2.2 LAT KRABANG INDUSTRIAL ESTATE

The Lat Krabang Industrial Estate is located 30 km east of Bangkok. Phases I and II have been completed and no remaining space is available. Many international manufacturers have already established their production plants within the estate.

The total area is 208 ha, of which the General Industrial Area (GIA) occupies 116 ha and the Export Processing Zone (EPZ) 20 ha. The number of workers in the GIA and EPZ as of 1987 was 3,500 and 5,100, respectively.

Phase III is under construction with a total area of 206 ha. Of this total, the GIA and EPZ are planned to be developed for 52 ha and 82 ha, respectively. Based on the area and the number of workers in Phases I and II, the numbers of worker in Phase III was estimated at 1,500 persons for the GIA and 22,500 persons for the EPZ. By using the relationship between the area and the number of workers described in 2.1.1, generated cargoes from the GIA and EPZ were estimated at 693,000 tons and 393,000 tons, respectively. Generated cargo traffic was estimated by means of the same method described in 2.1.1 at 590 trucks per day.

2.3 INLAND CONTAINER DEPOT

According to the Interim Report I of the Feasibility Study on Measures to Promote the Container Handling System through Laem Chabang Port conducted by JICA, September 1988, an Inland Container Depot (ICD) is proposed to be constructed in Lat Krabang.

The ICD is expected to reduce the total traffic volume on roads between the ICD and Laem Chabang Port and lighten the burden on the Laem Chabang Port in terms of port load and terminal congestion.

The estimated container cargo volumes through the ICD are 1.2 million tons in 1996 and 1.8 million tons in 2001, and the share of the Bangkok Metropolitan Area in origin and destination of cargoes is estimated over 80% in both years as shown in the following table:

CARGO VOLUME THROUGH THE ICD

(Unit: tons)

Origin/ Destination	1996	(%)	2001	(%)
Bangkok	961,200	(81)	1,507,700	(82)
Central	171,300	(14)	260,000	(14)
Northern	32,100	(3)	47,000	(3)
Northeastern	19,500	(2)	27,400	(1)
Total	1,184,100	(100)	1,843,400	(100)

The daily volume of traffic through the ICD was estimated to be 1,640 vehicles per day in 1996 and 2,520 vehicles per day in 2000, respectively, as shown below:

TRAFFIC VOLUME THROUGH THE ICD

(Unit: vehicles/day)

Origin/Destination	1996	2000
Bangkok	1,170	1,810
Central	360	550
Northern	70	100
Northeastern	40	60
Total	1,640	2,520

The daily volume of traffic between the ICD and Laem Chabang Port was estimated to be 420 vehicles per day in 1996 and 650 vehicles per day in 2000.

Figure 2.3.1 shows the proposed location for the ICD, which has six alternatives.

2.4 SECOND BANGKOK INTERNATIONAL AIRPORT

The Master Plan for the Second Bangkok International Airport was prepared by NACO and Thai Consultants in November 1984.

The new airport is to be located at Nong Ngu Hao, in Amphoe Bang Phli, Changwat Samut Prakan about 25 km east of Bangkok. The airport will have a total area of 3,172 ha with two parallel runways.

The ultimate traffic demand was forecasted at 65 million passengers and 2.5 million tons in the year 2010. Nearly 27,000 workers will be working at the airport in the same year.

Figure 2.4.1 shows airport access proposed in the said Master Plan. For the connecting road system outside the airport boundary, access from the south is indicated on Route 34 and from the north on Soi On Nut Road or Route 343 if implemented by that time. Rail was also considered one of the access means from the north. An expressway and a mass transit system were also proposed for access.

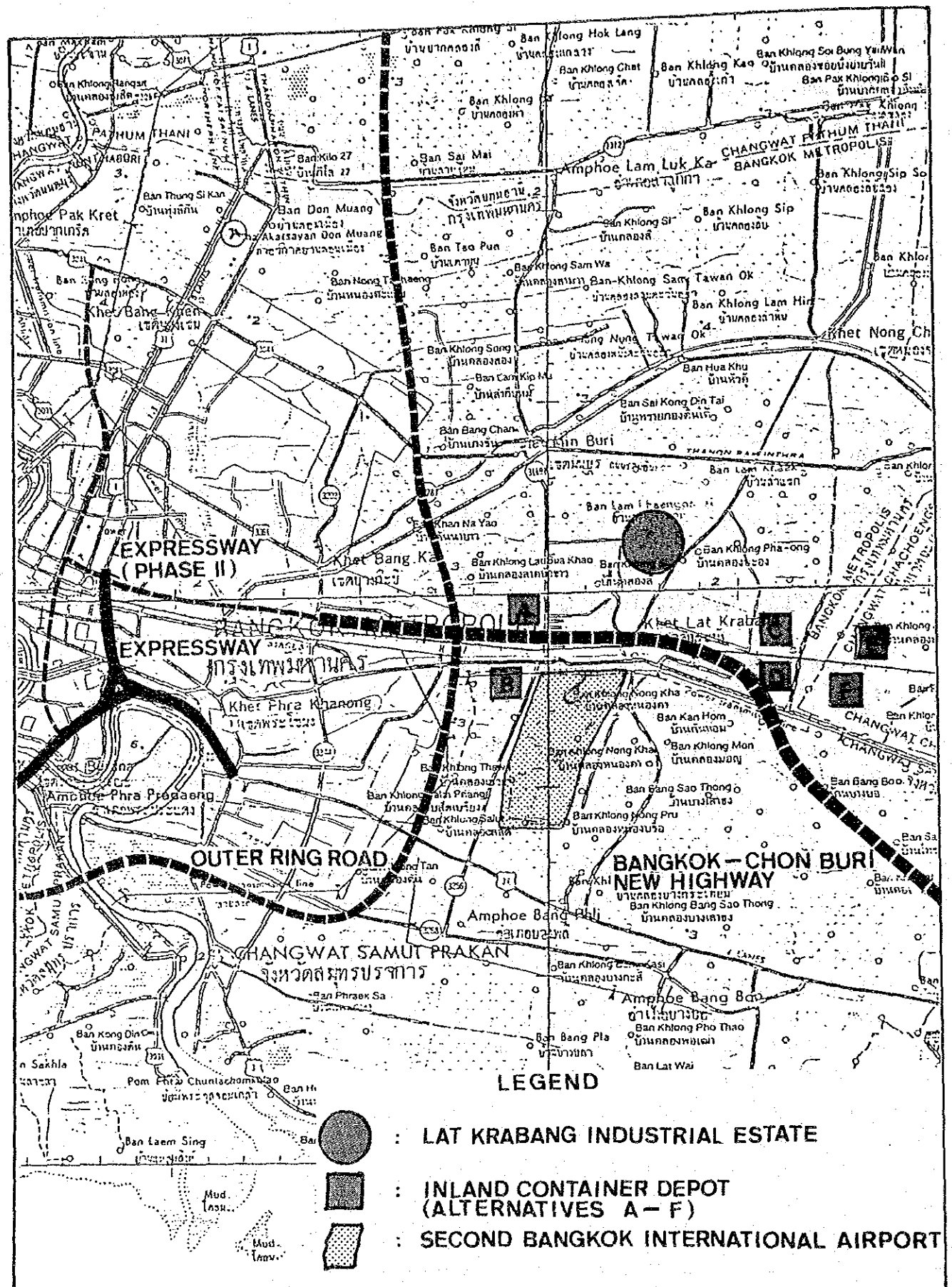


Figure 2.3.1 DEVELOPMENT PLAN RELATED TO BANGKOK – CHON BURI NEW HIGHWAY (ML-9)

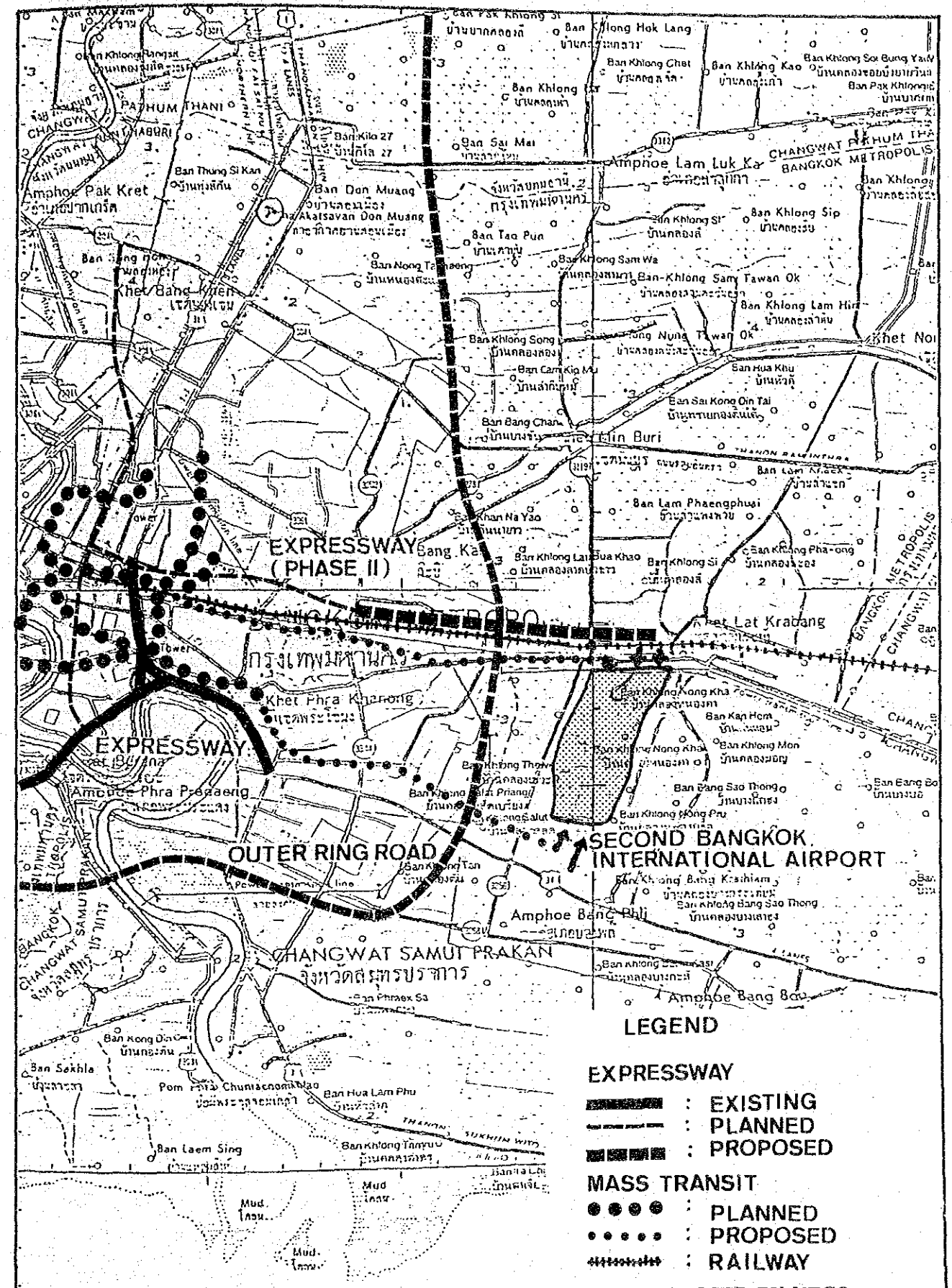


Figure 2.4.1 REGIONAL TRANSPORTATION SYSTEM PROPOSED BY NECO GROUP

CHAPTER 3

TRAFFIC SURVEYS AND FORECAST

CHAPTER 3
TRAFFIC SURVEYS AND FORECAST

3.1 METHODOLOGY

Elements of traffic forecasting procedures are shown in the following flow chart. This section describes each element.

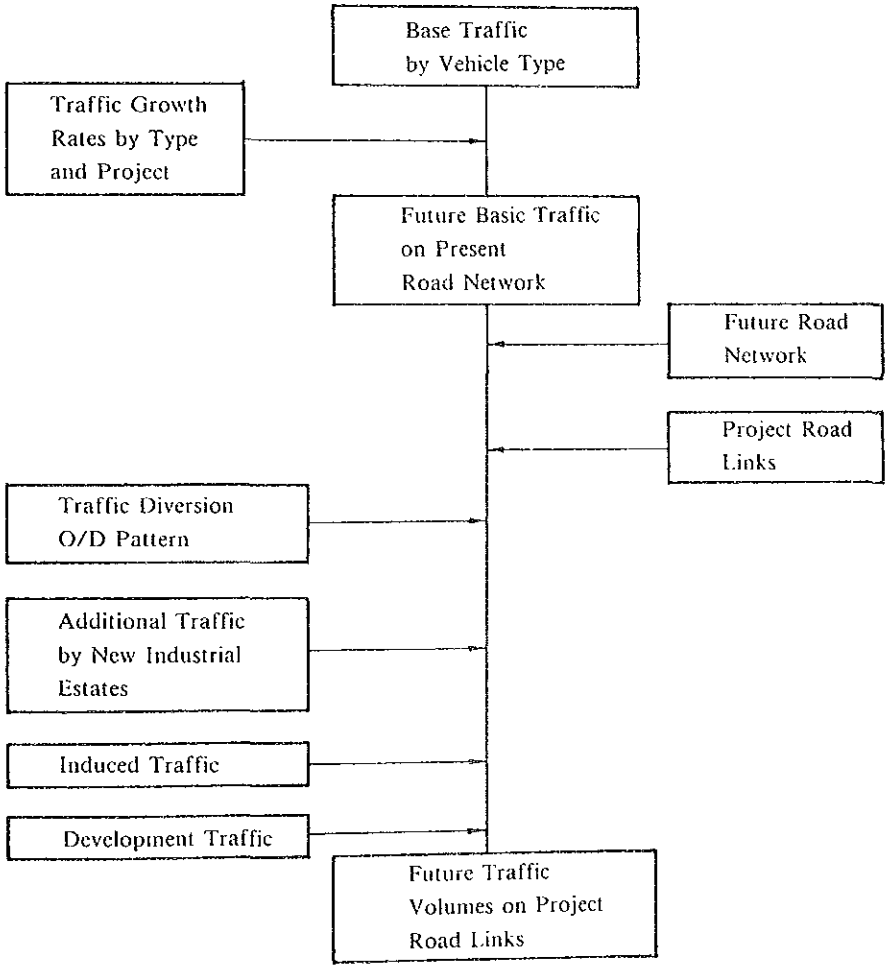


Figure 3.1.1 FLOW CHART OF TRAFFIC FORECAST PROCEDURES

1) Base Traffic

Base traffic is defined as the lastest traffic volume which is used for the estimation of future traffic volumes. Survey years of base traffic vary depending on data sources. Base traffic volumes by vehicle type and road link related to the project roads were determined based on the results of traffic surveys by the Study Team and traffic counts by DOH. Details are described in Section 3.4.1.

2) Traffic Growth Rates

Traffic growth rates by project and vehicle type were determined by the results of traffic forecasts carried out in the Master Plan phase. Details are described in Section 3.4.2.

3) Future Basic Traffic on Present Road Network

Future basic traffic by vehicle type on the present road links was obtained by expanding the base traffic volumes by means of the traffic growth rates.

4) Future Road Network

Planned highways such as the Outer Ring Road, which affect traffic volumes on the project road links because of traffic diversion, were taken into consideration in the future road network.

5) Project Road Links

The relationship of project road links and surrounding existing road links was examined in terms whether traffic diversion would occur. In case some diversion is expected, traffic volume was estimated by applying diversion rates.

6) Traffic Diversion Rates

Traffic diversion would occur in the following cases:

- Shortcut links
- Time delays by traffic congestion

In the first case, diversion rates by vehicle type were estimated from the O/D pair distributions surveyed by the Study Team. In the second case, volumes of through traffic out of traffic exceeding the road capacity were assumed as diverted traffic. Through traffic by vehicle type was determined based on the results of the license plate survey conducted by the Study Team.

Diverted traffic from adjacent highways was estimated for the ML-1 and ML-5 projects in Phase I and for ML-9, IM-11, IM-12, IM-13, IM-14, IM-15 and IM-22 in Phase II.

Details are described in Section 3.4.3.

7) Additional Traffic

Traffic generated in the Eastern Seaboard Industrial Estates, such as the Leam Chabang and Map Tha Phut projects, was taken into account.

The above traffic volumes were added to the ML-1 and ML-5 projects in Phase I and for ML-9 in Phase II.

Details are described in Sections 2.1.1 and 2.1.2.

8) Induced Traffic

Induced traffic is expected when travel speed increases by road improvement such as paving of laterite or earth surface roads. However, in the case of medium and heavy trucks, induced traffic was not considered because commodity flows would not be induced by an increase in travel speed.

Induced traffic was considered for unpaved sections on IM-1, IM-2, IM-11, IM-12, IM-13, IM-14, IM-15, IM-16, IM-17 and IM-22 in Phase II. No induced traffic was considered for already paved project roads.

Details are described in Section 3.4.4.

9) Development Traffic

In the Central Region, almost all areas have been fully developed as industrial or agricultural areas. However, in the area surrounding Bangkok, housing development is taking place along high-grade highways such as Route 34. This type of development traffic was taken into account.

Development traffic was considered for ML-7 in Phase I.

Details are described in Section 3.4.5.

10) Future Traffic Volumes

Future traffic volumes were estimated by combining factors 1) to 9) described above.

Results are shown in Section 3.4.7.

3.2 TYPE OF TRAFFIC AND VEHICLES

3.2.1 Type of Traffic

To estimate road user benefits, traffic was classified into four types: normal, diverted, induced and development traffic.

Normal traffic is defined as traffic which increases as a result of increases in population and growth of economic activities independent of road improvement or new construction.

Diverted traffic is defined as traffic which changes its route due to road improvement or new construction.

Induced traffic is defined as the extra traffic which is newly generated as a result of improvement in transport conditions such as increase in traffickability and decrease in travel time and cost by mainly improving road surface conditions, e.g., paving of laterite roads. Among the Phase I projects, none are expected to have induced traffic because these highways are already paved. Among the Phase II projects, induced traffic was considered for ten project roads.

Development traffic is defined as traffic which occurs because of additional population increases and economic activities attributable to road improvement or new construction. This type of traffic was considered only for ML-7 among Phase I projects.

3.2.2 Types of Vehicles

For the purpose of traffic surveys, all vehicles were classified into 11 types, and typical vehicle models for each type are shown below:

i) Passenger Car (P/C)	Vehicle with 1600 cc petroleum engine such as Toyota Corona C500.
ii) Light Bus (L/B)	Pickup truck with 85 hp diesel engine such as Nissan Big MTD 2500 DX. Seat capacity is approximately 14 persons.
iii) Medium Bus (M/B)	Bus with 140 hp diesel engine such as Isuzu MPR 59 LB. Seat capacity is approximately 40 persons.
iv) Heavy Bus (H/B)	Bus with 200 hp diesel engine such as Hino BY 347. Seat capacity is approximately 60 persons.
v) Pickup Truck	Vehicle with 2000 cc petroleum engine such as Toyota Hilux.

(P/P, P/T)	Capacity is approximately 1.4 tons.
vi) 4-wheel Truck (4WT)	Vehicle with 85 hp diesel engine such as Toyota Hilux. Capacity is approximately 4 tons.
vii) 6-wheel Truck (6WT)	Vehicle with 110 hp diesel engine such as Isuzu MPR 59 LV. Capacity is approximately 6 tons.
ix) 10-wheel Truck (10WT)	Vehicle with 10 or more wheels and 180 hp engine such as Hino FM 176. Capacity is approximately 15 tons.
x) Motorcycle	Two-wheel vehicle with petroleum engine such as Suzuki TR2.
xi) Others	Other vehicle with engine.

Further, pickup trucks were classified into passenger use (P/P) and truck use (P/T) according to the main purpose of usage.

For forecasting purposes, these vehicle classifications were combined into the following seven vehicle types, which are used by DOH:

	DOH Classification	JICA Classification
i)	Passenger Car (P/C)	Passenger Car (P/C)
ii)	Light Bus (L/B)	Light Bus (L/B)
iii)	Heavy Bus (H/B)	Medium (M/B) & Heavy (H/B) Bus
iv)	Light Truck (L/T)	Pickup (P/P, P/T) & 4-wheel Truck (4WT)
v)	Medium Truck (M/T)	6-wheel Truck (6WT)
vi)	Heavy Truck (H/T)	10-wheel Truck (10WT)
vii)	Motorcycle (M/C)	Motorcycle (M/C)

3.3 TRAFFIC SURVEYS

3.3.1 Introduction

Traffic surveys were conducted to determine O/D patterns, present volumes, turning movements and characteristics of vehicular trips of traffic on the study routes which were selected in the Master Plan phase.

Traffic surveys comprised a roadside interview survey, manual traffic counts, automatic traffic counts and a license plate survey.

3.3.2 Survey Location and Duration

A field reconnaissance was carried out to determine survey locations. During the reconnaissance, traffic conditions, the road network and areas to stop vehicles for interviewing together with the locations of police station were confirmed.

Based on the field reconnaissance results, one O/D survey point, three traffic count survey points, seven turning movement survey points and seven license plate survey points for Phase I and five O/D survey points, 25 traffic count survey points and one turning movement survey for Phase II were established as shown in Table 3.3.1 and Appendices 3.3.1 through 3.3.3.

The survey duration of roadside interviews and manual traffic counts was 12 hours and that of automatic counts 24 hours.

Table 3.3.1 SURVEY LOCATIONS

Phase I

Station	Route No.	Changwat	Amphoe	Survey Duration
OD11	3	Chon Buri	Chon Buri	12 h
C1	3267	Ang Thong	Maharat	12 h
C2	304	Bangkok	Min Buri	12 h
C3	3	Chon Buri	Sattahip	12 h
T1	304	Bangkok	Min Buri	12 h
T2	304	Chachoengsao	Chachoengsao	12 h
T3-T5	3	Chon Buri	Chon Buri	12 h
T6	3	Rayong	Klaeng	12 h
T7	3	Chanthaburi	Chanthaburi	12 h
L1-L7	3	Chon Buri	Chon Buri	12 h

Note: ODi - Roadside Interview Survey
Ci - Traffic Count Survey
Ti - Turning Movement Survey
Li - License Plate Survey

Table 3.3.1 SURVEY LOCATIONS (Cont'd)

Phase II

Station	Route No.	Changwat	Amphoe	Survey Duration
OD12	308	Ayutthaya	Bang Pa-in	12 h
OD13	3263	Ayutthaya	Sena	12 h
OD14	3064	Ang Thong	Ang Thong	12 h
OD15	3256	Samut Prakan	Bang Pli	12 h
OD16	314	Chachoengsao	Bang Pa Kong	12 h
C4	ML-3 TC-1	Chon Buri	Sattahip	12 h
C5	TC-2	Rayong	Rayong	12 h
C6	ML-8 3119	Bangkok	Lat Krabang	12 h
C7	On Nut	Bangkok	Lat Krabang	12 h
C8	IM-1 TC-1	Nakhon Phathom	Bang Len	12 h
C9	TC-2	Suphanburi	Bang Luang	12 h
C10	IM-2 TC-1	Kanchanaburi	Bo Phlói	12 h
C11	TC-2	Kanchanaburi	Lao Khwan	12 h
C12	IM-11 TC-1	Sing Buri	Bang Rachan	12 h
C13	TC-2	Sing Buri	Bang Rachan	12 h
C14	TC-3	Sing Buri	Tha Chang	12 h
C15	IM-12 TC-1	Ang Thong	Pho Thong	12 h
C16	TC-2	Ang Thong	Wiset Chaichan	12 h
C17	TC-3	Ayutthaya	Phak Hai	12 h
C18	IM-13 TC-1	Ayutthaya	Ayutthaya	12 h
C19	IM-14 TC-1	Ayutthaya	Wang Noi	12 h
C20	TC-2	Pathum Thani	Khlong Luang	12 h
C21	IM-15 TC-1	Pathum Thani	Thanyaburi	12 h
C22	TC-2	Bangkok	Min Buri	12 h
C23	IM-16 TC-1	Pathum Thani	Lam Luk Ka	12 h
C24	IM-17 TC-1	Chachoengsao	Chachoengsao	12 h
C25	TC-2	Bangkok	Lat Krabang	12 h
C26	IM-22 TC-1	Chachoengsao	Bang Nam Prio	12 h
C27	RH-2 TC-1	Nakhon Sawan	Chumsaeng	12 h
C28	RH-5 TC-1	Chon Buri	Nong Yai	12 h
T8	ML-3	Chon Buri	Sattahip	12 h

Note: ODi - Roadside Interview Survey
Ci - Traffic Count Survey
Ti - Turning Movement Survey

3.3.3 Interview Items

The question items for roadside interviews with drivers were categorized into the following:

- Origin and destination of trip
- Vehicle characteristics
- Vehicle usage
- Freight movement

Survey items are listed in Appendix 5.2.2 and survey forms are shown in Appendices 5.2.3(1) through 5.2.3(3) in the Master Plan Study.

3.3.4 Traffic Counts

Twelve-hour manual traffic counts were expanded to twenty-four hour counts by means of automatic traffic count data. Results of traffic counts by station and vehicle type are shown in Appendix 3.3.4. The results of turning movement surveys are shown in Appendix 3.3.5.

3.3.5 Number of Samples

The total number of effective samples was 1,749 in Phase I and 5,962 in Phase II. The number of samples and sampling ratios by direction and vehicle types are shown in Appendix 3.3.6. Sampling ratios of all vehicle types were 0.106 in Phase I and ranged from 0.147 to 0.446 in Phase II.

3.3.6 Seasonal and Weekly Fluctuations

According to survey results by DOH on national highways except for Routes 34 and 3, seasonal and weekly fluctuations in traffic counts were found to be minor and within a few percent of ADTs. In the case of Routes 34 and 3, weekly fluctuations were significant in the inbound direction on Sundays and the outbound direction on Saturdays. However, the effect of weekend fluctuations on ADTs was not high because only one weekend peak was counterbalanced by other weekday traffic volumes. According to DOH records, the maximum effect was at most less than 7% of ADT. Therefore, seasonal and weekly fluctuations were not taken into consideration.

3.3.7 Vehicle Characteristics

1) Average Permitted Capacity

Average permitted capacities are shown in Appendix 3.3.7. Average capacities are indicated in persons for passenger vehicles and in tons for trucks.

2) Average Actual Payload

Average actual payloads are shown in Appendix 3.3.8.

3) Empty Vehicle Ratio

Empty vehicle ratios are shown in Appendix 3.3.9.

4) Engine Capacity

Engine capacities by vehicle type are shown in Appendix 3.3.10.

5) Age of Vehicle

Ages of vehicles by vehicles type are listed in Appendix 3.3.11.

6) Number of Assistants

The number of assistants by vehicle type is shown in Appendix 3.3.12.

7) Average Trip Frequency

Average trip frequencies by vehicle type are shown in Appendix 3.3.13.

8) Vehicle Ownership

Distribution of vehicle ownership by vehicle type are shown in Appendix 3.3.14.

9) Trip Purpose

Distribution of trip purpose of vehicle drivers and bus passengers by vehicle type are shown in Appendix 3.3.15.

10) Fuel Type

Fuel types of vehicles by station and type are shown in Appendix 3.3.16.

11) Commodity Flow

Commodity flows at traffic survey stations by vehicle and commodity type are shown in Appendix 3.3.17.

3.3.8 Results of License Plate Survey

The results of the license plate survey are shown in Appendix 3.3.18. The table shows traffic volumes which pass through the main route of Route 3 and the Chon Buri Bypass by direction and vehicle type together with the diversion ratio to the Bypass.

In total, 31% of vehicles diverted from the main route to the Bypass. By direction, 20% of Bangkok-Patthaya traffic diverted to the Bypass; this was the lowest among all ratios by direction. On the other hand, ratios of Bangkok-Route 315/344 were high, more than 44%. By type, the diversion ratio of heavy truck was the highest at 79% and that of passenger car was the lowest at 13%. This phenomenon was considered to be caused by traffic control for heavy vehicles diverted to the Bypass.

3.4 TRAFFIC FORECAST

3.4.1 Base Traffic

The traffic counts by type were used as base traffic volumes which were obtained from traffic surveys in 1988 conducted by the Study Team and "Annual Average Daily Traffic" published by DOH in 1986 and 1987. Base traffic volumes by type and the study route with survey year are shown in Table 3.4.1:

Table 3.4.1 BASE TRAFFIC VOLUME

Phase I Projects (Unit: vehicles/day)

Project Code	Section	Year	Traffic Volume							
			MC	PC	LB	HB	LT	MT	HT	ADT
ML-1	3-0403-N	1988	985	1229	134	261	2921	1330	8896	14771
	3-0403-E	1988	1303	1381	372	135	3263	1375	9029	15555
	3-0403-S	1988	2043	1078	555	151	3141	919	6297	12141
	3-0403-s	1988	2043	1078	555	151	3141	919	6297	12141
	Average	-	1594	1192	404	175	3117	1136	7630	13652
ML-2	3-158KM	1986	2467	1748	1740	308	870	201	91	4958
	3-175KM	1988	3676	1078	2348	508	2356	301	109	6700
	Average	-	3072	1413	2044	408	1613	251	100	5829
ML-4	3-1000	1986	2697	1349	750	278	3230	655	840	7102
	3-1102	1988	1537	891	953	186	3851	566	856	7303
	316	1988	2395	920	1169	195	4500	373	210	7367
	Average	-	2210	1053	957	220	3860	531	635	7257
ML-5	BP-N	-	-	-	-	-	-	-	-	-
	BP-S	-	-	-	-	-	-	-	-	-
	BP-W	-	-	-	-	-	-	-	-	-
	3-0502	1988	2729	5724	2101	2447	7776	1383	2399	21830
	3-0601	1987	1682	5649	1925	1397	2830	1229	530	13560
ML-7	304-40KM	1988	935	1440	911	597	1680	911	387	5926
	304-J.314	1988	1512	1371	355	391	2967	597	440	6121
	Average	-	1224	1406	633	494	2324	754	414	6024
IM-23	3267- 5KM	1987	464	504	92	146	980	395	534	2651
	3267-20KM	1988	414	264	89	226	769	175	437	1960
	Average	-	439	384	91	186	875	285	486	2306

Note: ML-1: N: North section, E: East section, S: Upper south section, s: Lower south section
ML-5: BP-N: North section, BP-S: South section, BP-W: West section

BASE TRAFFIC VOLUME (cont'd)

(Unit: vehicles/day)

Phase II Projects

Project Code	Section	Year	Traffic Volume							
			MC	PC	LB	HB	LT	MT	HT	ADT
ML-3	3-0702	1988	4128	1473	721	47	293	2398	74	5006
	3-0800-W	1988	1370	696	779	237	2122	220	334	4388
	3-0800-E	1988	1895	806	668	249	3180	349	557	5809
	Average	-	2464	992	723	178	1865	989	322	5068
ML-9	34-0100-E	1987	1457	10126	875	1740	7306	2777	4750	27574
	3-0402&3	1988	3475	7380	741	2525	12673	2169	9707	35185
IM-1	PWD-N	1988	399	21	54	25	299	35	92	526
	PWD-S	1988	257	8	14	4	191	24	34	275
	Average	-	328	15	34	15	245	30	63	401
IM-2	3306-0100-W	1988	205	1	5	4	176	66	2	254
	3306-0100-E	1988	271	1	6	4	171	70	3	255
	Average	-	238	1	6	4	174	68	3	255
IM-11	RID-N	1988	844	38	12	38	229	55	33	405
	RID-M	1988	245	10	9	0	98	18	14	149
	RID-S	1988	610	73	26	2	275	285	60	721
	Average	-	566	40	16	13	201	119	36	425
IM-12	RID-N	1988	465	39	87	16	120	52	26	340
	RID-M	1988	443	24	0	0	221	68	8	321
	RID-S	1988	250	63	42	0	272	48	7	432
	Average	-	386	42	43	5	204	56	14	364
IM-13	PWD	1988	253	33	83	67	120	10	27	340
IM-14	RURAL-N	1988	423	9	4	0	91	29	31	164
	RURAL-S	1988	133	5	2	0	71	6	0	84
	Average	-	278	7	3	0	81	18	16	124
IM-15	RURAL-N	1988	227	30	6	1	187	78	77	379
	RURAL-S	1988	349	217	87	32	890	397	380	2003
	Average	-	288	124	47	17	539	238	229	1191
IM-16	3312	1988	355	50	39	51	344	37	19	540
	PWD	1988	151	7	77	0	148	7	35	274
	Average	-	253	29	58	26	246	22	27	407
IM-17	PWD-W	1988	529	69	281	7	558	164	88	1167
	PWD-M	1988	99	54	16	0	103	24	4	201
	PWD-E	1988	238	53	24	19	317	131	129	673
	Average	-	289	59	107	9	326	106	74	680
IM-22	RURAL	1988	141	3	0	1	26	1	0	31
RH-2	225-0100-N	1988	782	105	43	125	797	133	163	1366
	225-0100-S	1986	1279	1243	129	135	354	320	34	2215
	Average	-	1031	674	86	130	576	227	99	1791
RH-3	325-0200	1987	1222	2419	717	428	544	305	248	4661
RH-5	344-0200-N	1987	1162	1492	171	574	2017	279	678	5211
	344-0200-S	1988	493	937	88	324	2821	316	630	5116
	Average	-	828	1215	130	449	2419	298	654	5164

Note: N: North section, E: East section, S: South section, W: West section

3.4.2 Traffic Growth

Traffic growth rates were determined based on the results of the Master Plan Study, in which a region-wide network traffic projection was carried out based primarily on existing traffic, growth in population, gross provincial income and vehicle registrations. Later an analysis of the data from "Socio-Economic Survey in 1986" by NSO was carried out to verify the results of the Master Plan Study, which were found to be acceptable (see Appendix 3.4.1).

The adopted traffic growth rates for each link can be explained as follows:

- Determined traffic growth rates reflect growth of population, GDP, vehicle registration by type in each zone.

- Determined traffic growth rates are cumulative results of traffic among zones.

- Effects on traffic by the planned industrial estates are not incorporated.

Established traffic growth rates by vehicle type and period are shown in Appendix 3.4.2.

3.4.3 Diverted Traffic

Diverted traffic was considered for ML-1 and ML-5 in Phase I and for ML-9, IM-11, IM-12, IM-13, IM-14, IM-15 and IM-22 in Phase II.

On ML-1, when the traffic volume on Route 3 in Chon Buri City exceeds capacity, some traffic is expected to divert to the Chon Buri Bypass. From the results of the license plate survey, rates of divertible traffic were estimated by vehicle type as shown in Appendix 3.4.3. The rate for buses was assumed to be the average ratio of P/C, L/T, M/T and H/T. Vehicles tend to pass through the city when the traffic condition is fair. However, when traffic volume exceeds capacity in the city, the excess portion, which should not exceed the divertible traffic volume, may divert to the Bypass. This diverted traffic caused by this condition was added to the Bypass.

In Phase I, the Bangkok-Chon Buri New Highway was assumed to be constructed by 2000. After opening, traffic congestion on Route 3 and the Chon Buri Bypass will be lessened by traffic diversion to the new highway. This traffic diversion was estimated by applying traffic diversion rates established based on the O/D pair distribution on Route 34 surveyed by the Study Team (see Appendix 3.4.3.(1)).

On ML-5, traffic will divert mainly from Route 3. Based on the O/D zone pair distribution and traffic volume analysis of O/D survey results for Route 3, diversion rates were obtained (see Appendix 3.4.3.(1)). For the estimation of traffic volume, said diversion rates were ap-

plied to future traffic volumes on Route 3.

On ML-9, major traffic will be diverted from Routes 34 and 3. These diversions were estimated based on the results of O/D surveys on Routes 34 and 314. For the section between Bangkok and Lat Krabang, diverted traffic between Bangkok & Samut Prakan–Minburi, Bangkok–Samut Prakan and Bangkok-Lat Krabang & Nong Chok were also taken into account based on the O/D survey result on Route 3256 (see Appendix 3.4.3.(1)). Allocation of diverted traffic on ML-9 to connecting roads was made mainly based on the O/D survey results. In the case of the Bangkok side, the allocation was supplemented by population distribution along the connecting road because traffic zoning did not match the highway alignment. The patterns of distribution for the Bangkok side and the Chon Buri side are shown in Appendix 3.4.3.(2).

For IM projects in Phase II, diverted traffic was estimated by applying traffic growth to the present divertible traffic detected from O/D survey results. The base figures are shown in Appendix 3.4.3.(3).

There are many methods for estimating diverted traffic. DOH currently applies the following equation for traffic forecasts:

$$P = 100/(1+(T2/T1))^6$$

where, P : Diversion rate
T1: Trip time using old road
T2: Trip time using new road

Diverted traffic were also analyzed by applying this equation (see Appendix 3.4.4). The analysis resulted in figures similar to those obtained by the Study Team.

3.4.4 Induced Traffic

Induced traffic was estimated by applying the same equation which was used in the Master Plan phase:

$$Iij = (Lj/2/SA \times 60 + 15)^{Pi} \;/\; (Lj/2/SI \times 60 + 15)^{Pi}$$

where, Iij : Induced traffic ratio for vehicle type i on section j
Lj : Length of section j on the project road
SI : Passenger car speed in case of with project (km/h)
SA: Passenger car speed in case of without project (km/h)
Pi : Parameter of gravity model for vehicle type i
Assumption: Initial trip time is 15 minutes and average trip distance is L/2

In the case of motorcycles, the induced traffic ratio of ADT was applied. Results of the estimation are shown in the Route Report.

3.4.5 Development Traffic

In the Central Region, almost all areas have already been developed. Therefore no development traffic, which is defined as traffic generated due to the projects, was counted except for ML-7 in Phase I.

In ML-7, the location of the project is close to Bangkok. At present, a number of housing development projects have been completed or are ongoing between Bangkok and Min Buri. After the improvement of ML-7 (Rt. 304), housing developments will expand beyond Min Buri toward Chachoengsao as far as Route 34. Based on an analysis of DOH traffic counts on Route 34, approximately 25% were considered as development traffic comparing traffic volumes at around the 10 km and 30 km posts on Route 34. For ML-7, this ratio of development traffic and traffic volume on the Chachoengsao side were used to estimate future traffic on the Min Buri side in 2000 and 2008. In the case of 1994, one half of the development ratio was applied, taking into account the transient time.

In ML-5, some development traffic is expected. However, the traffic volume on ML-5 was estimated as diverted traffic from Route 3. Therefore, it can be considered that some development traffic was already taken into account. Although commercial facilities such as restaurants, gas stations, etc. will be constructed along the new project, the effect of these facilities on the traffic on this route was deemed to be small. Therefore, development traffic on ML-5 was not counted, to be on the conservative side.

3.4.6 Future Traffic

1) Road Sections

Future traffic volumes, which were estimated by means of the methods described above, are summarized in Table 3.4.2 and Figure 3.4.1, and tabulated in detail in Appendix 3.4.5.

Table 3.4.2 SUMMARY OF FUTURE TRAFFIC VOLUME

(Unit: vehicles/day)

Phase I Projects

Project Code	Section	Base ADT		Future ADT			
		Year	ADT	1992	1994	2000	2008
ML-1	3-0403-N	1988	14771	23700	28900	28300	55500
	3-0403-E	1988	15555	24700	30100	30100	58300
	3-0403-S	1988	12141	20400	25200	23100	48000
	3-0403-s	1988	12141	18500	23000	22400	37400
	Average	-	13652	21800	26800	26000	49800
ML-2	3-158KM	1986	4958	-	8100	11200	16600
	3-175KM	1988	6700	-	9500	12900	18700
	Average	-	5829	-	8800	12000	17600
ML-4	3-1000	1986	7102	-	13100	17700	25900
	3-1102	1988	7303	-	10300	14200	21400
	316	1988	7367	-	10400	14400	22000
	Average	-	7257	-	11300	15500	23100
ML-5	BP-N	-	-	15700	17400	25500	38500
	BP-S	-	-	3300	3300	5100	7200
	BP-W	-	-	12400	14100	20500	31300
	Average	-	-	10500	11600	17000	25700
ML-7	304-40KM	1988	5926	-	8800	13400	19600
	304-J.314	1988	6121	-	8100	11000	16100
	Average	-	6024	-	8500	12200	17900
IM-23	3267- 5KM	1987	2651	-	4300	5600	7900
	3267-20KM	1988	1960	-	2900	3800	5400
	Average	-	2306	-	3600	4700	6700

Note: ML-1: N: North section, E: East section, S: Upper south section, s: Lower south section
ML-5: BP-N: North section, BP-S: South section, BP-W: West section

SUMMARY OF FUTURE TRAFFIC VOLUME (Cont'd)

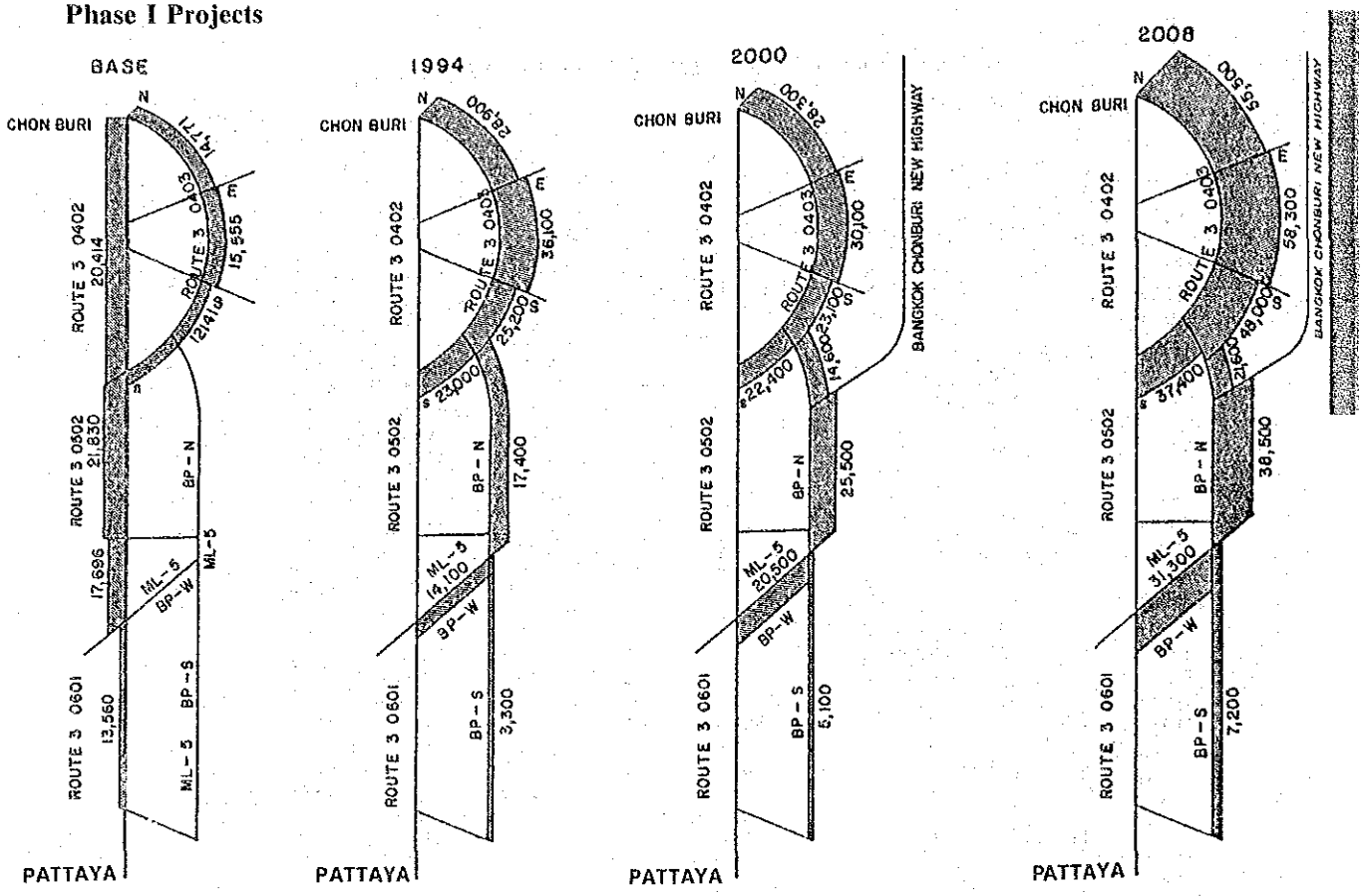
Phase II Projects

(Unit: vehicles/day)

Project Code	Section	Base ADT		Future ADT		
		Year	ADT	1994	2000	2008
ML-3	3-0702	1988	5006	7100	9800	14600
	3-0800-W	1988	4388	6600	9300	14000
	3-0800-E	1988	5809	8700	12200	18300
	Average	-	5068	7500	10400	15700
ML-9	1.SriNak'n-OuterR.	-	-	27700	39700	61300
	2.OuterR.-R.3119	-	-	25400	36300	55800
	3.R.3119-R.314	-	-	19900	28500	43600
	4.R.314-R.315	-	-	18800	27600	43500
	5.R.315-R.344	-	-	11300	16500	25800
	6.R.344-ML-5	-	-	17700	25500	38500
	Average	-	-	20200	29000	44800
IM-1	PWD-N	1988	526	800	1000	1400
	PWD-S	1988	275	400	600	800
	Average	-	401	600	800	1100
IM-2	3306-0100-W	1988	254	500	600	800
	3306-0100-E	1988	255	400	500	700
	Average	-	255	400	500	700
IM-11	RID-N	1988	405	700	1100	1600
	RID-M	1988	149	300	500	800
	RID-S	1988	721	1300	2000	3000
	Average	-	425	800	1200	1800
IM-12	RID-N	1988	340	700	1000	1500
	RID-M	1988	321	800	1200	1800
	RID-S	1988	432	1100	1600	2500
	Average	-	364	800	1300	1900
IM-13	PWD	1988	340	1100	1500	2100
IM-14	RURAL-N	1988	164	800	1000	1400
	RURAL-S	1988	84	700	900	1300
	Average	-	124	700	1000	1400
IM-15	RURAL-N	1988	379	1200	1700	2400
	RURAL-S	1988	2003	3300	4500	6600
	Average	-	1191	2300	3100	4500
IM-16	3312	1988	540	900	1200	1900
	PWD	1988	274	500	600	1000
	Average	-	407	700	900	1500
IM-17	PWD-W	1988	1167	1500	2100	3300
	PWD-M	1988	201	300	400	700
	PWD-E	1988	673	1000	1300	2100
	Average	-	680	900	1300	2000
IM-22	RURAL	1988	31	700	1100	1700
RH-2	225-0100-N	1988	1366	2000	2500	3200
	225-0100-S	1986	2215	3600	4600	6000
	Average	-	1791	2800	3500	4600
RH-3	325-0200	1987	4661	7200	9600	14200
RH-5	344-0200-N	1987	5211	7700	10600	15500
	344-0200-S	1988	5116	7200	9800	14300
	Average	-	5164	7400	10200	14900

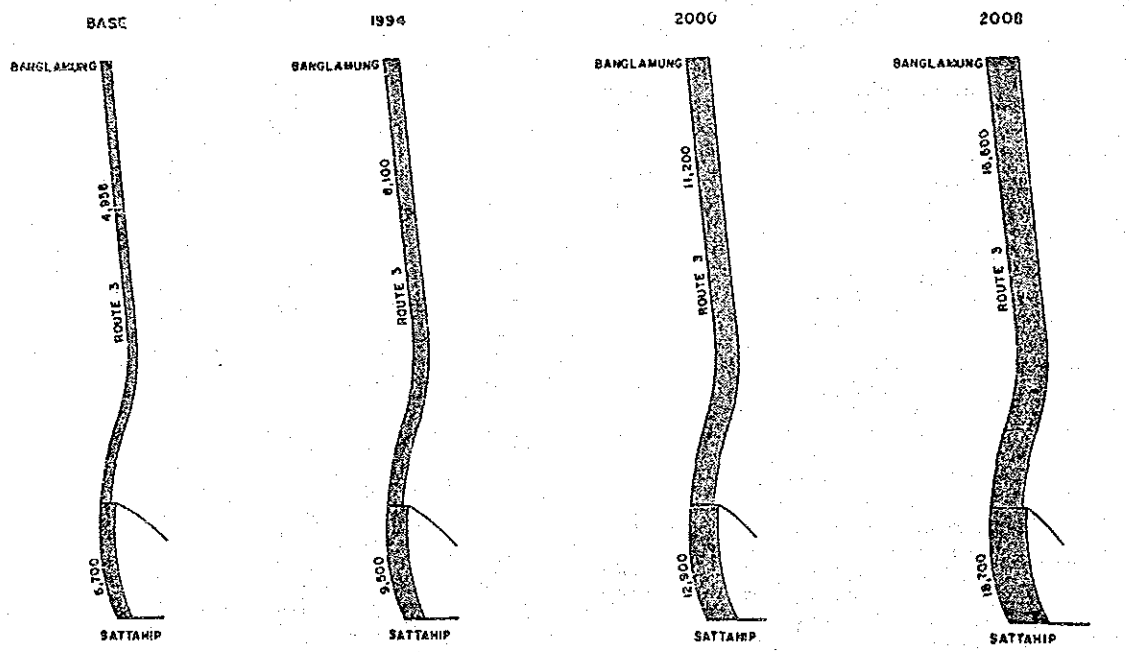
Note: N: North section, E: East section, S: South section, W: West section, M: Middle section

Phase I Projects



Projects ML-1 & ML-5

UNIT: VEHICLES/DAY

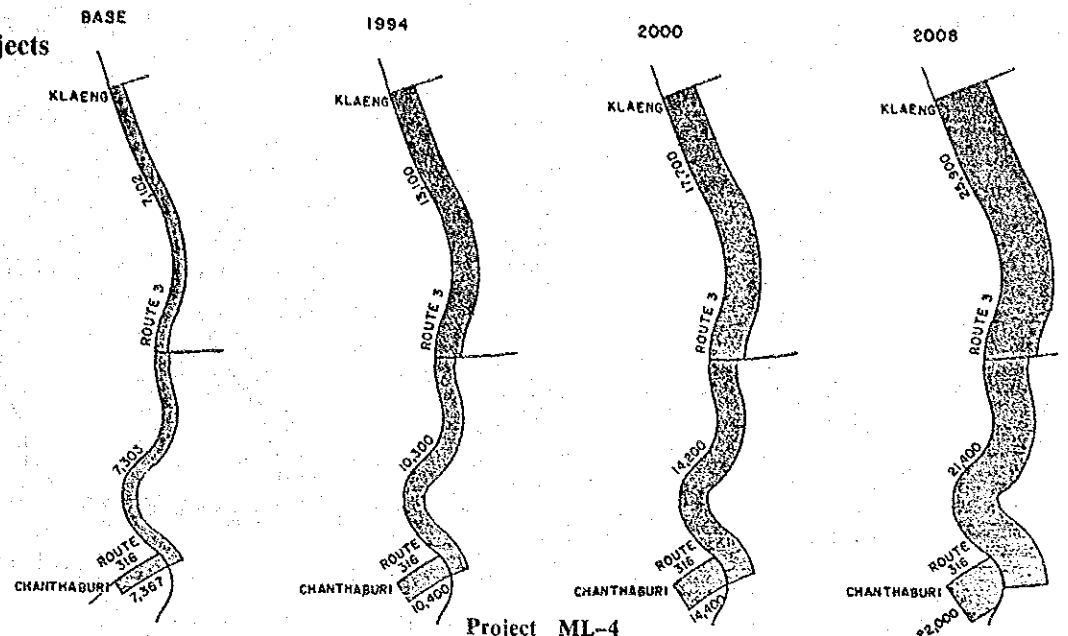


Project ML-2

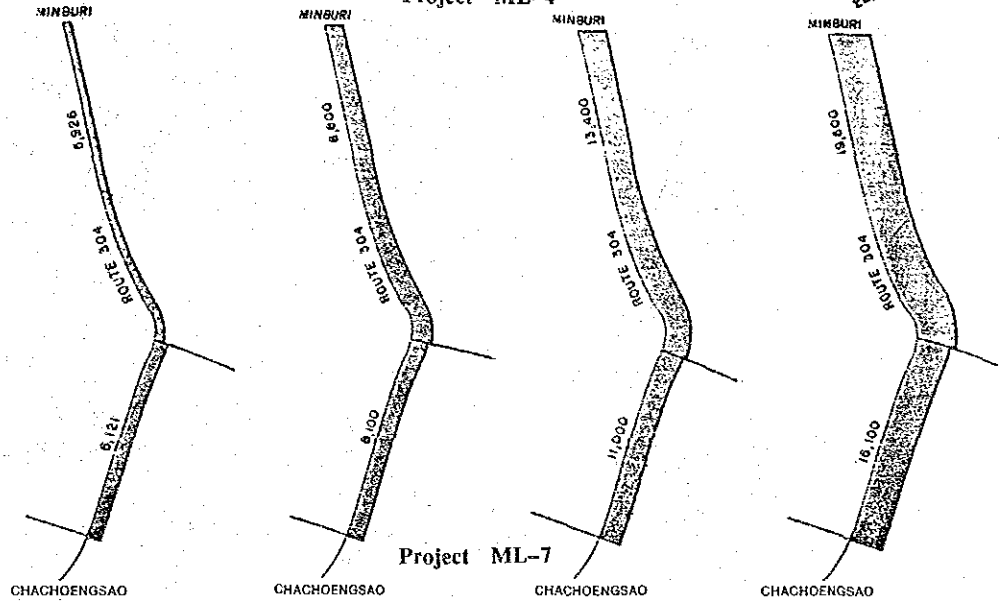
UNIT: VEHICLES/DAY

Figure 3.4.1 FUTURE TRAFFIC PATTERN (1)

Phase I Projects



Project ML-4



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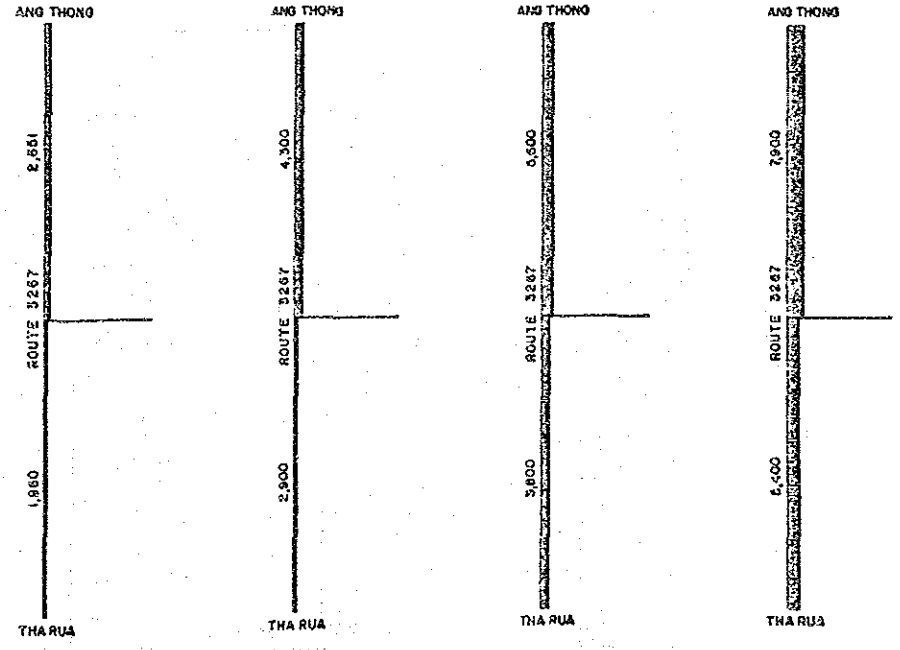
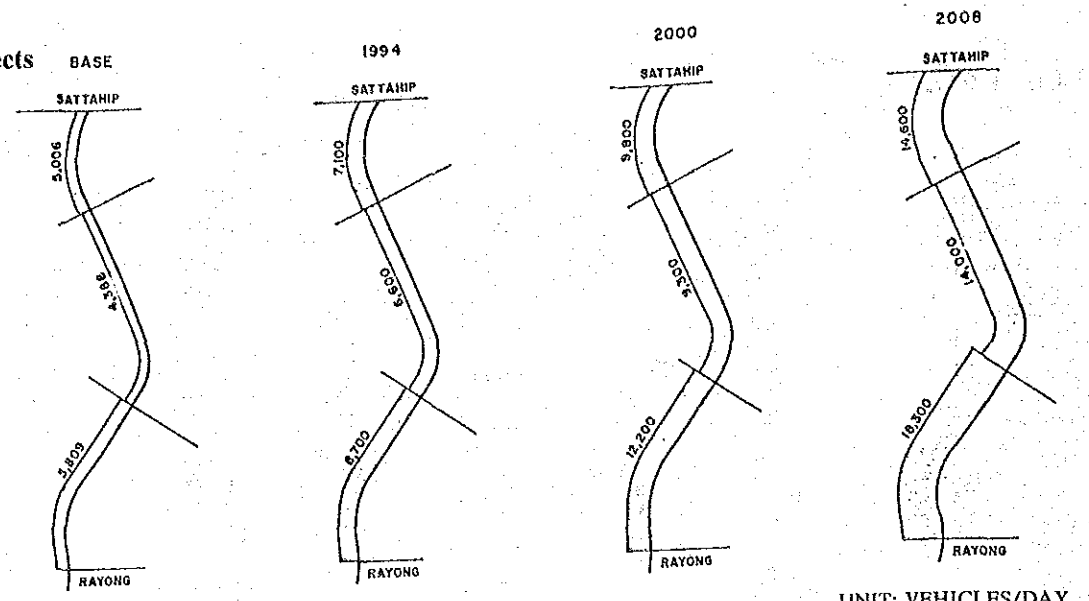


Project ML-23

UNIT: VEHICLES/DAY

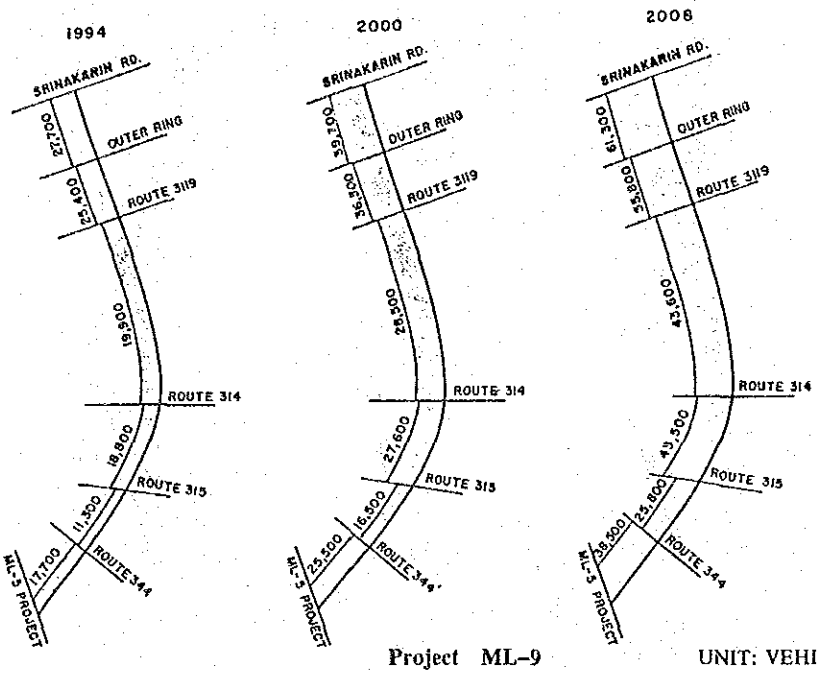
FUTURE TRAFFIC PATTERN (2)

Phase II Projects



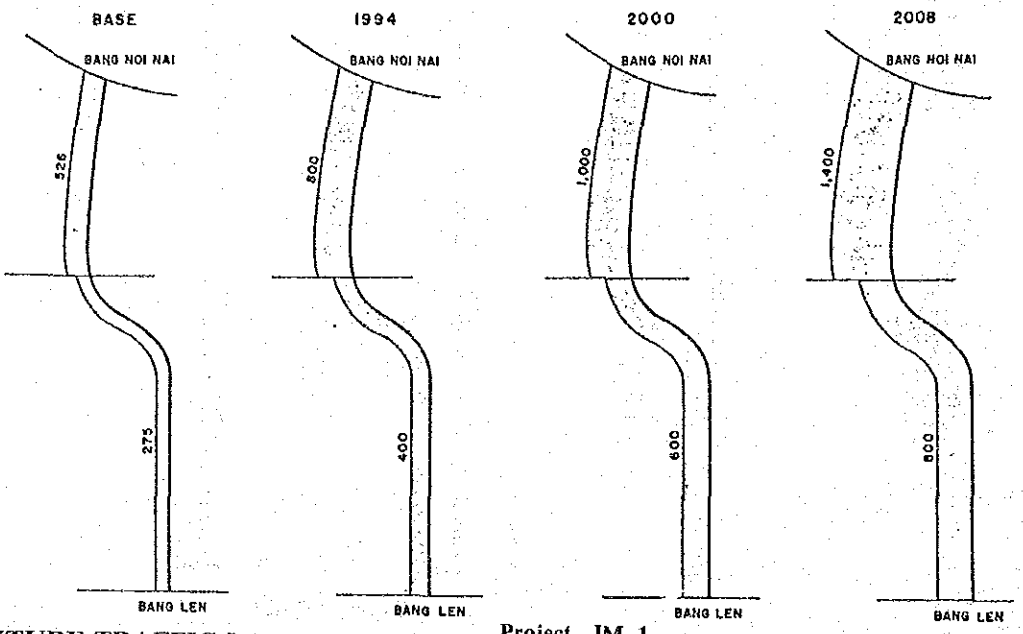
Project ML-3

UNIT: VEHICLES/DAY



Project ML-9

UNIT: VEHICLES/DAY

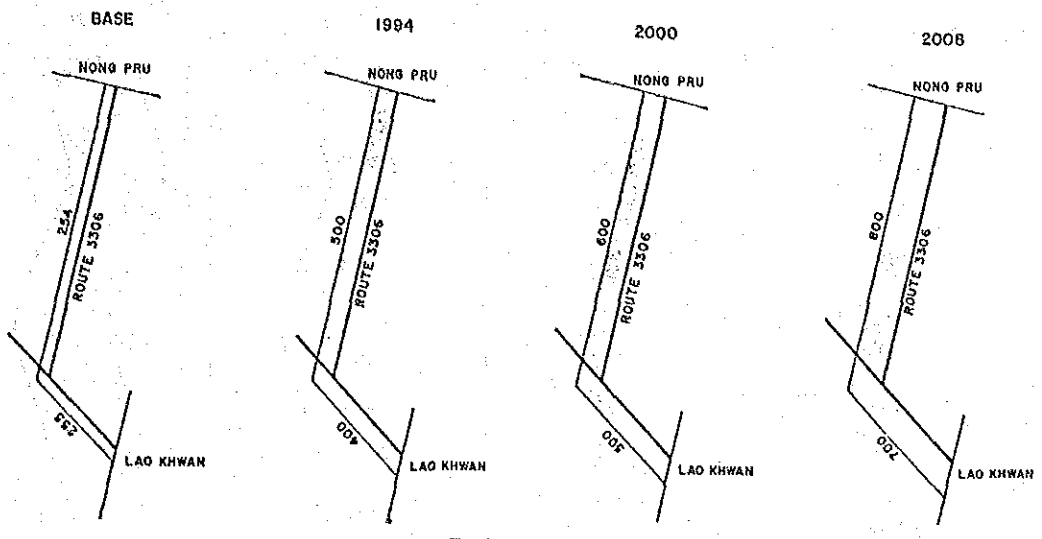


Project IM-1

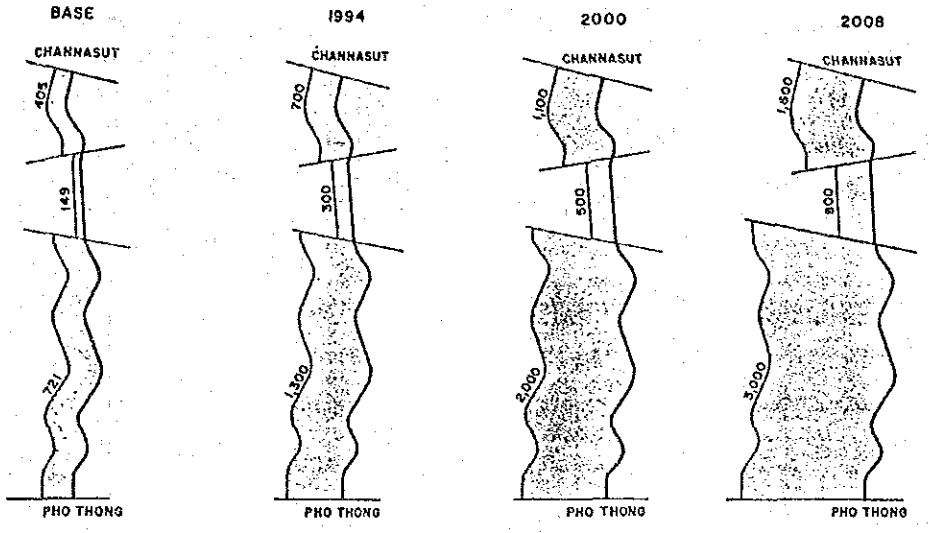
UNIT: VEHICLES/DAY

FUTURE TRAFFIC PATTERN (3)

Phase II Projects



Project IM-2 UNIT: VEHICLES/DAY



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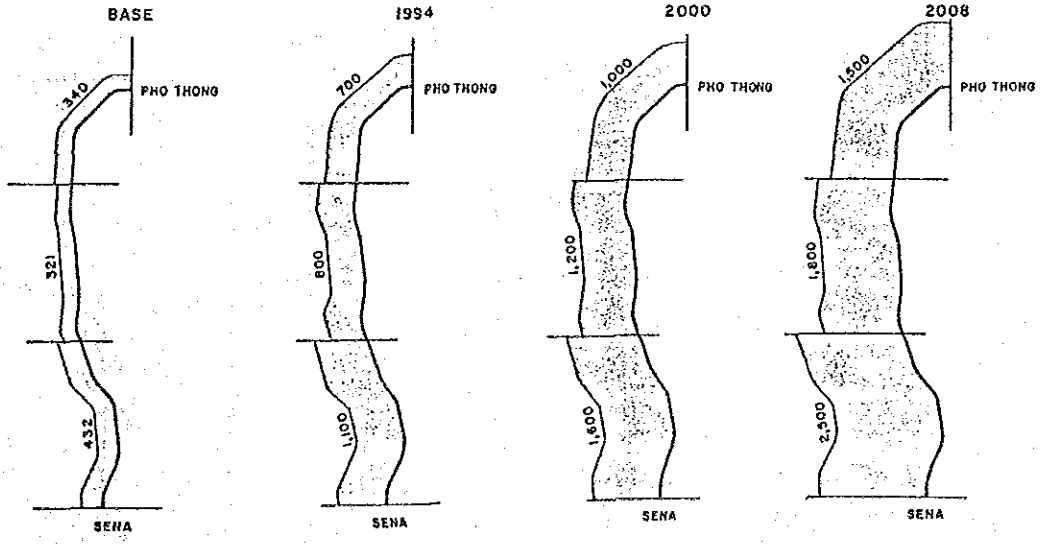
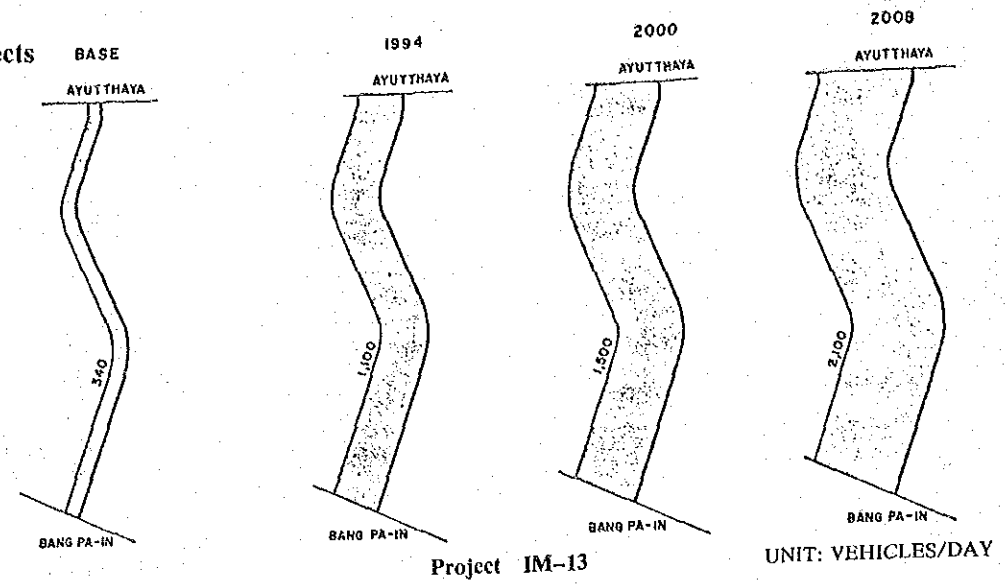


Project IM-12 UNIT: VEHICLES/DAY

FUTURE TRAFFIC PATTERN (4)

Phase II Projects



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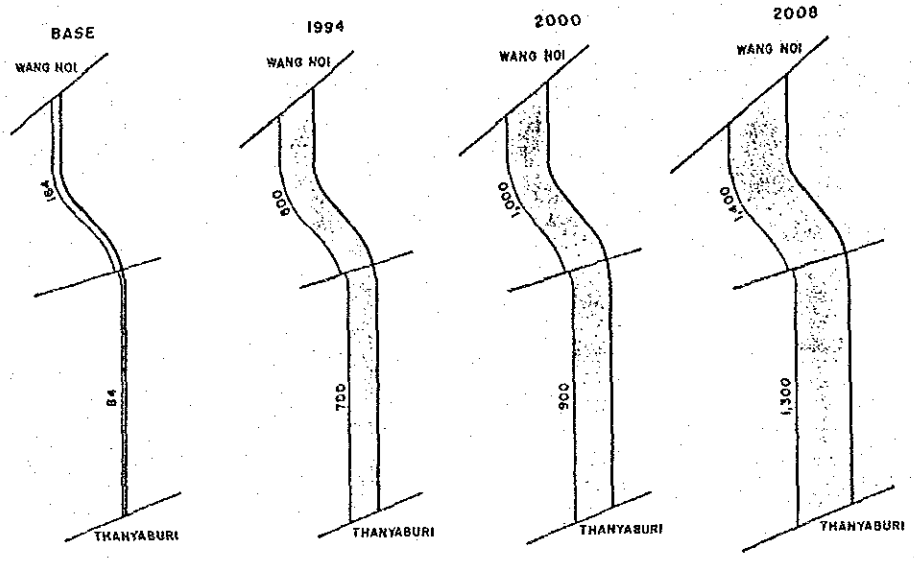

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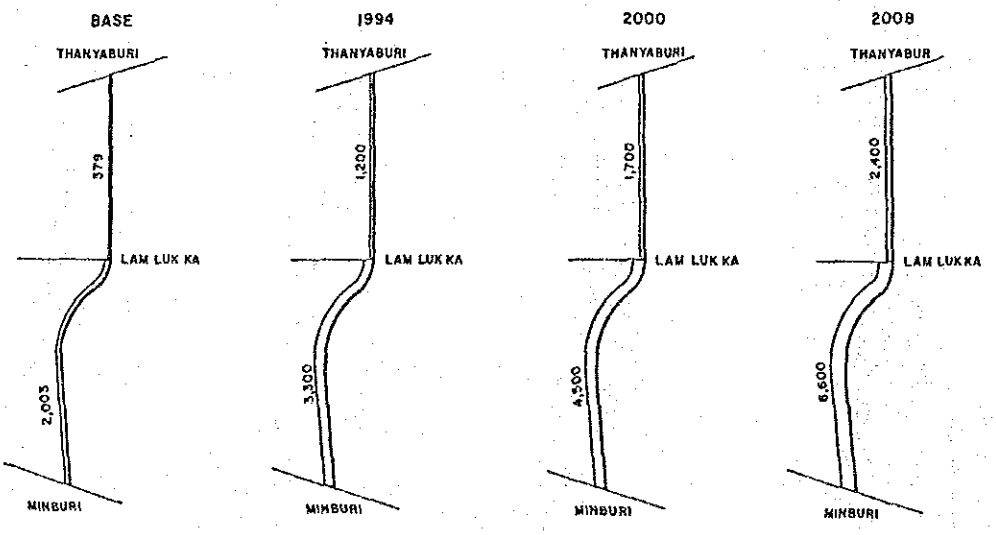
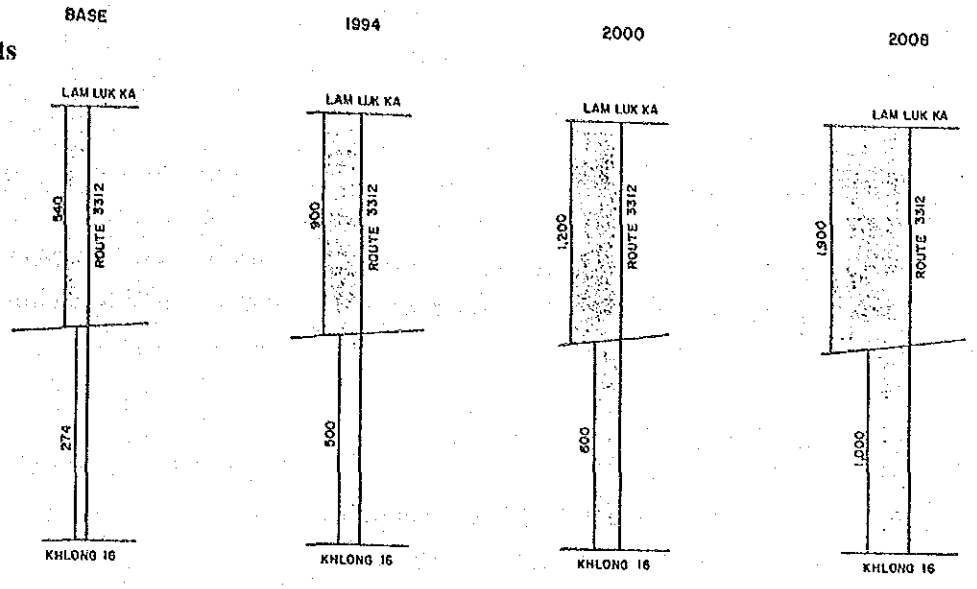


Project IM-15 UNIT: VEHICLES/DAY

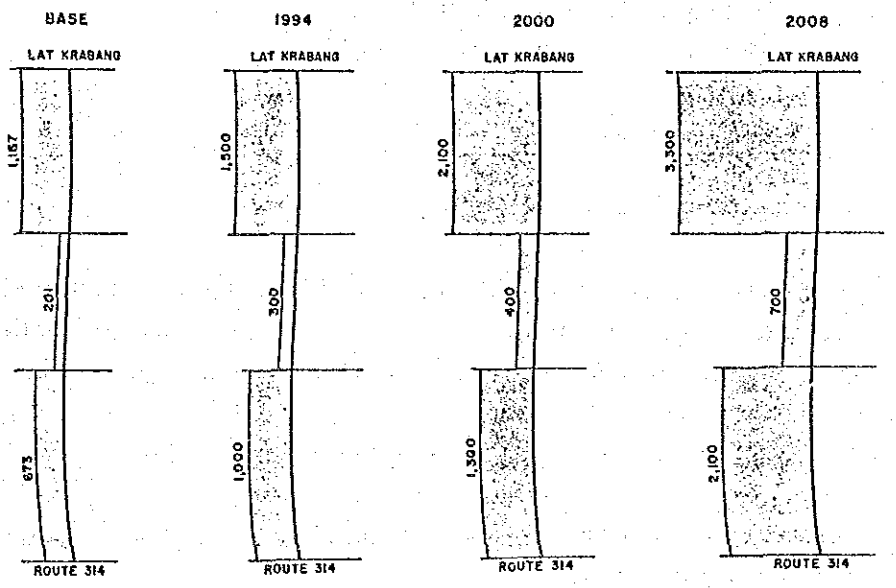
FUTURE TRAFFIC PATTERN (5)

Phase II Projects



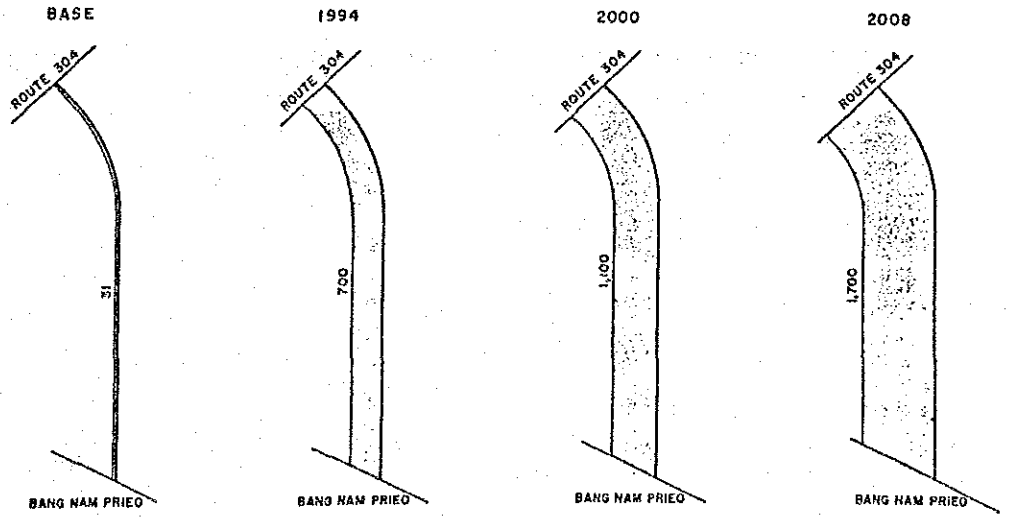
Project IM-16

UNIT: VEHICLES/DAY



Project IM-17

UNIT: VEHICLES/DAY



Project IM-22

UNIT: VEHICLES/DAY

FUTURE TRAFFIC PATTERN (6)

2) Intersections

Future traffic volumes at the following intersections where turning movement surveys had been done were estimated based on the peak hour survey results for each direction applying the same method as road sections:

Phase I Projects

- Route 304 - Route 314 (Chachoengsao)
- Route 3 - Chon Buri Bypass (Beginning)
- Chon Buri Bypass - Route 315
- Chon Buri Bypass - Route 344
- Route 344 - Route 3 (Klaeng)
- Route 3 - Route 316 (Chanthaburi)

Phase II Project

- Route 3 - Route 3126 (Sattahip)

As the peak hour ratio of diverted traffic to ML-1 and traffic volumes related to the Eastern Seaboard Industrial Estates, 1/8 or 0.125 was applied. It was assumed that this traffic passes through the existing intersections on ML-1 within the eight daytime hours.

Future turning movements are tabulated in Appendix 3.4.6.

For the following planned intersections, daily basis turning movements were obtained in the course of traffic forecasts:

Phase I Projects

- Intersection between Chon Buri Bypass and ML-5
- Branching point on ML-5
- Intersection between ML-5 and Route 3

Results are shown in Appendix 3.4.7.

For the engineering design of ML-9, on/off traffic volumes at intersections were estimated section by section. At intersections in Bangkok, on/off traffic was estimated using the results of a network traffic assignment for the Bangkok area in 2000, because traffic volumes on roads in the Bangkok area would be governed by traffic congestion in the area, and new road construction in future such as the Second Stage Expressway would have a large impact on traffic.

Results are shown in Appendix 3.4.8.

CHAPTER 4
ENGINEERING

CHAPTER 4
ENGINEERING

Engineering studies were composed of:

- Field surveys
- Preliminary design

Field surveys covering road inventory, topographic surveys, soil samplings, borings and soil testings were performed. Preliminary design was made based on the results of these surveys and available data.

4.1 FIELD SURVEYS

4.1.1 Inventory Survey and Field Reconnaissance

An inventory survey was conducted for existing routes and a field reconnaissance for new construction routes, totaling about 720 km in length, 220 km for Phase I projects and 500 km for Phase II projects.

An inventory survey with an accuracy at the prefeasibility study level was done in the Master Plan phase. Therefore, emphasis in the inventory survey was put on confirming the following matters as well as reviewing the performance in the Master Plan phase in order to improve the accuracy at the feasibility study level:

- Locations, types and dimensions of bridges and culvert structures
- Structures and obstacles which may cause difficulty of construction
- Boundaries of villages
- Catchment areas and drainage facilities
- Flooded areas
- Road surface conditions
- Widths of right-of-ways

In connection with the flooded areas, the survey stressed the following:

- Verification of high water levels and the nature and extent of flooding
- Locations of eroded embankments and scoured bridge foundations

In the inventory survey, a PSI survey was carried out for existing lanes of ML and RH Projects. The survey was done according to the following specifications:

- Rating: five ranks (good, good/fair, fair, fair/poor and poor)
- Number of persons engaged for rating: 8
- Survey speed: 50 km/h

For new construction routes ML-5 and ML-9, detailed reconnaissance was carried out to clarify the control points in determining their alignments.

Prior to the reconnaissance, routing studies were carried out on 1/50,000 topographic maps.

The principal check points in the reconnaissance were:

- Deep cuts
- High embankments
- Soil characteristics
- Required drainage structures
- River conditions and bridge locations
- Necessity of access roads for construction
- Difficulties of acquisition of right-of-ways

The results of the inventory surveys and the field reconnaissance are shown in the Route Report.

4.1.2 Route Survey and Topographic Mapping Survey

1) Route Survey

A route survey, which is composed of center line, profile and cross section surveys, was conducted for most of the projects by the Study Team. The surveyed length was about 430 km in total.

Projects which were not surveyed were a partial section of IM-7 and the whole of IM-1, IM-2, IM-4 and IM-5. For these projects, as-build plans or topographic maps prepared by DOH were utilized.

Horizontal and vertical alignments were surveyed by transit. Cross sections were surveyed by level at intervals of 200 m in principle and also at every marked change in topographic

feature.

The results of the route surveys were drawn at the following scales and were reduced to a scale of 1/25,000 as shown in the Route Report:

Center line	:	1/15,000
Profile	: Horizontal	1/15,000
	Vertical	1/1,000
Cross section	:	1/200

2) Topographic Mapping Survey

For the 10 main intersections along ML-1, ML-3, ML-4, ML-5, ML-7 and ML-9, topographic mapping surveys were carried out to design improvements of intersections. The total surveyed area was about 900,000 m^2.

The surveyed locations are shown below:

Project No.	Route No. or Name	Intersection
Phase I Projects		
ML-1	Chon Buri Bypass	(1) Beginning point (at Rt. 3)
ML-4	Rt. 3	(2) A. Klaeng (at Rt. 344)
		(3) Chanthaburi (at Rt. 316)
ML-5	Chon Buri-Pattaya New Highway	(4) Beginning point
		(5) Laem Chabang (at Rt. 3)
ML-7	Rt. 304	(6) Beginning point
		(7) End point (at Rt. 314)
Phase II Projects		
ML-3	Rt. 3	(8) End point at Sattahip
ML-9	Bangkok-Chon Buri New Highway	(9) Bang Pakorn (at Rt. 314)
		(10) Chon Buri (at Rt. 344)

The results of the topographic mapping surveys were made at the following specifications. The results are shown in the Route Report at the reduced scale of 1/4000:

Plan	:	1/500
Counter line	:	1.0 m

4.1.3 Material Source Survey and Soil Tests

Prior to carrying out soil samplings, data concerning the material sources and their quantities and qualities were collected at the Material and Research Division of DOH and at DOH Division Engineer Offices. By this process, data of materials for pavements and structures, laterite materials and crushed stones, etc., were collected.

Soil samplings of embankment materials from borrow pits were carried out for 23 samples in total. Soil samplings of subgrade for pavement design were made at about 10-km intervals for 52 samples in total.

The laboratory tests for samples thus collected by the Study Team were made by the Material and Research Division of DOH. The test items were as follows:

- Natural moisture content
- Particle size distribution
- Specific gravity
- Compaction
- CBR

The locations of material sources and their test results are shown in the Route Report.

4.1.4 Boring Survey

A boring survey was carried out at 17 sites to analyze soft ground and to design the foundation of bridges.

The sites are shown below:

BORING SITES

Project No.	Number of Borings	Location
Phase I Projects		
ML-1	1 (BH-2)	KM 0 + 000
ML-4	1 (BH-3)	KM 304 + 000
ML-7	1 (BH-1)	KM 59 + 790

Project No.	Number of Borings	Location
Phase II Projects		
IM-12	BH-1	20+400 LT
IM-14	BH-2	0+700 LT
IM-16	BH-3	4+900 RT
	BH-4	13+500 RT
	BH-5	20+500 RT
IM-17	BH-6	13+400 RT
	BH-7	16+700 RT
IM-22	BH-8	1+400 LT
	BH-9	5+500 LT
ML-3	BH-10	11+700 RT
	BH-11	22+300 LT
ML-9	BH-(1)	Khlong Prawat
	BH-(2)	Bang Pakong River
	BH-(3)	B. Bang Samae

Boring was composed of drilling a borehole with the standard penetration test (SPT), and collecting soil samples of each stratum for the following laboratory tests:

- Moisture content
- Unit weight
- Atterberg limits
- Sieve analysis
- Unconfined compression test (ML-9)
- Consolidation tests (ML-9)

The results of boring are presented in the form of a boring log with a graphical SPT plot and a description of each soil stratum. These are shown in the Route Report.

4.2 PRELIMINARY DESIGN

4.2.1 Design Standards

According to the highway classification of DOH, national and provincial highways are defined as follows:

National Highways: Roads which are of primary importance to the economic development, administration and defence of the Kingdom. The national highways are furthermore subclassified into two categories: primary highways and secondary highways.

Provincial Highways: Roads which are of secondary importance for national development but essential to efficient provincial administration, linking Amphoes (districts) and other important area centers to provincial capitals.

Based on these definitions, DOH classifies the existing study routes as follows:

	Phase I Projects	Phase II Projects
- Primary Highway	ML-1 (Rt.3, Chon Buri Bypass) ML-2 (Rt.3, Pattaya-Sattahip) ML-4 (Rt.3, Klaeng-Chanthaburi) ML-5 (Rt.36, Chon Buri-Pattaya New Highway)	ML-3 (Rt.3, Sattahip - Rayong) ML-9 (Rt.36, Bangkok - Chon Buri New Highway
- Secondary Highway	ML-4 (Rt.316, Chanthaburi) ML-7 (Rt.304, Min Buri-Chachoengsao)	
- Provincial Highway	IM-23 (Rt.3267, Rt.32-Tha Rua) ML-5 (Spur to Laem Chabang)	IM-2 (Rt.3306, Nong Prue-Lao Khwan) IM-13 (Rt.3059, Bang Pa-In-Ayuttaya) IM-16 (Rt.3312, Lam Luk Ka-Khlong 16)

ML-5 is a new construction route composed of two sections, a main section from the Chon Buri Bypass to Rt. 36, and a spur between the main section and Laem Chabang. ML-9 is also a new construction route between Bangkok and Chon Buri.

ML-9 (Bangkok–Chon Buri New Highway), linking up with ML-5 (Chon Buri–Pattaya New Highway) at the south of Chon Buri municipal area, will play a vital role as an arterial highway between Bangkok and Rayong by way of existing Route 36. These two highways, ML-9 and ML-5, are classified as a primary highway with the name of Rt. 36 as shown above.

The access portion of ML-5 to Laem Chabang is categorized as a provincial highway by DOH.

DOH has minimum design standards, P standard for primary highways, S standard for secondary highways and F standard for provincial highways. These are shown in Appendices 4.2.1 to 4.2.3, respectively.

As shown in these Appendices, the P standard is subclassified into four road classes from PD to P3, the S standard itno six road classes from SD to S5 and the F standard into seven classes from FD to F6 according to projected ADT.

Based on the specifications of DOH design standards and projected ADT, the road class to be applied to each study route was determined as follows:

APPLIED ROAD CLASS

Phase I Projects

Project No.	Route No.	Road Class of Existing Route	Projected ADT	Road Class Applied
ML-1	Chon Buri Bypass	P1	22,400–30,100	PD
ML-2	Rt. 3	P1/P3	11,200–12,900	PD
ML-4-1	Rt. 3	P1	14,200 –17,700	PD
ML-4-2	Rt. 316	S4	14,400	SD
ML-5(N)	Chon Buri Bypass to junction for Laem Chabang	New Plan	25,500	PD
ML-5(S)	Junction for Laem Chabang to Rt. 36	New Plan	5,100 (7,200)	P1
ML-5(W)	Access section for Laem Chabang	New Plan	20,500	FD
ML-7	Rt. 304	S3	11,000–13,400	SD
IM-23	Rt. 3267	F4	3,800– 5,600 (5,400– 7,900)	F1

Note: 1) Projected ADT shows average annual daily traffic at 7th year after opening (2000).
2) Projected ADT in parentheses shows average annual daily traffic at 15th year after opening (2008).
3) The road class of divided highways (PD, SD and FD) is applied to routes with more than 8,000 projected ADT at 7th year.
4) The road class of P1 and F1 is applied to routes with 4,000 to 8,000 projected ADT at 15th year.

Phase II Projects

Project No.	Route No.	Road Class of Existing Route	Projected ADT	Road Class Applied
ML-3	Rt. 3	P1/P2	9,300–12,200	PD
ML-9	Rt. 36	New Plan	16,500–39,700	PD
IM-1	Rt. 346-Rt. 3422	PWD (F5)	600– 1,000	F4
IM-2	Rt. 3306	F5	500– 600	F4
IM-11	B. Channasut –Rt. 3064	RID (F4)	500– 2,000	F2
IM-12	Rt. 3064 –Rt. 3263	RID (F4)	1,000– 1,600	F2
IM-13	Rt. 3059	F4/F5	1,500	F2
IM-14	Rt. 1–Rt. 305	Rural (F5)	1,600– 1,700	F3
IM-15	North Section (Rt. 305–Rt. 3312)	Rural (F5)	2,500	F2
	South Section (Rt. 3312–Rt. 304)	Rural (F4)	5,200	F1
IM-16	Rt. 3312	F5	600– 1,200	F3
IM-17	A. Lat Krabang –Rt. 314	PWD (F4/F5)	400 – 2,100	F2
IM-22	Rt. 304–Rt. 3124	Rural (F5)	1,100	F3

4.2.2 Geometric Design

(1) Design Speed

Based on the specifications in DOH standards, the following design speeds were adopted:

ADOPTED DESIGN SPEEDS

(Unit: km/h)

Terrain Conditions	Road Classes		
	P	S	FD, F1
Flat and Moderately Rolling	80–100	70–90	70–90
Rolling and Hilly	60– 80	55–70	55–70
Mountainous	50– 60	40–55	40–55

ML-9 (Bangkok–Chon Buri New Highway), which passes most of its length through flat paddy land, was designed for a speed of 120 km/h taking the controlled access operation of ML-9 in future into account.

(2) Geometric Design Criteria

The geometric design criteria corresponding to design speeds were determined based on AASHTO design criteria as follows:

GEOMETRIC DESIGN CRITERIA

Description (km/h)	Design Speed (km/h)							
	120	100	90	80	70	60	50	40
Minimum Radius of Curvature (m)	710	360	280	210	160	120	80	50
Minimum Stopping Sight Distance (m)	210	160	140	115	90	75	60	45
Maximum Gradient (%)	5	6	7	8	9	10	10	12

(3) Typical Cross Section

Typical cross sections were determined through studies of DOH standards and typical sections adopted for recent highway designs. They are given in Appendix 4.2.4 and also shown in the Route Report.

ML Projects, except for a section of ML-5 (south part), were designed as a four-lane highway. Their specifications are as follows:

- Carriageway width : 7.0 m
- Shoulder width : 2.5 m : left shoulder
  1.5 m : right shoulder
- Offset distance between two-lane centers : 20 m in general
- Gradient of embankment slope : 2:1

For some sections, however, the application of special typical cross sections were required as follows:

Built up sections in ML-4: A narrow right-of-way (40 m wide) and difficulties of land acquisition constrain improvement to a four-lane highway by using the existing lane. Two lanes in both directions were planned to be newly constructed (Appendix 4.2.4, ML-4 (b)).

Rt. 316 section in ML-4: Since this section passes through an urbanized area in Chanthaburi, a cross section with a narrow mounted medial strip was applied (ML-4 (c)).

ML-5 (south portion) is to newly construct an F1-class road and IM-23 is to improve from an F4-class to an F1-class road (ML-5(b) and IM-23). In these cases, both shoulders are 2.5 m wide.

ML-7: Two types, a 15-m offset distance and a mounted medial strip, were applied, because the existing road was constructed along the center line of the right-of-way (ML-7 (a), (b)).

(4) Alignment

1) Horizontal Alignment

The horizontal alignment for IM-Projects was designed to follow that of the existing road as much as possible. New alignment portions were introduced for IM-14 and IM-22, 9 km in total length. Detailed route descriptions are given in the Route Report.

The following are some comments on four-lane ML Projects:

ML-1: The existing two lanes of ML-1 were constructed by shifting the center line to the left side of the 60-m wide right-of-way on the assumption that ML-1 would be improved to a four-lane highway in future at that time. Therefore, a good alignment for the additional two lanes could be designed in the space of the right side. No additional land acquisition was required, except for areas for intersection improvement.

ML-2: Has a 50-m wide right-of-way broad enough to add new lanes. The new lane was designed to the left side of the existing lane for a 3.0-km long section from the origin point and shifted to the right side in the remaining section in order to construct in the space within the right-of-way. There is a sharp curve of about 200 m in radius at STA. 154. This was improved to an alignment which satisfies the geometric design criteria. In the terminal section, the distance between the centers of the existing and new lanes was gradually narrowed to smoothly connect with the existing road with a narrow median strip. No additional land acquisition is required.

ML-3: The right-of-way width is 40 m in general. In built-up sections, a special cross section within the 40-m wide right-of-way was applied. In other sections where it was judged to be easy to acquire land, a normal cross section was applied within a 55-m right-of-way.

ML-4: Has a 40-m wide right-of-way not broad enough to add a new lane. Acquisition of 20-m wide additional land was planned and the alignment of the new lane was designed there. For built-up sections difficult to obtain additional land and the Rt. 316 section in an urbanized area in Chanthaburi, the special cross sections described

in (3) above were applied.

ML-5: Is a new construction route planned in an 80-m wide right-of-way. The alignment was designed on the basis of the result of a topographic survey carried out by DOH without any problem.

ML-7: Has a 60-m wide right-of-way. The existing route, however, was constructed along the center line of the right-of-way. Therefore, the offset distance of 15 m was reluctantly applied due to constraints of the right-of-way. There are two sharp curves at STA. 37 and 55. These were improved to an alignment which satisfies the geometric design criteria. For an at-grade railway crossing at STA. 76, an overpass bridge was designed.

2) Vertical Alignment

The vertical alignment, except for new construction roads ML-5 and ML-9, was designed to follow that of the existing lane as much as possible. However, for ML-7, which passes on a soft ground area, the embankment height was determined to be somewhat higher than that of the existing lane considering the ground settlement expected.

3) Route Selection of ML-9

Under the condition that the beginning point and the end point of ML-9 are given, a corridor for establishing the route alignment was delineated taking the existing trunk highway network and topographic features into account, as shown in Figure 4.2.1.

The corridor length is about 80 km and its width is about 10 km. Within and around the corridor, the control matters which restrict the establishment of route alignment were examined on the topographic maps and through field investigations. The control matters are summarized by control item as shown in Table 4.2.1 and are also shown in Figure 4.2.1.

Three route alternatives were then proposed, basing their respective planning principles on different viewpoints.

In the route selection, primary concerns were paid among others on the route length, critical construction constraints and intersection locations. Comparative route alternatives are given in Figure 4.2.2. As the comparative study indicates, Alternative C is considered to be the most desirable route among the proposed route alternatives with respect to those physical control conditions.

Through discussions with DOH engineers, the C-route was selected for the subsequent feasibility study of ML-9.

Prior to commencing the feasibility study, a route survey along the selected route was carried out to identify the actual physical features such as terrain conditions, rivers and canals, and habitated areas.

For the route section between the beginning point and Lat Krabang, DOH already declared the acquisition of right-of-way with a width of 80 m. Therefore, the C-route for the section follows the alignment planned by the DOH.

Figure 4.3.3 shows the final route location of ML-9. Accumulative distance, deflection angles and radius of curvatures employed for ML-9 designs are given in Table 4.2.2. The net length of ML-9 is 81.7 km.

4.2.3 Earthwork Design

1) Embankment

The required minimum height of the road formation was determined mainly in consideration of the influence of the surrounding water level on the road structures, especially on the pavement structures. In this study, the minimum height of road formation was designed to be 70 cm above the surounding high water level estimated during the road inventory survey.

The side borrow method is common and economic for embankment construction in Thailand. In the Master Plan Study, this method was therefore applied to embankment construction for all projects except for ML-7. However, DOH recently decided as a general rule that embankments for main highways should be constructed by the borrow pit method, not by the side borrow method, because it is difficult to obtain good quality fill materials by the side borrow method, especially in areas of rice fields. Following this recent policy of DOH, the borrow pit method was applied for all projects, except for IM-2 located in a hilly area.

Locations of the borrow pits for each project were decided through discussions with engineers of concerned district offices of DOH. As described in 4.1.3, data for the qualities of materials in the borrow pits were collected mainly from the Material and Research Division of DOH.

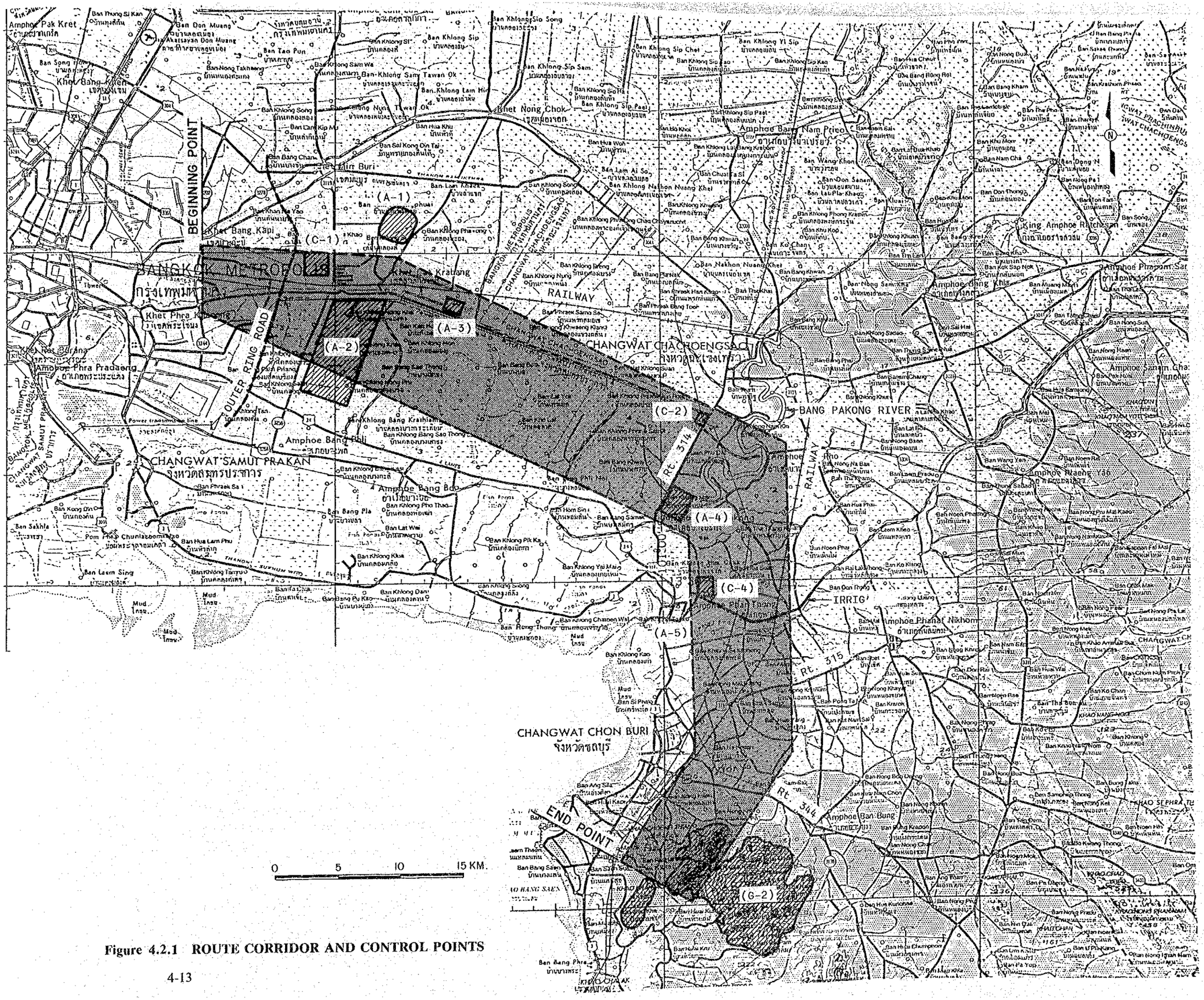
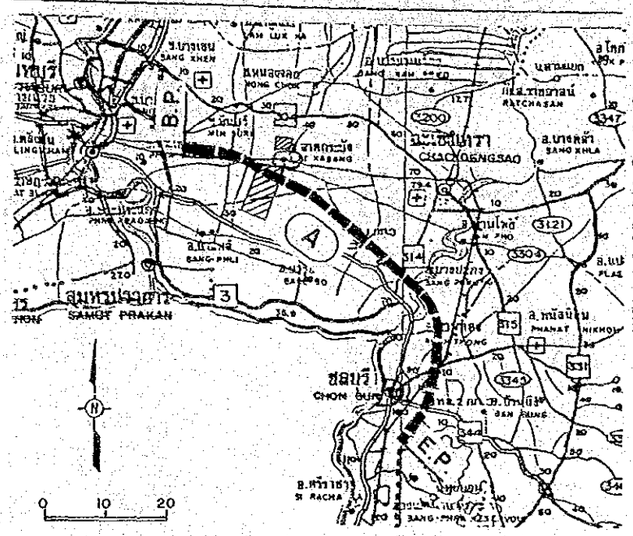
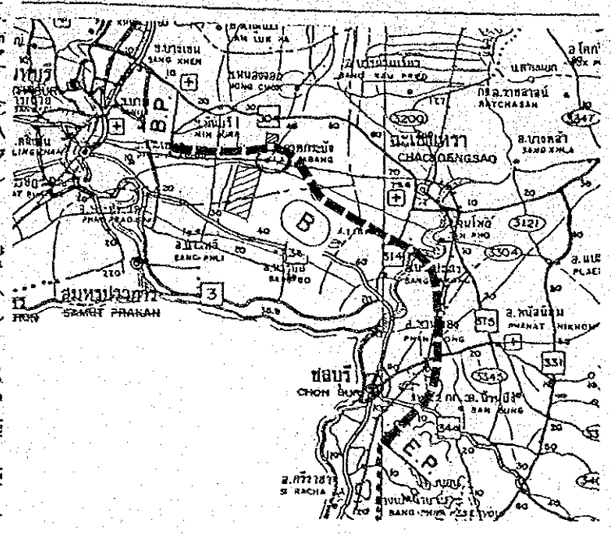
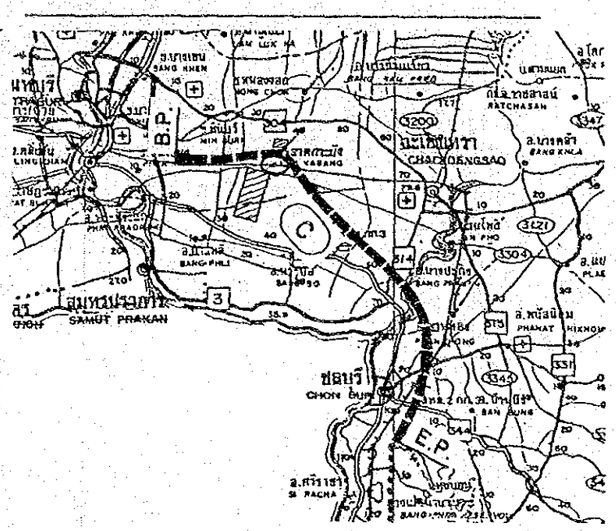


Figure 4.2.1 ROUTE CORRIDOR AND CONTROL POINTS

Figure 4.2.2 ROUTE COMPARISON FOR BANGKOK-CHON BURI NEW HIGHWAY (ML-9)

Highway Standard		National Primary Highway (PD) (Divided 4-lanes)
Design Speed		100 km/hr
Origin - Destination	Beginning Point	End of ETA 2nd-phase Project (Si Nakarin Road, Rt. 3344)
	End Point	Chon Buri - Pattaya New Highway (JICA Study Road ML-5)
Right of-way-width		80 meters

Route Alternatives	Route A	Route B	Route C
Alignment			
Route Length (km)	78.0	88.5	81.5
Route Characteristics	The Route aims at the shortest connection of the Origin point (end point of ETA Project) with the Destination (Chon Buri - Pattaya New Highway), avoiding the major CONTROL CONDITIONS such as large scale industrial facilities, temple and school and also taking the desirable crossing with River & Canal, Railway, Artery Roads and power transmission lines.	The Route detours the planned airport area (Nong Ngu Hao) and densely populated area of Amphoe Lat Krabang. Then it takes the alignment in parallel with the Study Road IM-17. The Route crosses at right angles to the Rt. 314 and Bang Pakong river. The latter half of the Route passes through the paddy field dotted with farmhouses. The Route is conveniently located for the Container Yard planned at around Amphoe Lat Krabang.	The first 25 kilometers of the Route is common to the Route B. Then it takes the direct alignment to Amphoe Bang Pakong. The latter half which follows the same route as the Route A takes the shortest course to the Destination.
Remarks	The Route passes : - the planned Nong Ngu Hao Airport site - amid the paddy field of rather soft soil ground - densely populated areas at crossings of highway Rt. 315 and Rt. 344. - sites close to power transmission towers and lines.	The Route is - around 10 kilometers longer in distance compared with Route A. - located a little far from Chon Buri municipal area.	The Route is well located eliminating the disadvantages seen in both Route A and Route B.

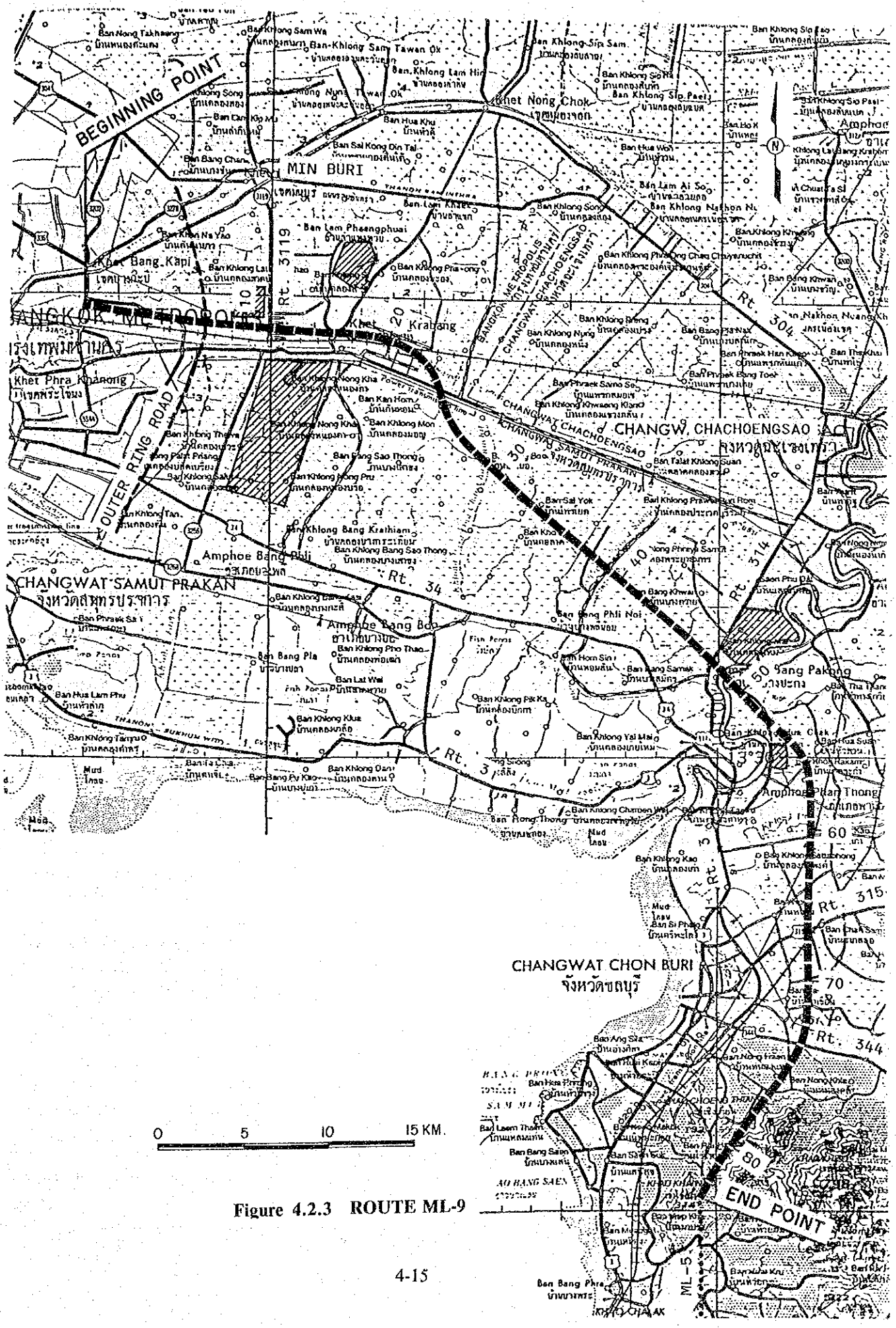


Figure 4.2.3 ROUTE ML-9

Table 4.2.1 CONTROL POINTS FOR BANGKOK-CHON BURI NEW HIGHWAY (ML-9)

Control Points	Planning Principle of Route Alignment	Control Objects	Remarks
Beginning Point End Point		End Point of ETA 2nd Stage Project Chon Buri - Pattaya New Highway (ML-5)	
Development Plans	Detouring the Development Zone	(A-1) Lat Krabang Industrial Estate (A-2) Proposed Nong Ngu Hao Airport Site (A-3) Privately-owned Industrial Estate (A-4) Bang Pakong Riverside Country-Club (A-5) Bang Pakong Industrial Estate	Estate Area ≒ 4 km2 Decreed Area ≒ 32 km2 Area ≒ 1.3 km2 { Orchard & Housing Area: 5 km2 { Golf Course 0.5 km2
Artery Roads to be Crossed	Crossing at Right Angle to Roads Junction Interchange Intersection	(B-1) Beginning Point (Si Nakarin Road) Rt.3344 (B-2) Junction with Bangkok Outer Ring Road (B-3) Intersection with Rt. 3119 (B-4) Intersection with Rt. 314 (B-5) Intersection with Rt. 315 and Railway (B-6) Intersection with Rt. 344 (B-7) End Point (Connecting with ML-5)	Confirm ETA Plan } Cross Measures (Over-pass/Under-pass)
Temple, Graveyard, School	Detouring the Objects	Δ marks on Map	
Large-scale Factory, Plants, Facility Yards	Detouring the Objects	(C-1) Inland Container Depot (C-2) EGAT Substation (Chachoengsao) (C-3) BKK Metal Company/Factory (C-4) EGAT Thermal Power Station (Bang Pakong)	Candidate depots : 6-depots
Big River to be Crossed	Crossing at Right Angle to River, Height Clearance	(D-1) Bang Pakong River (Width 350-400 m.)	Highest water level, Foundation Condition for Piers & Abutments
Railway Crossing	Crossing at Right Angle to Railway	(E-1) Bangkok - Chachoengsao (E-2) Chachoengsao - Sattahip	Confirming Double-Tracks Plan
Densely Populated Area	Detouring the Objects	marks on Map	
Medium/Small River & Canals	Bridge or Box Culvert Construction	(F-1) Canal Pla Thia (F-2) Canal Pla Ong Chao (F-3) Canal Prawet Buri Rom (F-4) Irrigation Canal (W = 30 m.)	
Unfavarable Topography	Detour	(G-1) Low-land Area (Soft Ground) (G-2) Mountain	
Power Transmission Line & Tower	Clearance under Power Lines	marks on Map	

Table 4.2.2 ROUTE LENGTH OF ML-9

I.P. No.	PI Station (km.+ m.)	Deflection Angle DD	MM	SS	LT or RT	Curve Radius (m.)	Tangent Length (m.)	Length Curve (m.)	PC Station (km.+ m.)	PT Station (km.+ m.)	Dist correct at PT (m.)
	000+774.552										
1	002+047.920	4	47	0	R	3,183.100	132.948	265.741	001+914.972	002+180.713	-34.493
2	002+595.731	12	0	0	L	770.497	80.983	161.373	002+514.748	002+676.121	
3	003+543.660	4	12	0	R	3,323.033	121.850	243.591	003+421.810	003+665.401	
4	004+514.520	2	30	0	L	11,459.156	250.040	500.000	004+264.480	004+764.480	-0.079
5	010+762.480	7	55	0	L	1,070.589	74.081	147.925	010+688.399	010+836.325	
6	013+370.000	13	0	0	L	572.958	65.280	130.000	013+304.720	013+434.720	
7	014+224.440	13	0	0	R	572.958	65.280	130.000	014+159.160	014+289.160	
8	018+478.640	14	10	0	R	8,000.000	994.090	1,978.040	017+484.550	019+462.590	
9	023+098.068	72	23	0	R	2,000.000	1,463.332	2,526.655	021+634.736	024+161.391	
10	026+831.254	45	57	0	L	4,000.000	1,695.840	3,207.915	025+135.414	028+343.329	
11	043+576.827	10	39	0	R	15,000.000	1,398.110	2,788.163	042+178.718	044+966.881	
12	052+378.999	18	42	0	L	6,000.000	987.915	1,958.259	051+391.084	053+349.343	
13	056+081.428	62	29	0	R	3,000.000	1,819.848	3,271.620	054+261.580	057+533.200	
14	062+688.519	8	38	0	L	15,000.000	1,132.244	2,260.201	061+556.276	063+816.477	
15	074+564.859	61	25	0	R	4,000.000	2,375.813	4,287.692	072+189.046	076+476.738	
16	081+276.402	41	45	0	L	2,500.000	953.407	1,821.687	080+322.995	082+144.682	
17	082+523.969										

Total Equation -34.572 m

Net Length 81,714.844 m

2) Countermeasures for Soft Ground

Soft ground questionable in terms of stability and settlement is generally said to be layers with the following characteristics:

CHARACTERISTICS OF SOFT GROUND

Ground	Peaty ground and clayey ground		Sandy ground
Stratum thickness	Less than 10 m	More than 10 m	—
N value	4 or fewer	6 or fewer	10 or fewer
qu (kg/cm^2)	Less than 0.6	Less than 1.0	

Judging from the above characteristics , the following projects are located in soft ground areas:

- Phase I Projects : ML-1 and ML-7

- Phase II Projects : ML-9, IM-12, IM-14, IM-16, IM-17 and IM-22

However, since IM Projects are only to improve existing roads and to construct pavements, no particular countermeasures for soft ground are required. Analysis, therefore, was made for three ML Projects: ML-1, ML-7 and ML-9.

a) ML-1 (Phase I)

At the beginning point of ML-1, the existence of a total of about 5.0 m of thick soft sandy clay layers with 40% to 80% in natural moisture content was found from Borehole BH-2 shown in the Route Report. Judging from the analysis of ML-7 described below, no severe problem as to soft ground is expected, because the thickness of the soft layer is relatively thinner and the natural moisture content is comparatively lower than those in ML-7. A bearing unit, however, was designed to the overpass bridge approaches as a precaution to expected faulting.

b) ML-7 (Phase I)

Borehole BH-1 shown in the Route Report revealed that ML-7 is located on very soft clayey layers of about 10.5 m in total thickness with 80% to 100% in natural moisture content. The average N value of the clayey layers was about 1.0.

Only a rough analysis was done for stability and settlement caused by the load of the embankment since consolidation tests were not performed.

i) Stability of Embankment

The critical height of the embankment (Hc) on soft ground is calculated by the following equation:

$$Hc = q_d/\gamma_e$$

where,

γ_e : Unit weight of embankment (kg/cm³)

q_d : Critical bearing capacity (kg/cm²): This is given by the table below:

Ground Conditions	q_d
Thick clayey ground or peat ground	3.6 Cu
Ordinary clayey ground	5.1 Cu
Thin clayey ground or peat ground	7.3 Cu

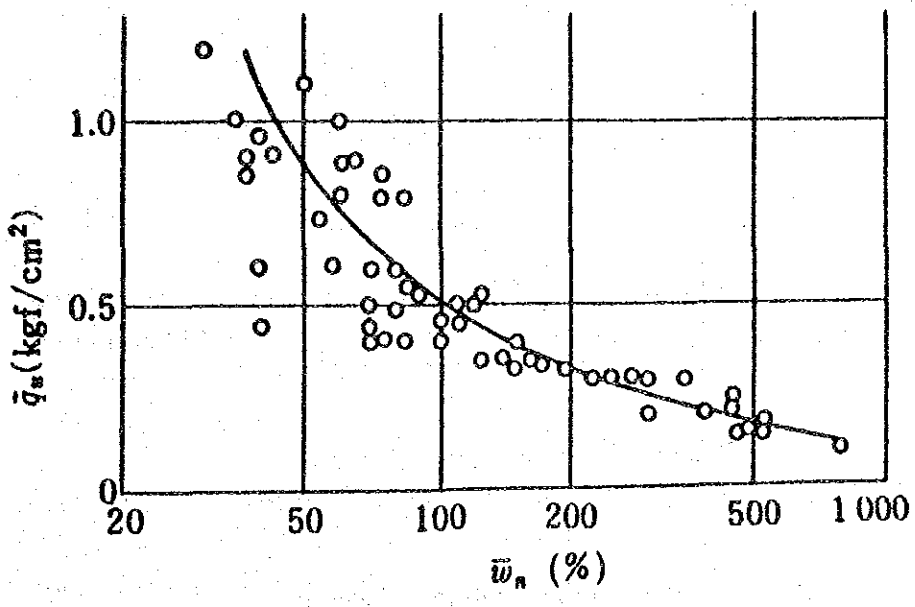
The apparent cohesion (Cu) in the above table was estimated as follows:

- The relationship between Cu and q_u is:

Cu : 1/2 q_u

q_u : Unconfirmed compressive strength (kg/cm²)

- q_u is estimated based on the natural moisture content (W_n) by the following figure:



Relationship between q_u and W_n

Variables in the equation were determined based on the results of the boring as follows:

γd : 0.002 kg/cm³ (2.0t/m³)
q_u : 0.5 kg/cm² ($W_n = 100\%$)
q_d : 3.6 Cu = 0.9 kg/cm² (thick soft ground layer)

The calculated Hc was 4.5 m. This height is on the safe side because, in the calculation by this equation, the strength increase of the soft layer induced by consolidation is disregarded.

The highest embankment planned in ML-7 was 4.5 m. This was designed in only very short sections close to bridges. Construction of the embankment can therefore be carried out without any problem as to stability.

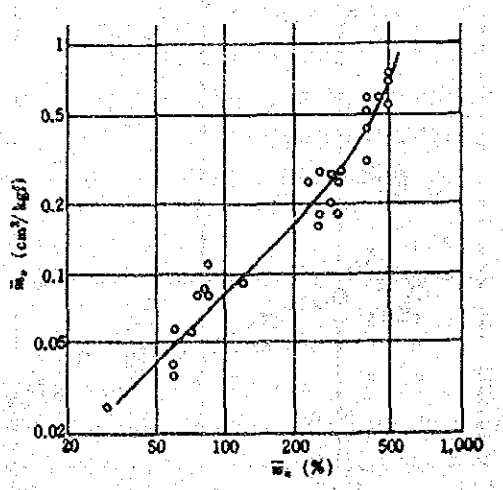
ii) Consolidation Settlement

Consolidation settlement (S) is roughly estimated by the following equation:

$$S = m_v * P * H$$

where, P : Stress increased by embankment (kg/cm²)
H : Thickness of soft layer (cm)
m_v : Average compression coefficient (cm²/kg)

m_v is given in the relationship with W_n as follows:



Relationship between W_n and m_v

Variables in the equation were as follows:

$P = 0.5\ kg/cm^2$: Average height of embankment is 2.5 m and unit weight of embankment is $2.0t/m^3$

$H = 1{,}050\ cm$: Thickness of soft layer

$m_v = 0.08$: W_n is 100%

S was therefore calculated to be 40 cm. Consolidation settlement usually ends up with two-thirds of the total amount by completion of the embankment. From this fact, about 30 cm of settlement is estimated during construction of ML-7. Therefore, an extra volume for the embankment caused by this settlement was considered in the estimate of earth work quantity.

Out of 40 cm of the total amount of the settlement, 30 cm of the settlement would be finished during the construction period. A residual settlement is estimated to be 10 cm in a simple calculation. A tolerable settlement after completion of pavements is commonly said to be about 10 cm. Therefore, no particular measures are required.

However, the actual residual settlement is likely to be considerably larger than this, because settlement by pumping up ground water and by secondary consolidation was not considered in this study.

Considering the above, the following measures should be applied at least:

- To apply AC pavements, since AC pavements are more flexible than PCC pavement against settlement and can be easily repaired.

- To apply bearing units to prevent faulting caused at bridge approaches.

c) ML-9 (Phase I)

ML-9 passes on a soft ground area over about 65 km between the beginning point and J.R. 315. Three borings carried out along this route, which are shown in the Route Report, revealed severer conditions than that of ML-7. A more detailed analysis, therefore, was performed based on the results of the consolidation tests.

The soft ground is composed mainly of two kinds of soil layers: inorganic clay and silt sand. The total soil layer is very thick. Rock or hard sand layers could not be found, although borings were drilled up to about 40 m in depth.