered Sandstone is expected in the Tunnel No.2 and is anticipated to adversely affect the degree of difficulty of construction and the costs.

3. No. 3 Tunnel Section

Two alternative Routes have been appraised in the Tunnel No.3 section. Alternative Route A contains a 1,000 long tunnel and Route B has no tunnel but a large open cut section. Figure 6.6-3 illustrates these two routes and Table 6.6-3 provides a summary of their essential characteristics.

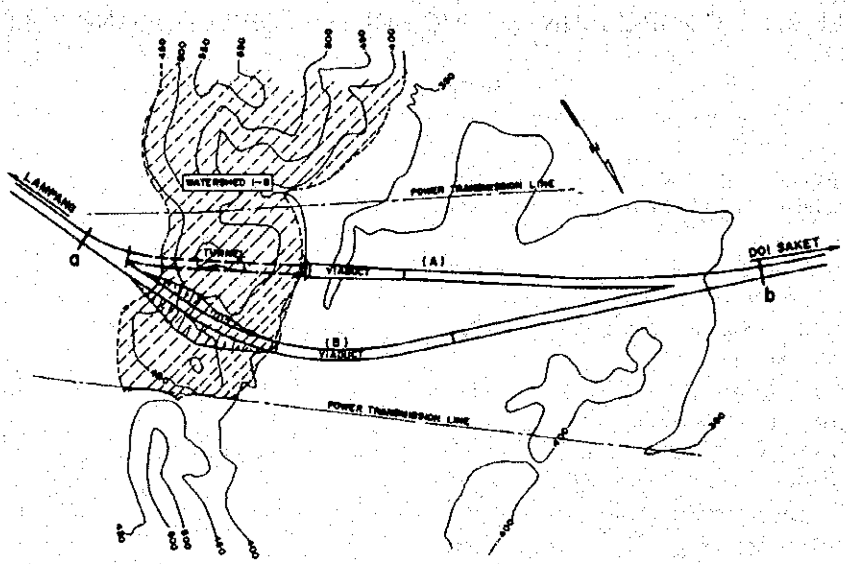


FIGURE 6.6-3 TWO ALTERNATIVE ROUTES FOR THE TUNNEL NO.3

TABLE 6.6-3 COMPARISON OF TWO ROUTES FOR TUNNEL NO. 3

	Route A	Route B
(1) Tunnel		
•Tunnel length (m)	1,000	0
•Proposed elevation (m)	400	400
(2) Alignment		
•Total length (m)	3,500	3,600
•Length in Watershed 1-B (m)	700	700
•Max. grade & its length (%/m)	2.5/3,500	4.5/700
•Min. curve radius & its length (m/m)	----	1,500/1,200
•Cut slope height (m)	20	70
•Bridge/viaduct length (m)	500	700
(3) Comments		High-cut is needed

Route A containing a 1,000 m. tunnel, is favored and has been adopted for preliminary design. Alternative Route B has 70 m. high cut slopes and has been excluded due to the anticipated adverse impact on the environment and aesthetic of the area. The plan and profile of preferred Route A are illustrated in DWD No. LD. 5-2 contained in the DRAWINGS.

The topography of the area around the NO.3 Tunnel consists of hills trending SE-NW. The altitude varies from 350 m. to 550 m. The range of hills is only about 1 km. wide. On the Doi Saket side the base of the hills is at an elevation of about 350 m. whereas on the Lampang side the base of the range is at an altitude of around 430 m. The slope angles are generally gentle except for a section of the western slope.

On the Lampang side the area of the portal is generally foothill terrain with gentle slopes. The slope angles for terrain over 440 m. in altitude are in the order of 40 deg. whereas slope angles below 440 m. are about 15 deg. At the actual site of the portal the slopes are steep and in excess of 40 deg.

The geological studies provided the following information:

The low hills and mountains are underlain by Carboniferous sedimentary rocks. The results of drilling on the Lampang side indicated weathered sandstone to a depth of 18.5 m. with an underlying bed of dark grey shale. The orientation of these beds is not known at this stage but alternating sandstone/shale sequences can be expected with superficial weathering near the surface. Unconfined compressive strength tests carried out on weathered sandstone and shale gave results of 4.8 MPa and 4.1 MPa respectively. Beneath the weathering profile higher intact rock strengths in the order of 20-30 MPa could be expected but fracturing will reduce the rock mass strength. Initially these rocks have been classified as soft rock for tunneling purposes.

6.6.2 Tunnel Body

1. Tunnel Cross Section

The internal space of the tunnel has been designed to be sufficient to comply with the clearance specifications as detailed in Section 6.2 "DESIGN STANDARDS". Amongst the cross section elements of the tunnel the widths of both shoulders can be varied to minimize construction costs. A 1.0 m shoulder width has been adopted as it is both economical and assists in discouraging vehicles stopping in the tunnel. Appendix 6.6-2 presents technical comparisons and costs for alternative internal arrangements. In addition to the roadway and shoulders the internal space has to be sufficient to accommodate ventilation facilities, lighting fixtures, fire prevention services, interior decorative finish and management facilities. In addition, the tunnel structure has to be designed to resist external loads such as earth and water pressure. To minimize the development of tensile stresses, cross sections of tunnels are usually designed in the form of an arch or a horse-shoe.

Figure 6.6-4 illustrates the cross section adopted for the preliminary design for both tunnels. The computation method used to select the radii and heights of the spring lines (SL) are presented in Appendix 6.6-3.

2. Classification of Natural Ground Conditions

The geological character of the line of construction for the tunnel has a dominant influence on the support system and method of construction adopted. The method of classifying the ground conditions used in this report is that developed by the JPHC. The basic classification system is presented in Appendix 6.6-4. The classes are illustrated in DWG No. LD. 5-6 in the DRAWINGS.

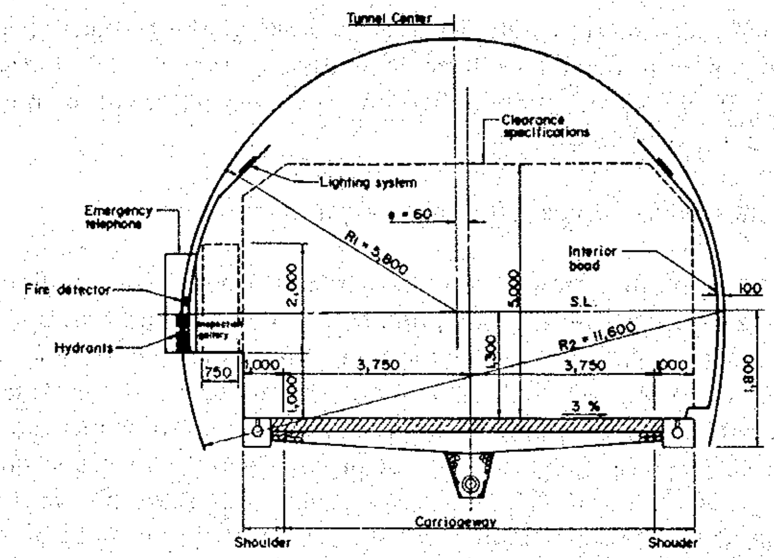


FIGURE 6.6-4 TUNNEL CROSS SECTION

3. New Austrian Tunneling Method

The "New Austrian Tunneling Method" (NATM) is a construction technique that takes advantage of the inherent strength of the natural ground enhanced by the use of rock bolts and shotcrete. Extensive research has been carried out in recent times and the techniques of analysis, equipment selection and construction sequencing have been greatly refined. It is proposed to use the NATM for both of the proposed tunnels on the Lampang - Doi Saket Route as it offers significant advantages over more conventional techniques. These are: 1) reduced construction time, 2) enhanced work safety, 3) reduced labor requirements and 4) reduced construction cost.

4. Support System

The stability of the tunnel is ensured with the application of rock bolts and shotcrete. The density of rock bolting and thickness and location of shotcrete varies according to the ground conditions encountered. Table 6.6-4 summarizes support requirements depending on a broad classification of ground conditions from soil, soft rock and hard rock. The intensity of joints and discontinuities (cracks) and the strength of the intact rock and soil will vary within these classes and detail adjustments to the support system need to be made to accommodate these. For the preliminary design of the two tunnels a standard support system has been adopted for costing purposes as illustrated in Figure 6.6-5 and summarized in Appendix 6.6-5. The actual support system will vary depending on the rock conditions encountered and the results of deflection surveys, bolt tensions and progressive geological mapping of the exposed surfaces.

TABLE 6.6-4 SELECTION PROCEDURE FOR SUPPORT SYSTEMS

Classi-fication of bed rock	Character-istics	Purpose for supporting	Supporting system shot-crete	Rock bolt	Steel rib	Concrete lining
Hard rock	Few joints	Rock fall	thin o	random o		
	Many joints without clay	Rock fall	o	crown o	▲	
	Many joints and crushed	Rock fall Loose earth pressure	o	o	▲	▲
Soft rock	High rock content	Rock fall	thin o	random o		
	Low rock content	Loose earth pressure	o	crown o	▲	▲
	Very low rock content	Earth pressure	o	o	o	o
Soil (less overburden)		Control of settlement Loose earth pressure	o	o	o	o

Notes: o = to set in normal
▲ = to set in accordance with necessity

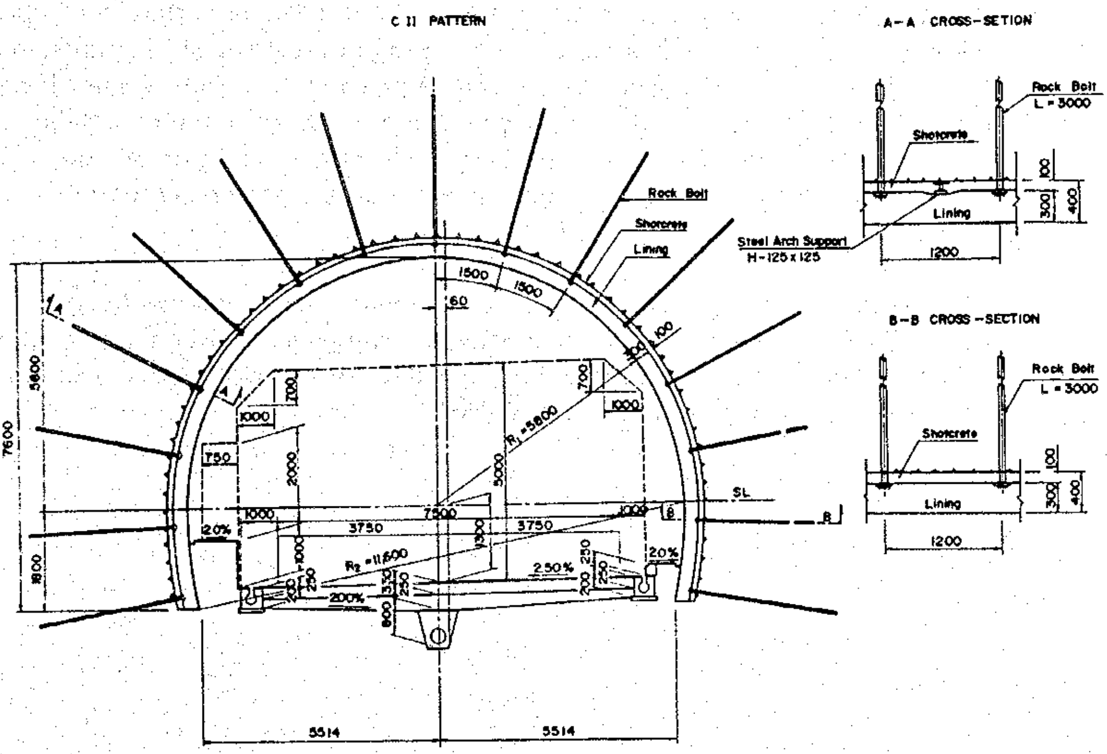


FIGURE 6.6-5 EXAMPLE OF SUPPORT PATTERN