CHAPTER 11

PRELIMINARY EVALUATION OF PROJECTS FOR IMPROVEMENT AND NEW CONSTRUCTION

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In Chapter 8, the following links were selected as the proposed projects to be studied in the preliminary evaluation process:

- ML Projects = 8 links 288.80 km
- IM Projects = 23 links 718.20 km

They are shown in Table 8.1.1 and their locations are shown in Figure 8.1.1.

11.1 FUTURE TRAFFIC ON PROJECT ROUTES

11.1.1 Traffic Forecast Procedures

The traffic forecast described in Chapter 5 was made based on trends of the number of registered vehicles and the results of O/D surveys at only 10 points set along some trunk highways in the whole study area. The main purpose of this forecasting exercise was to understand the general behavior of region-wide traffic. Assigned traffic volumes on each route in this forecasting exercise were not always accurate enough to be applied to the evaluation for particular projects. In consequence, traffic forecasts for the preliminary evaluation were made according to the following methods taking some part of the results obtained in Chapter 5:

a) Growth Rate Method

This was applied to all projects other than ML-1 and ML-5. The procedures are as follows:

- To estimate traffic volume by vehicle type for a certain year (base year) based on traffic count data measured by DOH or the Study Team. In this case, the traffic volume of each route assigned in Chapter 5 was disregarded.

- To estimate traffic growth rates by reverse calculation of assigned traffic by vehicle type for 1986, 1993, 2000 and 2008 forecasted in Chapter 5. For the road links whose traffic volume was not estimated in Chapter 5, the traffic growth rate calculated for road links close to the project route and with similar road conditions was applied. The traffic growth rate of motorcycles was assumed to be the same of that of ADT which is the weighted average of the rate for each vehicle.

- To estimate the future traffic volume on the project route by increasing the base traffic by means of the traffic growth rate.

b) Assignment Method

Since ML-1 was expected to attract much diverted traffic from Rt. 3 and ML-5 was to be a new construction road, the Growth Rate Method could not be applied. For these two projects, traffic volumes forecasted by the Assignment Method in Chapter 5 was applied for the purpose of preliminary evaluation.

As traffic volumes for motorcycles were not forecasted in the Assignment Method in Chapter 5, they were calculated by the following equations introduced by DOH:

$$M = 705 + 0.125 \times ADT \text{ on national highways}$$
$$r = 0.672$$

$$M = 540 + 0.206 \times ADT \text{ on provincial highways}$$
$$r = 0.677$$

where,

M : Number of motorcycles
ADT : Average daily traffic

11.1.2 Type of Traffic and Vehicles

a) Type of Traffic

For the purpose of estimation of road user benefits, traffic was classified into four types: normal, diverted, induced and development traffic.

Normal Traffic is defined as the traffic which takes place on the existing road, on which growth arises from the natural increase of population and economic activities independent of the road improvement.

Diverted Traffic is defined as the traffic which has changed its routes due to the improvement or new construction of the road. Diverted traffic was foreseen for some project routes.

However, it was considered in the preliminary evaluation only for the following project routes, for which a considerable volume was expected:

- IM-13: from Rt. 32
- ML-1 and ML-5: from Rt. 3

Induced Traffic is defined as the extra traffic which is newly generated as a result of the improvement in transport conditions such as decrease of travel time and cost. It was considered only for IM Projects which are to be upgraded to paved roads from laterite roads. On the other hand it was neglected for ML projects and RH projects which are originally paved road. Also for medium trucks and heavy trucks, the induced traffic was not considered for all projects, because the commodity flow would hardly be influenced by such changes.

The induced traffic was estimated by the following equation formulated by the Study Team:

$$Ii = (L/2/SA*60+15)^{Pi}/(L/2/SI*60+15)^{Pi}$$

where,

- Ii : Induced traffic ratio for vehicle type i
- L : Project road length (km)
- 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: Access at both ends of the trip outside of project link time is 15 minutes and average trip distance on project link is L/2.

The induced traffic ratio of motorcycles was assumed to be the same as that of ADT which is the weight of average of the ratios for each vehicle.

Development Traffic is defined as the traffic which occurs in excess of natural growth of population and economic activities due to the road improvement. However, this was disregarded in the preliminary evaluation.

b) Type of Vehicles

Vehicles were classified into seven types at this stage. They were motorcycle, passenger car, light bus and heavy bus for passenger traffic, and light truck, medium truck and heavy truck for freight traffic.

11.1.3 Base and Future Traffic Volumes

Base and future traffic volumes (ADT) forecasted through the procedures described above are summarized in Table 11.1.1 for ML Projects and Table 11.1.2 for IM Projects.

Details by vehicle type such as base and future traffic volumes, traffic growth rates and induced traffic ratios are shown in the Master Plan Route Report.

Table 11.1.1 TRAFFIC FORECAST ON ML PROJECTS

Route	Section	Base ADT		Future ADT		
		Year	ADT	1993	2000	2008
ML-1	3-0403-N	-	-	24203	36147	55092
	3-0403-E	-	-	25237	37821	57452
	3-0403-S	-	-	21704	33218	51122
	3-0403-s	-	-	2991	5173	8216
	Average	-	6964	18534	28090	42970
ML-2	3-0701	1986	4958	7673	11214	16629
ML-3	3-0800	1986	8830	14573	21749	32800
ML-4	3-1000	1986	7102	12474	17748	25857
	3-1102	1986	4863	7298	10666	15952
	Average	-	5983	9886	14207	20905
ML-5	BP-N	-	-	20805	33602	54389
	BP-M	-	-	20962	33835	54717
	Ave. N & M	-	-	20884	33719	54553
	BP-S	-	-	18048	29525	48078
	BP-W	-	-	2914	4310	6639
	Average	-	-	15682	25318	40956
ML-6	4-0502	1986	8004	15210	21925	32583
ML-7	304-47KM	1986	15110	21610	31302	47384
	304-73KM	1986	6583	9595	13852	20738
	Average	-	10847	15603	22577	34061
ML-8	340-0300	1986	5569	10109	14258	21311

Note: N: North section, E: East section, S: Upper south section, s: Lower south section, M: Middle section

Table 11.1.2 TRAFFIC FORECAST ON IM PROJECTS

Route	Section	Base ADT		Future ADT		
		Year	ADT	1993	2000	2008
IM-1	PWD	1986	300	553	754	1080
IM-2	3306-0100	1986	385	721	959	1332
IM-3	PWD	1988	174	282	400	573
	ARD	1987	165	236	327	470
	Average	-	170	259	364	522
IM-4		1988	112	180	268	391
IM-5	PWD/ARD	1988	87	142	202	294
IM-6	PWD	1987	68	133	162	209
IM-7	2321-1002	1988	46	65	86	121
		1988	63	88	118	164
	Average	-	55	77	102	143
IM-8	2247	1986	531	816	1118	1609
IM-9	PWD	1987	202	299	374	506
IM-10	3196	1987	550	1029	1462	2067
IM-11	RID-N	1988	463	1055	2312	3631
	RID-M	1987	280	700	1099	1643
	RID-S	1988	787	1745	4122	6449
	Average	-	510	1167	2511	3908
IM-12	RID	1987	240	513	945	1456
IM-13	PWD	1986	200	737	1071	1577
IM-14	RURAL	1988	196	320	443	631
IM-15	RURAL-N	1988	582	968	1402	2039
	RURAL-S	1988	1657	2563	3732	5519
	Average	-	1120	1766	2567	3779
IM-16	3312	1988	514	894	1281	2024
	PWD	1988	274	399	567	888
	Average	-	394	647	924	1456
IM-17	PWD	1988	1371	2162	3259	5086
IM-18	RID	1987	170	358	550	779
IM-19	RURAL	1988	183	277	403	565
IM-20	3249-0200	1986	179	315	464	692
	3249-0300	1986	144	254	368	542
	RURAL	1988	905	1431	2100	3107
	Average	-	409	667	977	1447
IM-21	3245-0402	1988	338	422	521	697
IM-22	RURAL	1988	121	194	284	418
IM-23	3267-0101	1986	2587	5730	7771	10980

11.2 ENGINEERING STUDY AND COST ESTIMATES

11.2.1 Inventory Survey and Field Reconnaissance

1) Inventory Survey

To collect information necessary for the road design, an inventory survey for the proposed projects was carried out with an accuracy at the level of prefeasibility study.

Major items surveyed were road length and width, general conditions of alignment, surface type, embankment height/cutting depth, location and condition of bridges, terrain, land use and name of villages along the routes, and the past record of flooding.

The results of the inventory survey are shown in Master Plan Route Report for each proposed project route. However, they were omitted for the projects selected as the subjects for the feasibility study to avoid repetition with the Feasibility Study Route Report.

2) Field Reconnaissance

For the sections which should be newly constructed, careful reconnaissance surveys were performed for the engineering design. Prior to the reconnaissance, desk studies were carried out based on 1/50,000 scale topographic maps.

The main check points in the reconnaissance were:

- Required embankment height
- Required cutting depth
- Required drainage structures
- River conditions and location and required length of bridges
- Difficulties in the acquisition of right-of-way

11.2.2 Design Standards

1) ML Projects

All project roads were classified as national highways in the highway classification of DOH.

DOH has a minimum standard for national highways under the name of P Standard and S Standard. The P Standard is subdivided into road classes from PD to P3 and the S Standard into six classes from SD to S5 according to the predicted ADT as shown in Table 11.2.1.

The road class was adopted individually to each project route corresponding to the road class of the concerned existing road and predicted ADT as shown in Table 11.2.2.

Table 11.2.1 P AND S STANDARDS

P STANDARDS

Class ( )	PD	P1	P1	P3
Average Daily Traffic (6)	Above 8,000	4,000-8,000	2,000-4,000	Below 2,000
Suggested Surface Type	High	High	Intermediate	Intermediate
Width of Carriageway (m)	Divided 2@7.00	7.00	6.50	6.00
Width of Shoulder (m)	2.50	2.50	2.25	2.00

S STANDARDS

Class ( )	SD	S1	S2	S3	S4	S5
Average Daily Traffic (6)	Above 8,000	4,000-8,000	2,000-4,000	1,000-2,000	300-1,000	Below 300
Suggested Surface Type	High	High	Intermediate	Intermediate	Intermediate To Low	Soil Aggregate
Width of Carriageway (m)	Divided 2@7.00	7.00	6.50	6.00	5.50	9.00
Width of Shoulder (m)	2.50	2.50	2.25	2.00	1.75	Travelled way

Note:
1. Class PD roads are required on the basis of a 7-year ADT projection or are justified by economic feasibility calculations.
2. Class P1 to P3 roads are required on the basis of a 15-year ADT projection.
3. Class SD roads are required on the basis of a 7-year ADT projection or are justified by economic feasibiity calculations.
4. Class S1, S2 and S3 are required on the basis of a 15-year ADT projection.
5. Class S1 roads may exceed an ADT projection of 8,000 beyond the 7th year and should be planned for upgrading to SD when ADT reaches 8,000 or it is shown to be economically viable.
6. Class S4 roads have a projected ADT more than 300 in 7 years and less than 1,000 in 15 years.
7. Class S5 roads have a projected ADT less than 300 in 7 years.

Table 11.2.2 APPLIED ROAD CLASS (P AND S CLASS ROADS)

Project No.	ADT after Opening		Road Class	
	7th year (2000)	15th year (2008)	Existing	Proposed
ML-1	18,606	27,641	P1	PD
ML-2	11,214	16,629	P1	PD
ML-3	21,749	32,800	P1	PD
ML-4	14,207	20,905	P1	PD
ML-5 (B.N.)	33,719	54,553	—	PD
(B.S.)	29,525	48,073	—	P1
(B.W.)	4,310	6,639	—	FD
ML-6	21,925	32,583	P1	PD
ML-7	22,577	34,061	S3	SD
ML-8 Rt. 340 Sect.	14,258	21,311	S3	SD
Outer Ring Road Sect.			P1	PD

Note: For ML-5: B.N.: Chon Buri Bypass to Rt. 3241, B.S.: Rt. 3241 - Rt. 36,
B.W.: Access to Laem Chabang

2) IM Projects

Considering the role and function of all projects, roads were classified as provincial roads defined in the highway classification of DOH.

DOH has minimum design standards for provincial roads under the name of F Standard. The F Standard is subdivided into seven road classes from FD to F6 according to the projected ADT as shown in Table 11.2.3:

Table 11.2.3 F STANDARDS

Class ( )	FD	F1	F2	F3	F4	F5	F6
Average Daily Traffic (6)	Above 8,000	4,000-8,000	2,000-4,000	1,000-2,000	300-1,000	Below	300
Design Speed (km/h) (3)							
Flat and moderately rolling	70-90				60-80	60	
Rolling and hilly	55-70				45-60	45	
Mountainous	40-55				30-45		
Maximum Gradient (%) (4)							
Flat and moderately rolling	6				8	12	
Rolling and hilly	8				10	12	
Mountainous	10				10	12	
Suggested Surface Type	High		Intermediate		Low	Soil Aggregate	
Width of Carriageway (m)	Divided 2@7.00	7.00	6.50	6.00	5.50	9.00	6.00
Width of Shoulder (m)	2.50	2.50	2.25	2.00	1.75	Travelled	Travelled
Right-of-way (m) (5)	40-60					20-40	

Note: 1. Class FD roads are required on the basis of a 7-year ADT projection or are justified by economic feasibility calculations.
2. Class F1 to F3 roads are required on the basis of a 15-year ADT projection.
3. Class F4 roads have a projected ADT more than 300 in 7 years and less than 1,000 in 15 years.
4. Class F5 roads have a projected ADT less than 300 in 7 years and more than 300 in 15 years.
5. Class F6 roads have a projected ADT less than 300 in 15 years.

In principle, the road class was adopted individually for each of roads corresponding to each predicted ADT as shown in Table 11.2.4. Exceptions, however, were made for some of the projects, considering the characteristics of project routes as follows:

IM-4 : F5 Standard is applicable from the 7th year ADT of 268. However, F4 Standard was applied since the ADT is close to 300.

IM-5 : F6 Standard is applicable from the 15th year ADT of 294. However, F5 Standard was applied because the ADT is close to 300.

IM-12: F3 Standard is applicable from the 15th year ADT of 1456. However, F2 Standard was applied, since diverted traffic is expected by connecting with IM-11 to which F2 Standard will be applied.

IM-14: F4 Standard is applicable from the 7th year ADT of 443. However, diverted traffic is expected by the connection with IM-15 to which F2 Standard will be applied. Therefore, application of the F2 Standard of IM-15 is desirable. However, a special standard (F4 Standard with F2 Standard pavement - 6.5 m in width) was applied owing to constraints of the right-of-way.

IM-17: F1 Standard is applicable from the 15th year ADT of 5,086, but F3 Standard was applied. Some sections of this link are now being constructed by the PWD according to the F4 Standard without pavement. Considering this circumstance, additional acquisition of the right-of-way to improve it to F1 class road was thought difficult at present.

For IM-6 and IM-7, F6 Standard was adopted from the 7th year ADTs of 162 in IM-6 and 102 in IM-7. Their existing conditions almost satisfy F6 Standard. Therefore, these two routes were excluded from the proposed projects subject to the preliminary evaluation.

Table 11.2.4 APPLIED ROAD CLASS (F CLASS ROADS)

Project No.	ADT after Opening		Road Class[1]	
	7th year (2000)	15th year (2008)	Existing	Proposed
IM-1	754	1,080	2	F3
IM-2	959	1,332	Laterite, Substandard	F3
IM-3	364	522	-do-	F4
IM-4	268	391	-do-	F4 *
IM-5	202	294	-do-	F5 *
IM-6	162	209	-do-	F6
IM-7	102	143	-do-	F6
IM-8	1,118	1,609	-do-	F3
IM-9	374	506	-do-	F4
IM-10	1,462	2,067	3	F2
IM-11	2,511	3,908	3	F2
IM-12	945	1,456	3	F2 *
IM-13	1,071	1,577	2	F3
IM-14	443	631	Laterite, Substandard	F4 * (6.5-m wide pavement)
IM-15	2,567	3,779	-do-	F2
IM-16	924	1,456	-do-	F3
IM-17	3,259	5,086	-do-	F3 *
IM-18	550	779	-do-	F4
IM-19	403	565	-do-	F3
IM-20	977	1,447	-do-	F4
IM-21	521	697	-do-	F4
IM-22	284	418	-do-	F4 *
IM-23	7,771	10,980	F4	F1

Note: 1. Road classes of the existing roads were estimated from the typical cross section.
2. PWD plans a 5-m wide pavement on a 8-m wide roadbed.
3. 8.0-m wide roadbed and 5.0-m wide carriageway.
* Exceptional application was applied.

11.2.3 Preliminary Design

1) Geometric Design

Alignment

Alignment was studied at the preliminary evaluation level on the basis of 1/50,000 scale topographic maps.

The alignment of ML Projects except for ML-5 was designed corresponding to the alignment of the existing roads. Since ML-5 is a new construction road, it was designed according to the alignment planned by DOH.

The alignment of the IM Projects was determined utilizing the existing alignment as much as possible in order to minimize the construction cost. The improvement of alignment was only considered for sections of poor existing alignment.

New construction sections for IM Projects were planned for about 8.8 km in total as shown below:

- IM-14 4.5 km (improvement of poor alignment)
- IM-22 4.3 km (shortcut)

For the routes close to canals, i.e., IM-10, IM-11 and IM-12, the centerline of the new alignment was shifted by 2.0 m from the centerline of the existing road to the opposite side of the canal in order to prevent erosion by the canal side embankment slope caused by flooding.

Route alignments for each project are shown on 1/50,000 scale topographic maps in the Master Plan Route Report.

Typical Cross Section

Major components of cross sections such as road width, surface type and cross slope are specified in DOH standards, and were used unchanged in this study. Other components such as embankment and cut slopes and minimum depth of side ditches were determined through a study of typical cross sections of DOH highway projects implemented recently.

The typical cross section applied to each project is shown in the Master Plan Route Report.

2) Earthwork

Required minimum heights of embankments were determined mainly in consideration of the influence of surface water on road structures. The minimum heights of embankment employed are shown below:

MINIMUM EMBANKMENT HEIGHT

Description	Minimum Height (m)
Ordinary Sections	1.0
Approach to Bridge in Flat Areas	2.0
Flood Sections	0.7 (above flood level)

The side-borrow method is the most common and economic method for embankment construction in Thailand. This method was, therefore, applied to most sections of the projects.

For IM-10, IM-11, IM-12 and ML-7, however, the borrow-pit method was adopted, in which embankment materials are carried from distant borrow pits, because there is not enough room to apply the side-borrow method within the right-of-way of these routes.

3) Pavement

The types of pavement applied are AC pavement, DBST and soil aggregate surface.

For the trunk highways under DOH, PCC pavement has sometimes been applied recently. However, only AC pavement was adopted in the preliminary evaluation for the purpose of evaluating on a equal basis. The thickness of the AC surface of existing trunk highways under DOH is commonly 5 cm, but a 10-cm thick AC surface was adopted in this study following the results of pavement studies in Chapter 12.

Typical pavement structures applied corresponding to each standard are shown below:

PD, SD, S1, FD, and F1 Standards

- AC		10 cm
- Crushed stone base	CBR > 80	20 cm
- Soil aggregate subbase	CBR > 20	20 cm
- Selected materials	CBR > 6	15 cm

F2, F3 and F4 Standards

- DBST		2.5 cm
- Crushed stone base	CBR > 80	1.5 cm
- Soil aggregate subbase	CBR > 20	20 cm
- Selected materials	CBR > 6	15 cm

F5 and F6 Standards

- Soil aggregate surface	CBR > 20	15 cm
- Selected material	CBR > 6	20 cm

Five-centimeter thick AC overly was planned in the 8th year after opening for all projects except IM-5 for which the F5 standard road (laterite surface) was applied.

In addition, for ML Projects except for ML-5, an AC overlay of 5 cm thick was also adopted to the existing lanes at the opening year for rehabilitating existing pavement.

4) Drainage

To maintain roads in all-weather condition, proper functioning drainage facilities are indispensable. The inventory survey revealed that the existing cross drainage was insufficient in number and capacity. Substantial improvement of drainage facilities is required for all project routes.

Pipe Culverts

Pipe culverts of minimum 100 cm in diameter were adopted considering easy maintainance.

The average interval of pipe culverts was determined corresponding to land use along the project route, as follows:

STANDARD INTERVAL OF PIPE CULVERT

Land Use	Standard Interval (m)
Paddy	200
Other	500

For existing pipe culverts, their extension was designed so as to match the additional width of the project road.

Box Culverts

2.4 m × 2.4 m double cell type concrete culvert boxes were adopted, based on to the typical structures employed by DOH.

Required locations were determined based on the inventory survey and reconnaissance.

5) Bridges

Existing bridges on IM-4, IM-5, IM-16 and IM-22 are mostly temporary wooden bridges, while those on the other projects are mostly permanent concrete bridges.

Among the concrete bridges, some bridges do not satisfy design loading and carriageway width required in the adopted standards. It was planned, therefore, to replace these bridges and all wooden bridges with standard concrete bridges or concrete box culverts.

In addition to the replacement of existing bridges, new concrete bridges were planned at river crossing sites where no bridges exist and also in new construction sections.

The lengths and location of bridges were determined using the data obtained in the inventory survey and the reconnaissance.

The types of bridges were selected in accordance with DOH standard bridge structures, taking the scale of rivers into account, as shown below:

TYPES OF BRIDGE STRUCTURE

Description	Type of Superstructure
Short Span Bridge	RC - Slab
Long Span Bridge	PC - Girder

11.2.4 Construction Quantities and Costs

1) Construction Quantities

Construction quantities by major work items were calculated on the basis of the engineering studies described in the previous sections. The major construction items are shown in Table 11.2.5.

Areas of land acquisition were calculated only for new construction sections, classified into developed and less developed land on the basis of data obtained during the inventory survey. However, no less developed land existed along the projects in this study.

The calculated quantities of each proposed route are presented in the Master Plan Route Report.

2) Construction Costs

The applied unit rates were those as of 1987. They were developed from DOH cost data.

The unit rates for the major items are shown in Table 11.2.5. They were applied for all proposed projects, disregarding the differential by area.

Construction costs by major work items were calculated by applying these unit rates to the estimated construction quantities. Costs of minor items, such as side ditches, slope protection, guard rails, traffic signs, etc., were estimated at 7% of the total cost of major work items. The direct construction cost was obtained by totalling these costs.

The total construction costs were calculated by adding the following cost items to the direct construction cost:

Physical Contingency	:	10% of direct construction costs
Engineering and Administration	:	10% of direct construction costs

The economic construction cost used in the economic evaluation was calculated by deducting the tax component of each work item from the financial construction cost. The percentages of economic costs and residual values included in the unit rate are shown in Table 11.2.5. They were determined based on the previous studies on similar types of construction in Thailand on the assumption that construction would be performed by local contractors.

Table 11.2.5 UNIT RATES OF MAJOR WORK ITEMS

Item	Unit	Financial Unit Rate (Baht)	Economic Cost (%)	Residual Value (%)
EARTHWORK			83	90
Clearing & Grubbing	ha	9,500		
Earth Excavation	m^3	16		
Embankment (side borrow)	m^3	40		
Embankment (borrow pit)	m^3	100		
PAVEMENT			83	50
Subbase (selected material)	m^3	180		
Subbase (soil aggregate)	m^3	220		
Base (soil aggregate)	m^3	350		
Shoulder (soil aggregate)	m^3	250		
Prime Coat	m^2	12		
DBST Surface	m^2	40		
AC Surface	ton	190		
STRUCTURES			83	50
RC Pipe Culvert (D = 1.00 equivalent)	m	1,800		
RC Box Culvert (2 × 2.4 × 2.4 equivalent)	m	20,000		
RC Bridge (W = 7.0, L = 10.0 equivalent)	m	60,000		
PC Bridge	m	80,000		
INTERCHANGES/INTERSECTIONS	no.	5,000,000– 30,000,000	83	50
LAND ACQUISITION				
Highly Developed Land	ha	200,000	—	

The financial and economic costs for each proposed route are summarized in Table 11.2.6 for ML Projects and Table 11.2.7 for IM Projects.

The construction period for each proposed route was estimated according to the project scale.

The construction period including the detailed design and the land aquisition and the ratio of yearly disbursement of construction cost were estimated as follows:

CONSTRUCTION PERIOD AND COST DISBURSEMENT RATIO (%)

Construction Cost (thousand Baht)	Construction Period (years)	Disbursement Ratio (%) 1st Year	2nd Year	3rd Year
Less than 13,000	2	20	80	
13,000 - 60,000	2	40	60	
More than 60,000	3	20	50	30

When the construction period was estimated, the rainy period of about five months was taken into account, considering the drop in work efficiency in that period.

Table 11.2.6 SUMMARY OF COSTS (ML PROJECTS)

(Unit: thousand Baht)

Route No.	Road Class	Length (km)	Financial Cost	Average Cost Per km	Economic Cost
ML-1	PD	13.8	112,932	8,132	93,940
ML-2	PD	27.3	167,168	6,123	139,053
ML-3	PD	48.8	284,713	5,834	236,830
ML-4	PD	61.3	445,894	7,274	370,904
ML-5	PD,P1,FD	48.8	518,297	10,621	447,526
ML-6	PD	22.8	155,216	6,808	129,111
ML-7	SD	41.0	421,562	10,282	350,662
ML-8	SD,PD	25.6	254,890	9,957	212,022
TOTAL		289.4	2,360,672		1,980,048

Table 11.2.7 SUMMARY OF COSTS (IM PROJECTS)

(Unit: thousand Baht)

Route No.	Road Class	Length (km)	Financial Cost	Average Cost Per km	Economic Cost
IM-1	F3	18.8	13,617	724	11,327
IM-2	F3	36.0	86,408	2,400	71,876
IM-3	F4	'33.6	79,643	2,370	66,249
IM-4	F4	34.0	80,852	2,378	67,255
IM-5	F5	69.1	104,873	1,518	87,235
IM-8	F3	16.8	42,394	2,523	35,263
IM-9	F4	18.0	43,633	2,424	36,295
IM-10	F2	34.8	124,047	3,565	103,185
IM-11	F2	41.0	132,540	3,233	110,250
IM-12	F2	50.0	178,910	3,578	14,821
IM-13	F3	16.2	13,193	814	10,975
IM-14	F4	24.4	69,706	2,857	58,589
IM-15	F2	24.3	62,268	2,562	51,796
IM-16	F3	20.8	82,226	3,953	68,397
IM-17	F3	29.3	79,437	2,711	66,078
IM-18	F4	26.7	68,086	2,550	56,635
IM-19	F3	27.3	70,595	2,586	58,723
IM-20	F4	44.5	105,575	2,372	87,820
IM-21	F4	18.3	41,755	2,282	34,733
IM-22	F4	16.5	61,211	3,710	51,774
IM-23	F1	26.5	95,561	3,606	79,490
TOTAL		626.9	1,636,530		1,228,766

11.3 BENEFITS ESTIMATION

Benefits due to the projects were estimated in terms of vehicle operating cost (VOC) savings and time savings between "with" and "without project" cases.

11.3.1 VOC Savings

(1) Vehicle Operating Costs on Level Tangent Roads

Vehicle operating costs on level tangent roads were estimated based on a DOH study dated September 1986.

In this DOH study, vehicles and road conditions were classified as follows:

- Vehicles: motorcycle (MC), passenger car (PC), light truck (LT), medium truck (MT), heavy truck (HT), light bus (LB), medium bus (MB) and heavy bus (HB).

- Road conditions: good paved (RC1), fair paved (RC2), poor paved (RC4), good laterite (RC3), fair laterite (RC5), poor laterite (RC6) and earth (RC7).

VOC components, running and fixed economic costs are given by the DOH study. They were updated based on the report "Quarterly Bulletin" prepared by the Bank of Thailand as shown in Appendices 11.3.1 and 11.3.2.

As seen in the above Appendices, these costs are given only for the three road conditions RC1, RC3 and RC6. Therefore, in the DOH study, the VOCs for the remaining four road conditions were estimated by modifying approximately those of the three road conditions.

Applying the updated results, VOCs in level tangent roads of the DOH study were modified and amended in the same manner as described above. This is shown in Table 11.3.1.

Table 11.3.1(a) ECONOMIC VEHICLE OPERATING COSTS

(Unit: Baht/km)

Speed (km/h)	ROAD CONDITION 1	2	3	4	5	6	7
MOTOR CYCLE							
20	0.68	0.78	0.86	0.96	1.05	1.22	1.54
30	0.63	0.72	0.81	0.90	0.98	1.16	1.45
40	0.58	0.67	0.74	0.85	0.96	1.17	1.46
50	0.55	0.63	0.71	0.84	0.96	1.20	
60	0.53	0.61	0.69				
70	0.55	0.63	0.70				
80							
90							
PASSENGER CAR							
20	2.53	2.93	3.30	3.70	4.06	4.81	6.02
30	2.27	2.62	2.98	3.37	3.74	4.48	5.60
40	2.04	2.37	2.69	3.14	3.56	4.42	5.52
50	1.93	2.26	2.58	3.07	3.54	4.49	
60	1.81	2.12	2.43				
70	1.72	2.06	2.38				
80	1.77	2.09	2.39				
90	1.80						
LIGHT TRUCK							
20	2.21	2.60	2.99	3.29	3.57	4.13	5.16
30	1.97	2.31	2.62	2.92	3.19	3.75	4.69
40	1.84	2.15	2.44	2.78	3.10	3.76	4.71
50	1.70	2.01	2.32	2.70	3.06	3.80	
60	1.64	1.94	2.22				
70	1.64	1.94	2.23				
80	1.65						
90							
MEDIUM TRUCK							
20	6.12	6.59	7.04	7.64	8.19	9.34	11.95
30	5.31	5.80	6.28	6.85	7.36	8.45	10.56
40	4.84	5.25	5.65	6.39	7.06	8.48	10.59
50	4.40	4.85	5.28	6.10	6.86	8.44	
60	4.07	4.50	4.93				
70	4.19	4.58	4.96				
80	4.28						
90							

Table 11.3.1(b) ECONOMIC VEHICLE OPERATING COSTS

(Unit: Baht/km)

Speed (km/h)	ROAD CONDITION 1	2	3	4	5	6	7
HEAVY TRUCK							
20	7.57	8.37	9.11	9.98	10.77	12.43	15.55
30	6.64	7.38	8.04	8.85	9.58	11.12	13.91
40	5.91	6.59	7.21	8.19	9.13	11.06	13.83
50	5.38	6.10	6.75	7.82	8.84	10.95	
60	5.10	5.73	6.31				
70	5.15	5.80	6.00				
80	5.27						
90							
LIGHT BUS							
20	3.40	3.72	4.01	4.30	4.54	5.07	6.33
30	2.93	3.22	3.50	3.78	4.03	4.54	5.68
40	2.67	2.94	3.21	3.56	3.88	4.54	5.68
50	2.44	2.71	2.98	3.39	3.77	4.56	
60	2.30	2.56	2.82				
70	2.29	2.56	2.83				
80	2.30						
90							
MEDIUM BUS							
20	6.01	6.50	6.97	9.02	8.12	11.66	11.60
30	5.22	5.68	6.12	8.05	7.24	10.63	10.48
40	4.75	5.19	5.60	7.62	7.00	10.61	10.52
50	4.33	4.76	5.15	7.25	6.76	10.54	
60	4.01	4.48	4.91				
70	4.14	4.55	4.94				
80	4.23						
90							
HEAVY BUS							
20	7.21	7.84	8.52	9.17	9.83	11.16	13.96
30	6.29	6.80	7.34	7.98	8.63	9.94	12.45
40	5.58	6.11	6.68	7.47	8.27	9.89	12.37
50	5.07	5.59	6.13	7.03	7.94	9.78	
60	4.77	5.26	5.78				
70	4.81	5.31	5.85				
80	4.92						
90							

(2) Additional Costs due to Road Geometry and Speed Change Cycle

(a) Gradients and Curves

Adjustment coefficients for additional costs due to gradients and curves by road class were estimated for each case of typical types of topography such as good, fair and poor based on the coefficients given in the report "Standardization of Vehicle Operating Costs for Thailand" (SVOCT) (see Appendix 11.3.3).

(b) Speed Change Cycle

Generally, VOCs are affected by deceleration and acceleration due to traffic frictions such as narrow and wooden bridges, villages, crossroads and other obstacles. In this study, the speed change cycle due to narrow and wooden bridges was considered using the coefficients given in SVOCT (see Appendix 11.3.3).

(3) VOC Savings

The VOC for each project route was calculated for with and without project cases based on the VOC per km including additional costs, traffic volume by vehicle type, traffic type and project length.

In the case of ML Projects, travel speeds in the without project case were calculated in connection with the road capacity as shown in Appendix 11.3.4. In this study, travel speed when traffic volume exceeds road capacity was limited to a capacity speed of 50 km/h.

VOC savings were estimated as the difference in total VOCs in the related road network of with or without project cases.

Traffic type was classified into normal, diverted and induced traffic at this stage. Among these, whole savings was counted for normal and diverted traffic, while one half of savings were counted for induced traffic.

The results of calculation of VOC savings are summarized in Tables 11.3.2 and 11.3.3 by project, and shown separately in the Master Plan Route Report.

11.3.2 Time Savings

Value of time was estimated separately for trips business purposes and trips for all other purposes by vehicle type. For the former, different average wages for crew and passengers were applied by vehicle type, but for the latter the same value was used for all vehicle types;

because the former could be considered to reflect that economic productivity is different by type of person, while the latter is sometimes called the equity value.

The wages of drivers and assistants were estimated by updating a previous JICA Study. The minimum wage rates were increased by 3.7 % on average. This is shown below:

WAGES OF VEHICLE CREW

Vehicle Type	Monthly Wage (Baht)	Working Hours (month)	Wage/Hour (Baht)
Motorcycle	3,100	240	12.9
Passenger Car	3,100	185	16.8
Light Bus	7,780	200	38.9
Medium Bus	7,780	200	38.9
Heavy Bus	7,780	200	38.9
Light Truck	6,220	220	28.3
Medium Truck	6,220	220	28.3
Heavy Truck	6,220	220	28.3

The equity value of time was also assumed at 5.44 Baht per hour by applying the same increase rate of the minimum wage.

The percentage of business trips was assumed for each vehicle type based on the results of the O/D survey conducted by the study team.

The time value by vehicle type was calculated based on wages estimated above as follows:

TIME VALUES

Vehicle Type	Vehicle Occupancy	Business & Work Trip Ratio (%)	Business & Work Pass. Wage (Baht/hr)	Calculation	Time Value
Motorcycle	1.2	15	13.0	1.2×10.15×13.0×0.85×5.44	7.3
Passenger Car	Driver + 1.4 Passengers	45.5	49.8	(0.455×(16.8+49.8×1.4×19.8)+ 0.545×2.4×5.44)	46.5
Light Bus	Crew + 6.3 Passengers	36.4	21.8	(1.0×38.9) +6.3×(0.364×21.8+0.636⊋ ×5.44)	110.7
Medium Bus	Crew + 16.6 Passengers	36.4	21.8	(1.0×38.9) +16.6×(0.364×21.8+0.636⊋ ×5.44)	228.1
Heavy Bus	Crew + 32.0 Passengers	36.4	21.8	(1.0×38.9) +32.0×(0.364×21.8+0.636⊋ ×5.44)	403.5
Light Truck	Crew	100.0	—	1.0×28.3	28.3
Medium Truck	Crew	100.0	—	—	28.3
Heavy Truck	Crew	100.0	—	—	28.3

Time savings were estimated as the difference in total time costs in the related road network of with or without project cases.

In the case of ML Projects, travel speeds in the without project case were estimated in the same manner as that in VOC savings.

The results of time saving calculations are summarized in Tables 11.3.2 and 11.3.3 by project, and shown separately in the Master Plan Route Report.

Table 11.3.2 BENEFITS OF ML PROJECTS

(Unit: thousand Baht)

Project	VOC Savings		Time Savings		Total Benefits	
No.	2,000	2,008	2,000	2,008	2,000	2,008
ML-1	24,605	11,628	38,051	17,476	62,656	29,104
ML-2	14,436	28,268	57,785	87,295	72,221	115,563
ML-3	45,101	64,406	112,890	109,954	157,991	174,360
ML-4	42,755	65,300	108,972	141,345	151,727	206,645
ML-5	83,359	138,186	417,943	682,281	501,302	820,467
ML-6	27,134	38,761	46,388	44,525	73,522	83,286
ML-7	60,732	71,163	130,666	118,064	191,398	189,227
ML-8	31,721	46,854	73,597	91,498	105,318	138,352

Table 11.3.3 BENEFITS OF IM PROJECTS

(Unit: thousand Baht)

Project	VOC Savings		Time Savings		Total Benefits	
No.	2000	2008	2000	2008	2000	2008
IM-1	3,492	5,008	1,661	2,356	5,153	7,364
IM-2	33,401	46,634	2,428	3,425	35,829	50,059
IM-3	9,890	14,135	1,404	2,035	11,294	16,170
IM-4	12,530	18,264	901	1,332	13,431	19,586
IM-5	9,704	14,045	4,526	6,649	14,230	20,694
IM-8	10,293	14,719	960	1,405	11,253	16,124
IM-9	4,592	6,314	206	281	4,798	6,595
IM-10	19,782	27,855	8,203	11,614	27,985	39,469
IM-11	59,461	95,427	12,800	19,232	72,261	114,659
IM-12	27,143	43,405	6,721	10,188	33,864	53,593
IM-13	4,950	7,245	2,916	4,244	7,866	11,489
IM-14	18,060	25,587	3,029	4,360	21,089	29,947
IM-15	21,243	31,228	3,334	4,977	24,577	36,205
IM-16	38,731	61,312	3,729	5,937	42,460	67,249
IM-17	69,221	107,977	9,353	14,837	78,574	122,814
IM-18	9,747	13,699	2,493	3,624	12,240	17,323
IM-19	10,303	14,450	936	1,327	11,239	15,777
IM-20	45,310	67,030	6,420	9,908	51,730	76,938
IM-21	7,693	10,164	846	1,181	8,539	11,345
IM-22	12,035	18,128	3,755	5,633	15,790	23,761
IM-23	51,179	71,880	23,149	33,225	74,328	105,105

11.4 PRELIMINARY EVALUATION

For the purpose of determining a priority order for the projects, an economic evaluation was conducted using the conventional benefit/cost analysis and ranking then in terms of internal rate of return (IRR).

(1) Economic Costs

Economic costs consist of:

- Economic project cost (see 11.2.2).
- Overlay cost at the beginning of the 8th year after opening (see 11.2.2).
- Residual value at the end of the evaluation period of 15 years. This cost takes a negative value (see 11.2.2).

(2) Economic Benefits

Economic benefits consist of:

- Saving in VOCs (see 11.3.1).
- Saving in time (see 11.3.2).

(3) Results of Evaluation

The calculated economic evaluation indicators and ranking by IRR are summarized in Tables 11.4.1 to 11.4.4 by ML and IM Projects. The cost and benefit statement is shown separately in the Master Plan Route Report.

Table 11.4.1 SUMMARY OF ECONOMIC EVALUATION OF ML PROJECTS

Project No.	Construction Cost (thousand Baht)	NPV (thousand Baht)	B/C Ratio	IRR (%)
ML-1	93,940	247,854	3.16	32.7
ML-2	139,053	252,008	2.45	23.9
ML-3	236,830	711,051	3.38	32.8
ML-4	370,904	441,050	1.95	21.0
ML-5	447,526	2,806,572	6.34	43.4
ML-6	129,111	313,019	2.95	29.6
ML-7	350,662	792,267	2.97	29.1
ML-8	212,022	377,014	2.46	24.7

Table 11.4.2 SUMMARY OF ECONOMIC EVALUATION OF IM PROJECTS

Project No.	Construction Cost (thousand Baht)	NPV (thousand Baht)	B/C Ratio	IRR (%)
IM-1	11,327	71,745	2.08	26.6
IM-2	71,876	147,991	2.62	27.0
IM-3	66,249	-8,470	0.90	10.7
IM-4	67,255	2,060	1.02	12.3
IM-5	87,235	-4,529	0.95	11.5
IM-8	35,263	33,337	1.80	20.8
IM-9	36,295	-10,138	0.76	8.7
IM-10	103,185	59,686	1.48	17.0
IM-11	110,250	302,931	3.23	28.6
IM-12	148,821	73,341	1.54	13.8
IM-13	10,975	36,636	3.38	38.5
IM-14	58,589	71,355	2.03	23.0
IM-15	51,796	100,712	2.62	28.0
IM-16	68,397	202,931	3.42	31.1
IM-17	66,078	441,966	6.34	45.6
IM-18	56,635	-48,977	0.62	6.2
IM-19	58,723	3,913	1.06	12.7
IM-20	87,820	109,928	1.99	21.8
IM-21	34,733	15,764	1.38	16.7
IM-22	51,774	45,848	1.78	20.1
IM-23	79,490	398,262	5.04	40.7

Table 11.4.3 RANKING BY IRR OF ML PROJECTS

Ranking	Project No.	Origin - Destination	Length (km)	IRR (%)
1	ML-5	Chon Buri Pattaya New highway	48.8	43.4
2	ML-3	A.Sattahip - C.Rayong	48.8	32.8
3	ML-1	Chon Buri Bypass	13.8	32.7
4	ML-6	C.Ratchaburi - J.R.35	22.8	29.6
5	ML-7	A.Min Buri - C.Chachoengsao	41.0	29.1
6	ML-8	B.Bang Muang - a.Lat Lom Kaew	25.6	24.7
7	ML-2	M.Pattaya - A.Sattahip	27.3	23.9
8	ML-4	A.Klaeng - C.Chanthaburi	61.3	21.0

Table 11.4.4 RANKING BY IRR OF IM PROJECTS

Ranking	Project No.	Origin - Destination	Length (km)	IRR (%)
1	IM-17	A.Lat Krabang - B.Khlong Tha Thua	29.3	45.6
2	IM-23	J.R.32 - J.R.3022	26.5	40.7
3	IM-13	A.Bang Pa-in - C.Ayutthaya	16.2	38.5
4	IM-16	A.Lam Luk Ka - B.Khlong 16	20.8	31.1
5	IM-11	B.Channa Soot - A.Pho Thong	41.0	28.6
6	IM-15	B.Klong Luang - A.Min Buri	24.3	28.0
7	IM-2	B.Nong Pru - A.lao Khawn	36.0	27.0
8	IM-1	A.Bang Len - B.Bang Noi Nai	18.8	26.6
9	IM-14	A.Wng Noi - A.Thanyaburi	24.4	23.0
10	IM-20	B.Khlong Takhian - J.R.3322	44.5	21.8
11	IM-8	B.Khao Noi - B.Chang Ko Nok	16.8	20.8
12	IM-22	A.Nong Chok - A.Bang Nam Prieo	16.5	20.1
13	IM-12	A.Pho Thong - A.Sena	50.0	17.3
14	IM-10	B.Reng Sung - C.Lop Buri	34.8	17.0
15	IM-21	B.Nong Chang - J.R.3138	18.3	16.7
16	IM-19	A.Sa Kaeo - DOH Const. Office	27.3	12.7
17	IM-4	B.Thong Lang - A.Lan Sak	34.0	12.3
18	IM-5	A.Lan Sak - B.Kao Chonkhon	69.1	11.5
19	IM-3	B.Nong Ei Pang - A.Sam Chuk	33.6	10.7
20	IM-9	B.Dilang - B.Wang Phloeng	18.0	8.7
21	IM-18	C.Nakhon Nayok - A.Ban Sang	26.7	6.2

CHAPTER 12

PRELIMINARY EVALUATION OF PROJECTS FOR REHABILITATION

CHAPTER 12
PRELIMINARY EVALUATION OF PROJECTS FOR REHABILITATION

In Chapter 8, eight links of 206.8 km in total were selected as the projects for rehabilitation to be studied in the preliminary evaluation. They are shown in Table 8.2.1 and Figure 8.2.1.

12.1 FUTURE TRAFFIC ON PROJECT LINKS

Traffic forecast was carried out according to the procedure described in Section 11.1.

Forecasted ADTs are shown below:

TRAFFIC FORECAST ON RH PROJECTS

Route	Section	Base ADT		Future ADT		
		Year	ADT	1993	2000	2008
RH-1	1-1001	1986	1522	2304	3217	4658
RH-2	225-0100	1986	2215	3449	4559	5970
RH-3	325-0200	1986	4638	7172	10000	14797
RH-4	332-0100	1986	1484	2570	4585	7120
RH-5	344-0200	1986	5868	8767	12613	18460
RH-6	3089-0101	1986	4242	5897	7963	11279
RH-7	3116-0100	1986	2738	3807	5151	7304
RH-8	3395-0100	1986	634	888	1303	1911

Future traffic volumes by vehicle type are shown in Table 12.1.1.

Table 12.1.1 TRAFFIC FORECAST ON RH PROJECTS

Route	Section	Year	MC	PC	LB	HB	LT	MT	HT	ADT
RH-1	1-1001	1986	1056	686	97	108	319	198	114	1522
		1993	1056	1078	143	159	499	270	155	2304
		2000	2233	1566	202	225	660	358	206	3217
		2008	3232	2388	302	336	852	495	285	4658
RH-2	255-0100	1986	1279	1243	129	135	354	320	34	2215
		1993	1279	1922	190	199	656	436	46	3449
		2000	2640	2599	269	281	772	577	61	4559
		2008	3503	3320	401	419	946	800	84	5970
RH-3	325-0200	1986	1275	2132	779	393	780	317	237	4638
		1993	1275	3648	1202	561	1037	404	320	7172
		2000	2748	5233	1657	773	1371	537	429	10000
		2008	4066	8051	2424	1068	1931	728	595	14797
RH-4	332-0100	1986	461	449	172	84	366	206	207	1484
		1993	461	853	342	134	573	320	348	2570
		2000	1424	1611	481	234	969	568	722	4585
		2008	2211	2483	698	340	1536	896	1167	7120
RH-5	344-0200	1986	1255	1547	412	691	1810	467	941	5868
		1993	1255	2353	613	1037	2665	706	1393	8767
		2000	2747	3410	969	1349	3910	1038	1937	12613
		2008	4152	5221	1640	1791	5776	1495	2537	18460
RH-6	3089-0101	1986	546	486	110	90	1053	1475	1028	4242
		1993	546	756	162	133	1435	2010	1401	5897
		2000	1025	1121	230	188	1902	2665	1857	7963
		2008	1452	1760	342	280	2635	3690	2572	11279
RH-7	3116-0100	1986	705	222	336	2	560	1351	267	2738
		1993	705	345	494	3	763	1838	364	3807
		2000	1316	512	700	4	1011	2442	482	5151
		2008	1857	804	1045	6	1400	3382	667	7304
RH-8	3395-0100	1986	263	109	82	76	193	53	121	634
		1993	263	170	121	112	248	72	165	888
		2000	540	251	171	159	405	96	221	1303
		2008	793	395	255	236	587	133	305	1911

12.2 ENGINEERING AND COST ESTIMATES

12.2.1 Engineering Survey

As described in Chapter 7, the following surveys were conducted to select priority links. The results were also applied to the preliminary design of the proposed projects.

- PSI survey (Appendix 7.2.1)
- Deflection survey (Appendix 7.2.1)
- Supporting capacity survey (Appendix 7.2.2)

12.2.2 Traffic Loading Analysis

The damage to road pavement caused by vehicles depends mainly on the magnitude of individual wheel loads and on the number of times that these loads are applied.

For rehabilitation design, the wheel loads of vehicles converted to equivalent standard 8,200 kg axle loads (ESA) were adopted based on an analysis of gross vehicle weight distribution and conversion factors of axle loads.

Only heavy vehicles such as 6-wheel trucks (MT), 10-wheel trucks (HT) and heavy buses (HB) were taken into consideration in the analysis of rehabilitation design, since loads imposed by light weight cars do not have a significant effect on the structural damage of pavement.

1) Future Traffic Volumes of Heavy Vehicles

From the future traffic volumes projected in Section 12.1, traffic volumes of heavy vehicles were selected for a 19-year period from 1990 to 2008 for each proposed project link.

2) Gross Vehicle Weight Distribution

Interviews with drivers on actual loading weights of MT, HT and HB were conducted at the 10 O/D survey points described in Section 5.2.

The gross vehicle weight distribution was calculated for each vehicle type based on the above survey.

3) Axle Load and ESA Conversion Factors

The shares of front axle and rear axle loads to the gross vehicle weight were surveyed on MT and HT by DOH. The shares of axle loads for heavy buses, however, was assumed to be the same as that of MT because there was no data available. Front and rear axle loads were calculated for each gross vehicle weight using the above shares.

The equivalent factors to ESA prepared in AASHTO Guide 1986 were applied. They are shown in Appendix 12.2.1.

The application was made on the following conditions:

- Pavement structural number (SN) = 2.0
- Terminal serviceability value (Pt) = 2.0
- Rear axle of HT is tandem and all other axles are single.

ESA conversion factors for MT, HT and HB were calculated as shown in Table 12.2.1 based on the equivalent factors to ESA, the share of axle load and the gross vehicle weight distribution. The ESA conversion factors thus determined are as follows:

ESA CONVERSION FACTORS

MT	HT	HB
0.63	1.58	0.60

Table 12.2.1(1) ESA CONVERSION FACTORS

MT

Gross Weight (ton)	Axle Load (ton)		Equivalence Factor			Frequency	ESA
	Front	Rear	Front	Rear	Total	(%)	Factor
4	1.68	3.32	0.0024	0.006	0.0084	43.28	0.364
5	1.95	3.05	0.0036	0.015	0.0186	8.14	0.151
6	2.16	3.84	0.0048	0.038	0.0428	9.54	0.408
7	2.38	4.62	0.0065	0.085	0.0915	9.85	0.901
8	2.56	5.44	0.0082	0.183	0.1912	7.23	1.382
9	2.75	6.25	0.0103	0.335	0.3453	6.26	2.162
10	2.90	7.10	0.0125	0.550	0.5625	5.18	2.913
11	3.08	7.92	0.0157	0.870	0.8857	3.02	2.675
12	3.24	8.76	0.0190	1.350	1.3690	2.33	3.190
13	3.45	9.55	0.0250	2.000	2.0250	0.51	1.033
14	4.64	10.36	0.0300	2.900	2.9300	0.85	2.491
15	3.77	11.23	0.0350	4.150	4.1850	0.40	1.674
16	3.87	12.13	0.0400	6.000	6.0400	1.20	7.248
17	4.01	12.99	0.0450	8.300	8.3450	1.37	11.433
18	4.14	13.86	0.0530	11.100	11.1530	0.23	2.565
19	4.33	14.67	0.0640	14.200	14.2640	0.17	2.425
20	4.52	15.48	0.0780	18.200	18.2780	0.00	0.000
21	4.62	16.38	0.0870	23.400	23.4870	0.00	0.000
22	4.84	17.16	0.1000	30.700	30.8000	0.00	0.000
23	5.06	17.94	0.1220	37.000	37.1220	0.06	2.122
24	5.28	18.72	0.1470	44.800	44.9470	0.06	2.697
25	5.50	19.50	0.1810	53.400	53.5810	0.28	15.003
Total						100.00	62.837
Factor							0.63

Table 12.2.1(2) ESA CONVERSION FACTORS

HT

Gross Weight (ton)	Axle Load (ton) Front	Rear	Equivalence Factor Front	Rear	Total	Frequency (%)	ESA Factor
8	2.83	5.17	0.0115	0.0158	0.0270	39.74	1.073
9	2.98	6.02	0.0138	0.027	0.0410	1.41	0.058
10	3.08	6.92	0.0158	0.044	0.0600	0.97	0.058
11	3.18	7.82	0.0178	0.067	0.0850	1.13	0.096
12	3.24	8.76	0.0188	0.103	0.1220	1.02	0.124
13	3.32	9.68	0.0205	0.153	0.1740	1.10	0.191
14	3.36	10.64	0.0220	0.220	0.2420	1.04	0.252
15	3.41	11.59	0.0230	0.310	0.3330	1.93	0.643
16	3.42	12.58	0.0230	0.430	0.4530	2.06	0.933
17	3.45	13.55	0.0240	0.600	0.6240	1.36	0.849
18	3.46	14.54	0.0240	0.820	0.8440	6.25	5.275
19	3.48	15.52	0.0250	1.100	1.1250	3.33	3.746
20	3.48	16.52	0.0250	1.410	1.4350	7.66	10.992
21	3.51	17.49	0.0260	1.800	1.8260	19.08	34.821
22	3.52	18.48	0.0260	2.350	2.3760	2.34	5.560
23	3.54	19.46	0.0265	3.000	3.0270	0.84	2.543
24	3.55	20.45	0.0270	3.800	3.8270	0.35	1.339
25	3.60	21.40	0.0290	4.600	4.6290	0.45	2.083
26	3.64	22.36	0.0300	5.700	5.7300	0.71	4.068
27	3.73	23.27	0.0330	6.800	6.8330	0.45	3.075
28	3.81	24.19	0.0360	8.000	8.0360	1.36	10.929
29	3.86	25.14	0.0390	9.400	9.4390	3.29	31.054
30	3.90	26.10	0.0400	11.200	11.2400	0.22	2.473
31	3.94	27.06	0.0430	13.000	13.0430	0.32	4.177
32	3.97	28.03	0.0540	16.200	16.2540	0.41	6.664
33	4.03	28.97	0.0600	19.000	19.0600	0.76	14.486
34	4.08	29.92	0.0650	22.000	22.0650	0.22	4.854
35	4.17	30.83	0.0700	25.000	25.0700	0.04	1.003
36	4.25	31.75	0.0750	28.500	28.5750	0.04	1.114
37	4.44	32.56	0.0770	30.600	30.6770	0.02	0.614
38	4.56	33.44	0.0840	36.400	36.4840	0.09	3.284
Total						100.00	158.161
Factor							1.58

Table 12.2.1(3) ESA CONVERSION FACTORS

HB

Gross Weight (ton)	Axle Load (ton) Front	Rear	Equivalence Factor Front	Rear	Total	Frequency (%)	ESA Factor
7	2.38	4.62	0.0065	0.085	0.0915	0	
8	2.56	5.44	0.0082	0.183	0.1912	5.30	1.013
9	2.75	6.25	0.0103	0.335	0.3453	29.39	10.148
10	2.90	7.10	0.0125	0.550	0.5625	40.86	22.984
11	3.08	7.92	0.0157	0.870	0.8857	17.74	15.712
12	3.24	8.76	0.0190	1.350	1.3690	6.09	8.337
13	3.45	9.55	0.0250	2.000	2.0250	0.62	1.271
14	4.64	10.36	0.0300	2.900	2.9300		
Total						100.00	59.465
Factor							0.60

4) Cumulative Number of ESA

Based on the ESA conversion factors, traffic volumes of heavy trucks, cumulative numbers of ESA were calculated for the project links as shown in Appendix 12.2.2.

12.2.3 Preliminary Design

In order to design overlay and reconstruction for the project links, the following design methods were applied:

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

1) Criteria for Rehabilitation

The Present Serviceability Index (PSI) developed in the AASHTO Road Test is widely applied to assess pavement conditions and rehabilitation requirements.

PSI is presented in five ranking classes from 0 (impassable road) to 5 (perfect road). The lowest allowable PSI used as criteria for rehabilitation is determined based on the lowest index that can be tolerated before rehabilitation becomes necessary.

Between actual surface conditions and measured PSIs, the following relationships were observed from the pavement surface condition surveys conducted in this study:

RELATIONSHIP BETWEEN SURFACE CONDITION AND PSI VALUE

PSI	Surface Condition	Possible Driving Speed (km/h)
2.5-3.0	Tolerable	More than 80
2.0	Tolerable but somewhat deteriorated	50
1.5	Deteriorated	20-30

AASHTO recommends that the lowest allowable PSI for major highways be 2.5 to 3.0. However, this value was assessed tolerable in observation of this study as described above. Considering the constraints on the DOH budget for rehabilitation, AASHTO's value was considered somewhat severe. Therefore, it was decided that a PSI value of 2.0 should be the threshold value for immediate road rehabilitation for all road classes.

2) Design Period

In DOH, pavements are in practice designed on condition that the design period is seven years. In this study, therefore, this period was also applied for rehabilitation design.

3) Rehabilitation Design by AASHTO Guide 1986 Method

a) Design Method

- Basic Design Equation for Flexible Pavements

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.29}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where,

- W_{18} : Predicted number of 18-kip equivalent single axle load applications.
- Z_R : Standard normal deviate.
- So : Combined standard error of traffic prediction and performance prediction.
- PSI : Difference between initial design serviceability index (Po) and design terminal serviceability index (Pt)
- M_R : Resilient moduls (psi)
- SN : Structural number

The design monograph to solve the equation is prepared in the AASHTO Guide 1986 as shown in Figure 12.2.1. In this study, however, a computer program was developed to analyze the equation.

- Determination of Layer Thickness of Initial Pavement Structure

The design Structural Number (SN) for an initial pavement structure obtained by the above equation is converted into actual thickness of surface, base and subbase courses by applying the following equation:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where,

a_1, a_2, a_3 : layer coefficients representative of surface, base and subbase course, respectively

D_1, D_2, D_3 : actual thickness (in inches) of surface, base and subbase courses, respectively

m_2, m_3 : drainage coefficients for base and subbase layers, respectively

- Determination of Overlay Thickness

The basic equation to obtain the SN of required overlay is as follows:

$$SNol = SNy - (F_{RL} \times SNxeff)$$

where,

SNol : Structural number of required asphalt concrete overlay

SNy : Structural number required for new pavement

F_{RL} : Remaining life factor

SNxeff $Cx \times SNo$ effective structural number of existing pavement at time overlay is placed

Cx : Condition value

SNo : Initial structural number of existing pavement

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R * S_o + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$

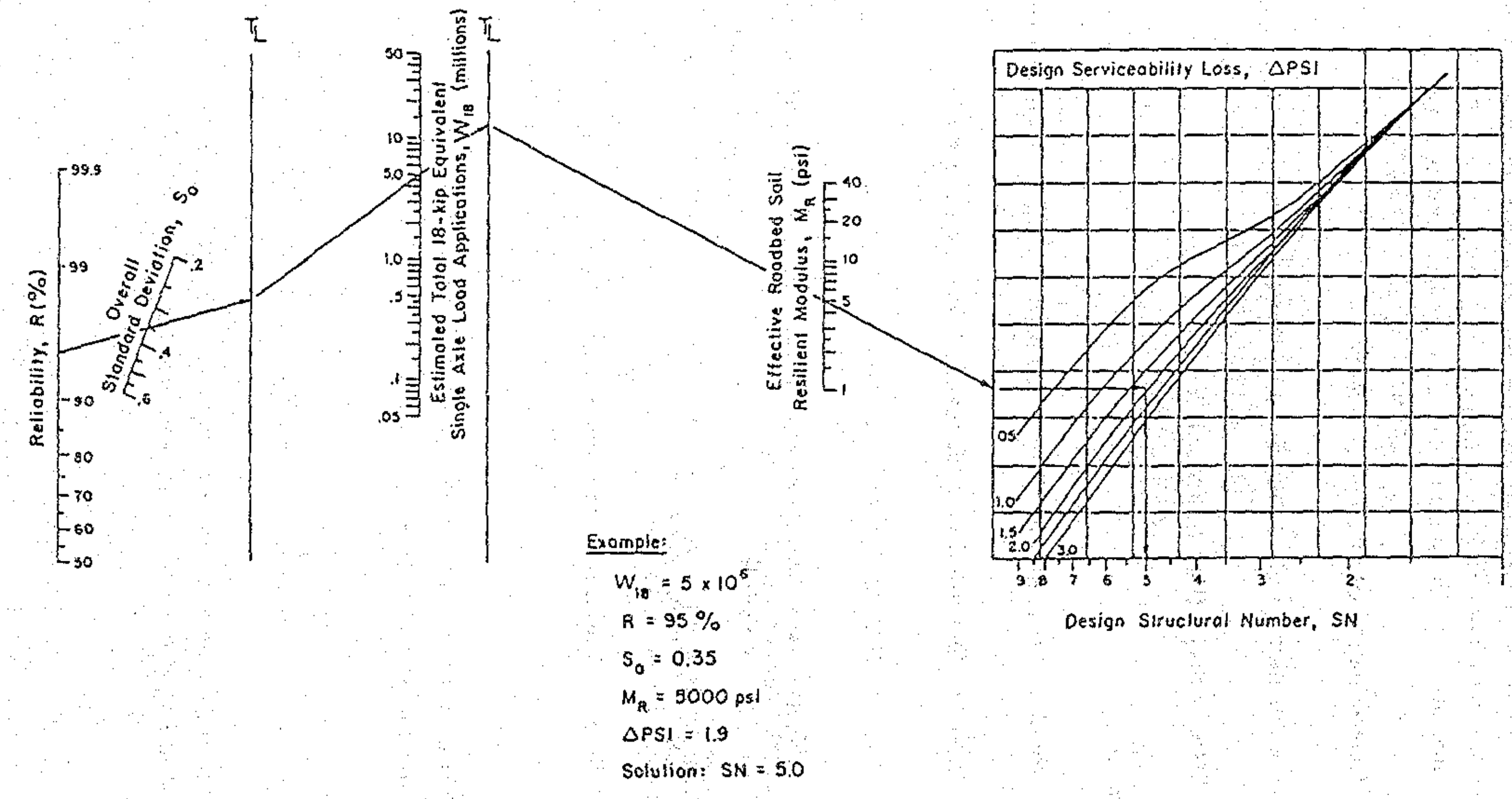


Figure 12.2.1 DESIGN CHART FOR FLEXIBLE PAVEMENT (AASHTO GUIDE 1986)

b) **Applied Design Variables**

W_{18} = Cumulative number of ESA for 7 years from 1990 to 1996 (refer to Appendix 12.2.2)

Z_R and So = These express standard normal deviate errors of traffic prediction and performance prediction. These were disregarded in this study.

ΔPSI = Initial design serviceability index (Po) of 4.6 and terminal design serviceability index (Pt) of 2.0 were selected. So ΔPSI is 2.6.

Mr (Psi) = 500 × CBR (refer to Appendix 7.2.2). This relationship is described in the AASHTO Guidelines. Seasonal effects, however, were disregarded in this study.

a_1, a_2 and a_3 = They were estimated using the figures in Appendix 12.2.3 as follows:

STRUCTURAL LAYER COEFFICIENT

Layer Material	Layer Coefficient	Remark
AC	0.45	E = 450,000 Psi (at 20°C)
UPM	0.29	E = 200,000 Psi (at 20°C)
DBST, SST	0.19	E = 100,000 Psi (at 20°C)
Base Course	0.13	Crushed Stone (CBR = 80)
Subbase	0.09	Soil Aggregate (CBR = 20)

m_2 and m_3 = These were disregarded in this study.

Cx = This determined only by NDT deflection. However, this was estimated from Appendix 12.2.4.
Applied Cxs and SNxeffs are shown in Table 12.2.2.

F_{RL} = This was disregarded in this study.

Table 12.2.2 ESTIMATED C_X AND SN_{XEFF}

Propose Route No.	Pavement Structure Layer	Thickness of Layer cm.	in.	Layer Cofficient	Initial Capacity	Structure Condition Value	Effective Capacity SNxeff.
RH-1	UPM	5	2	0.29	0.58	0.70	
						0.95	0.41
	Base Course	15	6	0.13	0.78	0.60	0.74
						0.95	0.51
	Sub Base	15	6	0.09	0.54	0.60	0.32
							1.66
	Total	35	-	-	1.90	-	1.20
RH-2	DBST	2.5	1	0.19	0.19	0.70	0.13
						0.95	0.74
	Base Course	15	6	0.13	0.78	0.60	0.47
						0.95	0.51
	Sub Base	15	6	0.09	0.54	0.60	0.32
							1.38
	Total	32.5	-	-	1.51	-	0.92
RH-3	DBST	2.5	1	0.19	0.19	0.70	0.13
	Base Course	15	6	0.13	0.78	0.95	0.74
	Sub Base	15	6	0.09	0.54	0.95	0.51
	Total	32.5	-	-	1.51	-	1.38
RH-4	DBST	2.5	1	0.19	0.19	0.70	0.13
						0.95	0.74
	Base Course	15	6	0.13	0.78	0.60	0.47
						0.95	0.34
	Sub Base	10	4	0.09	0.36	0.60	0.22
							1.21
	Total	27.5	-	-	1.33	-	1.08
RH-5	AC	5	2	0.45	0.90	0.70	0.63
						0.95	0.74
	Base Course	15	6	0.13	0.78	0.60	0.47
						0.95	0.51
	Sub Base	15	6	0.09	0.54	0.60	0.32
							1.81
	Total	35	-	-	2.22	-	1.35
RH-6	DBST	2.5	1	0.19	0.19	0.70	0.13
	Base Course	15	6	0.13	0.78	0.95	0.74
	Sub Base	15	6	0.09	0.54	0.95	0.51
	Total	32.5	-	-	1.51	-	1.38
RH-7	DBST	2.5	1	0.19	0.19	0.70	0.13
						0.95	0.74
	Base Course	15	6	0.13	0.78	0.60	0.47
						0.95	0.51
	Sub Base	15	6	0.09	0.54	0.60	0.32
							1.38
	Total	32.5	-	-	1.51	-	0.92
RH-8	DBST	2.5	1	0.19	0.19	0.70	0.13
						0.95	0.74
	Base Course	15	6	0.13	0.78	0.60	0.47
						0.95	0.51
	Sub Base	15	6	0.09	0.54	0.60	0.32
							1.38
	Total	32.5	-	-	1.51	-	0.92

4) Rehabilitation Design by DOH Method

The following procedures were taken to determine overlay thickness:

- Based on cumulative wheel loads (8.162t), the allowable deflection was derived from Figure 12.2.2. The DOH adopts a critical design line of a two-inch AC surface to determine the allowable deflection.

- percent reduction in deflection was calculated by the following formula:

$$\text{Percent reduction} = \frac{\text{Design Deflection-Allowable Deflection}}{\text{Design Deflection}} \times 100$$

- From Figure 12.2.3, the thickness to be increased in gravel equivalent was derived by applying the percent reduction in deflection.

- Required overlay thickness was calculated by transforming the increase in gravel equivalent to different layers of new surface by using the following conversion factors:

  - Thickness of asphalt concrete = 0.5 times gravel equivalent
  - Thickness of base = Thickness of gravel equivalent
  - Thickness of subbase = 1.5 times gravel equivalent
  - Thickness of subgrade = 2.0 times gravel equivalent

Deflections of existing pavement applied for design are shown in Appendix 7.2.2.

5) Design of Overlay and Reconstruction

Based on the criterion for rehabilitation previously established, sections with PSI value of 2.0 or less were taken as those for study.

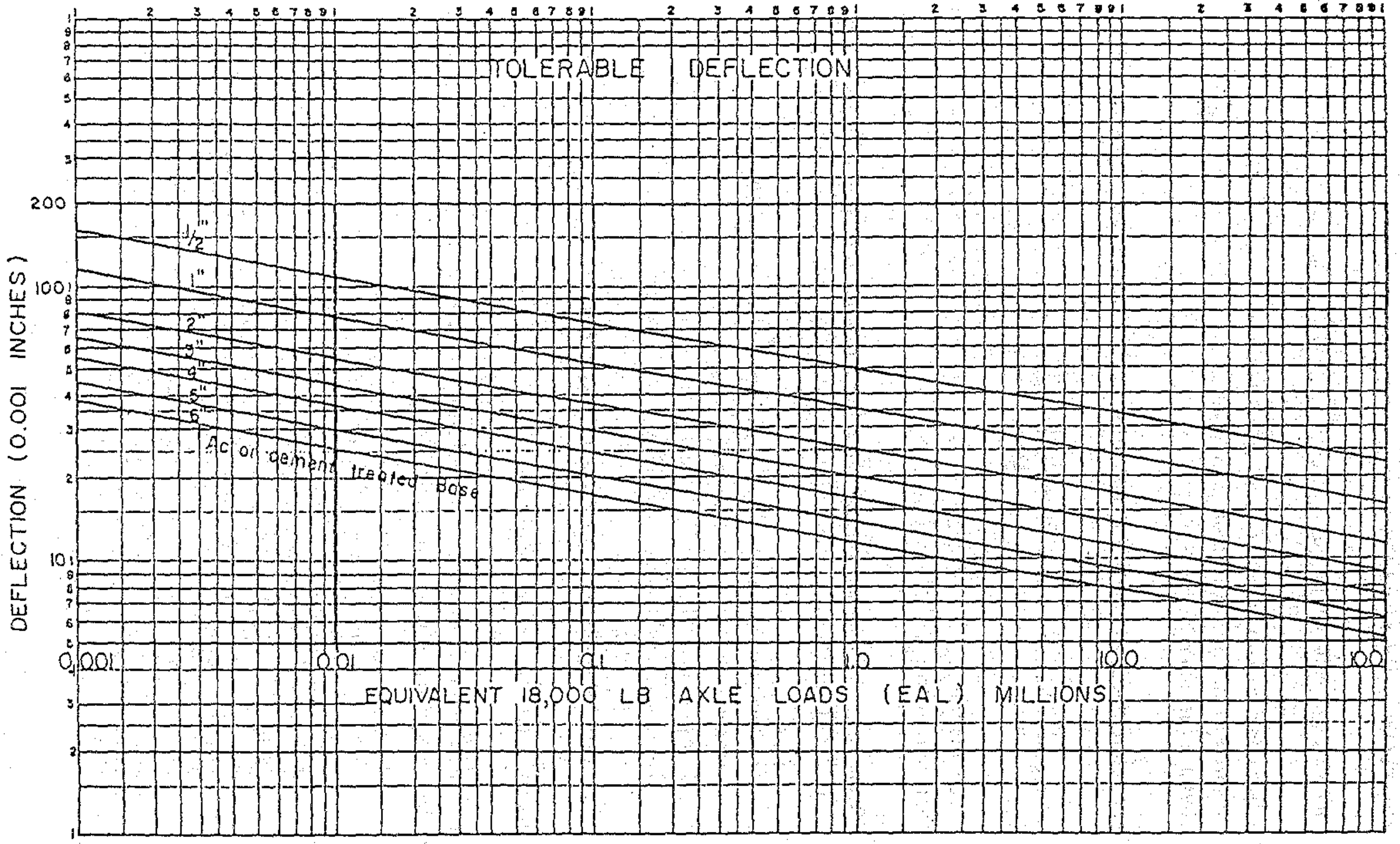


Figure 12.2.2 TOLERABLE DEFLECTION CURVE (DOH METHOD)

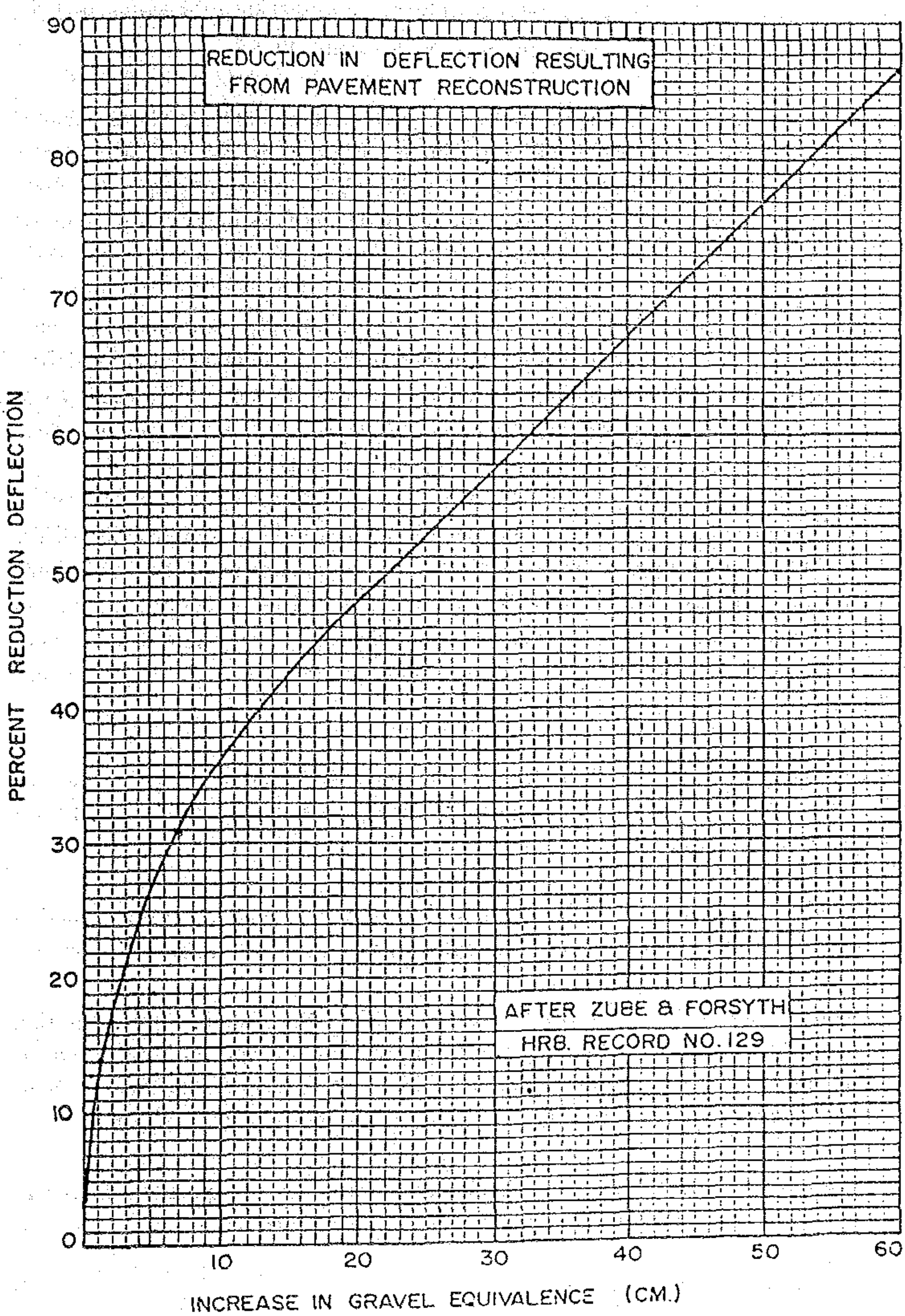


Figure 12.2.3. RELATIONSHIP BETWEEN REDUCTION DEFLECTION AND GRAVEL EQUIVALENCE (DOH METHOD)

Overlay thickness computation was carried out for all sections against the above criterion at every one-km interval. The results are shown in Appendix 12.2.5.

Application of two design methods, the AASHTO Guide-1986 and DOH Methods, resulted in significant differences in overlay requirement. On the one hand, the AASHTO Guide-1986 required a relatively thick overlay for all subject sections. This was because the subject sections were selected based on PSI and P included as a design variable in the design equation of this method.

On the other hand, the DOH Method required an overlay for only 3 km section in total, 2 km in RH-5 and 1 km in PH-8. Since the thickness of overlay is determined based on deflection of existing pavement and cumulative number of ESA in this method, no overlay was required for sections with low deflection and low cumulative number of ESA even where the existing surface was almost destroyed (less than 2.0 of PSI).

Sections to be rehabilitated should basically be selected based on the serviceability of the pavement, which can be expressed in terms of PSI. The strength of pavement, which may be expressed by deflection or CBR values, cannot be the final determinant in selecting sections to be rehabilitated, since the main purpose of pavement is to ensure a smooth and comfortable passage traffic. Only pavement surface conditions directly affect traffic passage conditions.

Therefore, the AASHTO Guide-1986 Method was thought to be more reasonable than the DOH Method, and the rehabilitation designs were made based on the results derived form the AASHTO Guide-1986 Method.

- Overlay = Thickness of overlay at units of 5 mm was determined at every one-km interval according to the thickness computed by the AASHTO Guide-1986 Method.

- Reconstruction = For sections with PSI values of 1.5 or less and sections requiring overlay thickness of more than 120 mm, reconstruction was applied. New pavement structures for reconstruction were designed by the AASHTO Guide 1986 Method. Recommended pavement structural components are shown in Figure 12.2.4.

Consequently, as shown in Table 12.2.3, rehabilitation measures were required for links with 171.2 km in total, 116.0 km for overlay and 55.2 km for reconstruction.

12.2.4 Construction Quantities and Costs

1) Construction Quantities

Based on typical cross sections of rehabilitation work obtained from overlay and reconstruction designs, construction quantities were calculated. They are given in Appendix 12.2.6.

2) Construction Costs

Construction unit rates were established, based on the latest bidding rates for similar projects in Thailand. This is shown in Table 12.2.4.

The following costs for miscellaneous works, physical contingencies and design/supervision are added to the direct construction cost as follows:

Miscellaneous = 7% of construction cost of major work items
Physical contingency = 10% of direct construction cost
Engineering and Supervision = 10% of direct construction cost

Construction costs by project link are summarized in Table 12.2.5, and detailed figures are given in Appendix 12.2.6.

RH-1

REQUIRED SN = 2.78

	THICKNESS	SN
A.C.	10 CM.	1.80
BASE	10 CM.	0.52
SUBBASE	15 CM.	0.54
TOTAL	35 CM.	2.86

RH-2

REQUIRED SN = 2.75

	THICKNESS	SN
A.C.	10 CM.	1.80
BASE	10 CM.	0.52
SUBBASE	15 CM.	0.54
TOTAL	35 CM.	2.86

RH-3

REQUIRED SN = 3.11

	THICKNESS	SN
A.C.	10 CM.	1.80
BASE	15 CM.	0.78
SUBBASE	15 CM.	0.54
TOTAL	40 CM.	3.12

RH-4

REQUIRED SN = 2.30

	THICKNESS	SN
A.C.	5 CM.	0.90
BASE	15 CM.	0.78
SUBBASE	20 CM.	0.72
TOTAL	40 CM.	2.40

RH-5

REQUIRED SN = 2.81

	THICKNESS	SN
A.C.	10 CM.	1.80
BASE	10 CM.	0.52
SUBBASE	15 CM.	0.54
TOTAL	35 CM.	2.86

RH-6

REQUIRED SN = 3.35

	THICKNESS	SN
A.C.	10 CM.	1.80
BASE	20 CM.	1.04
SUBBASE	15 CM.	0.54
TOTAL	45 CM.	2.38

RH-7

REQUIRED SN = 3.51

	THICKNESS	SN
A.C.	10 CM.	1.80
BASE	20 CM.	1.04
SUBBASE	20 CM.	0.72
TOTAL	50 CM.	3.56

RH-8

REQUIRED SN = 2.18

	THICKNESS	SN
A.C.	5 CM.	0.90
BASE	15 CM.	0.78
SUBBASE	15 CM.	0.54
TOTAL	35 CM.	2.22

Figure 12.2.4 RECOMMENDED PAVEMENT STRUCTURAL COMPONENTS FOR RECONSTRUCTION

Table 12.2.3 SUMMARY OF REHABILITATION WORKS

Project No.	Link No.	Link Length (km)	Length to be Rehabilitated	
			Overlay	Reconstruction
RH-1	1-1001	25.5	11.0 (t=65mm) 6.0 (t=90mm)	-
RH-2	225-0100	38.3	27.0 (t=75mm) 1.0 (t=95mm)	6.0
RH-3	325-0200	18	8.0 (t=100mm)	5.0
RH-4	332-0100	14.5	11.0 (t=60mm) 2.0 (t=75mm)	-
RH-5	344-0200	39.5	27.0 (t=55mm) 1.0 (t=80mm)	2.0
RH-6	3089-0101	27.8	16.0 (t=110mm)	5.0
RH-7	3116-0100	9.7	-	9.7
RH-8	3395-0100	33.5	1.0 (t=45mm) 5.0 (t=70mm)	27.5
Total		206.8	116.0	55.2

Table 12.2.4 UNIT RATES FOR MAJOR WORK ITEMS

Item		Unit	Financial Unit Rate Baht
Selected Material		m3	180
Removal of Existing Pavement Structure		m3	60
Subbase Soil Aggregate		m3	220
Base Course Crushed Stone		m3	350
Asphalt Concrete	t = 4.5cm	ton	86
Asphalt Concrete	t = 5.0cm	ton	95
Asphalt Concrete	t = 5.5cm	ton	105
Asphalt Concrete	t = 6.0cm	ton	114
Asphalt Concrete	t = 6.5cm	ton	124
Asphalt Concrete	t = 7.5cm	ton	143
Asphalt Concrete	t = 8.0cm	ton	152
Asphalt Concrete	t = 9.0cm	ton	171
Asphalt Concrete	t = 9.5cm	ton	180
Asphalt Concrete	t = 10.0cm	ton	190
Asphalt Concrete	t = 11.0cm	ton	209
Prime Coat		m2	12
Tack JCoat		m2	8
Shoulder Soil Aggregate		m3	250

Table 12.2.5 SUMMARY OF COSTS (RH PROJECTS)

(Thousand Baht)

Route No.	Link Length (km)	Length to be Rehabilitated (km)	Financial Cost	Average Cost (per km)	Economic Cost
RH-1	25.5	17.0	24,057	1,415	18,152
RH-2	38.3	34.0	44,986	1,323	33,944
RH-3	18.0	13.0	27,552	2,119	20,789
RH-4	14.5	13.0	12,597	969	9,505
RH-5	39.5	30.0	37,832	1,261	28,545
RH-6	27.8	21.0	42,768	2,037	32,270
RH-7	9.7	9.7	27,712	2,857	20,910
RH-8	33.5	33.5	59,051	1,763	44,557
TOTAL	206.8	171.2	276,555		208,672

12.3 BENEFITS ESTIMATION

The main benefits accruing from pavement rehabilitation are VOC savings and time savings. They were estimated by applying the VOC and time values described in Sections 11.3.1 and 11.3.2. Travel speed on existing roads was determined considering the relationship between PSI and travel speed.

Benefits were calculated for seven years after the completion of rehabilitation work.

The results of calculation of benefits by project are summarized in Table 12.3.1 and shown in Appendix 12.3.1 in detail.

Table 12.3.1 BENEFITS OF REHABILITATION PROJECT

(Unit: thousand Baht)

Project	VOC Savings		Time Savings		Total Benefits	
	1990	1996	1990	1996	1990	1996
RH-1	11,867	16,706	6,626	9,465	18,493	26,171
RH-2	42,828	56,705	28,011	38,180	70,839	94,885
RH-3	31,857	44,719	30,277	42,445	62,134	87,164
RH-4	7,722	16,070	4,416	8,365	12,138	24,435
RH-5	81,037	117,093	59,026	81,809	140,063	198,902
RH-6	52,267	70,694	20,569	28,554	72,836	99,248
RH-7	18,109	24,444	8,784	12,151	26,893	36,595
RH-8	26,904	39,848	40,602	59,652	67,506	99,500

12.4 PRELIMINARY EVALUATION

Economic evaluation for the project roads was conducted by means of the conventional benefit/cost analysis.

The calculated IRRs are shown in Table 12.4.1 and the cost and benefit statements in Appendix 12.4.1

Table 12.4.1 RANGING BY IRR OF RH PROJECTS

Ranking	Project	Link No.	Length (km)	IRR (%)
1	RH-5	344 0200	39.5	181.1
2	RH-3	325 0200	18.0	133.9
3	RH-6	3089 0101	27.8	111.8
4	RH-2	225 0100	38.3	106.1
5	RH-8	3395 0100	33.5	87.1
6	RH-4	332 0100	14.5	82.4
7	RH-7	3116 0100	9.7	77.0
8	RH-1	1 1001	25.5	65.9

CHAPTER 13

CONCLUSION AND RECOMMENDATION

CHAPTER 13
CONCLUSION AND RECOMMENDATION

13.1 SELECTION OF PROPOSED PROJECTS FOR FEASIBILITY STUDY

13.1.1 ML Projects

As described in Chapter 11, eight projects with 288.8 km in total length were evaluated in terms of IRR as shown in Table 13.1.1:

Table 13.1.1 RANKING BY IRR OF ML PROJECTS

Ranking	Project No.	Origin — Destination	Length (km)	IRR (%)
1	ML-5	Chon Buri-Pattaya New Highway	48.8	43.4
2	ML-3	A. Sattahip - C. Rayong	48.8	32.8
3	ML-1	Chon Buri Bypass	13.8	32.7
4	ML-6	C. Ratchaburi - J.R.35	22.8	29.6
5	ML-7	A. Min Buri - C. Chachoengsao	41.0	29.1
6	ML-8	B. Bang Muang - A. Lat Lum Khaew	25.6	24.7
7	ML-2	M. Pattaya - A. Sattahip	27.3	23.9
8	ML-4	A. Klaeng - C. Chanthaburi	61.3	21.0
Total	8 projects		288.8	

The results indicate that all projects are feasible enough for early implementation.

Among them, projects related to the Eastern Seaboard Development Program, which is a key target of the Sixth Plan: ML-5, ML-3, ML-1, ML-7 and ML-2, were selected as proposed projects for feasibility study.

Although unrelated to the above Program, ML-4 was additionally selected because of its importance as being the only trunk highway leading to the eastern area along the Gulf of Thailand.

13.1.2 IM Projects

As described in Chapter 11, 21 projects with 629.9 km in total length were evaluated in terms of IRR as shown in Table 13.1.2:

Table 13.1.2 RANKING BY IRR OF IM PROJECTS

Ranking	Project No.	Origin - Destination	Length (km)	IRR (%)
1	IM-17	A. Lat Krabang - B. Khlong Tha Thua	29.3	45.6
2	IM-23	J.R.32 - J.R. 3022	26.5	40.7
3	IM-13	A. Bang Pa-In - C. Ayutthaya	16.2	38.5
4	IM-16	A. Lam Luk Ka - B. Khlong 16	20.8	31.1
5	IM-11	B. Channasut - A. Pho Thong	41.0	28.6
6	IM-15	B. Khlong Luang - A. Min Buri	24.3	28.0
7	IM-2	B. Nong Pru - A. Lao Khwan	36.0	27.0
8	IM-1	A. Bang Len - B. Bang Noi Nai	18.8	26.6
9	IM-14	A. Wang Noi - A. Thanyaburi	24.4	23.0
10	IM-20	B. Khlong Takhian - J.R.3322	44.5	21.8
11	IM-8	B. Khao Noi - B. Chang Ko Nok	16.8	20.8
12	IM-22	A. Nong Chok - A. Bang Nam Prieo	16.5	20.1
13	IM-12	A. Pho Thong - A. Sena	50.0	17.3
14	IM-10	B. Reng Sung - C. Lop Buri	34.8	17.0
15	IM-21	B. Nong Chang - J.R.3138	18.3	16.7
16	IM-19	A. Sa Kaeo - DOH Const. Office	27.3	12.7
17	IM-4	B. Thong Lang - A. Lan Sak	34.0	12.3
18	IM-5	A. Lan Sak - B. Kao Chonkhon	69.1	11.5
19	IM-3	B. Nong Ei Pang - A. Sam Chuk	33.6	10.7
20	IM-9	B. Dilang - B. Wang Phloeng	18.0	8.7
21	IM-18	C. Nakhon Nayok - A. Ban Sang	26.7	6.2
Total	21	projects	626.9	

Among them, projects for the feasibility study were selected by applying the following principles:

- To follow basically the ranking order of IRR
- To apply a threshold IRR of 12%, which has usually been adopted in various studies in Thailand
- To consider the possible number of projects to be implemented during the 6th Highway Plan

By the first two criteria, the projects up to the 17th rank of IRR can be selected. However, 11 projects were finally selected considering the remaining budget in the 6th Highway Plan applicable to projects selected in the Study in the 6th Highway Plan.

Following the ranking order of IRR, IM-20 of the 10th rank and IM-8 of the 11th rank ought to be selected. However, they were replaced by IM-22 of the 12th rank and IM-12 of the 13th rank after a discussion with DOH. The reasons are as follows:

- IM-22, connecting Rts. 304 and 3124, is to be an effective shortcut linking the north-eastern area in the Region with Bangkok.

- IM-12 is to be an arterial provincial road along the west bank of the Chao Phya River in the central area of the Region by linking with IM-11. This was included in the project for the feasibility study.

While IM-22 and IM-12 have regional importance, IM-20 and IM-8 mainly play a local role in the area concerned.

13.1.3 RH Projects

As described in Chapter 12, eight links with 206.8 km in total were evaluated in terms of IRR as shown in Table 13.1.3:

Table 13.1.3 RANKING BY IRR OF RH PROJECTS

Ranking	Project No.	Link No.	Route No	Length (km)	IRR (%)
1	RH-5	0200	344	39.5	181.1
2	RH-3	0200	325	18.0	133.9
3	RH-6	0101	3089	27.8	111.8
4	RH-2	0100	225	28.3	106.1
5	RH-8	0100	3395	33.5	87.1
6	RH-4	0100	332	14.5	82.4
7	RH-7	0100	3116	9.7	77.0
8	RH-1	1001	1	25.5	65.9
Total	8 projects			206.8	

In the selection of the proposed projects for the feasibility study, priority was put on national highways in view of their importance, and the ranking order of IRR was respected.

As a result, projects of national highways up to the 3rd rank of IRR were selected as proposed projects for the feasibility study.

RH-4 (Rt.332) was omitted, since it was judged that urgent implementation was not required because an adjacent national highway (Rt. 3) was picked as two of the selected ML Projects (ML-2 and ML-3).

RH-1 (Rt. 1) was also omitted. This section is still a part of Rt. 1. However, it has not been functioning as a national highway recently because the majority of through traffic has been diverted to Rt. 32 which is a shortcut to the Northern Region.

13.1.4 Project Phasing in Feasibility Study

Proposed projects for the feasibility study selected in the previous sections were classified into 2 groups: Phase I Projects and Phase II Projects as follows:

Phase I Projects: This group is composed of projects for which early implementation is required. Their feasibility studies were requested to finish well before the end of the Study.

Phase II Projects: This group is composed of the remaining projects. Their feasibility studies were to finish by the end of the Study.

Through a series of discussions with DOH, high priority was given to ML Projects especially related to the Eastern Seaboard Development Program in the light of the development policies of the Thai Government. As a result, ML-5, ML-1, ML-7 and ML-2 were picked as Phase I Projects. The remaining IM Projects and RH Projects were classified into Phase II Projects.

However, there were some exceptions. Although ML-3 is related to the Eastern Seaboard Development Program, it was replaced by ML-4, because it was judged form its location that ML-3 is not as urgent as other ML Projects picked. On the other hand, ML-4 is very important since it is the only trunk highway connecting the eastern area in the Central Region.

Only IM-23 was selected as a Phase I Project among IM Projects, because it was judged to require urgent improvement because of the deterioration of its pavement.

The Study Team recommended that, a new road directly linking Bangkok with the area related to the Eastern Seaboard Development Program should be built by extending ML-5. Otherwise, road congestion on Rts. 3 and 34 will become so severe that effective operaiton of the Eastern Seaboard Development Program will not be possible.

According to the recommendation, DOH subsequently requested that the Government of Japan carry out a feasibility study for this new highway by including it in this study. Following the request from DOH, this project was included in the feasibility study as ML-9 and classified into Phase II projects.

The list of the proposed projects thus classified are shown in Tables 13.1.4 and 13.1.5 and Figure 13.2.1.

Table 13.1.4 PHASE I PROJECTS

Project No.	Origin - Destination	Length (km)
ML Projects (5 projects)		192.20
ML-1	Chon Buri Bypass	13.60
ML-2	M. Pattaya - A. Sattahip	27.27
ML-4	A. Klaeng - C. Chanthaburi	61.86
ML-5	Chon Buri - Pattaya New Highway	50.33
ML-7	A. Min Buri - C. Chachoengsao	40.94
IM Projects (1 project)		26.87
IM-23	J.R. 32 - J.R. 3022	26.87
Total	6 projects	220.87

Table 13.1.5 PHASE II PROJECTS

Project No.	Origin - Destination	Length (km)
ML Projects (1 project)		126.3
ML-3	A. Sattahip - C. Rayong	44.6
ML-9	Bangkok-Chun Buri	81.7
IM Projects (10 projects)	279.8	
IM-1	A. Bang Len - B. Bang Noi Nai	18.7
IM-2	B. Nong Pru - A. Lao Khawn	35.9
IM-11	B. Channasut - A. Pho Thong	40.7
IM-12	A. Pho Thong - A. Sena	51.0
IM-13	A. Bang Pa-In - C. Ayutthaya	17.8
IM-14	A. Wang Noi - A. Thanyaburi	25.6
IM-15	B. Khlong Luang - A. Min Buri	24.7
IM-16	A. Lam Luk Ka - B. Khlong 16	20.8
IM-17	A. Lat Krabang - B. Khlong Tha Thua	28.7
IM-22	A. Nong Chok - A. Bang Nam Prieo	15.9
RH Projects (3 projects)		96.7
RH-2	Rt. 225	39.5
RH-3	Rt. 325	17.9
RH-5	Rt. 344	39.3
Total	15 projects	502.8

13.2 PROJECTS PROPOSED FOR NEXT STAGE

13.2.1 ML Projects

Even if all the ML Projects committed by DOH and picked as subjects for the feasibility study in the Study were implemented, there remain a considerable number of road sections whose traffic volumes in 2000 are beyond their tolerable capacities.

These were selected as projects which should be implemented in the next stage. They are shown in Table 13.2.1 and Figure 13.2.1:

Table 13.2.1 ML PROJECTS PROPOSED FOR NEXT STAGE

Project No.	Origin - Destination	Length (km)
ML-6 (Rt. 4)	C. Rachaburi - J.R. 35	22.8
ML-8 (Rt. 340)	B. Bang Muang - A. Lat Lum Khaew	25.6
ML-101 (New Highway)	Outer Ring Road - C. Nakhon Pathom	30.0
ML-102 (Rt. 1)	C. Nakhon Pathom - J.R. 1072	18.0
ML-103 (Rt. 4)	A. Hua Hin - C. Prachuap Khiri Khan	93.0
ML-104 (Rt. 304)	C. Chachoengsao - J.R. 319	37.0
ML-105 (Rt. 305)	A. Thanyaburi - A. Ongkharak	35.0
ML-106 (Rt. 323)	C. Kanchanaburi -J.R. 3398	7.5
ML-107 (Rt. 344)	J.R. 3345 - J.R. 331	10.5
ML-108 (Rt. 3091)	J.R. 4 - C. Samut Sakhon	20.0
ML-109 (Rt. 3111)	O.R.R.- A. Sanakhok	17.0
ML-110 (Rt. 3119)	A. Min Buri - J.R. 3256	10.5
ML-111 (Rt. 3256)	J.R. 3119 - J.R. 34 - J.R. 3268	17.0
ML-112 (Rt. 3414)	J.R. 4 - J.R. 338	10.0
Total	14 projects	353.9

A new highway between the Outer Ring Road and Nakhon Pathom in the above table is planned as a parallel road with Rt. 4. The new road will be important not only to alleviate road congestion on Rts. 4 and 338 but also to develop the surrounding areas.

At present, ML-5 is to end at J.R. 36. The section from this end point to Pattaya is not so congested. However, direct linking of Bangkok with Pattaya, a noted international tourist resort, is desirable by extending ML-5 in this direciton. Although this extension was not included in Table 13.2.1, it should be reconsidered as a future project.

13.2.2 IM Projects

The following projects are proposed to be implemented in the next stage:

- Projects omitted as subjects for the preliminary evaluation, although they were given high priority in Chapter 6.

- Projects omitted as subjects for the feasibility study, although they showed more than 12% of IRR in the preliminary evaluation.

They are shown in Table 13.2.3 and Figure 13.2.1.

Table 13.2.2 IM PROJECTS PROPOSED FOR NEXT STAGE

Project No.	Origin - Destination	Length (km)
IM-20	B. Khlong Takhian - J.R. 3322	44.5
IM-8	B. Khao Noi - B. Chang Ko Nok	16.8
IM-10	B. Reng Sung - C. Lop Buri	34.8
IM-21	B. Nong Chang -J.R. 3138	18.3
IM-19	A. Sa Kaeo - DOH Const. Office	27.3
IM-4	B. Thong Lang - A. Lan Sak	34.0
IM-101	J.R. 3209 - End of Rt. 3361	11.8
IM-102	A. Bang Khla - A. Phanom Sarakham	10.0
IM-103	J.R. 3017 - J.R. 21	18.5
IM-104	J.R. 3089 - J.R. 3209	24.5
IM-105	J.R. 324 - J.R. 3081	14.3
IM-106	B. Phanomrok - B. Nong Bua	39.6
IM-108	A. Tak Fa - J.R. 3004	28.7
Total	13 projects	323.1

13.2.3 RH Projects

The following projects are proposed to be implemented in the next stage:

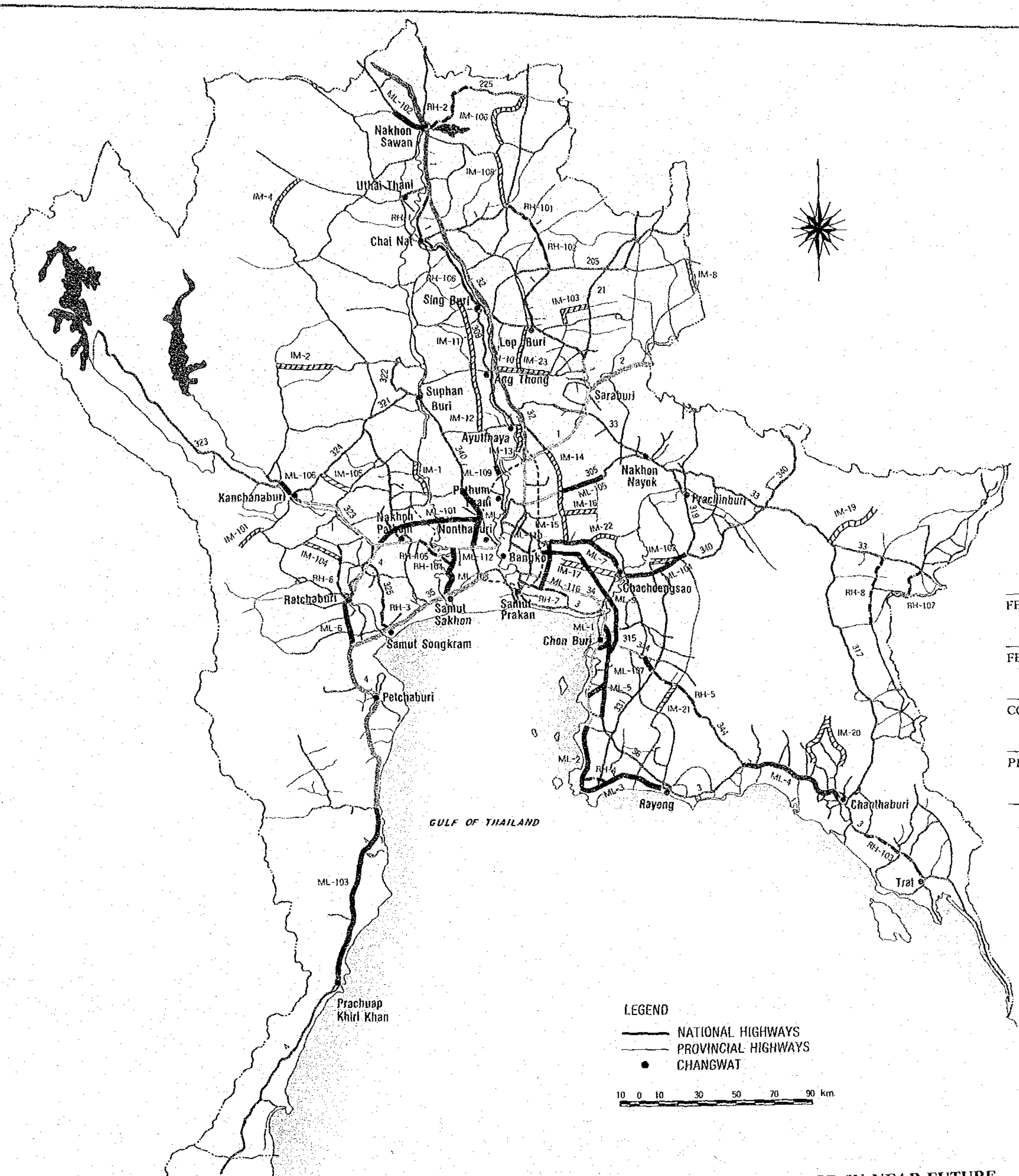
- Projects omitted as subjects for the preliminary evaluation, although they were given high priority in Chapter 7.

- Projects omitted as subjects for the feasibility study, although they showed high IRR.

They are shown in Table 13.2.3 and Figure 13.2.1.

Table 13.2.3 RH PROJECTS PROPOSED FOR NEXT STAGE

Project No.	Route No.	Link No.	Length (km)
RH-1	1	1001	25.5
RH-4	332	0100	14.5
RH-6	3089	1001	27.8
RH-7	3116	0100	9.7
RH-8	3395	0100	33.5
RH-101	1	0700	41.1
RH-102	1	0801	8.2
RH-103	3	1300	42.7
RH-104	4	0100	3.6
RH-105	4	0201	27.8
RH-106	311	0200	49.7
RH-107	3067	0100	40.0
Total	12 projects		324.1



LEGEND

	ML Projects	IM Projects	RH Projects	Total
FEASIBILITY STUDY PHASE I	5 projects 192.2 km	1 project 26.9 km	——	6 Projects 219.1 km
FEASIBILITY STUDY PHASE II	2 project 126.3 km	10 project 279.8 km	3 projects 93.7 km	15 Projects 502.8 km
COMMITTED ROUTE	4 Routes 412 km	——	——	4 Routes 412 km
PROPOSED FOR NEXT STAGE	14 Projects 353.9 km	13 Projects 323.1 km	12 Projects 324.1 km	39 Projects 1,000.1 km

Figure 13.2.1 PROJECTS TO BE IMPLEMENTED IN NEAR FUTURE

13.2.4 Intersections to be Improved

Intersections to be improved were identified in Chapter 10. They are shown in Table 13.2.4. and Appendix 10.4.1.

Table 13.2.4 INTERSECTIONS REQUIRING DETAILED ANALYSIS

Seq No.	Route No.	District Code	Type	Capacity Level
1	1-32	413	3	Over
2	1-309, 3189	413	4	Near
3	1-33, 329	430	4	Over
36	3-3 (Beg. of Chon Buri Bypass)	422	3	Over
37	3-315	422	4	Near
38	3-344	422	4	Over
41	3-3241	422	(4)	Near
56	3-3154	423	3	Over
64	4-3091, 3414	410	4	Over
65	4-3415	410	3	Over
67	4-3094	410	3	Near
68	4-4, 3097	410	4	Over
80	4-35	335	3	Over
87	4-326	333	3	Near
104	32-3267, 3341	413	4	Over
119	34-3413	420	3	Over
123	35-3097	415	3	Over
139	304-314	421	3	Near
142	304-3121	421	4	Over
209	340-3242	410	4	Over
210	340-3215	410	4	Near
271	3089-3090, 3357	335	4	Near

Note: Near : Signalized intersection which is close to capacity
Over : Signalized intersection to be improved to a grade separation

Intersections designated as Over are recommended for immediate implementation. However, detailed studies are required about how to improve them.

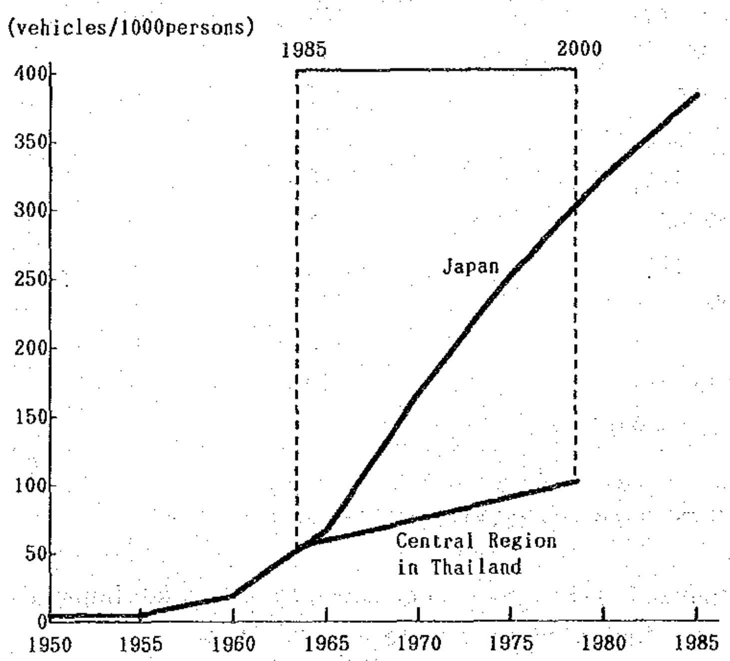
13.3 RECOMMENDATION

13.3.1 National Highway Network

As described in Chapter 9, traffic forecasts in this study were obtained primarily on the basis of the relationship between the number of registered vehicles and GPP observed so far in Thailand. The results presented in this report should be considered as conservative estimates. Past experience elsewhere has shown that the number of registered vehicles could grow faster when GDP exceeds a certain level.

The following figure shows changes in the number of registered vehicles per 1,000 people in Japan since 1963, when the level of GNP was roughly equivalent to Thailand in 1986. On the other hand, the number of registered vehicles in Japan increased sixfold in the ensuing 22-year period. The increase for the study area for the 14-year period form 1986 to 2000 estimated in this study was only 2.15 times, since the latter was essentially a result of linear extrapolation of past trends.

TREND OF REGISTERED VEHICLES PER PERSON



It is likely that the number of registered vehicles will grow faster than the estimates used in this study. Moreover, Thailand's GDP itself will grow much faster than assumed in this study, judging from the recent transformation of the Thai economy. Taking the faster GDP growth coupled with the accelerated growth in vehicle ownership into consideration, it is certain that traffic will grow well above the figures obtained by the conservative forecast in this study. It is likely that new construction of multilane highways will be required for many more sections.

Road development plans have usually been established in the past to accommodate traffic demand which was assumed to increase along the extended line of past trends. This can be called the traffic trend type plan.

An alternative approach is possible in that the effects of highways on economic development are explicitly recognized. Traffic is expected to be generated following the induced economic development. This can be called the development type plan. There, however, must exist certain conditions in order for this type of plan to be valid. There must be either economic resources in the area waiting to be tapped or existing highways so congested to make other areas with new highways economically more attractive.

On both accounts, the road network in the Central Region deserves a planning review by the development type approach considering the highly congested highways around Bangkok and the ample natural and human resources in up-country areas. This approach nicely fits two of the key targets of the Sixth Plan: decentralization of industrial activities and equalization of regional disparity.

Considering the current and future position of Thailand in terms of economic development and motorization, a development type plan applied nationwide will result in a highway network combined with an intercity expressway system.

13.3.2 Provincial Road Network

As described in sections 13.1 and 13.2, 24 routes of 629.8 km in total length were selected as subjects for the feasibility study or projects proposed for the next stage. However, these projects alone are thought to be inadequate even for Thailand to have a road density on the average of other countries.

In this study, 22 Blocks (areas surrounded by paved roads) were selected based on M value as areas which require more paved roads. 85 links with 2.017 km in total length were identified as the routes required for the above selected Blocks.

M value is an index of road requirement deduced by a comparative analysis of existing road densities in various countries. In order to make the road density in the study area comparable to the international level, improvement of the above routes is required.

13.3.3 Rehabilitation

DOH has already established a manual for the selection of sections to be rehabilitated. However, a design method for pavement structures including their rehabilitation has not yet been designated.

Sections to be rehabilitated should basically be determined based on an assessment of pavement conditions, which may be expressed in terms of serviceability.

Serviceability and deflection (supporting capacity) have little correlation. Therefore, in the case that a design method based only on deflection such as the California Method, which used to be applied in DOH, was applied, overlays have been designed regardless of degree of deterioration of the pavement. From this point, a design method based on serviceability of the pavement and the supporting capacity such as AASHTO Design Guide for Pavement Structures 1986 is recommended. However this method is very complicated.

The overlay design method must be simple enough to be adopted widely by engineers. The Study Team, therefore, recommends that a simple method of overlay design be established specifically for Thailand.

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