The results of the three borings are summarized below:

- B-1 = Clay layer of 14.0 m thick (moisture content = 80% to 130%, Qu = 0.8 kg/cm^2 to 1.6 kg/cm^2)
- B-2 = Clay layer of 14.0 m thick (moisture content = 40% to 85%, Qu = 0.8 kg/cm^2 to 1.8 kg/cm^2)
- B-3 = Clay layer of 11.0 m thick (moisture content = about 50%, Qu = 0.9 kg/cm^2 to 1.0 kg/cm^2

As to thickness, B-1 and B-2 are the same at 14.0 m, but B-3 at 11.0 m is a little thinner than the others.

For Qu, B-3 is a little lower than others, but this value is thought unreliable, judging from its relatively low moisture content.

As described above, since there are no major differences in thickness and nature among the three borings, an analysis was carried out for B-1, which indicated a somewhat poorer nature than the others.

i) Stability of Embankment

Stability of embankments was analyzed by the following equation:

$$F_s = \frac{(C_{uo} \times l + W \times \cos\alpha \times \tan\phi_u)}{W \cdot \sin\alpha}$$

where,

C_{uo} : Apparent cohesion (t/m^2)

ϕu : Angle of shear registance = 0° in this case

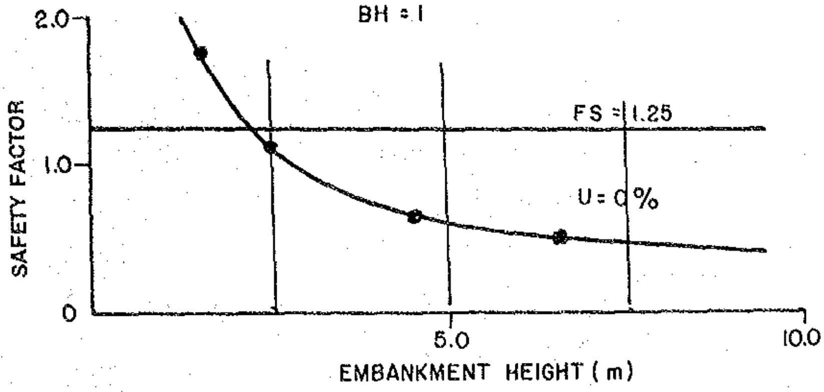
l : Length of sliding surface (m)

W : Total weight of soil (t/m)

α : Average incline degree of sliding surface (°)

The calculation was made by computer for embankment heights of 1.5 m, 2.5 m, 4.5 m and 6.5 m. Some examples of the calculation are shown in Appendix 4.2.5.

The following figure shows the calculation results:



In order to prevent slide failures during embankment work, a safety factor of at least 1.25 is necessary. From the above figure, about 2.3-m high embankments incorporate the safety factor of 1.25.

In the above calculation, increase of cohesion owing to consolidation is disregarded. However, the degree of consolidation when the embankment is completed was estimated to be 5 to 10% in the settlement analysis. Therefore, about 2.5-m high embankments, a little higher than the above figure, can be constructed without any particular countermeasures.

Embankments higher than 2.5 m were planned for a 17-km long section. For this section, some countermeasure should be applied to prevent sliding failures.

There are many kinds of countermeasures to prevent sliding failures such as a counter fill, reinforced earth methods, sand compaction piles, and lime or cement stabilization piles.

Among them, a counter fill or reinforced earth methods are recommended from the economic viewpoint. However, in this study, a counter fill was applied considering that it can be used as a subgrade of frontage road which will be planned in future.

The planned counter fill is shown in Route Report. This volume was included in the earth work quantity.

ii) Settlement

Applying the boring test results, settlement was calculated by the following equations by computer:

i) Consolidation settlement

$$S_c = \frac{(e_o - e_1)}{1 + e_o} \times H$$

where,

e_0 : Initial void ratio
e_1 : Void ratio after consolidation
H : Thickness of subject layer

ii) Immediate settlement

$$Si = \frac{q_e \times B_m V \times n}{E}$$

where,

q_e : Embankment load (t/m^2)
B_m : Width of load (m)
E : Average modulus of deformation of subject layers (t/m^2)
n : Factor

iii) Settlement time

$$t = \frac{(H_o/2)^2 \times T_u}{Cvo}$$

where,

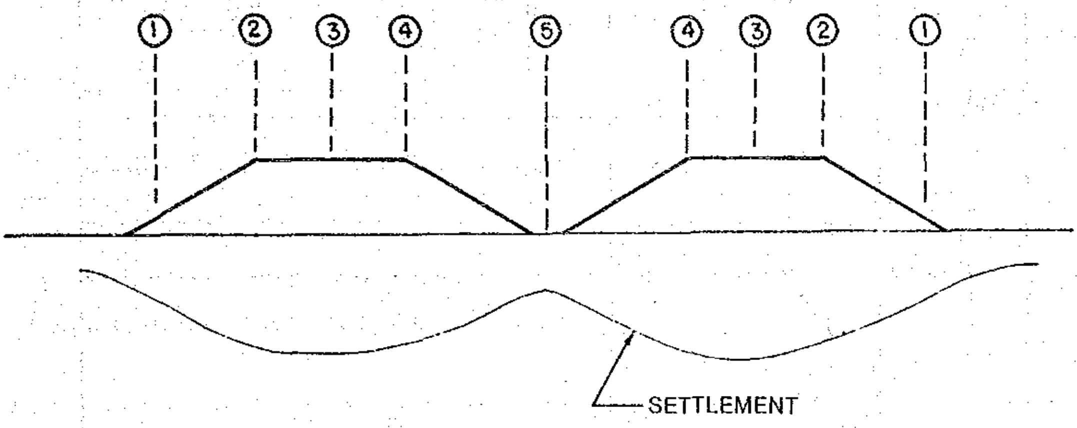
H_o : Converted thickness of subject layers (cm)
Cvo : Converted coefficient of consolidation (cm^2/sec)
T_u : Time coefficient

The calculated total amounts of settlements for embankment heights of 1.5 m, 2.5 m, 3.5 m and 4.5 m are shown in Table 4.2.3.

Table 4.2.3 TOTAL AMOUNT OF SETTLEMENT

(cm)

Embankment Height (m)	Kinds of Settlement	Calculated Points				
		1	2	3	4	5
1.5	Consolidation	45	75	95	85	61
	Immediate	10	16	20	18	13
	Total	55	91	115	103	74
2.5	Consolidation	63	131	156	151	121
	Immediate	14	29	34	33	27
	Total	77	160	190	184	148
3.5	Consolidation	75	181	206	211	186
	Immediate	18	42	48	49	43
	Total	93	223	254	260	229
4.5	Consolidation	84	222	248	256	236
	Immediate	21	55	62	64	59
	Total	104	277	310	320	295



As seen in the above table, estimated settlement at the center of the embankment reaches 1.0 m to 3.0 m corresponding to the height of the embankment.

Calculated settlement times are shown in Table 4.2.4 and Figure 4.2.4.

Table 4.2.4 SETTLEMENT TIME AT CENTER OF EMBANKMENT

Embankment Height (m)		Degree of Consolidation (%)					
		10	20	30	40	60	95
1.5	days	130	510	1,170	2,080	4,940	18,620
	Settlement (cm)	10.0	19.0	28.0	38.0	57.0	90.0
2.5	days	160	610	1,400	2,490	5,680	22,330
	Settlement (cm)	16.0	31.0	47.0	62.0	93.0	148.0
3.5	days	190	740	1,690	2,990	6,810	26,770
	Settlement (cm)	20.0	41.0	62.0	83.0	124.0	196.0
4.5	days	230	870	2,000	3,550	8,090	31,780
	Settlement (cm)	25.0	50.0	75.0	99.0	149.0	236.0

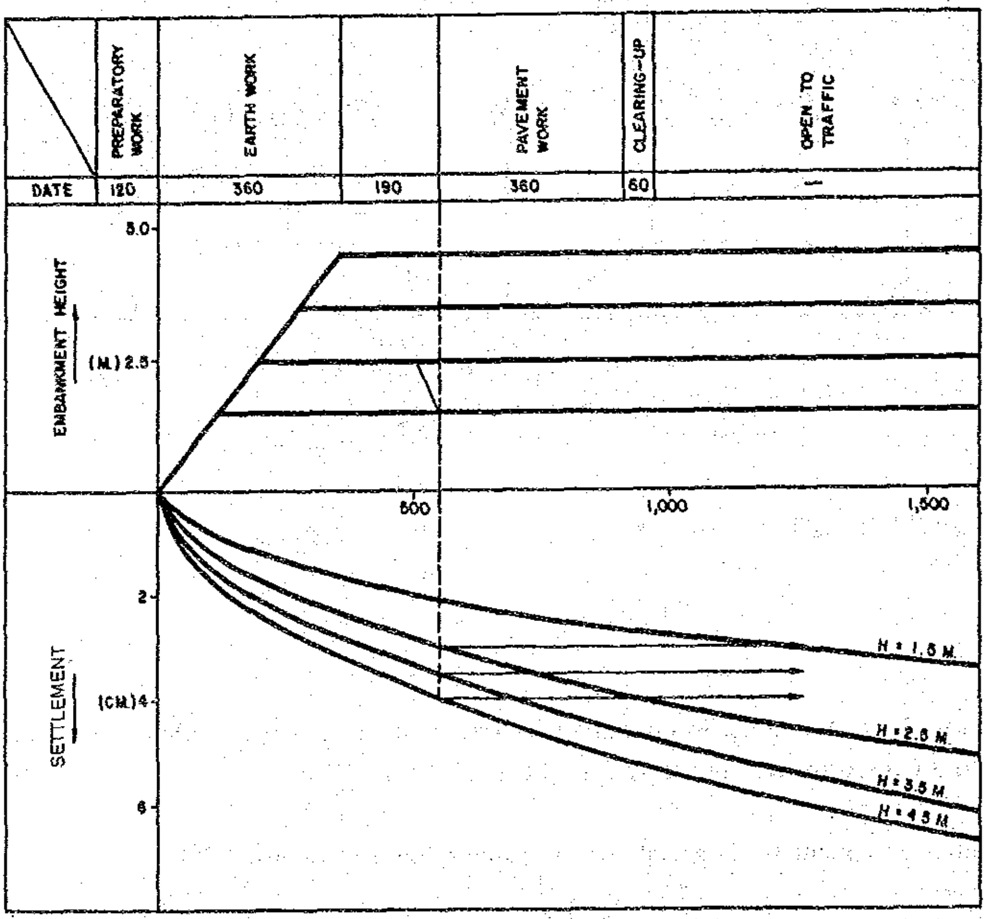


Figure 4.2.4 SETTLEMENT TIME CURVE

As seen in Figure 4.2.4, speed of settlement is very slow owing to its very thick consolidation layer and single drain condition. Assuming that the construction period is three years and the work schedule is as shown in Figure 4.2.4, residual settlement at the time of commencing pavement work is estimated as follows:

RESIDUAL SETTLEMENT AT CENTER OF EMBANKMENT

Embankment Height (m)	Settlement (cm)			
	Total	At Start Point of Pavement	Residual	Degree of Consolidation (%)
1.5	95	20	75	21
2.5	156	30	126	19
3.5	206	36	170	17
4.5	248	40	208	16

As described above, a tolerable residual settlement for maintaining a good pavement conditions is generally said to be about 10.0 cm. However, the estimated residual settlement reaches 75 cm, even in the case of a 1.5-m high embankment as shown in the above table. Some countermeasures are required.

There are many measures to promote or prevent consolidation settlement such as sand mats, the surcharge method, drain piles, sand compaction piles and lime or cement stabilization piles.

Among them, sand mats are applied to most cases of road embankments on soft ground as an essential measure to promote settlement.

Drain piles (sand piles, paper drains, etc.) and compaction piles used to be widely applied to reduce residual settlement in Japan, especially for expressway construction on soft ground. However, this is not the case recently, because they began to be thought of as an uneffective and unprofitable measure compared to their expensive cost, as a result of post-inspection.

The surcharge method is still applied to many cases in Japan. Its adaptability was therefore examined. The proposed embankment is 1.5 m for most sections. If the following thick surcharge fills are applied to this 1.5-m high embankment and removed just before the start of paving, the effect of the surcharge is estimated from Figure 4.2.4 as follows:

EFFECT OF SURCHARGE FILL ON 1.5 M HIGH EMBANKMENT

Surcharge Height (m)	Height of Surcharge + Proposed Emb. (m)	Settlement (cm)			Effect (m)
		Final for Proposed Emb.	At Start of Paving	Residual	
0	1.5	95	20	25	—
1.0	2.5	95	30	65	10
2.0	3.5	95	36	59	16
3.0	4.5	95	40	45	30

As seen in the above table, a 1.0-m thick surcharge can reduce the residual settlement only by 30 cm against 75 cm of that in the case of no surcharge. Even in the case of a 3.0-m thick surcharge, it is only 30 cm. This is because of the very thick consolidation layer and single drain condition.

Only consolidation settlement caused by embankment load has been discussed thus far. However, a considerable amount of settlement caused by secondary consolidation and pumping up of ground water is also expected. These cannot be dealt with only by countermeasures applied to road construction.

Appropriate measures against settlement could not be found in this study. The same problems which existing Rt. 34 has encountered, i.e., repeated raising of the embankment and repeated pavement rehabilitation after opening, may not be averted in ML-9.

In order to make the number of times of such work as few as possible, the following countermeasures were applied, although they are far from being perfect:

- To apply sand mats as a measure to promote settlement. Other methods are not recommendable, since they are thought to be uneconomical.

- To apply 50.0-cm high extra fill for sections with the embankment of lower than 2.0 m in proposed height to reduce the number of times of raising work expected after opening. Although the extra fill is desirable for other high embankment sections, it was not applied in this case, because a counter fill is required to prevent sliding failures.

- To apply AC pavements. It was described above that AC pavements are more appropriate than PCC pavements for roads on soft ground. In Japan, there is an example in which a highway was opened with AC pavement which was constructed up to a binder course, and then a wearing course was constructed after settlement had become stable.

- To apply bearing units for bridge approaches to prevent faulting.

In the estimation of work quantities, volumes of the sand mats and the extra fill, as well as an extra embankment caused by settlement which will occur during embankment work, were considered.

4.2.4 Pavement Design

Two types of pavement design for improvement, new construction and for rehabilitation were carried out.

Pavements for new construction were designed and classified into two types: a high class pavement and a low class pavement. High class pavements are asphalt concrete pavement (AC pavement) and portland cement concrete pavement (PCC pavement), and a low class pavement is double bituminous surface treatment (DBST).

A high class pavement was applied to projects with more than 1,000 in ADT in the 7th year after opening, and a low class pavement to other projects following the recent pavement policy of DOH. Their application was as follows:

- High class pavements: All ML and IM Projects except for IM-2
- DBST : IM-2

For projects to which high class pavements were applied, both AC pavement and PCC pavement were designed. After a simple comparison between the two types of pavement from the technical and economic viewpoints, the pavement type to be applied was decided.

Design for rehabilitation was carried out for following two kinds of overlay:

Initial overlay: Existing lanes of all ML Projects, IM-23 and all RH Projects

Overlay for maintenance: All projects of AC pavements at the 10th year after opening

The initial overlay was designed by PCC for projects with heavy traffic (ML-1 and IM-23), and by asphalt concrete for remaining projects.

1) Pavement Design for New Construction

a) Design Methods

DOH has not yet established its own authorized design method. Therefore in this study pavements were designed by applying the following three methods, and then their results were reviewed to determine the appropriate one to be applied in this study:

- AASHTO Design Guide for Pavement Structures 1986 (AASHTO Method)

- A Guide to Structural Design of Pavements for New Roads: Road Research Laboratory (Road Note 29 Method)

- Manual of AC Pavements and Manual of PCC Pavements: Japan Road Association (JRA Method)

Descriptions of the above design methods are shown in Appendices 4.2.6, 4.2.7 and 4.2.8, respectively.

b) Cumulative Number of ESA

The cumulative number of ESA used for the pavement design by the AASHTO Method and the Road Note 29 Method was calculated based on ESA conversion factors and traffic volumes of heavy vehicles in one direction for the subject projects.

The ESA conversion factors applied are shown below, which were obtained in the Master Plan Study.

ESA CONVERSION FACTORS

MT	HT	HB
0.63	1.58	0.60

The traffic volumes of heavy vehicles in one direction were derived from the results of the traffic forecast described in section 3.4.6.

Cumulative numbers of ESA calculated for each project are shown in Appendix 4.2.9.

c) Design Period

According to DOH design standards, pavements are designed based on the cumulative number of ESA predicted during the first seven years after construction. This means that the design period is seven years.

The design period of DOH, however, is thought too short. In the AASHTO Method, the design period is expressed in terms of performance period. This refers to the period of time that an initial pavement structure lasts before it needs rehabilitation. The minimum performance period recommended in this Method is at least 10 years. In the Road Note 29 Method, it is suggested that a flexible pavement should normally be designed for a life of 20 years and a rigid pavement for a life of 40 years.

Considering these recommendations, the following design periods were applied to pavement designs for new construction:

- AC pavement : 10 years
- PCC pavement : 20 years

d) Results of Design

Required thicknesses of pavement structures were determined by giving two design factors: traffic volumes and bearing capacities of subgrades, by the design charts or the design tables shown in Appendices 4.2.6 to 4.2.8.

The traffic volumes for the applied design methods are expressed in following terms:

- ASSHTO Method and Road Note 29 Method: Cumulative numbers of ESA for design periods (10 years for AC pavement and 20 years for PCC pavement) These were derived from Appendix 4.2.9.

- JRA Method: Traffic classifications (L,A,B,C and D) determined based on daily traffic volumes of heavy vehicles at the 5th year after new pavement. These were also derived from Appendix 4.2.9.

The bearing capacities of subgrades are expressed in terms of Mn in the AASHTO Method and design CBR in the Road Note 29 Method and the JRA Method. However, Mn can be estimated from the design CBR as described in Appendix 4.2.6.

The design CBRs were determined based on the results of CBR tests for each project by the following equation:

$$\text{Design CBR} = \text{Average CBR} - \frac{\text{Max. CBR} - \text{Min. CBR}}{C}$$

where,

C: Factors shown below

FACTORS TO DETERMINE DESIGN CBR

Number of Tested CBRs	2	3	4	5	6	7	8	9	Over 10
C	1.41	1.91	2.24	2.48	2.67	2.83	2.96	3.08	3.18

Variables calculated for pavement design, design CBRs, cumulative number of ESA and traffic classifications are shown in Table 4.2.5.

Table 4.2.5 DESIGN VARIABLES

Project No.	Design CBR of Subgrade	Cumulative No. of ESA W18 × 10³ 10 years	20 years	Traffic Loading Class of JRA
Phase I Projects				
ML-1	8.0	60,233	145,978	D
ML-2	11.4	1,709	4,326	B
ML-4-1	8.7	7,785	18,643	C
ML-4-2	8.7	2,194	5,402	B
ML-5N	8.0	20,418	51,660	D
ML-5W	8.0	14,500	36,936	D
ML-5S	8.0	5,916	14,722	C
ML-7	7.0	5,226	13,155	C
Phase II Projects				
ML-3	5.71	4,910	12,168	C
M1-9-1	4.23	17,668	45,399	D
ML-9-2	4.23	14,579	37,271	D
ML-9-3	4.23	20,659	51,901	D
IM-1	5.43	528	1,307	A
IM-2	13.95	151	360	L
IM-11	5.34	1,317	3,713	B
IM-12	4.13	532	1,470	A
IM-13	5.92	631	1,578	A
IM-14	2.14	1,756	4,330	B
IM-15	4.59	4,372	11,048	B
IM-16	4.22	280	740	L
IM-17	4.58	809	2,139	A
IM-22	4.64	217	577	L

Based on these design variables, the thicknesses of pavements structures for AC and PCC pavement were determined by the three design methods design applied. The results are shown in Table 4.2.6.

Table 4.2.6 RESULTS OF PAVEMENT DESIGN

Project No.	Thickness of Pavement Structure (cm)					
	PCC PCC+SBC	ACC AC+ACC+SBC	PCC PCC+SBC	ACC AC+BC+SBC	PCC PCC+SBC	ACC AC+BC+SBC
Phase I Projects						
ML-1	30 + 15	10+25+30	30 + 15	10+(22)+20	30 + 15	15+(13)+15+15
ML-2	15 + 15	5+20+15	20 + 15	6+(9)+15	25 + 15	5+(8+10)+25
ML-4-1	23 + 15	10+20+15	23 + 15	9+(12)+15	30 + 15	10+(10)+15+15
ML-4-2	18 + 15	5+20+20	20 + 15	7+(9)+15	25 + 20	5+(10)+25
ML-5N	28 + 15	10+20+20	28 + 15	10+(14)+18	30 + 15	15+(13)+15+15
ML-5W	25 + 15	10+20+15	25 + 15	10+(13)+18	30 + 15	15+(13)+15+15
ML-5S	23 + 15	7.5+20+15	23 + 15	9+(11)+15	30 + 15	10+(10)+15+15
ML-7	23 + 15	10+20+15	23 + 15	8+(11)+15	30 + 15	10+(10)+15+20
IM-23	-	-	-	-	-	-
Phase II Projects						
ML-3	23 + 15	10+20+20	23 + 15	10+(10)+30	28 + 15	10+(12)+20+25
ML-9-1	28 + 15	10+28+30	26 + 15	10+(13)+30	30 + 15	15+(18)+20+20
ML-9-2	25 + 15	10+25+30	25 + 15	10+(12)+30	30 + 15	15+(18)+20+20
ML-9-3	28 + 15	13+25+30	26 + 15	10+(14)+30	30 + 15	15+(18)+20+20
IM-1	-	5+20+20	-	5+10+15	-	5+20+25
IM-2	-	2.5+15+15	-	5+10+10	-	5+10+10
IM-11	-	7.5+20+20	-	7.5+10+25	-	5+(10)+15+25
IM-12	-	10+20+15	-	5+10+30	-	5+20+30
IM-13	-	10+20+15	-	5+10+30	-	5+20+30
IM-14	-	10+20+30	-	5+10+35	-	5+(10)+20+25
IM-15	23 + 15	10+20+20	23 + 15	7.5+(10)+30	25 + 15	5+(10)+15+25
IM-16	-	5+20+15	-	5+10+25)	-	5+15+15)
IM-17	-	7.5+20+15	-	5+10+25)	-	5+20+25)
IM-22	-	5+20+15	-	5+10+25)	-	5+15+15)

Note: ( ) Bituminous Stabilization Base Course
) DBST

Structural compositions for designed AC and PC pavements were drawn based on the above results. They are illustrated in Appendix 4.2.10.

The three design methods applied result in some differences in required thickness and structural compositions.

For AC pavement, the AASHTO Method and the Road 29 Method require almost the same thick asphalt concrete surface and the JICA Method a relatively thick one for highways with high traffic volumes. On the other hand, for highways with low traffic volumes, the Road Note 29 Method and the JRA Method require almost the same thick asphalt concrete surface, while the AASHTO Method requires a relatively thick one.

The Road Note 29 Method and the JRA method recommend applying a bituminous treated base course including rolled asphalt for AC pavement of highways with high traffic volumes. The AASHTO Method, however, gives no such recommendation and allows a crushed stone base course even in the case of highways with high traffic volumes.

For PCC pavement, the AASHTO Method and the Road Note 29 Method also require almost the same thick concrete slab and the JRA method a relatively thick slab. In the JRA Method, it is recommended to place an asphalt concrete intermediate course between a crushed stone base and concrete slabs for highways with high traffic volumes to improve durability and watertightness of the base. Other methods, however, have no specifications for this matter.

These design methods were not established only on theoretical grounds. They were mainly developed empirically by reflecting the actual conditions of the soil, meteorology and construction practices of the countries and regions concerned. It is therefore very difficult to select an appropriate method for Thailand by desk work comparison alone.

The AASHTO Method however was provisionally selected as the appropriate method from the following reasons:

- The AASHTO Method is the newest design method and is established based on an analysis of the results of the AASHTO Road Test carried out on a tremendous scale.

- The AASHTO Method and the Road Note 29 Method require almost the same thickness for the surface course of AC pavement and for the concrete slabs of PCC pavement in most cases.

Although application of the AASHTO Method has been decided on, the structual composition of the PCC pavement designed by this method was modified by adding an asphalt concrete intermediate course as shown in Appendix 4.2.10, because the asphalt concrete intermediate course was judged to be very effective in extending the life of PCC pavement from the experience of the Study Team.

As described above, for AC pavement, a bituminous treated base course is recommended in the Road Note 29 Method and the JRA method. However, it was not adopted because data which prove its effectiveness could not be found.

In recent PCC pavements of DOH, an intermediate sand layer between a subbase course and concrete slabs is adopted. Such a design, which provides an uncompactable layer with a low bearing capacity, is doubtful in prolonging the life of the pavement.

e) Selection of Applied Pavement Types

A comparative study of construction costs was carried out for AC and PCC pavement designed by the AASHTO Method.

Conditions for the comparison were as follows:

- Design life was 10 years for AC pavement and 20 years for PCC pavement.
- For AC pavement, a 5.0-cm thick overlay was planned at the 10th year after opening.
- Applied construction costs were quoted from Chapter 5.
- The overlay cost was converted to the present cost at an annual interest of 12%.

The results are shown below:

COMPARISON OF CONSTRUCTION COSTS

(Unit: Baht/m²)

Project No.	AC Pavement			PCC Pavement
	Initial	Overlay	Total	
Phase I Projects				
ML-1	315	77	392	577
ML-2	196	37	233	270
ML-4-1	297	54	351	483
ML-4-2	189	46	244	326
ML-5N	303	69	372	404
ML-5W	296	65	361	372
ML-5S	243	58	301	351
ML-7	327	62	389	497
Phase II Projects				
ML-3	309	52	361	481
ML-9-1	397	71	468	587
ML-9-2	382	71	453	536
ML-9-3	335	69	404	547
IM-15	348	53	401	513

According to this result, AC pavement is economic for all projects, even considering the overlay costs in AC pavement.

However, DOH insisted on applying PCC pavement to highways with high traffic volumes since there are many AC pavements which had deteriorated earlier than expected in Thailand.

Through a series of discussions with DOH, the pavement types to be applied to each project were determined as follows:

PCC pavement : ML-1, ML-5 and a section of ML-9 on solid ground

DBST : IM-2

AC pavement : All other projects

PCC pavements were generally applied to highways with high traffic volumes. However, AC pavements were applied to ML-7 and some sections of ML-9 despite their high traffic volumes. This is because they are located in soft ground areas.

The pavements applied to each project are shown in the Route Report.

f) Pavement Design for Rehabilitation

i) Initial Overlays

Overlays were designed for two types: overlays by asphalt concrete and by PCC. Overlays by PCC were adopted for ML-1 and ML-23, considering their high traffic volumes of heavy vehicles, and by asphalt concrete for the remaining projects.

The AASHTO Method (Appendix 4.2.6) was applied to overlay design. It is thought to be the most reasonable design method because overlays are designed based on the degree of deterioration of pavement which is expressed in terms of PSI.

As described in the Master Plan Study, the criterion for selecting sections to be overlaid is a PSI of 2.0. Sections to be overlaid can be easily selected by comparing this threshold value with PSIs measured.

However, PSIs measured at the present time must be decreased until years when overlay work will start. Overlays for existing lanes of ML Projects are scheduled to start in 1993, and for IM-23 and RH Projects in 1992. Therefore, the decrease in PSIs was estimated by the chart prepared in this study shown in Appendix 4.2.11.

The results are shown in Appendix 4.2.12. This disclosed that overlays are required for the whole section of all concerned projects at the scheduled year. In other words, PSI values of the whole section of these projects were estimated to reach 2.0 or less of PSI by the years scheduled to start initial overlays.

Variables for the design were determined in the same manner as the pavement design for new construction, adding assessment of existing pavements as follows:

- Design periods are 10 years for overlays by AC pavement and 20 years for overlays by PCC pavement.

- Cumulative numbers of ESA were derived from Appendix 4.2.9.

- Design CBRs were determined based on CBR tests of existing subgrades.

- Variables for assessing existing pavements were obtained by following the procedures described in Appendix 4.2.6.

The required thicknesses of overlays are shown in Table 4.2.9.

In Japan and the USA, it is customary to plan an asphalt concrete overlay of about 5.0 cm in thickness, even if a thicker overlay is called for by design computation. Following this practice, as for overlay by asphalt concrete, a 5.0-cm thick overlay was actually applied disregarding the above calculated thickness in this study.

On the other hand, for overlays by PCC, overlay of the calculated thickness was applied as is.

In the case of overlay by PCC over existing AC pavements in ML-1 and IM-23, a 3.5-cm thick asphalt concrete layer was applied as a levelling course.

Table 4.2.9 REQUIRED THICKNESS OF OVERLAY

Project No.	Type of Overlay	Design CBR	Cumulative No. of ESA W18 × 10	Required D or SN	FRL × Dxeff or SNexff	Overlay Dol or SNol	Overlay Thickness (cm)
Phase I Projects							
ML-1	PCC	28.2	145,978	D = 30cm	—	D = 30cm	30
ML-2	AC	10.5	1,709	2.30	1.05	1.25	7.0
ML-4	AC	9.6	7,785	3.20	1.41	1.79	10.0
ML-7	AC	6.0	5,226	3.25	1.41	1.84	10.0
IM-23	PCC	6.0	10,336	D = 23cm	—	D = 23cm	23
Phase II Projects							
ML-3-1	PM	6.3	5,710	3.60	1.43	2.17	12.2
ML-3-2	AC	6.3	5,710	3.60	2.13	1.47	8.3
RH-2	AC	6.0	1,218	2.60	1.39	1.21	6.8
RH-3	AC	5.8	2,532	2.90	1.39	1.51	8.5
RH-5	AC	8.7	5,271	3.30	2.13	1.17	6.6

Note: PM = Penetration macadam.

ii) Overlays in Maintenance Stage

AC pavements and initial asphalt concrete overlays were designed for 10 years as the design period. Overlays in the maintenance stage were therefore planned for AC pavements at the 10th year after construction.

The design of thickness of the overlay in the maintenance stage requires assessing pavement conditions after 10 years. However, this is practically impossible. For this reason and the practice in Japan and the USA described above, the overlay in the maintenance stage was applied as a uniform 5.0 cm in thickness.

4.2.5 Drainage Design

The drainage design, i.e., the location, type and size of required drainage facilities, was determined based on the design discharge calculated by the appropriate formulae, corresponding to the extent of the catchment area and an examination of existing drainage facilities checked in the inventory survey.

1) Pipe Culverts

Pipe culverts ranging from 80 cm to 150 cm in diameter were applied because of easy maintenance and availability. Standard drawings of pipe culverts are shown in Appendix 4.2.13.

Pipe culverts were installed at the selected sag points based on the results of topographic surveys and as-built plans of the existing roads prepared by DOH.

Extension of existing pipe culverts was planned when they are more than 80 cm in diameter and in good condition. Those less than 80 cm in diameter and in poor condition were planned to be replaced with pipes of more than 80 cm in diameter.

2) Box Culverts

Reinforced concrete box culverts (2.4 m × 2.4 m) with head walls and aprons were adopted as the standard type. In the case that a bigger flow capacity was required, a double cell culvert of this standard size was used. Standard drawings of box culverts are shown in Appendix 4.2.13.

3) Discharge Computation

a) Rainfall Intensity

Rainfall intensity was determined based on the rainfall intensity duration curve for a frequency of 10, 20, 50 or 100 years. Rainfall intensity-duration curves from the four observatory stations in the Region were applied to the projects as follows:

APPLICATION OF RAINFALL INTENSITY-DURATION CURVES

Observatory Station	Project No.
Lop Buri	IM-23, IM-2, IM-11 and IM-12
Chon Buri	ML-1, ML-2 and ML-5
Chanthaburi	ML-4 and ML-3
Bangkok	ML-7, IM-1, IM-13, IM-14, IM-15, IM-16 IM-17, IM-22 and ML-9

Note: Rainfall intensity-duration curves by station are shown in Appendix 4.2.14.

b) Rational Formula

The following rational formula was adopted to compute the design discharge where the catchment area was less than 50 km^2:

$$Q = 0.278 \cdot C \cdot I \cdot A$$

where,

Q: Design discharge (m^3/sec)

C: Run-off coefficient
I : Rainfall intensity (mm/hr)
A: Catchment area (km^2)

The coefficient of run-off was determined by the graph used by DOH as shown in Appendix 4.2.15, which corresponds to the rainfall intensity and the topographic features in the catchment area. The rainfall intensity was determined from the rainfall intensity-duration-frequency curve and the time of concentration computed by the following equation:

$$T_c = \left(\frac{0.87\, L^3}{H}\right)^{0.385}$$

where,

T_c : Time of concentration (hr)
L : Stream length (km)
H : Stream fall (m)

Catchment areas were measured on 1:50,000 topographic maps.

c) Snyder's Equation

Snyder's equation was used to compute the following design discharge where the catchment area was more than 25 km^2:

$$Q = 0.001 \cdot q_p \cdot (\alpha \cdot i - \pi) \cdot tr \cdot A$$

where,

Q : Design discharge (m^3/sec)
q_p: Peak discharge ($1/sec/km^2$)
α : Reduction of point rainfall intensity for large catchment areas
i : Rainfall intensity (mm/hr)
π : Infiltration capacity (mm/hr)
tr : Critical duration of rainfall (hr)
A : Catchment area (km^2)

In the above equation, the peak discharge (q_p) is expressed by the following formula:

$$q_p = \frac{k_p}{tr}$$

where,

k_p : peak discharge coefficient

The critical duration of rainfall (tr) is expressed by the following equation:

$$tr = \frac{1.5}{5.5} \times L^{0.6} \times L_1^{0.3}$$

where,

L : Length of stream from source to structure site (km)

L_1 : L_c/L; L_c is the length of stream from the nearest center of gravity of the catchment area to the structure site (km)

Snyder's equation is derived from the curves developed by the U.S. Weather Bureau and are taken from Ven Te Chow's "Handbook of Applied Hydrology". These are shown in Appendices 4.2.16 to 4.2.19.

Catchment basins pictured for IM-2 and ML-3 and their results of discharge computation were shown as examples in Appendices 4.2.20 and 4.2.21, respectively.

4.2.6 Bridge Design

The number and length of required bridges are shown in Table 4.2.8 by type. The list includes all bridges for grade separation of intersections, replacement for existing wooden or narrow concrete bridges as well as for bridges crossing over rivers and canals.

The type of bridge to be applied was determined based on the following idea:

Steel Box Girder = Curve bridges at intersections

Steel I Girder = Skew bridges with less than 60 degrees in intersection angle

PC Box Girder = Bridges with more than 30 m in span

PC I Girder = Bridge which ranges from 25 m to 30 m in span

PC Box Girder (in situ) = Extraordinarily long span bridge

Slab Bridge = Bridges with less than 25 m in span

Since a common type of substructure applied by DOH is a pile bent pier and an abutment with concrete piles, it was also employed in this study in general. In bridges at intersections, however, a wall type of pier was applied considering the landscape and damage by vehicles.

The length of concrete piles was determined to be 15m for bridges in ML-7, 10 m for those at intersections at the beginning point of ML-1 and 7 m for those in the other study routes based on an analysis of the boring results.

An average of 20-m long bearing units was designed for bridge approach sections in ML-7 and for the intersection at the beginning point of ML-1 where settlement of the soft ground is expected. The general views of the designed bridges and the bearing units are shown in the Route Report.

Phase I Projects

Project No.	Type	Number of Bridge	Length (m)
ML-1	PC I Girder	6	147
	PC Box Girder	4	140
	Steel I Girder	2	58
	Steel Box Girder	7	175
	Sub Total	19	450
ML-2	Slab Bridge	10	218
ML-4	Slab Bridge	35	754
	PC Box Girder	2	118
	Sub Total	37	872
ML-5	Slab Bridge	20	542
	PC I Girder	6	220
	Steel Box Girder	13	490
	Sub Total	39	1252
ML-7	Slab Bridge	28	825
	PC I Girder	5	1084
	Sub Total	33	1909
IM-23		-	-
Total		138	4701

Phase II Projects

ML-3	Slab	11	210
ML-9	Slab	12	1496
	PC Girder	4	788
	PC Box	10	504
	PC Box (in situ)	2	520
	Sub Total	88	3308
IM-1	Slab	3	37
IM-2	Slab	-	-
IM-11	Slab	1	27

Phase II Projects

Project No.	Type	Number of Bridge	Length (m)
IM-12	Steel I Girder	1	17
	Slab	1	70
	Sub Total	2	87
IM-13		-	-
IM-14	Slab	3	140
IM-15	Slab	6	72
IM-16	Slab	9	377
IM-17	Slab	3	65
IM-22	Slab	6	225
Total		134	4548
Grand Total		272	9249

4.2.7 Intersection Design

(1) Analysis Approach

An assessment of traffic capacity against future traffic volumes at major intersections related to the study routes was carried out. The major intersections taken up in the study were 17 as listed in the following table and also shown in Figure 4.2.5.

STUDY INTERSECTIONS

Phase I Projects

Seq. No.	Project Name	Studied Intersection	
		Location	Existing Control
IS-1	ML-1 (Rt.3, Chon Buri Bypass)	Beginning point	Signalized
IS-2	ML-1 (Rt.3, Chon Buri Bypass)	Intersection with Rt.315	Signalized
IS-3	ML-1 (Rt.3, Chon Buri Bypass)	Intersection with Rt.344	Signalized
IS-4	ML-4 (Rt.3, Klaeng-Chantha Buri)	Klaeng (Intersection with Rt.344)	Unsignalized
IS-5	ML-4 (Rt.3, Klaeng-Chantha Buri)	Chantha Buri (Intersection with Rt.316)	Unsignalized
IS-6	ML-5 (Chon Buri-Pattaya New Highway)	Beginning point	(New Plan)
IS-7	ML-5 (Chon Buri-Pattaya New Highway)	Diversion point of Access Road to Laem Chabang	(New Plan)
IS-8	ML-5 (Chon Buri-Pattaya New Highway)	Laem Chabang (Intersection with Rt.3)	(New Plan)
IS-9	ML-7 (Rt.304, Min Buri - Chachoengsao)	Min Buri (Beginning point)	Unsignalized
IS-10	ML-7 (Rt.304, Min Buri - Chachoengsao)	Chachoengsao (Intersection with Rt.314)	Unsignalized

Phase II Projects

Seq. No.	Project Name	Studied Intersection	
		Location	Existing Control
IS-11	ML-3 (Rt.3, Sattahip - Rayong)	Beginning point	Unsignalized
IS-12	ML-9 (Bangkok - Chon Buri New Highway)	Beginning point (Intersection with Rt.3344)	(New Plan)
IS-13	--- do ---	Intersection with Bangkok Outer Ring Road	(New Plan)
IS-14	--- do ---	Intersection with Rt.3119	(New Plan)
IS-15	--- do ---	Intersection Rt.314	(New Plan)
IS-16	--- do ---	Intersection Rt. 315	(New Plan)
IS-17	--- do ---	Intersection Rt. 344	(New Plan)

Intersection conditions and traffic movements of the study intersections are shown in Appendix 4.2.22.

The survey of turning movements of vehicles at each intersection was conducted in the field, and future turning movements were forecasted for the design target year of 2000. (Descriptions of the traffic survey and forecast are given in Chapter 3).

The usual practice of a phased approach for the improvement of intersections is given in the Master Plan Study Report (see Chapter 10). The intersection improvement study was proceeded with the analysis flow shown in Figure 4.2.6.

Topographic maps for some of the proposed intersection sites were prepared for the preliminary improvement design. For the existing intersections to be improved, major physical features such as geometry, number and use of lanes, channelization and traffic control were observed through the field investigations.

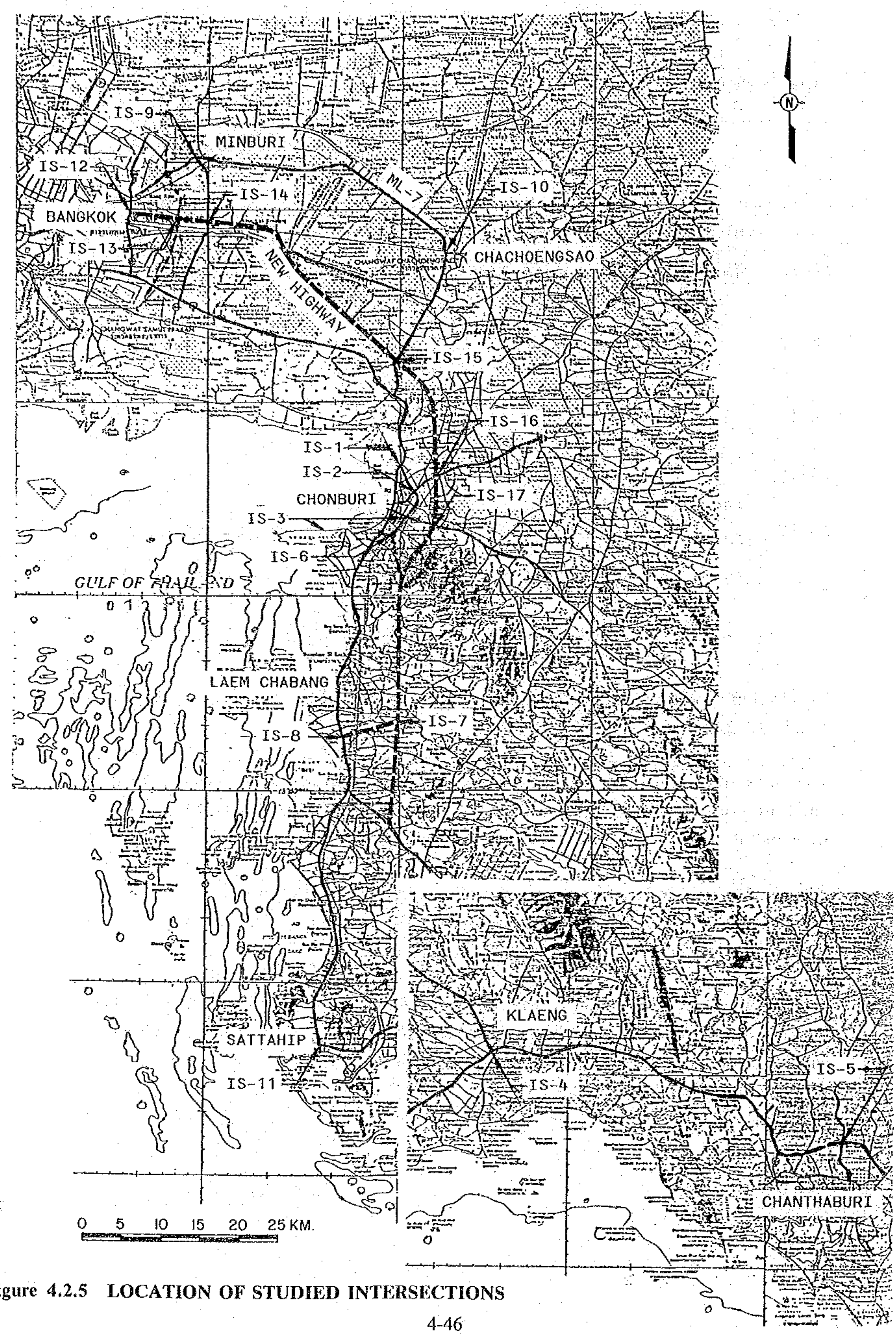


Figure 4.2.5 LOCATION OF STUDIED INTERSECTIONS

(2) Turning Movements

Surveys of turning movements of vehicles were carried out at the existing intersections by dividing vehicles into seven types as described in Chapter 3. In the capacity analysis of each intersection, these various types of vehicles were categorized into three groups taking the respective vehicle characteristics into account as follows:

1.	Motorcycle	MC (Motorcycle)
2.	Passenger Cars	PC (Passenger Car)
		LB (Light Bus)
		LT (Light Truck)
3.	Trucks	HB (Heavy Bus)
		MT (Medium Truck)
		HT (Heavy Truck)

Conversion factors for motorcycles and trucks into passenger car equivalents were employed at 0.5 for motorcycles and 1.5 for trucks.

By introducing the peak hour factor (PHF), all traffic volumes were converted into flow rates for the peak 15-min interval on the basis of the results of the traffic surveys.

(3) Unsignalized Intersections

1) Methodology

The procedure employed for the capacity analysis of unsignalized intersections follows the same methodology as given in the Master Plan Study Report. It is based on the use of gaps in the major road traffic stream by vehicles crossing or turning into the stream. The gaps in the major road traffic flow are used by a number of competing flows. The priority order for the utilization of gaps by vehicles is in the following order:

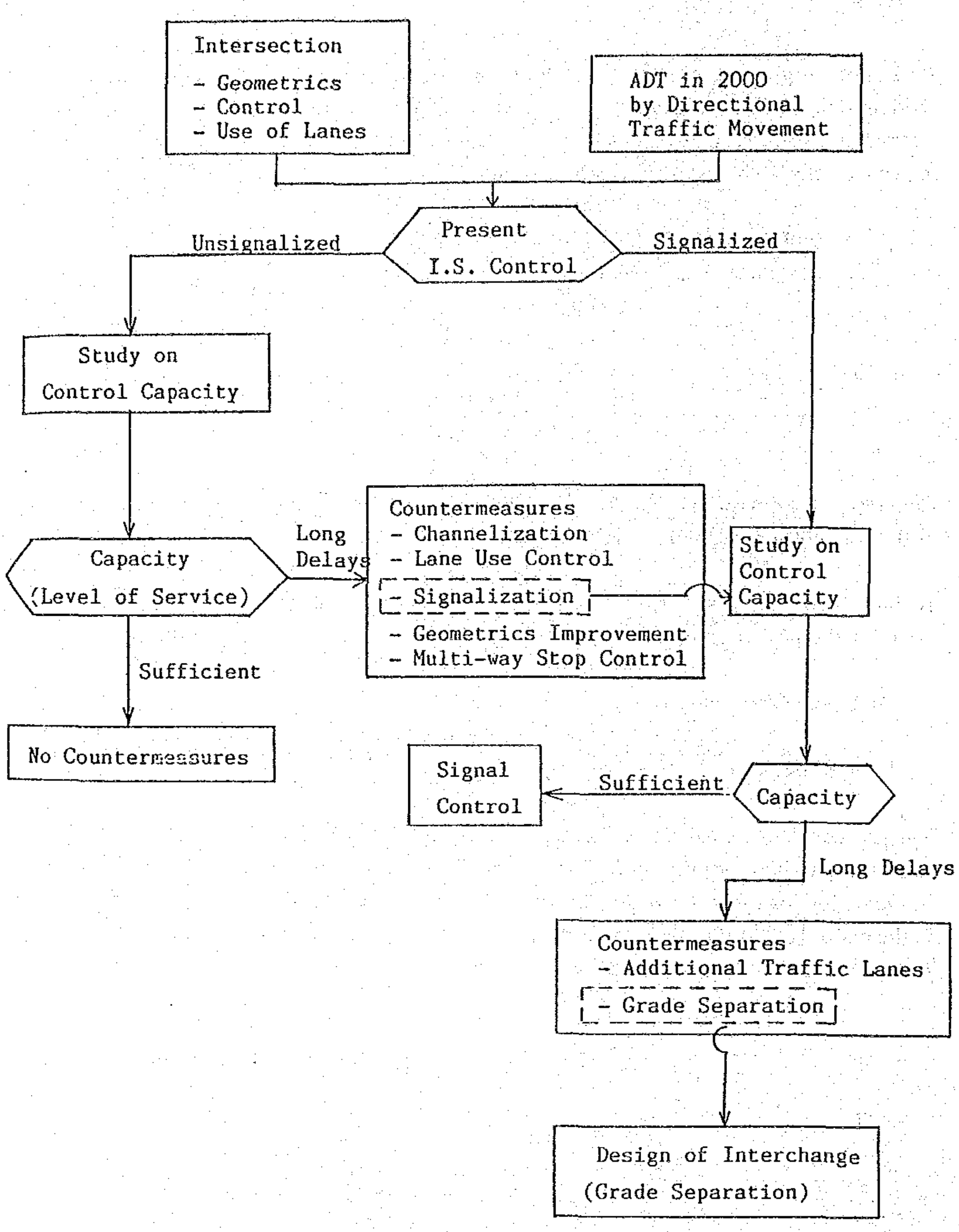
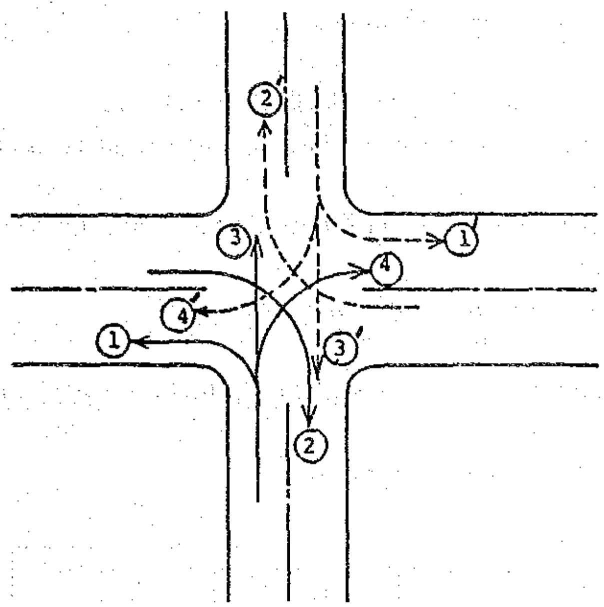


Figure 4.2.6 **FLOW OF INTERSECTION ANALYSIS**

(1) Left turns from the minor road
(2) Right turns from the major road
(3) Through movements from the minor road
(4) Right turns from the minor road



The critical gap size for each vehicle maneuver with respect to the major highway running speeds was directly introduced from the HCM as follows:

CRITICAL GAP SIZE

Vehicle Maneuver	Average Running Speed (major roads)	
	50 km/h	90 km/h
(1) Left Turn from Minor Road*	5.5 sec	6.5 sec
(2) Right Turn from Major Road	5.5	6.0
(3) Through from Minor Road*	6.5	8.0
(4) Right Turn from Minor Road*	7.0	8.5

Note: * Gap sizes are for Stop Control for minor road

The gap sizes given in the above table are different from those used in the Master Plan Study, in that the major roads were supposed to be two lane irrespective of primary/secondary or provincial highways. As all intersections taken up for the Feasibility Study are located on major four-lane roads, the gap sizes given in the above table were used by referring to the HCM.

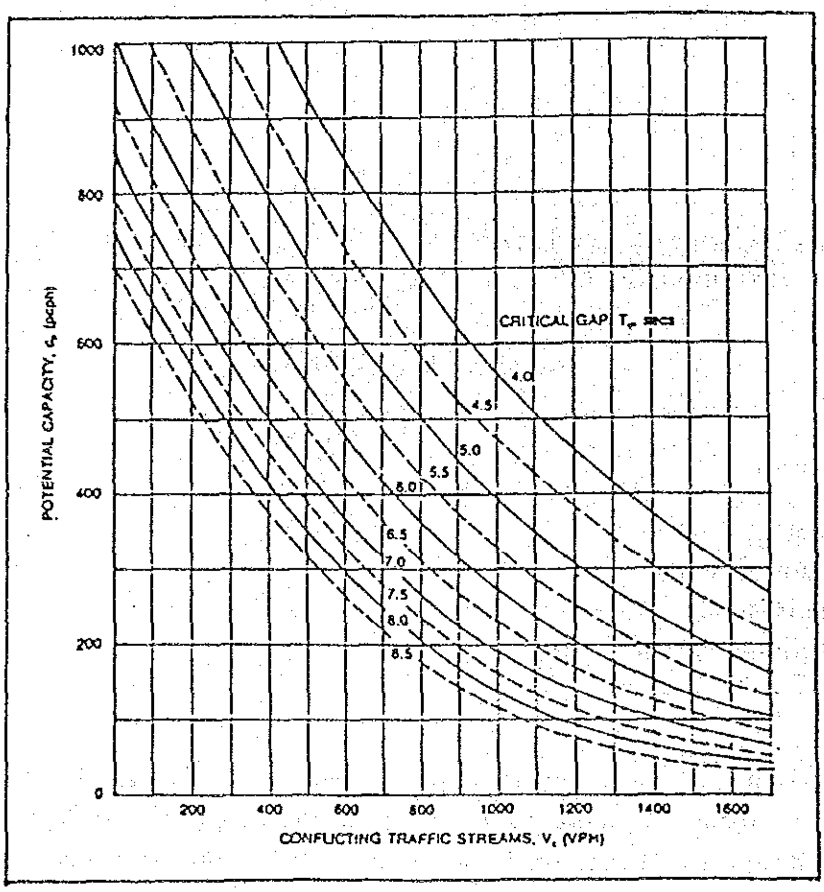
The average running speed on major roads in the proximity of the proposed existing intersections was set at 50 km/h, observed at the sites. For the Bangkok–Chon Buri New Highway (ML-9), it was set at 90 km/h due to its desirable horizontal and vertical alignments.

The potential capacity of a movement is defined as the "ideal" capacity for a specific subject movement, assuming the following conditions:

1. Traffic on the major roadway does not block the minor road.
2. Traffic from nearby intersections does not back up into the intersection under consideration.
3. A separate lane is provided for the exclusive use of each minor street movement under consideration.
4. No other movements impede the subject movement.

The potential capacity in passenger cars per hour is selected from the following figure (HCM):

Potential Capacity



A solution for the capacity of each lane on the minor approaches to a Stop- or Yield-controlled intersection is given in the level-of-service criteria. It is related to general delay ranges. The criteria are given below:

LEVEL OF SERVICE CRITERIA FOR UNSIGNALIZED INTERSECTIONS (HCM)

Reserve Capacity (pcph)	Level of Service	Expected Delay to Minor Road Traffic
>400	A	Little or no delay
300–399	B	Short traffic delays
200–299	C	Average traffic delays
100–199	D	Long traffic delays
0– 99	E	Very long traffic delays
Less than 0	F	Serve congestion

They are based on the reserve, or unused, capacity of the lane in question. This value is computed as:

$$CR = CSH - V$$

where,

CR : Reserve or unused capacity of lane in pcph
CSH : Shared-lane capacity of lane in pcph
V : Total volume or flow rate using lane in pcph

Intersections with low levels of service of D, E or F were considered to be subject to the studies of signalized intersections.

2) Analysis of Level of Service

Level-of-service analyses on the existing five unsignalized intersections (IS-4, IS-5, IS-9, IS-10 and IS-11), and nine newly proposed intersections, were carried out.

The level of service for all crossing or turning movements at each intersection was analysed.

3) Evaluation

In the analysis of level of service described above, possible improvement measures to the existing intersections such as channelization or addition of traffic lanes were taken into calculation procedures. However, the study results show that each intersection will have at least one low level of service movement at the target year of 2000. Therefore, it is required that all fourteen intersections be subject to the study of signalized intersections. The analytical results are given in Appendix 4.2.23.

(4) Signalized Intersections

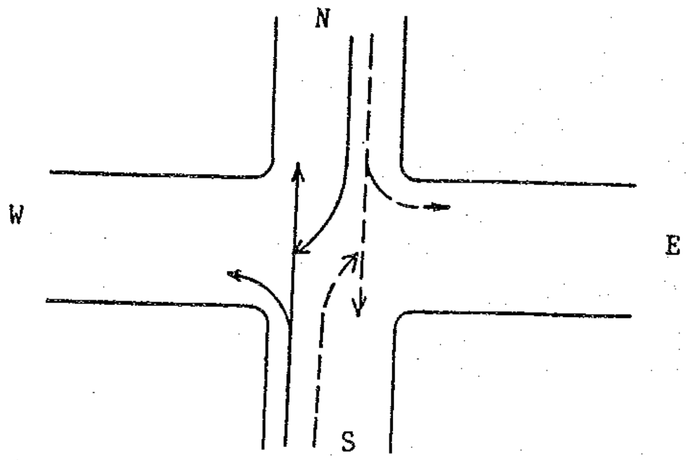
1) Methodology

To proceed with a preliminary assessment of the signalized intersections, a method shown in HCM was employed. The method provides a broad assessment of whether the intersection under consideration is likely to be oversaturated for a given set of demand volumes and geometrics.

The following information on intersection geometrics and turning or crossing movements are required to evaluate the probable capacity of signalized intersections:

Geometrics : Number and use of lanes
Volumes : Given in vph for each movement

As phased signal design is not exactly known in this stage, the critical lane volumes are identified by considering conflicting movements given in the following figure:



For a N-S road, critical conflicts are the S→E movement with the S-bound through movement and the N→W movement with the N-bound through movement.

The critical volume for a N-S road is the largest sum among S→E volume plus the maximum single-lane volume for the S-bound through, plus left-turn movement, or N→W volume plus the maximum single-lane volume for the N-bound through, plus left-turn movement. The critical volume for an E-W road is obtained in a similar way.

The total critical volume for the intersection is the sum of the critical volumes for the N-S and E-W roads.

The critical volume for the intersection is compared with the criteria to generally determine the probable traffic conditions at the intersection. The capacity criteria in HCM are given for normally occurring situations as follows:

CAPACITY CRITERIA FOR SIGNALIZED INTERSECTIONS (HCM)

Critical Volume for Intersection (vph)	Relationship to Probable Capacity
0 to 1,200	Under Capacity
1,201 to 1,400	Near Capacity
> 1,401	Over Capacity

The values given in the above table represent the range of normally occurring situations as follows:

- Cycle lengths from 30 to 120 seconds
- Heavy vehicle share up to 10 %
- Level terrain
- Standard lane width from 3 to 3.5 m

The results of the traffic survey for the study roads show that the heavy vehicle content ranges from 10 to 40%. Therefore, it is considered that the capacity criteria for the evaluation of the signalized intersections have to be set lower than those given in the above table, taking the present traffic conditions into consideration. The capacity criterion for Over Capacity was tentatively set at 1,200 vph in the study.

2) Capacity Analysis

Capacity analyses of the signalized intersections were carried out for all 17 intersections, and the analytical results are given in appendix 4.2.24. The following is a summary of the analyses:

Intersection	Critical Volumes (vph)	Capacity
IS - 1	1320	Over
IS - 2	1270	Over
IS - 3	1900	Over
IS - 4	720	
IS - 5	730	
IS - 6	1340	Over
IS - 7	800	
IS - 8	1710	Over
IS - 9	320	
IS - 10	420	
IS - 11	570	
IS - 12	2670	Over
IS - 13	2500	Over
IS - 14	1470	Over
IS - 15	1300	Over
IS - 16	1870	Over
IS - 17	2140	Over

3) Evaluation

The analytical results of the signalized intersections indicate that the critical volume for IS-4 (Klaeng), IS-5 (Chanthaburi), IS-7 (Chon Buri - Pattaya New Highway, Diversion Point), IS-9 (Min Buri), IS-10 (Chachoengsao) and IS-11 (Sattahip) is less than the capacity criterion of 1,200 vph. Accordingly these intersections will be sufficiently controlled by traffic signals.

The other intersections have critical volumes more than the capacity criterion. Accordingly, they are required to have grade-separation control.

IS-7 (Chon Buri - Pattaya New Highway, Division to Laem Chabang) has a critical volume of less than 1,200. However, grade-separation control was recommended because of the traffic increase due to the extension of the New Highway to Pattaya from Rt. 36.

(5) Summary of Analysis

The capacity analyses for intersections are summarized as follows:

Phase I Projects

Project Seq. No.	Location	Existing Control	IS Improvement Signalized	Grade Separation
IS-1	Chon Buri Bypass, Beginning point	Signalized		Grade Separation
IS-2	Chon Buri Bypass, Rt. 315	Signalized		Grade Separation
IS-3	Chon Buri Bypass, Rt. 344	Signalized		Grade Separation
IS-4	Klaeng	Unsignalized	Signalized	
IS-5	Chantha Buri	Unsignalized	Signalized*	
IS-6	Chon Buri-Pattaya New Hwy., Beginning point	(New Plan)		Grade Separation
IS-7	Chon Buri-Pattaya New Hwy., Laem Chabang	(New Plan)		Grade Separation
IS-8	Chon Buri-Pattaya New Hwy., Laem Chabang	(New Plan)		Grade Separation
IS-9	Min Buri	Unsignalized	Signalized	
IS-10	Chachoengsao	Unsignalized	Signalized*	

* Including channelization

Phase II Projects

Seq. No.	Location	Control	Signalized	Grade Separation
IS-11	Sattahip	Unsignalized	Signalized	
IS-12	Bangkok - Chon Buri New Hwy. Rt.3344	(New Plan)		Grade Separation
IS-13	Bangkok - Chon Buri New Hwy. Outer Ring Road	(New Plan)		Grade Separation
IS-14	Bangkok - Chon Buri New Hwy. Rt. 319	(New Plan)		Grade Separation
IS-15	Bangkok - Chon Buri New Hwy. Rt.314	(New Plan)		Grade Separation
IS-16	Bangkok - Chon Buri New Hwy. Rt.315	(New Plan)		Grade Separation
IS-17	Bangkok - Chon Buri New Hwy. Rt.344	(New Plan)		Grade Separation

(6) Intersection Design

Based on the capacity analyses for the proposed intersections, improvement designs for each subject intersection were carried out mainly on the basis of the design criteria stipulated in A Policy in Geometric Design of Highways and Streets 1984: AASHTO.

For designs of loop ramps, however, an exceptional design speed of 35 to 40 km/h was adapted, considering the limitation of right-of-ways.

A summary of the designed intersections is shown in Table 4.2.8 and the detailed drawings are given in the Route Report.

Figure 4.2.7 SUMMARY OF INTERSECTION DESIGN

Phase I Projects

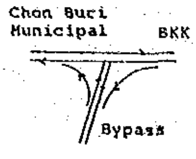
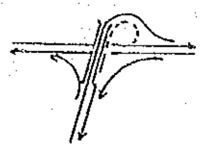
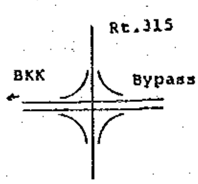
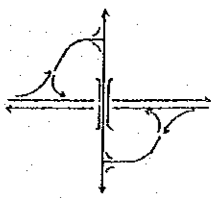
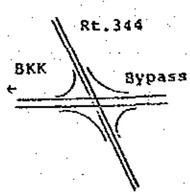
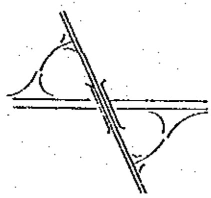
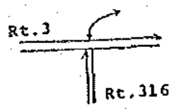
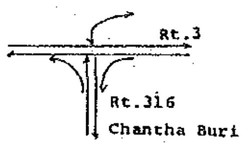
Seq. No.	Improvement Points	Existing Conditions	Improvement Plan
IS-1	- A Trumpet type intersection was planned. - An overpass bridge was designed for a traffic flow from Chon Buri Bypass to Bangkok. - For a traffic flow from Chon Buri to Chon Buri Bypass, an existing at-grade intersection shall be remained because of low traffic volume in this direction. However, the room for the ramp way construction is remained for the future increasing traffic volumes.		
IS-2	- A partial cloverleaf type was planned. - In order not to interrupt traffic flow on Chon Buri Bypass, Rt.315 was designed to cross over Chon Buri Bypass. For right-turn traffic from Chon Buri Bypass, a two-quadrant cloverleaf type ramp was planned.		
IS-3	The same type of intersection as IS-2 was planned.		
IS-5	- Only two channels were designed for left-turn traffic from Rt.3 and Rt.316.		

Figure 4.2.7 SUMMARY OF INTERSECTION DESIGN (Cont'd)

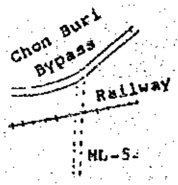
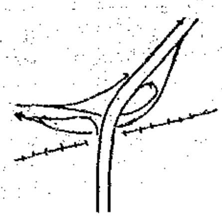
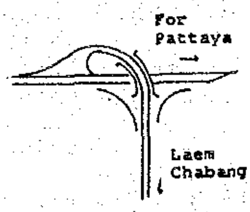
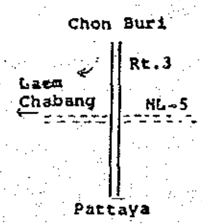
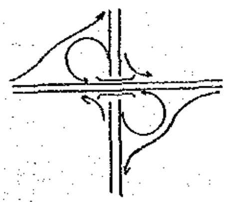
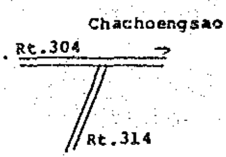
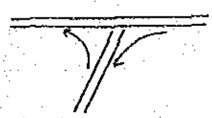
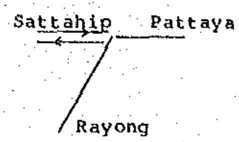
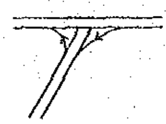
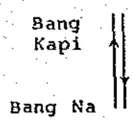
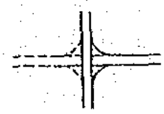
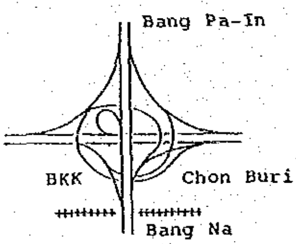
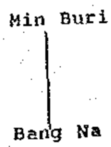
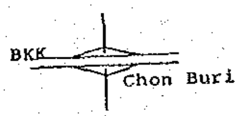
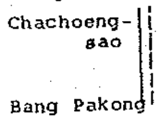
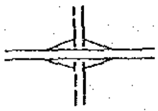
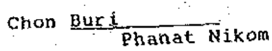
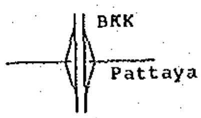
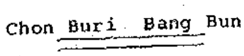
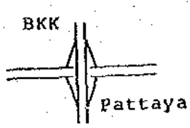
Seq. No.	Improvement Points	Existing Conditions	Improvement Plan
IS-6	- A modified Y-type intersection was planned. - For traffic flows in all directions, a grade separation crossing over Chon Buri Bypass and a railway closely located was designed. - In order to shorten the overpass bridge, the lane to Pattaya was shifted to the railway side.		
IS-7	- A trumpet type intersection was planned. - A overpass bridge was designed for a traffic flow to Laem Chabang.		
IS-8	- A partial cloverleaf type interchange was planned. - ML-5 was designed to cross over Rt.3 by a overpass bridge - For a traffic flow from Pattaya to ML-5 and a right-turn traffic from Chonburi to Laem Chabang, loop ramps were designed. - since forecasted traffic flows from ML-5 to Chon Buri and from Laem Chabang to Pattaya were low, they were planned to be treated by U-turn on Rt.3.		
IS-10	Only two channels were designed for left-turn traffic.		

Figure 4.2.7 SUMMARY OF INTERSECTION DESIGN (Cont'd)

Phase II Projects

<table>
<tr><th>Seq. No.</th><th>Improvement Points</th><th>Existing Conditions</th><th>Improvement Plan</th></tr>
<tr><td>IS-11</td><td>- Two channels were planned for left-turn traffics (Pattaya to Rayong, Rayong to Sattahip)</td><td></td><td></td></tr>
<tr><td>IS-12</td><td>- ETA Second Stage elevated expressway is planned to extend upto the IS-12 intersection in the near future. Therefore, this intersection is to be operated by at-grade signal control until ETA's Flyover is constructed.</td><td></td><td></td></tr>
<tr><td>IS-13</td><td>- Traffic volume of the New Highway and Bangkok Outer Ring Road are as high as 25,000 - 33,000 ADT. They are proposed to be high class road in that the design speed is 100 km/hr. As both highways are expected to open to traffic at the same time in 1984, Junction style interchange was planned in this intersection.</td><td>(New Plan)</td><td></td></tr>
<tr><td>IS-14</td><td>- Normal diamond - type interchange was designed within 80 meters wide right-of-way (New Highway : Overpass)</td><td></td><td></td></tr>
<tr><td>IS-15</td><td>--- do ---</td><td></td><td></td></tr>
<tr><td>IS-16</td><td>--- do ---</td><td></td><td></td></tr>
<tr><td>IS-17</td><td>--- do ---</td><td></td><td></td></tr>
</table>

CHAPTER 5

CONSTRUCTION AND MAINTENANCE COSTS

CHAPTER 5
CONSTRUCTION AND MAINTENANCE COSTS

5.1 CONSTRUCTION COSTS

5.1.1 Quantities

DOH has standard specifications and payment items for highway construction.

The major work items were established based on the standard specifications with some additions especially required in road improvement works. The work items were finalized as follows:

	Unit
EARTH WORK	
Clearing and Grubbing	ha
Roadway Excavation (Unclassified)	m^3
Roadway Excavation (Classified)	m^3
Embankment (Common)	m^3
Embankment (Borrow)	m^3
Sand Mat	m^3
Removal of Existing Structures	each
SUBBASE and BASE COURSES	
Subbase	m^3
Aggregate Base	m^3
Shoulder (Soil Aggregate)	m^3
SURFACE COURSES	
Asphaltic Prime Coat	m^2
Asphaltic Tack Coat	m^2
Double Bituminous Surface Treatment	m^2
Asphalt Concrete Surfacing	ton
Portland Cement Concrete Pavement	m^3

STRUCTURES (Equivalent)	
RC Pipe Culvert (D = 1.00 m)	m
RC Box Culvert (2-2.40 × 2.40 m)	m
RC Bridge (W = 11.00 m)	m
PC Bridge (W = 11.00 m)	m
Bearing Unit	m^2
LAND ACQUISITION (Average)	ha

The quantities by work item listed above were computed based on preliminary design drawings on the following scales:

Plan	:		1 : 15,000
Profile	:	Horizontal	1 : 15,000
		Vertical	1 : 1,000
Cross Section	:		1 : 200

The quantities by work item and land area to be acquired by study route are summarized in Table 5.1.1.

The quantity of asphalt concrete of the intermediate layer and of the shoulder requirement for PCC pavement was included in the item of asphalt concrete surfacing, and the double bituminous surface treatment was applied for shoulder pavement in built-up sections in the AC pavement routes.

Quantities for the initial overlay of the existing lanes were included in work items concerned, while quantities for a 5-cm thick overlay planned at the 10th year after construction in AC pavement were excluded. It was calculated separately as shown in Section 5.2.

Table 5.1.1 SUMMARY OF CONSTRUCTION QUANTITIES

Phase I Projects

Item	Unit	ML-1	ML-2	ML-4	ML-5	ML-7	IM-23
EARTH WORK							
Clearing and Grubbing	ha	69	68	179	417	98	52
Roadway Excavation (Unclassified)	m3	15,000	16,000	298,000	496,000	52,000	0
Roadway Excavation (Classified)	m3	1,000	0	0	0	41,000	3,200
Embankment (Common)	m3	12,000	10,000	209,000	392,000	36,000	0
Embankment (Borrow)	m3	284,000	742,000	1,255,000	1,529,000	1,260,000	120,500
Removal of Existing Structure	Each	0	5	6	0	0	0
SUBBASE and BASE COURSES							
Subbase	m3	23,650	40,750	100,700	108,000	68,000	12,900
Aggregate base	m3	0	48,600	121,400	0	80,100	15,050
Shoulder (Soil Aggregate)	m3	51,000	29,400	65,200	49,100	47,800	30,100
SURFACE COURSES							
Asphaltic Prime Coat	m2	166,200	218,600	556,600	698,400	350,600	53,800
Asphaltic Tack Coat	m2	95,250	190,500	780,100	0	573,000	161,250
Double Bituminous Surface Treatment	m2	0	25,500	113,900	0	6,600	0
Asphalt Concrete Surfacing	ton	32,750	47,500	155,800	85,100	107,100	32,800
Portland Cement Concrete Pavement	m3	67,200	0	0	163,500	0	41,900
STRUCTURES (Equivalent)							
RC Pipe Culvert (D=1.00 m)	m	778	2,060	3,476	1,808	2,249	367
RC Box Culvert (2-2.40x2.40 m)	m	30	30	14	250	14	0
RC Bridge (W=11.00 m)	m	0	218	754	542	825	0
PC Bridge (W=11.00 m)	m	520	0	118	710	1,084	0
Bearing Unit	m2	480	0	0	0	15,840	0
LAND ACQUISITION (Average)	ha	24	0	88	417	2	0

Phase II Projects

Table 5.1.1 SUMMARY OF CONSTRUCTION QUANTITIES (Cont'd)

Item	Unit	ML-3	ML-9	IM-1	IM-2	IM-11	IM-12	IM-13	IM-14
EARTH WORK									
Clearing & Grubbing	ha	169	660	14	26	34	54	22	44
Roadway Excavation (Unclassified)	m3	320,300	0	10,100	43,200	19,800	21,400	19,700	25,100
Roadway Excavation (Classified Unsuitable Material below Grade)	m3	0	280,300	0	0	0	0	0	0
Embankment (Common)	m3	0	0	0	187,000	0	0	0	0
Embankment (Borrow)	m3	690,000	4,585,200	69,300	0	213,700	553,200	139,500	251,300
Sand Mat	m3	0	1,108,500	0	0	0	0	0	0
Removal of Existing Structure (+Detour)	ea	0	0	3	0	0	1	0	1
BASE & SUB-BASE									
Sub-Base	m3	102,400	394,300	16,000	17,600	21,500	28,600	11,500	49,900
Aggregate Base Course	m3	146,100	278,700	25,000	48,300	62,700	78,000	27,100	36,600
Shoulder (Soil Aggregate)	m3	58,500	175,900	10,200	20,100	30,900	38,200	13,100	16,300
SURFACE									
Asphalt Prime Coat	m2	552,400	1,425,700	12,400	234,900	306,600	380,900	132,200	178,000
Asphalt Tack Coat	m2	789,600	848,100	0	0	0	128,600	114,300	152,400
Double Bituminous Surface Treatment	m2	356,000	545,900	0	197,700	0	0	79,100	0
Asphalt Concrete Surfacing	ton	147,400	277,600	12,000	100	46,700	77,600	27,000	36,000
Portland Cement Concrete Pavement	m3	2,100	65,500	0	0	0	0	0	0
STRUCTURE (Equivalent Cost)									
R/C Pipe (Dia a.00 m.)	m	880	1,632	75	110	250	260	20	180
R/C Box Culvert (2 - 2.40 x 2.40)	m	13	217	0	7	0	24	7	16
R/C Bridge (9.0 m. Width)	m	210	1,750	37	0	27	70	0	140
P/C Bridge (9.0 m. Width)	m	0	4,772	0	0	0	0	0	0
Bearing Unit	m2	0	30,800	0	0	0	0	0	0
LAND ACQUISITION									
Developed Land	ha	0	129	0	0	2	0	4	16
Less Developed Land	ha	40	530	2	0	0	7	0	0
INTERCHANGE/INTERSECTION									
Interchange/Intersection	nos	0	-	0	0	0	0	0	0

Table 5.1.1 SUMMARY OF CONSTRUCITON QUANTITIES (Cont'd)

Phase II Projects

Item	Unit	IM-15	IM-16	IM-17	IM-22	RH-2	RH-3	RH-5
EARTH WORK								
Clearing & Grubbing	ha	21	19	29	40	-	-	-
Roadway Excavation (Unclassified)	m3	7,100	8,000	2,100	3,500	36,700	14,000	-
Roadway Excavation (Classified Unsuitable Material below Grade)	m3	0	0	0	0	-	-	-
Embankment (Common)	m3	0	0	0	0	-	-	-
Embankment (Borrow)	m3	139,600	171,300	205,800	177,900	-	-	-
Sand Mat	m3	0	0	0	0	0	0	0
Removal of Existing Structure (+Detour)	ea	6	0	0	0	-	-	-
BASE & SUB-BASE								
Sub-Base	m3	27,900	27,100	24,000	16,600	17,500	6,600	-
Aggregate Base Course	m3	39,200	29,400	29,100	22,500	12,700	4,400	-
Shoulder (Soil Aggregate)	m3	19,600	13,300	14,000	10,200	3,100	2,700	8,000
SURFACE								
Asphalt Prime Coat	m2	191,100	143,100	142,100	109,500	59,300	17,900	-
Asphalt Tack Coat	m2	166,300	122,600	0	0	262,700	128,000	281,400
Double Bituminous Surface Treatment	m2	70,800	0	0	0	59,300	17,900	-
Asphalt Concrete Surfacing	ton	39,200	28,900	21,600	16,500	30,000	14,600	32,200
Portland Cement Concrete Pavement	m3	0	0	0	0	-	-	
STRUCTURE (Equivalent Cost)								
R/C Pipe (Dia a.00 m.)	m	100	840	10	280	-	-	-
R/C Box Culvert (2 - 2.40 x 2.40)	m	9	35	9	15	-	-	-
R/C Bridge (9.0 m. Width)	m	72	337	65	225	-	-	-
P/C Bridge (9.0 m. Width)	m	0	0	0	0	-	-	
Bearing Unit	m2	0	0	0	0	-	-	
LAND ACQUISITION								
Developed Land	ha	0	0	0	0	-	-	-
Less Developed Land	ha	0	0	0	23	-	-	-
INTERCHANGE/INTERSECTION								
Interchange/Intersection	nos	0	0	0	0	-	-	-

5.1.2 Unit Costs

5.1.2.1 Financial Unit Costs

The unit costs in 1988 were derived from both actual contract unit costs in similar construction projects in the Region and preliminary unit costs estimated by the Study Team.

Due consideration was paid to the hauling charge of construction materials from the sources to the construction sites.

Materials such as bitumen, cement and reinforcing steel bars were assumed to be transported to the project site from Bangkok.

Borrow pits for embankment materials, laterite sources for subbase and shoulders and rock quarries for base, asphalt concrete surface, cement concrete slab and structures were determined route by route through the site investigation and discussions with DOH (see the Route Report). The shortest routes for hauling these materials were examined on the basis of the existing road network connecting the study routes with the sources.

Hauling distances from these sources to the study routes are shown below:

Project No.	Length (km)	Distance from Bangkok (km)	Hauling Distance (km)		
			Embankment	Subbase	Crushed Rock
Phase I Projects					
ML-1	13.60	90	17.00	17.00	11.00
ML-2	27.27	150	27.00	28.00	21.00
ML-4	61.86	310	14.00	17.00	16.00
ML-5	50.33	120	10.00	14.00	17.00
ML-7	40.94	40	70.00	53.00	70.00
IM-23	26.87	120	27.00	35.00	35.00
Phase II Projects					
ML-3	44.6	180	10	15	17
ML-9.1	25.0	15	95	83	98
ML-9.2	22.0	40	80	67	62
ML-9.3	34.7	65	15	15	15
IM-1	18.7	53	31	53	62
IM-2	35.9	145	—	17	36
IM-11	40.7	140	23	58	63
IM-12	51.0	90	23	63	68
IM-13	17.8	55	29	52	57
IM-14	25.6	60	25	52	13
IM-15	24.7	25	25	18	88
IM-16	20.8	30	25	02	97
IM-17	28.7	40	44	51	64
IM-22	15.9	55	25	56	13
RH-2	39.5	235	—	35	62
RH-3	17.9	72	—	38	43
RH-5	39.3	124	—	40	38

As a result, the unit costs to be employed were modified and estimated on the basis of the above assumptions and considerations, and are summarized in Table 5.1.2.

Table 5.1.2 UNIT COSTS OF MAJOR WORK ITEMS

Phase I Projects (Unit: Baht)

Item	Unit	ML-1	ML-2	ML-4	ML-5	ML-7	IM-23
EARTH WORK							
Clearing and Grubbing	ha	10,000	10,000	10,000	10,000	15,000	10,000
Roadway Excavation (Unclassified)	m3	18	18	18	18	18	18
Roadway Excavation (Classified)	m3	38	38	38	38	38	38
Roadway Excavation (Unsuitable Material below Grade)	m3						
Embankment (Common)	m3	33	33	33	33	33	33
Embankment (Borrow)	m3	77	110	83	71	168	110
Removal of Existing Structure	each	60,000	60,000	60,000	60,000	60,000	60,000
SUBBASE and BASE COURSES							
Subbase	m3	141	163	141	133	203	168
Aggregate base	m3	257	278	269	272	349	308
Shoulder (Soil Aggregate)	m3	166	190	166	157	236	196
SURFACE COURSES							
Asphaltic Prime Coat	m2	11	11	11	11	11	11
Asphaltic Tack Coat	m2	5	5	5	5	5	5
Double Bituminous Surface Treatment	m2	31	32	32	32	33	32
Asphalt Concrete Surfacing	ton	890	896	901	902	921	907
Portland Cement Concrete Pavement	m3	1,574	1,589	1,635	1,609	1,657	1,630
STRUCTURES (Equivalent)							
RC Pipe Culvert (D=1.00 m)	m	1,800	1,800	1,800	1,800	1,800	1,800
RC Box Culvert (2-2.40x2.40 m)	m	9,000	9,000	9,000	9,000	10,000	10,000
RC Bridge (W=11.00 m)	m	64,000	63,000	63,000	63,000	66,000	63,000
PC Bridge (W=11.00 m)	m	91,000	86,000	86,000	86,000	96,000	90,000
Bearing Unit	m2	2,200	2,200	2,200	2,200	2,500	2,200
LAND ACQUISITION (Average)	ha	2,500,000	-	940,000	750,000	3,000,000	-
Sub-total (a)							
Miscellaneous Work (a) x 7%							

Table 5.1.2 UNIT COSTS OF MAJOR WORK ITEMS (Cont'd)

Phase II Projects

(Unit: Baht)

Item	Unit	ML-3	ML-9 (I)	ML-9 (II)	ML-9 (III)	IM-1	IM-2	IM-11	IM-12	IM-13
Earth Work										
Clearing & Grubbing	ha	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Roadway Excavation (Unclassified)	m3	18	18	18	18	18	18	18	18	18
Roadway Excavation (Classified Unsuitable Material below Grade)	m3	38	51	51	38	38	38	38	38	38
Embankment (Common)	m3	33	33	33	33	33	33	33	33	33
Embankment (Borrow)	m3	82	187	177	95	127	72	111	111	123
Sand Mat	m3	0	309	275	252	0	0	0	0	0
Removal of Existing Structure (+Detour)	Ea	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Base & Sub-Base										
Sub-Base	m3	145	229	221	145	194	140	215	218	209
Aggregate Base Course	m3	272	348	339	266	350	277	339	343	335
Shoulder (Soil Aggregate)	m3	170	265	256	170	225	165	249	252	243
Surface										
Asphalt Prime Coat	m2	11	11	11	11	11	12	12	11	11
Asphalt Tack Coat	m2	5	5	5	5	5	6	6	5	5
Double Bituminous Surface Treatment	m2	32	33	33	32	33	32	33	33	33
Asphalt Concrete Surfacing	ton	905	926	927	898	925	905	927	930	920
Portland Cement Concrete Pavement	m3	1,628	1,665	1,668	1,567	1,675	1,620	1,689	1,687	1,653
Structure (Equivalent Cost)										
R/C Pipe (01.00 m.)	m	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
R/C Box Culvert (2 - 2.40 x 2.40 m.)	m	9,000	13,000	13,000	13,000	10,000	9,000	10,000	10,000	10,000
R/C Bridge (11 m. Width)	m	63,000	66,000	69,000	69,000	66,000	63,000	66,000	66,000	66,000
P/C Bridge (11 m. Width)	m	86,000	105,000	105,000	105,000	96,000	86,000	96,000	96,000	96,000
Bearing Unit	m2	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Land Acquisition										
Developed Land	ha	1,250,000	2,000,000	1,250,000	1,500,000	50,000	20,000	200,000	200,000	200,000
Less Developed Land	ha	625,000	1,000,000	625,000	625,000	35,000	12,000		75,000	

Table 5.1.2 UNIT COSTS OF MAJOR WORK ITEMS (Cont'd)

Phase II Projects

(Unit: Baht)

Item	Unit	IM-14	IM-15	IM-16	IM-17	IM-22	RH-2	RH-3	RH-5
Earth Work									
Clearing & Grubbing	ha	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Roadway Excavation (Unclassified)	m3	18	18	18	18	18	18	18	18
Roadway Excavation (Classified Unsuitable Material below Grade)	m3	51	51	51	51	51	38	38	38
Embankment (Common)	m3	33	33	33	33	33	33	33	33
Embankment (Borrow)	m3	115	115	115	150	115	0	0	0
Sand Mat	m3	0	0	0	0	0	0	0	0
Removal of Existing Structure (+Detour)	Ea	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Base & Sub-Base									
Sub-Base	m3	208	224	229	201	207	185	190	194
Aggregate Base Course	m3	339	354	357	340	345	339	320	312
Shoulder (Soil Aggregate)	m3	241	259	264	234	240	215	221	225
Surface									
Asphalt Prime Coat	m2	11	11	11	11	11	12	11	11
Asphalt Tack Coat	m2	5	5	5	5	5	6	5	5
Double Bituminous Surface Treatment	m2	33	33	33	33	33	33	32	33
Asphalt Concrete Surfacing	ton	923	927	928	924	922	926	915	917
Portland Cement Concrete Pavement	m3	1,655	1,673	1,694	1,674	1,665	1,689	1,636	1,649
Structure (Equivalent Cost)									
R/C Pipe (01.00 m.)	m	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
R/C Box Culvert (2 - 2.40 x 2.40 m.)	m	10,000	10,000	10,000	13,000	10,000	13,000	13,000	13,000
R/C Bridge (11 m. Width)	m	66,000	66,000	66,000	69,000	66,000	66,000	66,000	66,000
P/C Bridge (11 m. Width)	m	96,000	96,000	96,000	105,000	96,000	96,000	105,000	86,000
Bearing Unit	m2	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Land Acquisition									
Developed Land	ha	250,000	250,000	100,000	1,250,000	1,250,000	0	0	0
Less Developed Land	ha		100,00	100,00	625,000	500,000	0	0	0

5.1.2.2 Economic Unit Costs and Foreign and Local Currency Portions of Unit Costs

The economic unit cost to be used for economic evaluation was computed by deducting the tax component of each work item from the financial unit cost. The percentage of tax components included in the unit cost are shown in Table 5.1.3.

The percentage of foreign and local currency portions of the financial unit cost by work item are shown in Table 5.1.3, divided into the two cases that construction is performed by local contractors and by foreign contractors.
Both percentages for tax and currency portions were quoted from the Feasibility Study Handbook for Improvement and New Construction Road Projects (FSH).

Table 5.1.3 PERCENTAGE OF ECONOMIC COST/FOREIGN AND LOCAL CURRENCY PORTIONS

(Unit: Baht)

Item	Unit	Taxes %	Economic Cost %	Foreign Contractor		Local Contractor	
				Local %	Foreign %	Local %	Foreign %
EARTHWORK							
Clearing & Grubbing	ha	15	85	46	54	54	46
Roadway Excavation (Unclassified)	m3	16	84	47	53	55	45
Roadway Excavation (Classified)	m3	16	84	47	53	55	45
Embankment (Common)	m3	14	86	45	55	53	47
Embankment (Borrow)	m3	14	86	45	55	53	47
Sand Mat	m3	14	86	45	55	53	47
Removal of Existing Structure	each	16	84	45	55	53	47
SUBBASE and BASE COURSES							
Subbase	m3	17	83	48	52	56	44
Aggregate base	m3	16	84	43	57	51	49
Shoulder (Soil Aggregate)	m3	17	83	47	53	55	45
SURFACE COURSES							
Asphaltic Prime Coat	m2	7	93	33	67	41	59
Asphaltic Tack Coat	m2	7	93	33	67	41	59
Double Bituminous Surface Treatment	m2	9	91	40	60	48	52
Asphalt Concrete Surfacing	ton	10	90	39	61	47	53
Portland Cement Concrete Pavement	m3	10	90	60	40	71	29
STRUCTURES (Equivalent)							
RC Pipe Culvert (D=1.00 m)	m	12	88	63	37	74	26
RC Box Culvert (2-2.40 x 2.40 m)	m	10	90	63	37	74	26
RC Bridge (W=11.0 m)	m	13	87	60	40	71	29
PC Bridge (W=11.0 m)	m	13	87	60	40	71	29
Bearing Unit	m2	13	87	60	40	71	29
LAND ACQUISITION (Average)	ha	0	100	100	0	100	0
Sub-total (a)							
Miscellaneous Work (a) x 7 %		13	87	48	52	57	43
Design and Supervision		0	100	100	0	100	0

5.1.3 Construction Costs

Construction costs of major work items were estimated based on the unit costs and work quantities. The cost of miscellaneous work such as slope protection, concrete ditches, guard rails, and traffic signs and markings was estimated at 7% of the total cost of major work items. The total construction costs were computed by adding the following cost items to the above construction costs:

- Physical contingency: 10% of direct construction costs
- Design and construction supervision: 10% of direct construction costs
- Land acquisition cost

The financial and economic construction costs for each study route are summarized below. The breakdown is shown in the Route Report.

SUMMARY OF CONSTRUCTION COSTS

(Unit: thousand Baht)

Project No.	Length (km)	Financial Cost	Economic Cost
Phase I Projects			
ML-1	13.60	347,856	317,675
ML-2	27.27	224,503	197,763
ML-4	61.86	593,260	534,823
ML-5	50.33	1,105,048	1,020,239
ML-7	40.94	754,017	664,890
IM-23	26.87	164,043	147,322
Subtotal	220.87	3,188,727	2,882,712
Phase II IM & ML Projects			
ML-3	44.6	417,200	373,297
ML-9	81.7	3,569,696	3,214,898
IM-1	18.7	49,294	43,295
IM-2	35.9	46,437	40,627
IM-11	40.7	139,179	122,930
IM-12	51.0	245,340	216,902
IM-13	17.8	81,048	71,884
IM-14	25.6	136,369	120,628
IM-15	24.7	115,250	101,977
IM-16	20.8	118,251	104,335
IM-17	19.2	97,534	85,744
IM-22	15.9	95,838	85,714
Subtotal	396.6	5,111,436	4,582,231
Phase II RH Projects			
RH-2	39.5	52,949	47,511
RH-3	17.9	23,668	21,257
RH-5	39.3	42,381	38,360
Subtotal	96.7	118,998	107,128
Grand Total	714.17	8,419,161	7,572,071

Construction costs estimated through detailed engineering and cost examinations in this Feasibility Study phase were considerably different from those roughly estimated in the pre-feasibility study in the Master Plan Study. The reasons are as follows:

- Construction quantities were calculated based on a more accurate design on the basis of topographic surveys.

- Authough embankments were planned by the side borrow method for most projects in the Master Plan Study, this was changed to the borrow pit method except for IM-2.

- For IM Projects except for IM-23, DBST was applied in the Master Plan Study, but this was changed to AC pavement except for IM-2.

5.1.4 Residual Values

Based on FSH, the residual value in the case of a 15-year lifetime was estimated as follows:

Earthworks : RV = 100(1 − 0.0067 × 15) = 90%
Pavement : RV = 100(1 − 0.0333 × 15) = 50%
Major Structure: RV = 100(1 − 0.0333 × 15) = 50%

where, RV : Residual value
C : Initial cost = 100
t : Analysis period of time in years = 15

Residual values for each study route are also shown in the Route Report.

5.1.5 Construction Schedule

Taking into account each contractor's capability to supply construction equipment, the labor force required and financial preparation, the project size manageable by one contractor was determined as follows:

- Road Length : 15 km to 20 km
- Embankment Volume : Less than 500,000 m^3
- Construction Period : 3 years for ML Projects and 2 years for IM Projects

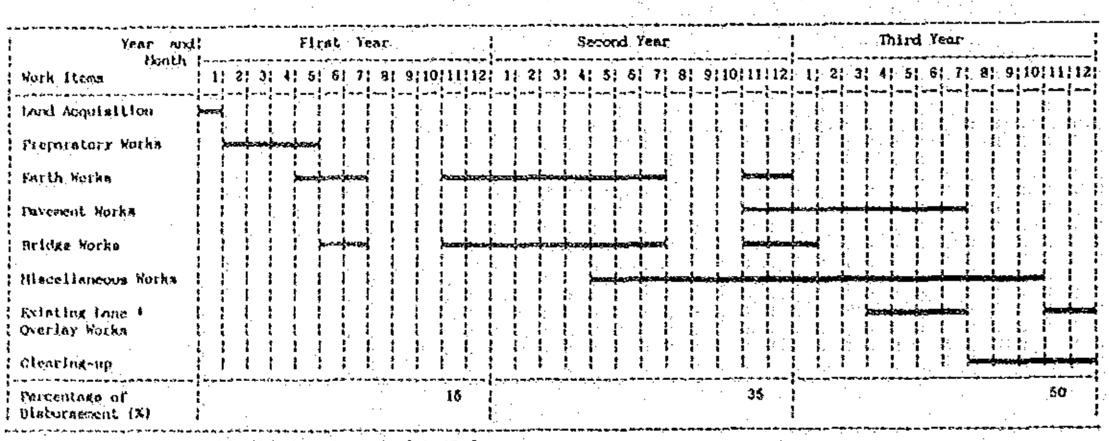
The following assumption was made in order to prepare the construction schedule:

REQUIRED CONSTRUCTION PERIOD

Work Item	Monthly Performance or Required Period
Land Acquisition	Payment in the first year of construction
Preparatory Works	4.0 months
Earth Works	40,000 m^3/month
Pavement Works	2 km - 4 km/month
Bridge Works	8.0 months/50 m total span length
	12.0 months/100 m total span length
	14.0 months/more than 200 m total span length
Existing Lane Overlay Works	4 km/month
Cleaning-up	2 months

In addition to this assumption, considering the rainy season from August to October in which no major work can be executed, the construction schedules were prepared as shown in Figures 5.1.1, 5.1.2 and 5.1.3.

ML Projects and IM-12 were scheduled for a 3-year construction period to start at the beginning of 1991 and be completed by the end of 1993. For ML-1 and ML-5, however, an alternative construction schedule from the beginning of 1989 to the end of 1991 was prepared, corresponding to the year 1992 when Laem Chabang Port will be operated.



x = This item is not required in ML-5
( ) = Alternative schedule for ML-1 and ML-5 Projects

Figure 5.1.1 CONSTRUCTION SCHEDULE FOR ML PROJECTS AND IM-12

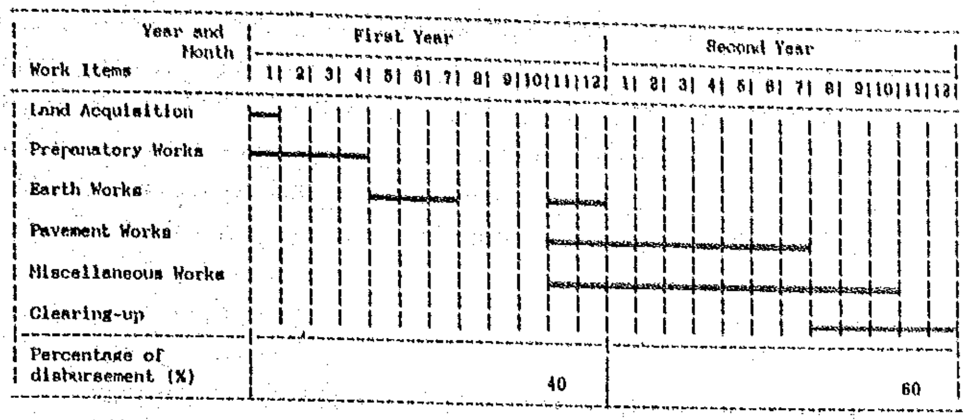


Figure 5.1.2 CONSTRUCTION SCHEDULE FOR IM PROJECTS

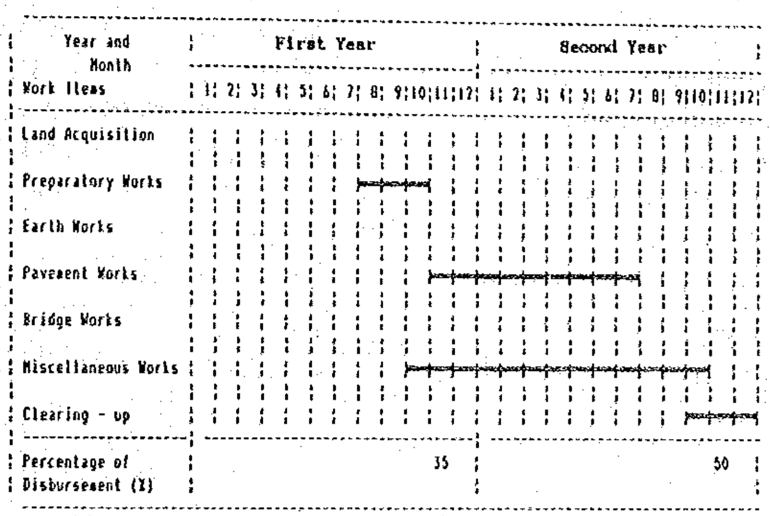


Figure 5.1.3 CONSTRUCTION SCHEDULE FOR RH PROJECTS

On the other hand, IM Projects except for IM-12 were scheduled for a 2-year construction period to start one year later than ML Projects and to be completed in the same year as the ML Projects, based on their smaller scale of construction. RH Projects were also scheduled for 2-year construction; however, in reality, their main work can be completed within one year.

5.2 MAINTENANCE COSTS

DOH maintains highways under its responsibility by 12 divisions which are further divided into 73 districts. In 1987 DOH spent 2,448 million Baht on maintenance according to its annual report. However, this budgetary category does not include the administrative costs of maintenance. Table 5.2.1 shows actual expenditures by DOH budget category for the calendar year 1987. The total administrative cost, excluding those for highway police, construction management and land acquisition, was 1,315 million Baht in 1987. It is reasonable to assume that road maintenance takes up to 50% of this amount, i.e., 658 million Baht, or 27% of the direct maintenance expenditure. Thus the direct maintenance cost should be increased by a factor of 1.27 to obtain the total cost including overhead.

Table 5.2.1 BUDGET AND ACTUAL EXPENDITURE 1987

(Unit: Baht)

Item	Budget	Actual Exp.
1. Administrative	1,990,031,935	1,940,606,214.43
1.1 General Management	980,272,280	974,582,693.26
1.2 Engineering Admin.	85,647,012	82,688,941.87
1.3 Operating Management	285,698,070	257,978,071.91
1.4 Land Acquisition	371,633,630	368,133,887.08
1.5 Construction Management	67,841,660	63,998,420.06
1.6 Highway Police	198,939,283	193,224,200.25
2. Special Construction	160,950,605	160,944,750.66
3. National Construction	1,361,711,755	1,349,429,153.27
3.1 National Highway Constr.	504,836,511	502,472,351.28
3.2 Minor Constr. for Secondary Highways	856,875,244	846,956,801.99
4. Provincial Constr.	2,073,881,592	2,025,271,050.19
5. Maintenance	2,489,644,537	2,448,002,880.66
5.1 Routine	1,066,395,472	1,065,645,210.02
5.2 Special	1,432,249,065	1,382,357,670.64
6. Interior Security	486,121,876	480,290,555.37
Total	8,562,342,300	8,404,544,604.58

Maintenance work is classified into four types by DOH: routine maintenance, periodic maintenance, special maintenance and betterment, and emergency maintenance. If an area requiring maintenance exceeds 10% of the road surface, then the subject road is eligible for the special maintenance budget, not the routine maintenance budget. Table 5.2.2 shows the breakdown of maintenance expenditures in 1987. Equipment costs of routine maintenance are accounted separately but those of periodic and special maintenance are not, since such maintenance is normally done by contract.

Table 5.2.2 MAINTENANCE EXPENDITURE 1987

Item	Amount (million Baht)	Percent (%)
Routine Maintenance		
Materials and Labor	751.0	28.7
Equipment	470.1	18.0
Periodic Maintenance	803.0	30.7
Special and Betterment	457.0	17.5
Emergency Work	40.0	1.5
Administrative	95.8	3.6
Total	2,616.9	100.0

Note: Totals in Tables 5.2.1 and 5.2.2 do not agree due to a minor difference in classification.

Efforts have been made continuously in DOH to reflect actual maintenance needs and work costs in the maintenance budget allocation. The so-called K-Factor Method was introduced in the mid-1960s. By this method, the standard maintenance cost per km for each type of road (laterite, asphalt and concrete) is modified by Ka and Km factors. The Ka factor is calculated from the physical features of the subject road and traffic volume, whereas the Km factor reflects the locational cost differential. The Ka factor for asphalt roads includes 12 parametric factors, none of which reflects the surface condition. Obviously the underlying assumption here is that AC pavement requires routine maintenance regularly. The Ka factor for PCC pavement, however, does include parametric factors reflecting the surface condition. The K-Factor Method has been used to allocate the budget for routine and special maintenance. Factors for each road in each district have been calculated and updated by an elaborate computer system.

However, it has become increasingly recognized that a calculated allocation can be significantly different from actual maintenance requirements, particularly in the case of special maintenance of asphalt roads because the K-Factor Method pays little attention to the actual surface conditions of asphalt roads. In 1986 the Thai Pavement Management System (TPMS) was introduced. TPMS is a system adopted from the BMS System, a pavement maintenance management system developed in the U.K. TPMS puts priorities among the various maintenance requirements of a large number of roads based on two level field investigations, first at the local level with minimal skill and measurements, and second with skilled personnel and measurement devices. TPMS accepts unit costs of maintenance work by type and by area and produces prioritized lists of maintenance projects with cost estimates. TPMS was implemented and used for the allocation of special maintenance budget for the year 1987.

For the purpose of project evaluation in this study, only routine and periodic maintenance were considered. Based on the overall performance of highways in Thailand, particularly in recent years, it was decided that maintenance cost estimates as calculated by the K-Factor Method would represent a fair estimation of what is actually needed to maintain the existing and proposed roads. Tables 5.2.3 shows routine maintenance cost estimates for each project and existing road. Base standard per km costs in the K-Factor Method are provided for two-lane roads. Routine maintenance costs for four-lane roads are obtained by doubling the amount for two-lane roads. The calculation of routine maintenance costs for ML-1 and ML-2 are shown in Appendix 5.2.1.

Table 5.2.3 ROUTINE MAINTENANCE COSTS

Phase I Projects

(Unit: million Baht/year)

Route	Length (km)	Existing 1994	Existing 2008	Proposed 1994	Proposed 2008
ML-1	13.6	0.368	0.368	0.419	0.660
ML-2	27.3	0.644	0.714	0.735	1.276
ML-4	61.9	1.809	1.883	2.111	3.252
ML-5	50.3	*	*	1.781	2.202
ML-7	40.9	1.038	1.146	1.262	2.100
IM-23	26.9	0.518	0.606	0.272	0.348

Phase II Projects

(Unit: million Baht/year)

Route	Length (km)	Existing 1994	Existing 2008	Proposed 1994	Proposed 2008
ML-3	44.6	1.020	1.221	0.714	1.164
ML-9	81.7	*	*	1.303	1.818
IM-1	18.7	0.318	0.326	0.180	0.314
IM-2	35.9	0.469	0.538	0.403	0.651
IM-11	40.7	0.690	0.782	0.435	0.707
IM-12	51.0	0.874	0.965	0.516	0.942
IM-13	17.8	0.197	0.197	0.171	0.282
IM-14	25.6	0.275	0.314	0.267	0.443
IM-15	24.7	0.382	0.407	0.287	0.440
IM-16	20.8	0.255	0.267	0.192	0.331
IM-17	19.2	0.388	0.442	0.295	0.504
IM-22	15.9	0.188	0.190	0.155	0.262
RH-2	39.5	0.646	0.761	0.376	0.701
RH-3	17.9	0.364	0.459	0.239	0.431
RH-5	39.3	0.757	0.831	0.662	0.918

As described in Section 4.2.4, a 5-cm thick asphaltic concrete overlay was planned in the 10th year for AC pavement, but there are no overlay requirements for PCC pavement since the design life is set at 20 years for the latter. Table 5.2.4 shows the periodic maintenance costs for each of the study routes.

Table 5.2.4 PERIODIC MAINTENANCE COSTS

Phase I Projects

Route	Overlay	
	Year	Cost (thousand Baht)
ML-1	—	—
ML-2	2004	39,874
ML-4	2004	90,658
ML-5	—	—
ML-7	2004	59,603
IM-23	—	—

Phase II Projects

Route	Overlay	
	Year	Cost (thousand Baht)
ML-3	2004	61,748
ML-9	2004	187,544
IM-1	2004	11,036
IM-2	2004	6,318
IM-11	2004	28,448
IM-12	2004	35,762
IM-13	2004	12,348
IM-14	2004	16,446
IM-15	2004	18,592
IM-16	2004	13,434
IM-17	2004	19,995
IM-22	2004	10,203
RH-2	—	—
RH-3	—	—
RH-5	—	—