7.9.5 Ranking and Evaluation

Scores provided to each proposed route for each sub-criterion are summed up by each major category of criteria; i.e. Isolation, Health, Education and Disparity. Then aggregating them a total score of social impacts is obtained by each proposed route. In this study, equal weight was assigned among sub-criteria and major criteria, viewing that arbitral weighting without any background of the established policies may mislead the judgement.

In ranking the proposed routes by magnitude of social impacts, this Study employed a kind of group ranking method paying attention not to the precise figure of the scores but only to their order of magnitude. Ranking was made as follows:

Rank A: routes of which scores are higher than the average value
Rank B: routes of which scores fall into between the average value and 2/3 of the average
Rank C: routes of which scores are lower than 2/3 of the average value

As summarized in Table 7.9.3, 11 routes fell into Rank A and are deemed to have significant impacts from a social viewpoint.

Table 7.9.1 CRITERIA AND INDICATORS OF SOCIAL IMPACTS

Criteria		Indicators
I.	Isolation	
I - 1	Improvement of Access to Amphoe	Per capita savings of average traveling time to Amphoe centers
I - 2	Improvement of Access from Amphoe to Artery Highway	Per capita savings of average traveling time from Amphoe to nearest artery highways
I - 3	Alleviation of Impassability	Duration of impassability a year by disaster
II.	Health	
II - 1	Improvement of Access to Hospital	Per capita savings of average traveling time to Amphoe level Hospitals
II - 2	Improvement of Access to Medical Facilities	Per capita savings of average traveling time to medical facilities such as health centers
III.	Education	
III - 1	Improvement of Access to Secondary School	Savings per student of average traveling time to secondary schools
III - 2	Improvement of Teacher Intensity	Ratio of University graduate teachers to student; Total number of teachers to student
IV.	Disparity	
IV - 1	Alleviation of Income Disparity	Difference between disparity indices* of with project and without project

* Average of N.E./Per capita crop production value in Influence area

Table 7.9.2

Table 7.9.2 SCORES OF SOCIAL IMPACTS

Proposed Route	Population 1993 (1,000)	Score											
		Isolation				Health			Education			Disparity	Total Score
		to Amphoe	to Hwy	Impassability	Sub-Total	to Hospital	to Med. Facil	Sub-Total	to School	Teacher	Sub-Total		
IM - 1	29.3	100	117	658	876	147	84	231	117	130	247	0	1376
IM - 2	13.2	76	115	0	191	60	60	120	63	85	148	268	727
IM - 3	30.0	65	96	108	269	140	76	216	56	66	122	0	608
IM - 4	29.3	59	111	108	278	126	44	170	112	100	212	0	660
IM - 5	34.3	47	0	0	47	47	32	79	32	74	116	89	331
IM - 6	5.8	253	0	0	253	200	344	544	252	85	337	0	1134
IM - 7	11.7	335	100	550	985	265	416	681	361	110	471	161	3432
IM - 8	23.0	76	0	0	76	60	60	120	82	100	182	54	432
IM - 9	32.5	59	0	50	109	42	28	70	40	128	168	0	347
IM - 10	39.5	41	107	0	148	72	32	104	48	103	151	196	599
IM - 11	8.7	153	222	0	375	119	104	223	160	87	247	71	916
IM - 12	22.9	115	194	183	492	112	104	216	83	115	198	71	972
IM - 13	18.7	79	259	167	505	70	72	142	88	85	173	0	800
IM - 14	12.8	133	350	500	983	207	136	343	232	114	346	268	1940
IM - 15	42.4	61	64	0	125	102	40	142	64	75	139	125	531
IM - 16	11.1	68	196	0	264	105	180	285	150	114	164	143	956
IM - 17	29.5	59	189	0	248	133	84	217	71	74	145	71	681
IM - 18	61.3	59	15	108	182	51	60	110	36	102	138	179	610
IM - 19	43.2	115	100	33	248	77	40	117	91	110	201	107	673
IM - 20	20.1	71	204	0	275	109	116	225	101	91	192	89	781
IM - 21	53.3	35	96	0	131	49	56	105	37	105	142	89	467
IM - 22	14.9	255	78	0	333	188	204	392	190	176	366	125	1216
IM - 23	30.9	76	100	0	176	86	72	158	25	129	154	0	488
IM - 24	5.4	218	100	0	318	167	172	339	135	99	234	0	1379
IM - 25	44.4	79	61	142	282	56	40	96	58	86	144	125	647
IM - 26	39.2	53	0	492	545	49	48	97	58	114	172	89	903
IM - 27	36.5	44	0	83	127	40	36	76	62	88	150	107	400
IM - 28	46.3	56	126	142	324	44	64	108	33	89	122	161	715
IM - 29	71.8	35	0	25	60	28	28	56	31	148	179	232	527
IM - 30	48.6	41	111	33	185	28	36	64	33	93	126	89	464
IM - 31	62.2	56	0	50	106	40	32	72	36	127	163	89	430
IM - 32	24.1	82	100	0	152	130	132	262	188	111	299	0	743
IM - 33	22.8	165	220	0	385	130	196	326	163	98	261	286	1258

Table 7.9.3 RANKING OF SOCIAL IMPACTS

Proposed Route	Isolation	Health	Education	Disparity	Overall
IM - 1	A	A	A	C	A
IM - 2	C	C	B	A	B
IM - 3	B	A	C	C	B
IM - 4	B	B	A	C	B
IM - 5	C	C	C	B	C
IM - 6	B	A	A	C	A
IM - 7	A	A	A	A	A
IM - 8	C	C	B	C	C
IM - 9	C	C	B	C	C
IM - 10	C	C	B	A	B
IM - 11	A	A	A	B	A
IM - 12	A	A	B	B	A
IM - 13	A	B	B	C	B
IM - 14	A	A	A	A	A
IM - 15	C	C	C	A	C
IM - 16	B	A	A	A	A
IM - 17	B	A	B	B	B
IM - 18	C	C	C	A	B
IM - 19	B	C	A	A	B
IM - 20	B	A	B	B	B
IM - 21	C	C	B	B	C
IM - 22	A	A	A	A	A
IM - 23	C	B	B	C	C
IM - 24	A	A	A	C	A
IM - 25	B	C	B	A	B
IM - 26	A	C	B	B	A
IM - 27	C	C	B	A	C
IM - 28	A	C	C	A	B
IM - 29	C	C	B	A	C
IM - 30	C	C	C	B	C
IM - 31	C	C	B	B	C
IM - 32	C	A	A	C	B
IM - 33	A	A	A	A	A

CHAPTER 8

EVALUATION OF PROPOSED LINKS FOR REHABILITATION

CHAPTER 8

EVALUATION OF PROPOSED LINKS FOR REHABILITATION

8.1 PROPOSED LINKS

The proposed links for rehabilitation identified in identification process were 28 links, 774 km in total length as given in Table 6.6.1 and also shown in Figure 6.6.1.

8.2 EVALUATION FLOW

Evaluation analyses for rehabilitation links were proceeded laying emphasis on the calculation of overlay thickness and the analysis of VOC savings accrued from roughness improvement of paved road.

Overlay thickness required for the respective proposed links were determined through the comparative studies on thickness analysis employing some deflection criterion curves.

With the object of obtaining data for analysis of benefits and overlay plannings, field surveys on roughness and PSI (Present Serviceability Index) ratings of pavement surface were carried out. Supplemental deflection survey for several links was also conducted to update the rather old data.

Finally, using the calculated rehabilitation costs and benefits, benefit-cost ratio and internal rate of return (IRR) were calculated.

The evaluation flow for the rehabilitation links is shown in Figure 8.2.1.

8.3 ENGINEERING STUDY AND COST ESTIMATES

8.3.1 Field Surveys

1) Deflection Survey

To update the rather old data used for link identification for rehabilitation, field deflection survey was conducted. It was carried out from September to October, 1982. The links subjected to the survey are as follows:

Link No.	Route - Link	Length (km)
RH - 5	201 - 0100	40
- 6	- 0200	25
- 7	- 0300	17
- 8	- 0400	38
-15	213 - 0100	43
-16	214 - 0100	28
-17	- 0200	19

The surveyed data for the above links were computerized for ready application to pavement design.

2) Roughness Survey

For evaluation and comparison of paved surfaces, roughness survey was conducted. The roughness was measured using a Mays Ride Meter (MRM) installed in a passenger vehicle.

The principle of the MRM instrument is that it measures the displacement of the rear axle of the vehicle relative to its body, thus giving an indirect measurement of roughness in both ways of graphical oscillation chart and roughness summation expressed in figures.

Field survey was carried out for 35 links of proposed links and additional links, totaling about 1,000 km. The roughnesses measured at constant vehicle speed of 60 km/hr were printed on a strip paper together with landmarks and bridge locations and at the same time, they were numerically accumulated every one kilometer basis. Figure 8.3.1 shows typical roughness charts characteristic to respective surface conditions.

Average roughness and analyzed standard deviation for each link is summarized in Table 8.3.1. Measured roughness by every 1 km is graphically shown in Appendix 8.1 together with pavement deflection values.

3) Pavement Condition Survey

In order to correlate the measured roughness with PSI, a condition rating survey for pavement condition was carried out by a panel of engineers. The field work was conducted in November 1982 for 40 sections totaling about 460 km of paved road of asphaltic concrete (AC), surface treatment (ST) and penetration macadam surfaces (PM).

In order to facilitate recognition of pavement deficiencies by the raters, the most common signs of distresses were selected referring to the standard nomenclatures as defined in the HRB Report1/ as given in Table 8.3.2.

The condition surveys for all the items described in Table 8.3.2 were carried out by rating their deficiencies in a scale of 0 to 5 listed on the listing form as shown in Figure 8.3.2. The assignment of rating classes with respect to the actual surface conditions were understood among raters prior to the start of ratings through trial practices. The ratings thus obtained by individual rater were analyzed and average rating points and ranges were calculated. They are given in Table 8.3.3.

1/: Standard Nomenclature and Definitions for Pavement Components and Deficiencies. HRB Special Report 113.

4) Roughness - PSI Relationships

In order to correlate roughness with serviceability index, PSI and measured roughness values given in Table 8.3.3 were plotted by surface type. Then following three curves for different surface types were derived referring to the calibration formula introduced in HRB Report[1/].

$$PSI = 5.e^{-\left[\frac{\ln(M-Mo)}{8.515}\right]^5}$$

Where M = Measured Roughness Count (mm/km)

Mo = 1,500 mm/km for A.C.

= 2,500 mm/km for S.T.

= 3,200 mm/km for P.M.

The PSI-roughness relationships are shown in Figure 8.3.3.

8.3.2 Design Standard

Horizontal and vertical alignments of the proposed links for rehabilitation are satisfactorily suitable for the respective design standard of the DOH. Therefore no improvement works of alignments were considered. However, carriageway and roadbed widths were checked through the field surveys and road inventory data. The carriageway and roadbed widths employed in the Study are as follows:

[1/] : Method for Measuring Serviceability Index with the Mays Ride Meter. HRB Special Report 133.

Road Width by Proposed Link

Road Class	Proposed Link	Carriageway and Roadbed (m)		Remarks
		Existing Width	Improved	
P2	RH-1	7/10		
P3	PH-2, RH-3	6/10		
S1	RH-19, RH-20, RH-21	7/12		
S3	RH-4, RH-5, RH-6			
	RH-7, RH-8	6/8		
	RH-9, RH-10, RH-11			
	RH-12	6/10		
	RH-13, RH-14	5/6	6/10	Reconstruction 7th year ADT (1700 1900)
	RH-15, RH-16, RH-17	6/9		
	RH-18	6/8		
F4	RH-22	5/8		
	RH-23, RH-24	6/8		
	RH-26	5/8	5.5/9	Reconstruction
	RH-25, RH-27	5/7		
	RH-28	5.5/9		

Typical cross sections for overlay and reconstruction works are shown in Figure 8.3.4.

8.3.3 Traffic Analysis

For the analysis of overlay thickness and calculation of rehabilitation benefits, traffic data were analyzed.

1) Base Traffic and Growth Rate

Traffic volumes surveyed by the DOH were available for past 10 years (1972 - 1981). Future traffic volumes by vehicle type were forecasted basing on the traffic volumes in 1981.

Growth rates of traffic in the Northeastern Region was adopted from the previous studies[1] which was slightly revised from the SRNT studies, as follows:

Traffic Growth Rate (% P.a.)

Year	Primary Highway		Secondary Highway		Provincial Paved Road	
	P	F	P	F	P	F
1982 - 1987	3.8	4.9	3.8	5.2	6.6	4.5
1978 - 2001	3.8	3.8	3.8	3.8	5.5	3.6

Note: P: Vehicles for passengers
F: Vehicles for Freights

Forecasted traffic by proposed link is given in Appendix 8.2.

2) ESA[2] Conversion Factors

a) Gross Vehicle Weight Distribution

Gross vehicle weight distribution in the Northeastern Region was interpreted from the survey reports[3] of the DOH. Location of vehicle weight survey of the DOH is shown in Appendix 8.3.

As loads imposed by passenger cars do not contribute significantly to the structural damage of road pavements, medium and heavy trucks and buses were taken into the analyses. Gross vehicle weight distribution for 6-wheel trucks and 10-wheel trucks are shown in Appendix 8.4.

1/ : Increasing Rate of Traffic by Region (1982-2001), DOH.

2/ : ESA: Equivalent Standard 8,200 kg Axle Loads.

3/ : Loaded vehicle weighing survey-Northeast, Traffic Engineering Office, DOH, 1980.

b) Empty Ratio

For establishing the ESA, the share of unloaded vehicles must be known. According to the DOH's survey as shown in Appendix 8.4, the empty ratio is as unreasonably high as 80 % for 6-wheel trucks and 44 % for 10-wheel trucks.

The results of the Team's O/D Survey revealed that the vehicle empty ratio is around 40 % for 6-wheel trucks and 30 % for 10-wheel trucks as shown below.

Truck Empty Ratio (%)

Location*	Paved National Road		Unpaved Provincial Road	
	6-wheel	10-wheel	6-wheel	10-wheel
1	45(133)	43(105)		
2			100(4)	
3			38(11)	100(3)
4	40(194)	35(159)		
5			46(11)	67(3)
6	35(95)	31(112)		
7	48(33)	10(44)		
Weighted Average	41	33	51	83

( ): No. of vehicles interviewed.

* : Location of survey is shown in Appendix 8.3.

From these two survey results, empty ratios for 6-wheel and 10-wheel trucks were decided as follows:

Truck Empty Ratio (%)

	6-wheel trucks	10-wheel trucks
National Road	40	35
Provincial Road	50	50

c) Traffic Equivalent Factor

Axle load distribution survey conducted by the DOH shows the share of rear axle(s) load increases as the increase of gross vehicle weight in both 6-wheel trucks and 10-wheel trucks as shown in Appendix 8.5. On the basis of the actual survey results, axle load distribution was calculated as shown in table of Appendix 8.5.

To use the flexible pavement design procedure described later, mixed traffic must be converted to an equivalent number of 8,200 kg single axle load.

To express varying axle loads in terms of a common denominator, it is necessary to develop traffic equivalence factors. The equivalence factors derived at AASHO Road Test were employed in this Study. They are shown in Appendix 8.6.

d) ESA Conversion Factors for Trucks

With the axle loads, axle loads conversion factors and gross vehicle weight distribution, equivalent standard 8,200 kg axle load number (ESA) was calculated for 6-wheel and 10-wheel trucks as given in Table 8.3.4.

e) ESA Conversion Factors for Buses

Average passenger occupancies for buses surveyed during the team's O/D Survey period are as follows:

Average Passenger Occupancies (%)

Location* No.	Paved National Road M / B	Paved National Road H / B	Unpaved Provincial Road M / B	Unpaved Provincial Road H / B
1	26(21)	40(114)		
2			5(8)	0
3			31(9)	0
4	19(92)	38(114)		
5			19(8)	0
6	19(74)	35(50)		
7	27(38)	42(16)		
Weighted Average	21	39	19	

( ): No. of buses interviewed.

* : Location of survey is shown in Appendix 8.3.

On the other hand, PRI study1/ indicates that average occupancies of medium and heavy buses are 18 and 27 respectively in the Northeastern Region.

Concerning the axle loading distribution for buses only limited data are available as given in the previous report1/. It derives the ESA conversion factors for heavy buses as 0.61 on the basis of the actual load survey at the Eastern Bus Terminal in Bangkok.

f) Summary of ESA Conversion Factors

Summarizing the foregoing analyses, ESA conversion factors to be used for the Study are given in the following table:

1/: Feasibility Study of Provincial Road Improvement, Louis Berger International, Inc. Dec. 1981.

ESA Conversion Factors

Class	6-wheel Truck1/	10-wheel Truck1/	Heavy Bus
National Highway	0.81	1.28	0.61
Provincial Road	0.68	0.99	

1/: Refer to Table 8.3.4 (a) - (d).

3) Cumulative Numbers of ESA

With the use of the foregoing conversion factors, cumulative numbers of ESA for respective traffic volumes were calculated by proposed link. They are shown in Appendix 8.7, separating past traffics and future traffics in the design period.

8.3.4 Overlay Design

1) Design Deflection

Deflection survey by the DOH has been conducted every 50 meter intervals. The method of deflection measurements is based on the WASHO (Western Association of State Highway Officials) method in principle. The deflection obtained by the WASHO procedures is a rebound deflection.

The deflection readings at the field survey must be corrected for the temperature variations and moisture fluctuations of the subgrade soils which will vary through the year. However, the DOH employs temperature adjustments only. For thicker pavement surfaces, temperature adjustments are made by the following formula in the DOH pavement design:

$$d = 0.0002'' (90 - F_t)$$

Where, d : deflection adjustment (inch)

F_t : Pavement temperature (^oF)

Those adjusted deflection values are treated every 1 km basis, viz, 20 deflection data for 1 km.

Although it is impossible to determine the true population mean and standard deviation deflection of a pavement section, the average and standard deviation obtained from a set of measured data are used to determine deflection values corresponding to the designated probability level. DOH employs the deflection level that only approximately 7 % of the overlay would be underdesigned and subject to distresses. Thus, the DOH has adopted the following value as design deflection in overlay design:

$$Dd = D + 1.5\ \sigma$$

Where, Dd : Design deflection
D : Average deflection
σ : Standard deviation

2) Comparative Studies on Overlay Design

To strengthen the distressed flexible pavements, various kinds of methods of overlay design have been introduced by different organizations. Those methods can be broadly classified into two groups:

(a) Design method with the use of pavement deflection, and
(b) Design method by pavement component analysis.

The design methods employed for the comparative analysis in the Study are as follows:

Design Method
- Pavement Deflection
  - Asphalt Institute Method *
  - Japan Road Associations Method
  - TRRL** Method *
  - TRRL Method in the Tropics *
  - Overlay Thickness Formula by Ruiz *
  - Canada Method
  - California Method *
- Pavement Component
  - Asphalt Institute Method
  - Japan Road Associations Method

On the basis of the results of trial overlay designs using the methodologies mentioned above, five methods of them were selected for further comparative studies through the discussions with the DOH.

The selected five methods indicated with * mark are all deflection dependent methods as shown in deflection-life relationship chart (Figure 8.3.5).

The selected methods are briefly explained hereunder;

Method		Traffics used for the Design	Tolerable Deflection and Thickness Design Charts
(A)	Asphalt Institute[1/]	DTN[2/]	refer to Figure 8.3.6 (a)
(B)	TRRL[3/]	ESA	Figure 8.3.6 (b)
(C)	TRRL Tropics[4/]	ESA	Figure 8.3.6 (c)
(D)	Ruiz's Formula[5/]		Figure 8.3.6 (d)
(E)	California Divisioon of Highways[6/]	ESA TI[7/]	Figure 8.3.6 (e)

** TRRL, Transport and Road Research Laboratory, United Kingdom

Note 1/ : The Asphalt Institute Manual NO. 17

2/ : DTN : Design Traffic Number

3/ : TRRL Report LR 571

4/ : TRRL Report LR 444

5/ : Highway Research Record 129

Ruiz's expression for calculating the necessary overlay thickness:

$$h = \frac{R}{0.434} \cdot \log \frac{Do}{Dh}$$

Where, h : Overlay thickness (cm)
Do : Deflection of existing pavement
Dh : Deflection after overlay construction
R : Deflection reduction factor (=12)

6/ : Highway Research Record 129

Percent reduction in deflection: (P)

$$P = \frac{dr - dt}{dr}$$

Where, dr = Design deflection
dt = Tolerable deflection

Increase in Gravel equivalence

Gravel thickness ——→ AC thickness
(factor 1:2)

7/ : TI : Traffic Index

Using these method, overlay thickness computation was carried out for all proposed links every one kilometer basis. The results are shown in Appendix 8.8. Table 8.3.5 shows the computation results for RH-1 link, giving different overlay thicknesses by each method. It is due to the tolerable deflection criterion curves inherent to each design method.

Through the discussions with the DOH, method (E) established by California Division of Highways was employed among the methods owing to its conservative outcomes compared with other methods. This method is also employed by the DOH for pavement design incorprating slight modification to the derivation of traffic analysis.

3) Design of Overlay and Reconstruction

In order to establish the rehabilitation plans and measures, required overlay thickness calculated and roughness conditions together with existing geometric features of road were further refined. As the results, the sections of each link in Table 8.3.6 were deemed necessary to be either overlayed or reconstructed. Those links of RH-7, 8, 11 and 25 are required for neither overlay nor reconstruction during the design period due to their comparatively good deflection conditions. However, those links may be subject to the routine maintenance as the pavement surface deteriorates.

Figure 8.3.7 illustrates the overlay or reconstruction sections by proposed link. Reconstruction sections were introduced due to their considerably thick overlays required or narrow carriageway/roadbed widths.

As the Table 8.3.6 shows, link length required for rehabilitation measures are 468 km in total, 370 km for overlay and 98 km for reconstruction.

8.3.5 Work Quantities and Construction Cost

1) Work Quantity

With the results of overlay and reconstruction designs, work quantities were calculated basing on the typical cross sections shown in Figure 8.3.4. They are given in Appendix 8.9.

2) Construction Cost

Construction unit rates were established as given below, referring to the previous bidding rates in similar projects in Thailand.

Unit Rates For Major Work Items

(Reconstruction and Overlay)

Work Item	Unit of Quantity	Financial Unit Rate (B)	Tax Component (%)	Remarks
Clearing and Grubbing	ha	15,000	9	
Embankment	m^3	45	9	
Scarifying (A)	m^2	20	10	For Asphalt Concrete
Scarifying (B)	m^2	7	10	For DBST
Soil Aggregate Subbase	m^3	105	11	
Crushed Stone Base	m^3	370	8	
Soil Aggregate Shoulder	m^3	105	11	
Tack Coat	m^2	10	10	
Asphalt Concrete Surface				
T = 40 mm	m^2	88	10	
T = 50 mm	m^2	110	10	
T = 80 mm	m^2	176	10	
T = 100 mm	m^2	220	10	
T = 120 mm	m^2	264	10	

Construction costs were calculated by applying unit rates to the respective work items.

Following rates of costs for miscellaneous works, physical contingencies and design/supervision are added to the direct construction cost:

Applied Rates for Cost Estimate

	Overlay	Reconstruction
Miscellaneous1/	3.5	7.0
Physical Contingency2/	15.0	15.0
Design/Supervision2/	8.0	10.0

1/ : Rate to construction cost of major work items

2/ : Rate to direct construction cost.

Construction cost by proposed link is summarized in Table 8.3.7 and detailed figures are given in Appendix 8.9.

8.4 ESTIMATION OF BENEFIT

8.4.1 Approach

The main benefit accrued from pavement rehabilitation is the savings of vehicle operating costs (VOCs) in case of with project. Valuation of VOCs on paved roads to be rehabilitated was made using the relationship between VOC and surface roughness developed in the Study.

From the PSI-Roughness relationship curves given in Figure 8.3.3, it was assumed that the roughnesses at the beginning stage of newly paved surface and at its terminal serviceability time are respectively 1,500 mm/km (PSI = 5) and 5,500 mm/km (P_t1/ = 2.0).

As the DOH employs the policy of pavement design for 7-year period, it was also assumed that the terminal serviceability ($P_t = 2.0$) would be brought approximately at 7th year after opening to traffic.

1/: P_t : Terminal Serviceability Index

With these premises, roughness - time relationships for new pavement surface was derived as shown in Figure 8.4.1. In the case of without overlay, roughness in the design period was supposed to increase at the same rate of overlayed case.

8.4.2 Vehicle Operating Costs on Paved Roads

Vehicle operating costs on level tangent paved road mentioned in 7.5.3 are used in the Study, as follows:

Basic Vehicle Operating Costs

Vehicle	P/C	L/B*	H/B	L/T**	M/T	H/T
VOCs (B/km)	1.937	3.491	5.506	2.007	3.865	6.532

Note: * Including Light Bus and Medium Bus.

** Including Pick-up Truck and 4-wheel Truck.

For the purpose of estimation of VOC savings after overlaying in rehabilitation projects, it is required to elaborate a method to value VOC on paved roads more in detail corresponding to surface roughness.

By analyzing the results of the roughness and PSI survey, the previous TRRL'S Kenya Study and the SRNT, the relationship between roughness values and VOCs were derived. As a consequence, the following formula was obtained.

$$C = a \cdot R + b$$

where, C : Vehicle operating costs (฿/km)

R : Roughness Value (mm/km)

Vehicle Type	a (10^{-4})	b
P/C	1.29	1.724
L/B	3.02	2.977
H/B	4.79	4.692
L/T	1.78	1.704
M/T	2.98	3.368
H/T	5.02	5.678

Using the above formula, VOCs on the existing paved roads to be rehabilitated and also on the overlayed roads were calculated according to their measured roughness values.

8.4.3 Vehicle Operating Costs Savings

VOCs savings were calculated for 7 years after completion of rehabilitation works. Forecasted traffic volumes for 6 types of vehicles as given in Appendix 8.2 were used for the analysis. VOCs savings by proposed link are given in Appendix 8.10.

8.5 ECONOMIC EVALUATION

8.5.1 Approach

Economic evaluation for 24 links out of 28 links originally proposed was performed under the usual benefit-cost analyses.

As work quantities of overlay works and reconstruction are relatively small, benefits were supposed to accrue at year of investment and for 7 years thereafter.

8.5.2 Evaluation and Ranking

The calculated IRR together with link characteristics are summarized in Table 8.5.1. As the table shows, 19 links were feasible in terms of IRR, more than 12 %, and 5 links were less than 12 %.

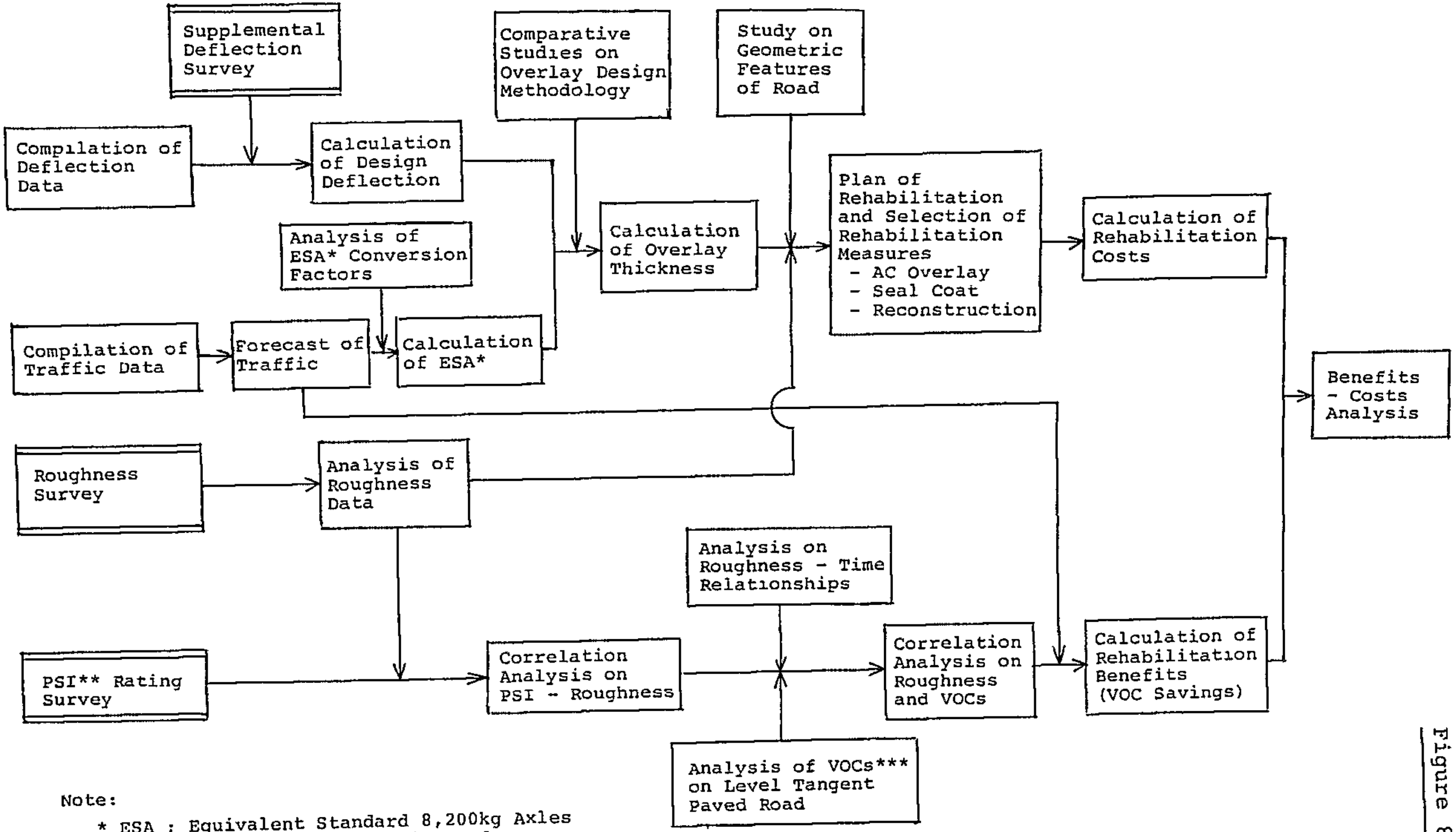
Following table shows IRR rankings for proposed links. It also shows disbenefits of VOCs savings in case that the project implementation is delayed for two years.

Ranking by IRR

Link No.	Length (km)	IRR (%)	Amount of Disbenefit[1/] (10^3 B)	Remarks
RH - 22	8	118.1	8,840	Overlay
RH - 2	10	91.9	10,337	"
RH - 18	30	82.8	27,914	"
RH - 5	23	69.7	18,173	"
RH - 15	44	56.8	28,537	"
RH - 6	25	48.8	14,085	"
RH - 16	14	43.1	7,645	"
RH - 17	9	34.5	3,862	"
RH - 23	16	34.5	13,584	"
RH - 24	16	29.8	14,849	"
RH - 19	46	28.9	40,520	Overlay/ Reconstruction
RH - 4	9	27.9	3,298	Overlay
RH - 20	6	25.7	7,145	"
RH - 26	22	22.7	17,548	Reconstruction
RH - 21	13	20.7	5,507	Overlay
RH - 9	7	20.3	2,084	"
RH - 10	5	19.6	3,302	Reconstruction
RH - 1	28	13.3	7,124	Overlay
RH - 28	18	13.1	3,876	"
RH - 14	27	11.7	20,045	Reconstruction
RH - 3	46	11.0	10,142	Overlay
RH - 12	6	10.1	1,290	"
RH - 13	24	9.9	17,129	Reconstruction
RH - 27	16	7.3	2,518	Overlay

[1/]: Disbenefits of VOCs Savings due to 2-years delay of implementation.

Figure 8.2.1 EVALUATION FLOW FOR REHABILITION



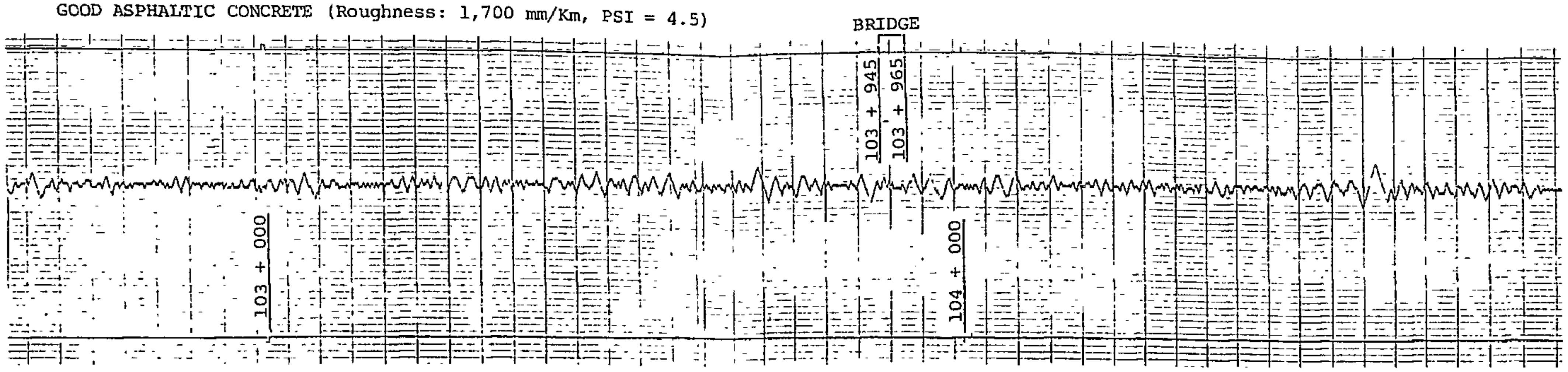
Note:
* ESA ; Equivalent Standard 8,200kg Axles
** PSI ; Present Serviceability Index
*** VOC ; Vehicle Operating Costs
▭ ; Field Surveys

Figure 8.3.1 TYPICAL ROUGHNESS CHARTS

RH-2 (24-0500)

KP 103 ∿ 104

GOOD ASPHALTIC CONCRETE (Roughness: 1,700 mm/Km, PSI = 4.5)

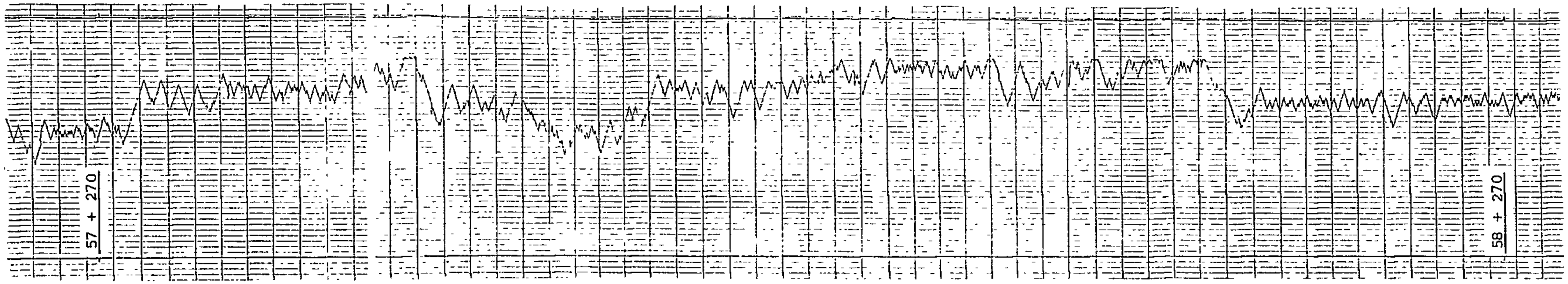


K.P.	ROUGHNESS (mm/km)
102	
103	1597
104	1754
105	1744
106	2028
107	1632
108	2099
109	2215
110	1876

RH-19 (304-0800)

KP 57 ∿ 58

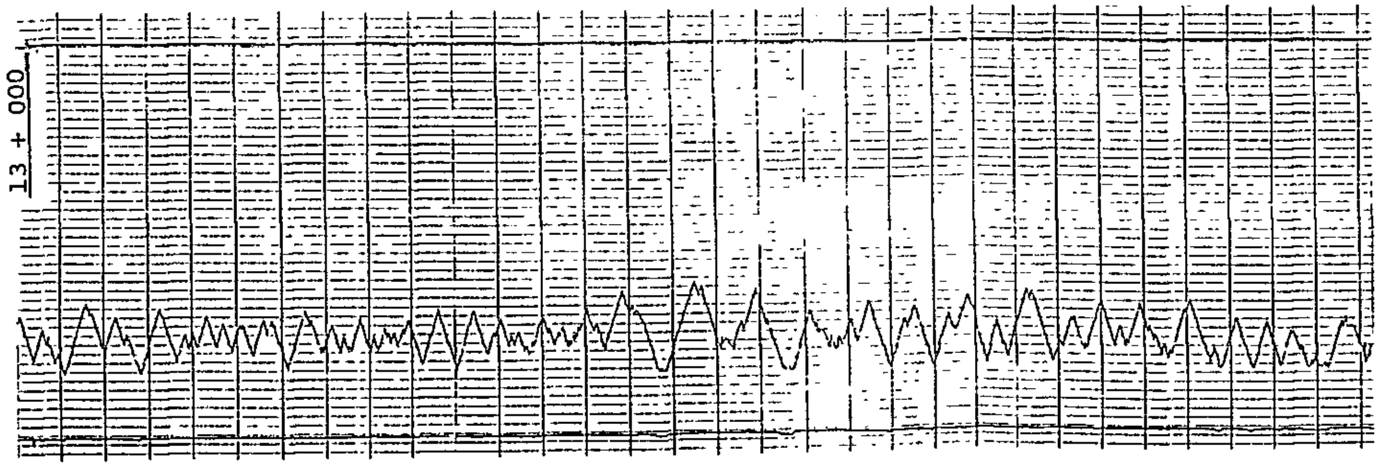
BAD ASPHALTIC CONCRETE (Roughness: 6,400 mm/Km, PSI = 1.9)



RH-13 (208-0100)

KP 13 ∿ 14

FAILED SURFACE TREATMENT (Roughness: 5,900 mm/Km, PSI = 2.2)



RH-28 (2175-0100)

KP 0 ∿ 1

GOOD SURFACE TREATMENT (Roughness: 2,700 mm/Km, PSI = 4.5)

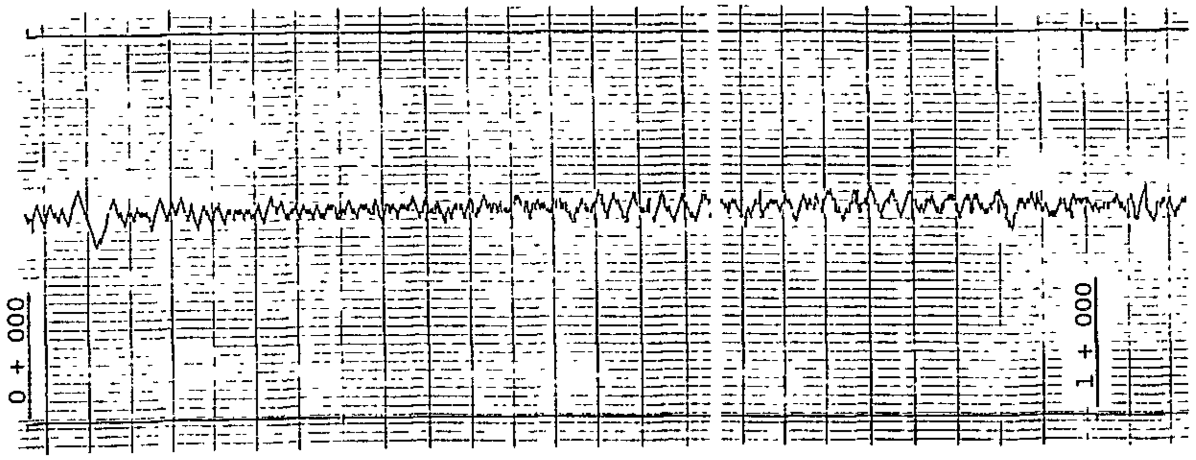


Table 8.3.1 LIST OF MEASURED ROUGHNESS FOR REHABILITATION LINKS

Proposed Route						K.P.	Roughness mm/km		Remarks
Route	Link	Surface Type	Link Length (Km)	Origin	Destination	(Km) - (Km)	Average ($\bar{R}$)	Standard Diviation	
24	200*	AC	42	J. to A.Chokchai	J. to A.Lamplaimat	0 - 42	2094	353	** The very high standard deviation is due to the high variation of roughness. It is more proper to divide this link into 3 sections as follows: **Section 1 : km 102 - 111** $\bar{R}$ = 1919 mm/km S = 336 mm/km **Section 2 : km 111 - 117** $\bar{R}$ = 7575 mm/km S = 464 mm/km **Section 3 : km 117 - 138** $\bar{R}$ = 2048 mm/km S = 669 mm/km
	300*	AC	32	J. to A.Lamplaimat	J. to C.Buriram	42 - 74	2406	509	
	400	AC	28	A. Nang Rong	A. Prakhon Chai	74 - 102	2637	703	
	500	AC	36	A. Prakhon Chai	A. Prasat	102 - 138	2909	2154**	
	600	AC	50	A. Prasat	A. Sangkha	138 - 188	3174	1040	
	1001	DT	40	A. Warin Chamrap	A. Det Udom	0 - 40	2977	681	
201	100	DT	39	A. Sikhui	A. Dan Khun Thot	0 - 39	5022	1043	
	200	DT	25	A. Dan Khun Thot	A. Nong Bua Khok	39 - 64	4093	573	
	300	DT	17	A. Nong Bua Khok	A. Chatturat	64 - 81	5277	819	
	400	DT	38	A. Chatturat	A. Chaiyaphum	81 - 119	4888	676	
202	301*	PM	15	J. to A.Bua Yai	Nakhon Ratchasima 1 Dist.	51 - 66	4897	420	
	400*	PM	19	J.B. Sida	J.A. Prathai	66 - 85	5168	426	
	500	DT	40	A. Prathai	A. Phrayakkhamphum Phisai	10 - 50	3754	547	
207	100	DT	37	B. Wat	A. Prathai	448 - 485	4553	565	
207	202	DT	35	A. Prathai	A. Nong Song Hong	485 - 498	4191	667	
208	100	DT	31	A. Tha Phra	A. Kosum Phisai	0 - 31	4296	793	
	200	DT	29	A. Kosum Phisai	C. Maha Sarakham	31 - 60	5026	1466	
213	100	DT	44	C. Maha Sarakham	A. Kalasin	0 - 44	4019	870	
214	100	DT	28	A. Kalasin	B. Lam Chai	0 - 28	3610	513	
	200	DT	19	A. Lam Chai	C. Roi Et	28 - 47	3661	889	
	800	PM	30	C. Surin	A. Prasat	0 - 30	4238	837	
	900*	PM	40	J.R. 24 (A.Prasat)	Chong Chom	29 - 69	3447	570	
219	100*	PM	19	J.R. 24 (A.Prakhon Chai)	B. Salang Thon	25 - 44	4129	549	
	200*	PM	25	B. Saland Thon	J. Buri Ram Dist. Off.	0 - 25	3906	657	
304	800	AC	46	A. Buphai	B. Takhop	55 - 101	4164	1408	
	902	AC	6	(Bypass)	A. Pak Thong Chai	101 - 107	4615	854	
	904	AC	26	A. Pak Thong Chai	(Route 2)	107 - 133	2423	1170	
2023	100	PM	8	B. Nam Kong	A. Si That	0 - 8	3711	523	
2039	101	DT	16	A. Nam Phong	A. Kranuan	0 - 16	4394	851	
	102	DT	17	A. Nam Phong	A. Kranuan	16 - 33	4666	699	
2057	100*	AC	23	J.R. 2(A.Ban Phai)	A. Mancha Khiri	0 - 23	1676	258	
2071	100	DT	28	A. Chokchai	A. Khonburi	0 - 28	5397	572	
2109	100	DT	24	A. Nam Phong	A. Ubolratana Dam	0 - 24	7608	1731	
2160	100	DT	20	B. Wat	A. Kong	0 - 20	4638	2087	
2175	100	DT	34	B. Wang Hin	A. Chum Phuang	0 - 34	2940	554	

* Additional roughness survey was carried out to these links.

Table 8.3.2 RATING ITEMS ON PAVEMENT CONDITION SURVEY

Pavement Deficiency	Description
Rutting/Waves	• Longitudinal depressions that form under traffic in the wheel paths and have a minimum length of approximately 6 meters/Longitudinal or transverse undulations in the surface of the pavement, consisting of alternate valleys and crests approximately 60 cm or more apart.
Cracking (Longitudinal/ Transverse)	• A crack or break in the pavement surface. (Approximately parallel to centerline/at right angles to centerline)
Cracking (Alligator/ Block)	• Interconnected or interlaced cracks forming a series of small polygons that resemble an alligator's hide./ Interconnected cracks forming a series of large polygons usually with sharp corners or angles.
Pothole	• Bowl-shape hole of various sizes in the pavement.
Bump	• Localized upward displacement of the pavement.
Bleeding	• Free bitumen on the surface of the pavement.
Shoving	• Displacement or bulging of paving material in the direction of loading or pressure.
Other items taken into ratings	
Driving Comfort, Speed Change Cycle due to Surface Defects	• Owing to the various pavement deficiencies as indicated above, operating speed is interrupted thus giving discomfort to passesgers.
Patching	• Partially rehabilitated area with asphaltic materials.

Figure 8.3.2 PSI RATING FORM

THE ROADS DEVELOPMENT STUDY IN THE NORTHEASTERN REGION
IN THE KINGDOM OF THAILAND

PAVEMENT CONDITION RATING

FROM ·
TO

PAVEMENT TYPE : AC☐ PM☐ ST☐

DISTRICT
ROUTE :
LINK :

DATE :

RATING	5	4	3	2	1	0
1 Driving Comfort						
2 Speed Change Cycle due to surface condition						
3 Patching						
4 Rutting						
5 Longitudinal or Transvers Cracking						
6 Alligator Cracking						
7 Pot hole						
8 Bumping						
9 Bleeding						
10 Shoving						

Summation of Points__________ ÷ 10 • Ride Rating ☐

REMARK

Table 8.3.3 ROUGHNESS AND PSI

Route		Section Km	Roughness	PSI	
			(mm/Km)	Average	Range
AC	24 - 0200*	10 - 20	1880	4.32	4.2 ∿ 4.5
		25 - 30	2656	3.30	3.2 ∿ 3.5
	0300*	45 - 60	2508	3.58	3.1 ∿ 3.9
	0400	75 - 85	2707	3.36	3.2 ∿ 3.6
	0500	101 - 111	1919	4.20	4.1 ∿ 4.4
		111 - 117	7575	1.58	1.3 ∿ 1.7
		120 - 130	2111	4.00	4.0
	304 - 0800	57 - 67	5823	1.80	1.7 ∿ 1.9
		67 - 73	5370	2.08	1.9 ∿ 2.3
		78 - 88	3127	3.40	3.2 ∿ 3.6
		88 - 92	4476	2.72	2.6 ∿ 2.9
	0902	102 - 107	4661	2.84	2.5 ∿ 3.1
	0904	115 - 125	1698	4.42	4.3 ∿ 4.6
	2057 - 0100	0 - 23	1680	4.48	4.4 ∿ 4.7
ST	201 - 0200	45 - 55	3858	3.46	3.4 ∿ 3.5
	0300	70 - 80	5850	2.82	2.7 ∿ 3.0
	202 - 0500	14 - 24	3761	3.70	3.5 ∿ 3.9
	207 - 0100	450 - 470	4338	3.24	3.0 ∿ 3.3
	0202	484 - 498	4237	3.44	3.1 ∿ 3.8
	208 - 0100	15 - 25	4319	2.40	2.2 ∿ 2.7
	0200	35 - 45	5173	2.16	1.9 ∿ 2.4
		49 - 55	6912	1.72	1.4 ∿ 2.3
	213 - 0100	0 - 10	4365	3.32	3.0 ∿ 3.7
		29 - 38	3254	3.98	3.8 ∿ 4.1
	214 - 0100	0 - 10	3824	3.06	2.5 ∿ 3.5
		14 - 24	3144	3.96	3.9 ∿ 4.2
	0200	33 - 45	3235	3.40	3.3 ∿ 3.5
	2039 - 0101	0 - 16	4395	3.04	3.0 ∿ 3.1
	0102	16 - 33	4667	3.24	3.2 ∿ 3.4
	2071 - 0100	0 - 28	5398	2.80	2.7 ∿ 2.9
	2109 - 0100	0 - 24	7608	1.76	1.3 ∿ 2.0
	2160 - 0100	0 - 10	3533	2.70	2.6 ∿ 2.8
		12 - 19	5007	2.52	2.4 ∿ 3.0
PM	202 - 0301*	51 - 66	4897	3.48	3.4 ∿ 3.8
	214 - 0800	10 - 20	4378	2.73	2.6 ∿ 2.8
		20 - 25	5554	2.92	2.6 ∿ 3.2
	0900	30 - 50	3472	4.10	3.8 ∿ 4.2
	219 - 0100*	43 - 25	4152	3.54	3.4 ∿ 3.8
	0200*	3 - 17	3491	4.12	3.9 ∿ 4.2
		18 - 23	4729	3.66	3.1 ∿ 4.0

* : Those links are not included in the proposed links.

Figure 8.3.3

Figure 8.3.3 PSI VERSUS ROUGHNESS BY SURFACE TYPE

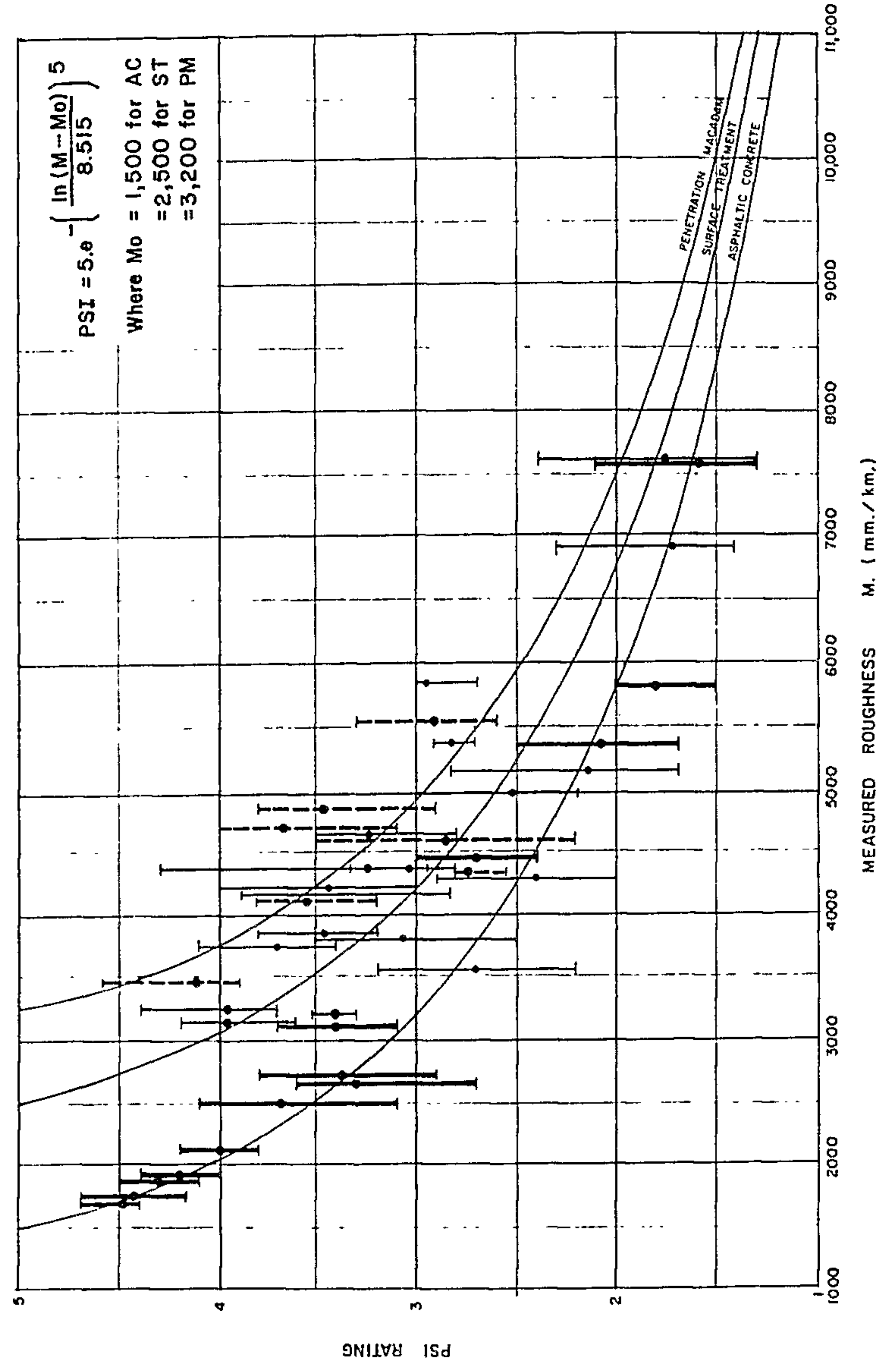
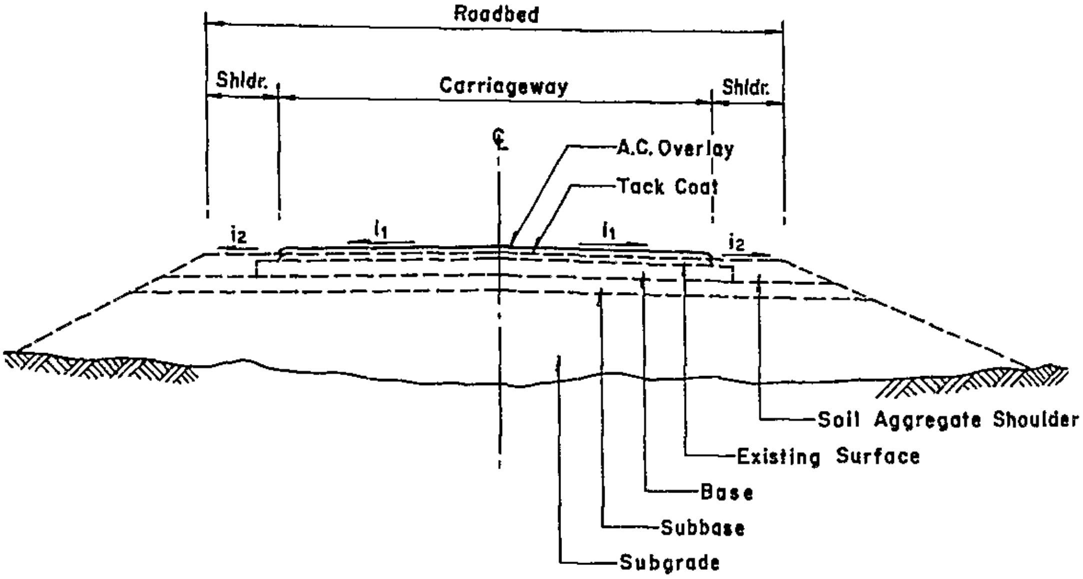


Figure 8.3.4 TYPICAL OVERLAY AND RECONSTRUCTION SECTIONS

OVERLAY



RECONSTRUCTION

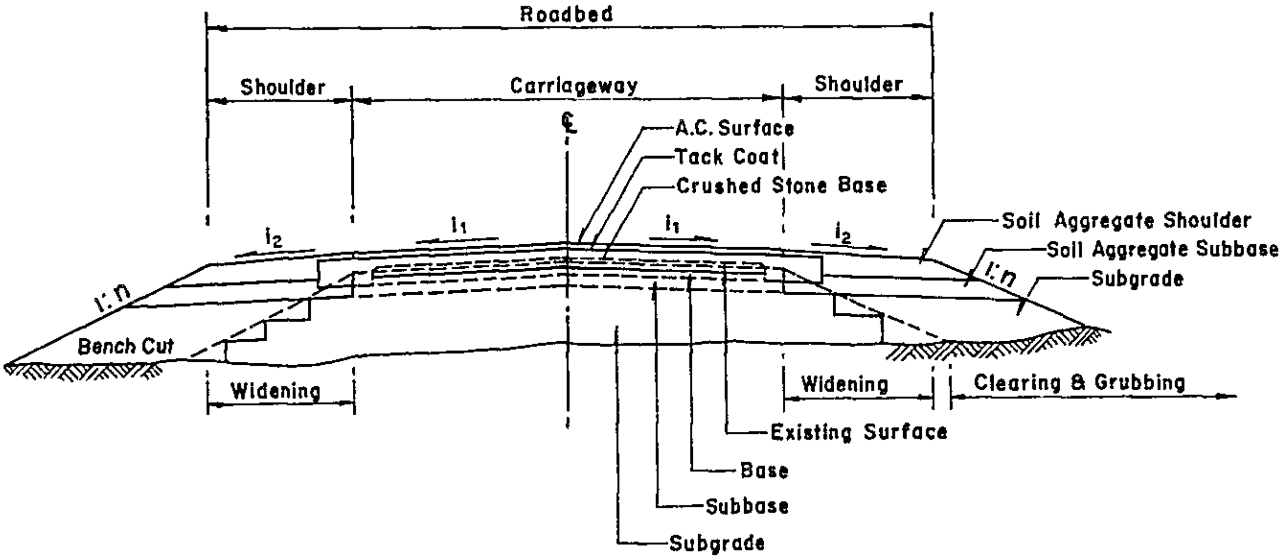


Table 8.3.4(a)

Table 8.3.4(a) ESA CONVERSION FACTORS

6-Wheel Trucks (National Road)

Gross Weight (ton)	Axle load (ton)		Equivalence Factor			Frequency	E S A
	Front	Rear	Front	Rear	Total	(%)	Factor
4	1.68	2.32	0.0024	0.006	0.0084	40.0	0.336
5	1.95	3.05	0.0036	0.015	0.0186	1.555	0.029
6	2.16	3.84	0.0048	0.038	0.0428	2.938	0.126
7	2.38	4.62	0.0065	0.085	0.0915	5.187	0.475
8	2.56	5.44	0.0082	0.183	0.1912	7.081	1.354
9	2.75	6.25	0.0103	0.335	0.3453	7.431	2.566
10	2.90	7.10	0.0125	0.55	0.5625	9.330	5.248
11	3.08	7.92	0.0157	0.87	0.8857	6.564	5.814
12	3.24	8.76	0.0190	1.35	1.369	5.360	7.338
13	3.45	9.55	0.025	2.00	2.025	3.626	7.343
14	3.64	10.36	0.030	2.90	2.93	6.226	18.242
15	3.77	11.23	0.035	4.15	4.185	2.077	8.692
16	3.87	12.13	0.040	6.00	6.04	1.383	8.353
17	4.01	12.99	0.045	8.30	8.345	0.344	2.871
18	4.14	13.86	0.053	11.10	11.153	0.381	4.249
19	4.33	14.67	0.064	14.20	14.264	0.277	3.951
20	4.52	15.48	0.078	18.20	18.278	0.245	4.478
Total						100	81.465
Factor							0.81

Table 8.3.4(b)

Table 8.3.4(b) ESA CONVERSION FACTORS

6-Wheel Trucks (Provincial Road)

Gross Weight (ton)	Axle load (ton)		Equivalence Factor			Frequency	E S A
	Front	Rear	Front	Rear	Total	(%)	Factor
4	1.68	2.32	0.0024	0.006	0.0084	50.0	0.420
5	1.95	3.05	0.0036	0.015	0.0186	1.296	0.024
6	2.16	3.84	0.0048	0.038	0.0428	2.448	0.105
7	2.38	4.62	0.0065	0.085	0.0915	4.323	0.396
8	2.56	5.44	0.0082	0.183	0.1912	5.900	1.128
9	2.75	6.25	0.0103	0.335	0.3453	6.192	2.138
10	2.90	7.10	0.0125	0.55	0.5625	7.775	4.373
11	3.08	7.92	0.0157	0.87	0.8857	5.470	4.845
12	3.24	8.76	0.0190	1.35	1.369	4.466	6.114
13	3.45	9.55	0.025	2.00	2.025	3.022	6.119
14	3.64	10.36	0.030	2.90	2.93	5.188	15.201
15	3.77	11.23	0.035	4.15	4.185	1.731	7.244
16	3.87	12.13	0.040	6.00	6.04	1.152	6.958
17	4.01	12.99	0.045	8.30	8.345	0.287	2.395
18	4.14	13.86	0.053	11.10	11.153	0.318	3.547
19	4.33	14.67	0.064	14.20	14.264	0.230	3.281
20	4.52	15.48	0.078	18.20	18.278	0.205	3.747
Total						100	68.035
Factor							0.68

Table 8.3.4(c)

Table 8.3.4(c) ESA CONVERSION FACTORS

10-Wheel Trucks (National Road)

Gross Weight (ton)	Axle load (ton)		Equivalence Factor			Frequency	E S A
	Front	Rear	Front	Rear	Total	(%)	Factor
8	2.83	5.17	0.0115	0.0158	0.027	35.0	0.945
9	2.98	6.02	0.0138	0.027	0.041	0.163	0.007
10	3.08	6.92	0.0158	0.044	0.060	0.325	0.020
11	3.18	7.82	0.0178	0.067	0.085	0.598	0.051
12	3.24	8.76	0.0188	0.103	0.122	0.761	0.093
13	3.32	9.68	0.0205	0.153	0.174	0.924	0.161
14	3.36	10.64	0.022	0.22	0.242	1.086	0.263
15	3.41	11.59	0.023	0.31	0.333	1.574	0.524
16	3.42	12.58	0.023	0.43	0.453	2.114	0.958
17	3.45	13.55	0.024	0.6	0.624	3.955	2.468
18	3.46	14.54	0.024	0.82	0.844	7.806	6.588
19	3.48	15.52	0.025	1.1	1.125	12.633	14.212
20	3.48	16.52	0.025	1.41	1.435	12.900	18.512
21	3.51	17.49	0.026	1.8	1.826	5.419	9.895
22	3.52	18.48	0.026	2.35	2.376	1.952	4.638
23	3.54	19.46	0.0265	3.0	3.027	2.277	6.892
24	3.55	20.45	0.027	3.8	3.827	2.004	7.669
25	3.60	21.40	0.029	4.6	4.629	2.277	10.540
26	3.64	22.36	0.03	5.7	5.73	2.654	15.207
27	3.73	23.27	0.033	6.8	6.833	1.900	12.983
28	3.81	24.19	0.036	8.0	8.036	0.976	7.843
29	3.86	25.14	0.039	9.4	9.439	0.436	4.115
30	3.90	26.10	0.04	11.2	11.24	0.215	2.417
31	3.94	27.06	0.043	13.0	13.043	0.052	0.678
Total						100	127.679
Factor							1.28

Table 8.3.4(d) ESA CONVERSION FACTORS

10-Wheel Trucks (Provincial Road)

Gross Weight (ton)	Axle load (ton)		Equivalence Factor			Frequency	E S A
	Front	Rear	Front	Rear	Total	(%)	Factor
8	2.83	5.17	0.0115	0.0158	0.027	50.0	1.35
9	2.98	6.02	0.0138	0.027	0.041	0.125	0.005
10	3.08	6.92	0.0158	0.044	0.060	0.250	0.015
11	3.18	7.82	0.0178	0.067	0.085	0.460	0.039
12	3.24	8.76	0.0188	0.103	0.122	0.585	0.071
13	3.32	9.68	0.0205	0.153	0.174	0.711	0.124
14	3.36	10.64	0.022	0.22	0.242	0.836	0.202
15	3.41	11.59	0.023	0.31	0.333	1.211	0.403
16	3.42	12.58	0.023	0.43	0.453	1.626	0.737
17	3.45	13.55	0.024	0.6	0.624	3.042	1.898
18	3.46	14.54	0.024	0.82	0.844	6.005	5.068
19	3.48	15.52	0.025	1.1	1.125	9.718	10.933
20	3.48	16.52	0.025	1.41	1.435	9.923	14.240
21	3.51	17.49	0.026	1.8	1.826	4.168	7.611
22	3.52	18.48	0.026	2.35	2.376	1.501	3.566
23	3.54	19.46	0.0265	3.0	3.027	1.751	5.300
24	3.55	20.45	0.027	3.8	3.827	1.541	5.897
25	3.60	21.40	0.029	4.6	4.629	1.751	8.105
26	3.64	22.36	0.03	5.7	5.73	2.042	11.701
27	3.73	23.27	0.033	6.8	6.833	1.461	9.983
28	3.81	24.19	0.036	8.0	8.036	0.751	6.035
29	3.86	25.14	0.039	9.4	9.439	0.335	3.162
30	3.90	26.10	0.04	11.2	11.24	0.165	1.855
31	3.94	27.06	0.043	13.0	13.043	0.040	0.522
Total						100	98.822
Factor							0.99

Figure 8.3.5

Figure 8.3.5 DEFLECTION - PAVEMENT LIFE RELATIONSHIP

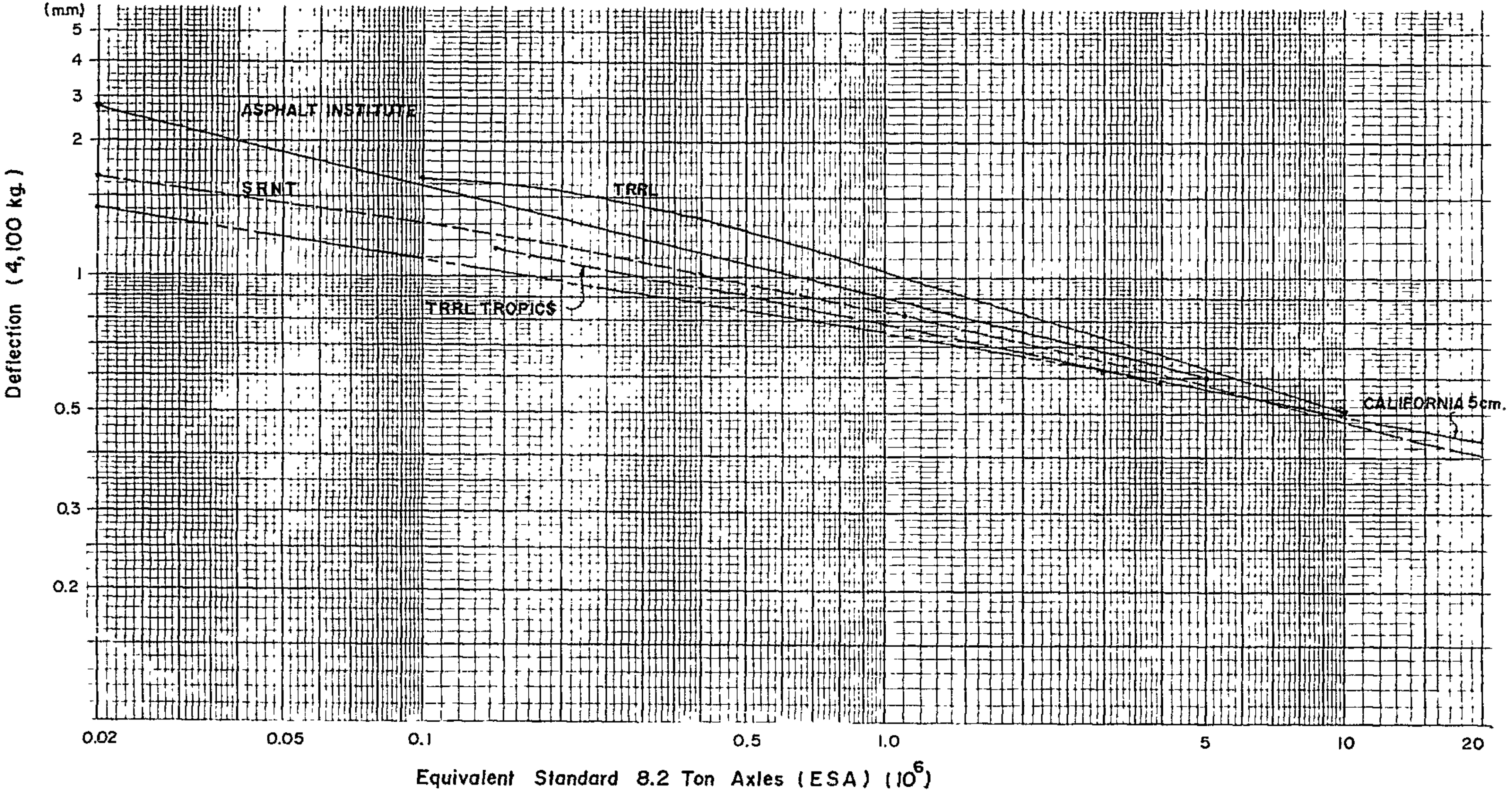
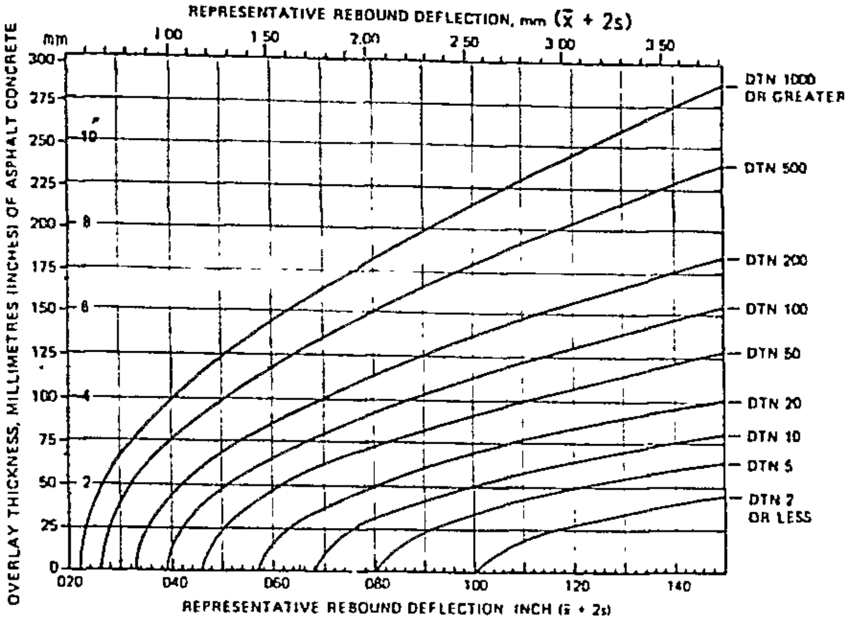
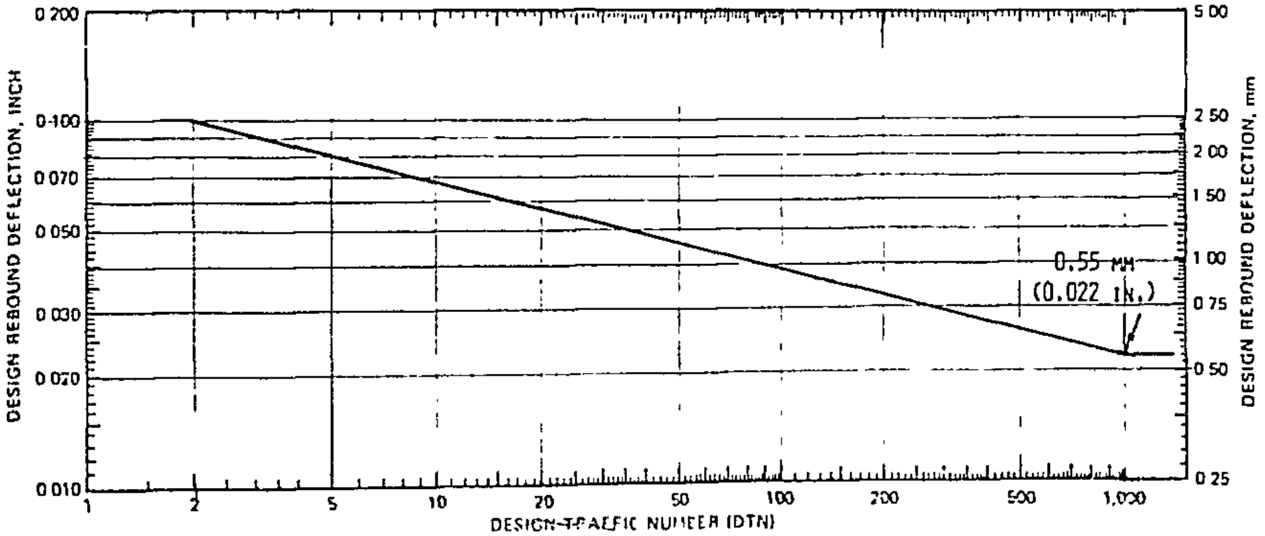


Figure 8.3.6(a) OVERLAY DESIGN -- ASPHALT INSTITUTE METHOD

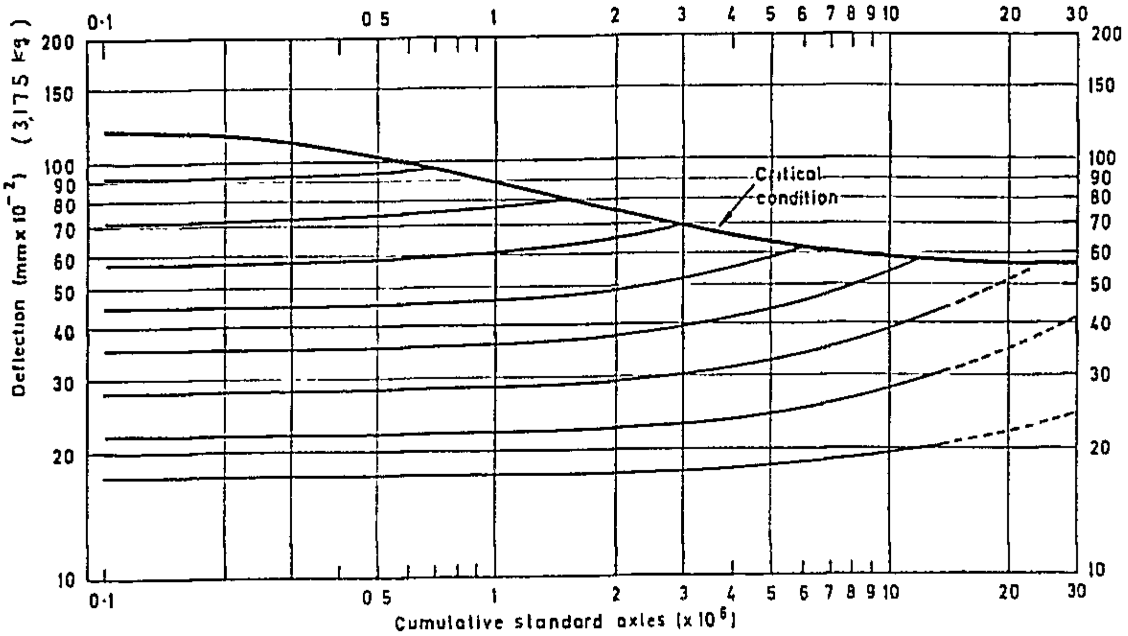


Asphalt concrete overlay thickness required to reduce pavement deflection from a measured to a design deflection value (rebound test).

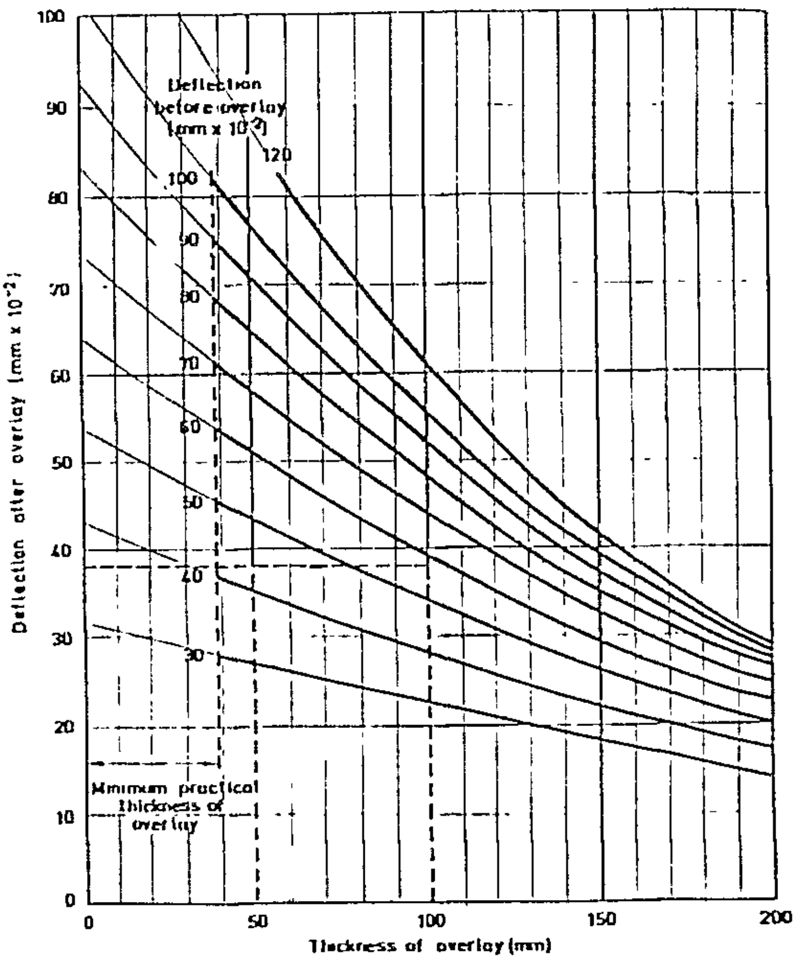


Design Rebound Deflection Chart

Figure 8.3.6(b) OVERLAY DESIGN -- TRRL METHOD

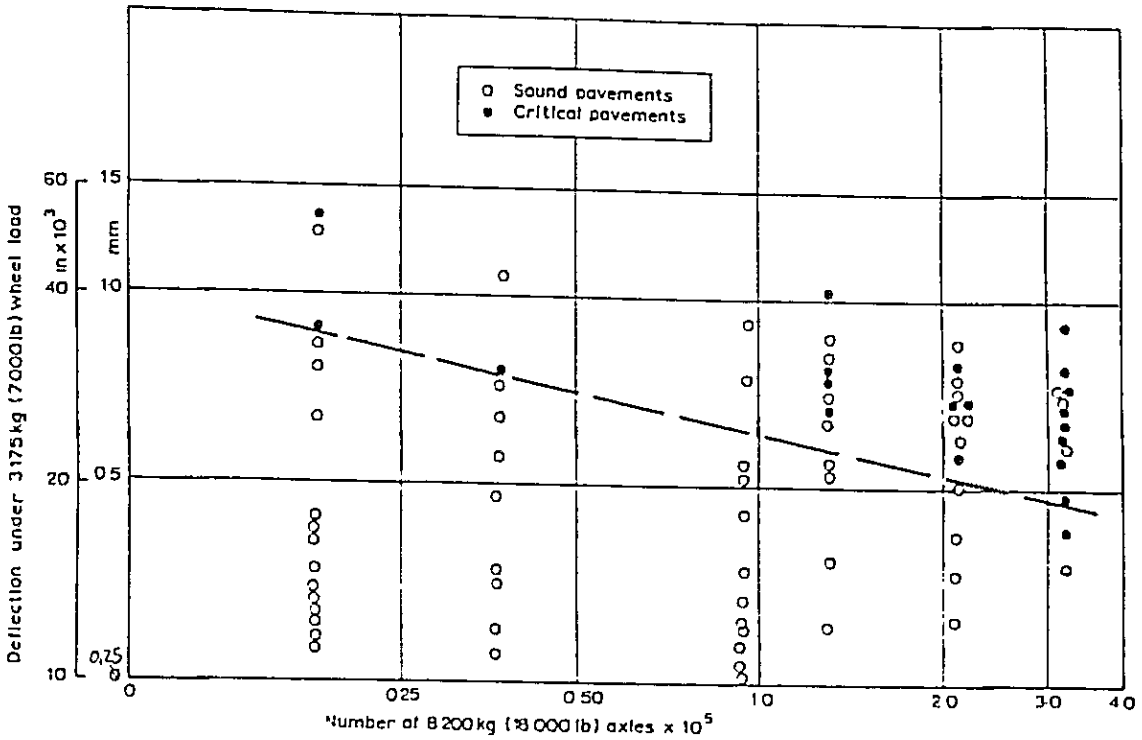


DEFLECTION-LIFE RELATIONSHIPS FOR PAVEMENTS WITH UNBOUND-BASES

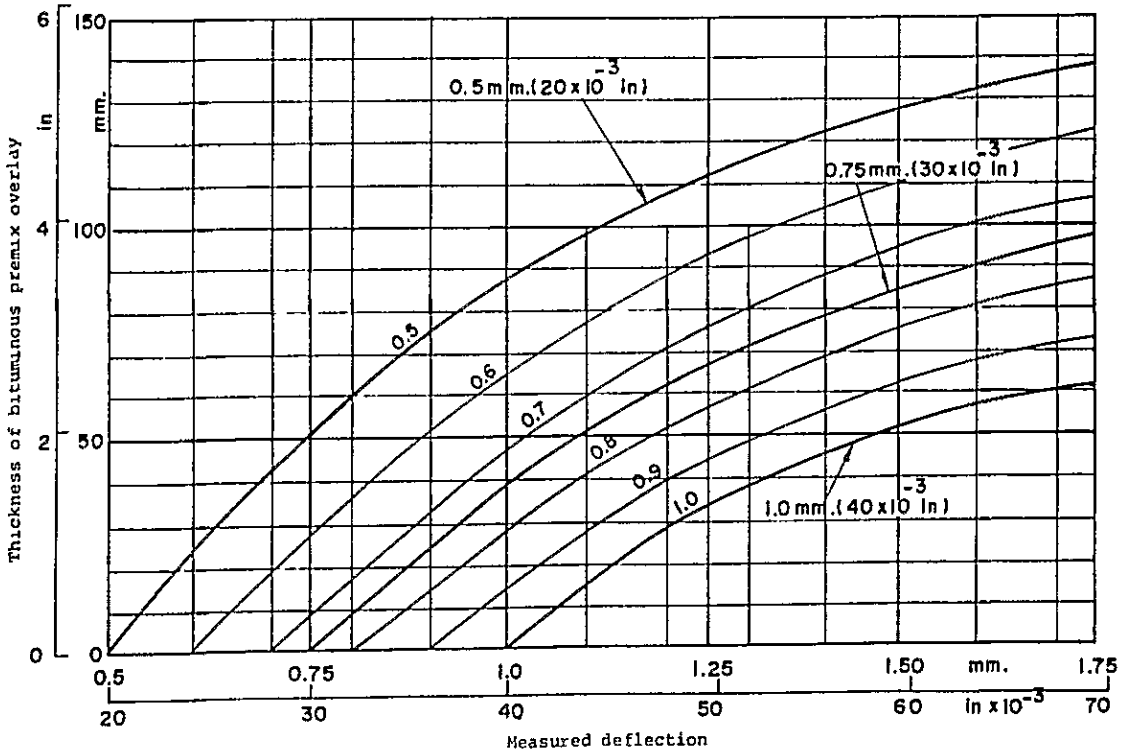


OVERLAY DESIGN CHART

Figure 8.3.6(c) OVERLAY DESIGN -- TRRL METHOD IN THE TROPICS



TENTATIVE DEFLECTION CRITERION CURVE FCR 75=10=100 mm (3 TO 4 in) BITUMEN MACADAM SURFACTINGS ON CRUSHED STONE BASES IN A WT TROPICAL ENVIRONMENT



THE THICKNESS OF BITUMINOUS PREMIX OVERLAY REQUIRED TO REDUCE THE DEFLECTION OF A PAVEMENT TO DESIGNATED VALUES

Figure 8.3.6(d)

Figure 8.3.6(d) OVERLAY DESIGN -- RUIZ's FORMULA

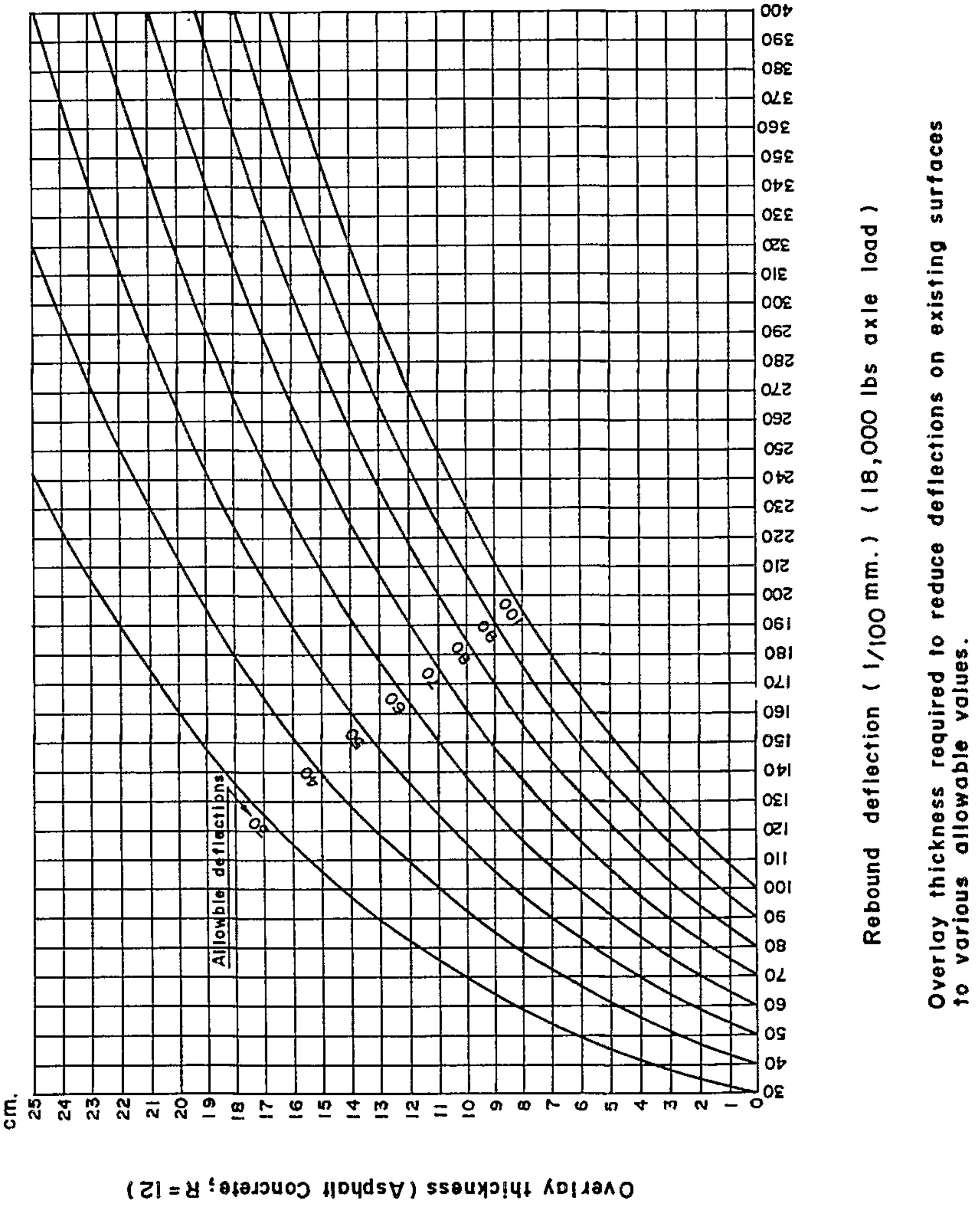
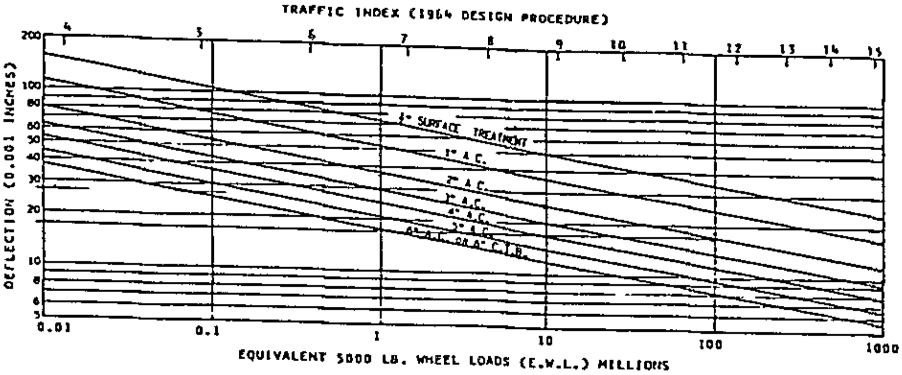
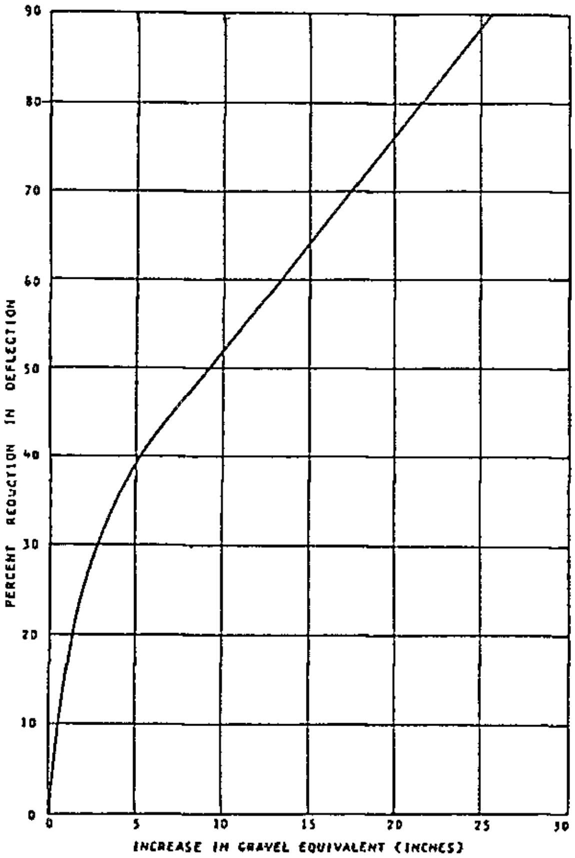


Figure 8.3.6(e) OVERLAY DESIGN -- CALIFORNIA DIVISION OF HIGHWAYS' METHOD



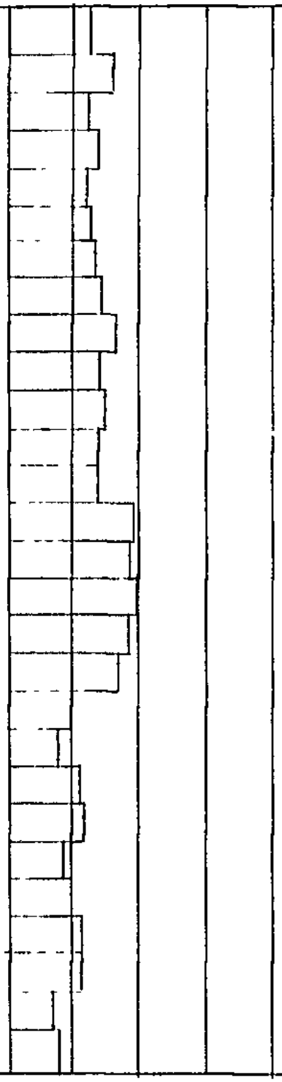
Variation in Tolerable Deflection Based on A.C. Fatigue Tests, California Method of Overlay Design



Reduction in Deflection Resulting from Pavement Reconstruction, California Method of Overlay Design

Table 8.3.5 COMPARATIVE STUDIES ON OVERLAY DESIGN

RH-I(24-0400)

Section (Km.)-(Km.)	Average Deflection $\overline{X}$ (m.m.)	Standard Deviation σ (m.m.)	Design Deflection $\overline{X}$+1.5σ(m.m.)	Roughness (10^3mm/Km.) 0 2 4 6 8	Overlay Thickness (mm) A1	A2	B	C	D	E	Remarks.
74 - 75	0.6433	0.2704	1.0490		28	45	12	32	30	31	
75 - 76	0.7241	0.2095	1.0383		26	40	0	31	28	30	
76 - 77	0.7881	0.2606	1.1790		44	57	30	47	44	49	
77 - 78	0.5560	0.2330	0.9056		0	23	*	13	13	14	
78 - 79	0.5040	0.1922	0.7922		0	0	*	0	0	3	
79 - 80	0.5394	0.2037	0.8449		0	3	*	3	4	8	
80 - 81	0.5970	0.2038	0.9027		0	19	*	12	12	14	
81 - 82	0.6136	0.1564	0.8433		0	0	*	3	4	8	
82 - 83	0.7940	0.1665	1.0437		27	38	10	32	28	31	
83 - 84	0.5625	0.1367	0.7675		0	0	*	0	0	0	
84 - 85	0.8525	0.1415	1.0648		30	39	12	34	31	34	
85 - 86	0.7019	0.1961	0.9960		18	34	0	25	21	24	
86 - 87	0.9562	0.1740	1.2171		48	56	33	51	47	57	
87 - 88	0.7802	0.1445	0.9969		18	31	0	25	22	24	
88 - 89	0.7038	0.1146	0.8758		0	0	*	8	9	11	
89 - 90	0.6090	0.1342	0.8103		0	0	*	0	0	4	
90 - 91	0.8868	0.1801	1.1570		42	51	26	45	42	46	
91 - 92	0.6376	0.0953	0.7806		0	0	*	0	0	2	
92 - 93	0.7700	0.1607	1.0110		20	34	0	27	25	26	
93 - 94	0.6913	0.1150	0.8638		0	0	*	7	7	10	
94 - 95	0.7548	0.1105	0.9205		0	13	0	14	13	15	
95 - 96	0.7370	0.3539	1.2678		53	67	39	56	53	67	
96 - 97	0.6917	0.1160	0.8658		0	0	*	7	8	10	
97 - 98	0.6539	0.1147	0.8279		0	0	*	0	0	7	
98 - 99	0.5870	0.1466	0.8068		0	0	*	0	0	4	
99 -100	0.5817	0.1526	0.8107		0	0	*	0	0	5	
100 -101	0.6327	0.1687	0.8857		0	11	*	9	10	12	
101 -102	0.5470	0.0602	0.6373		0	0	*	*	0	0	

Note;

A1; Asphalt Institute Method (Design Def. $\overline{X}$ + 1.5σ)

A2; Asphalt Institute Method (Design Def. $\overline{X}$ + 2.0σ)

B; TRRL Method

C; TRRL in the Tropics Method

D; Ruiz's Formula

E; California Method

* Pavement failure within design period is not foreseen.

Table 8.3.6 REHABILITATION MEASURES

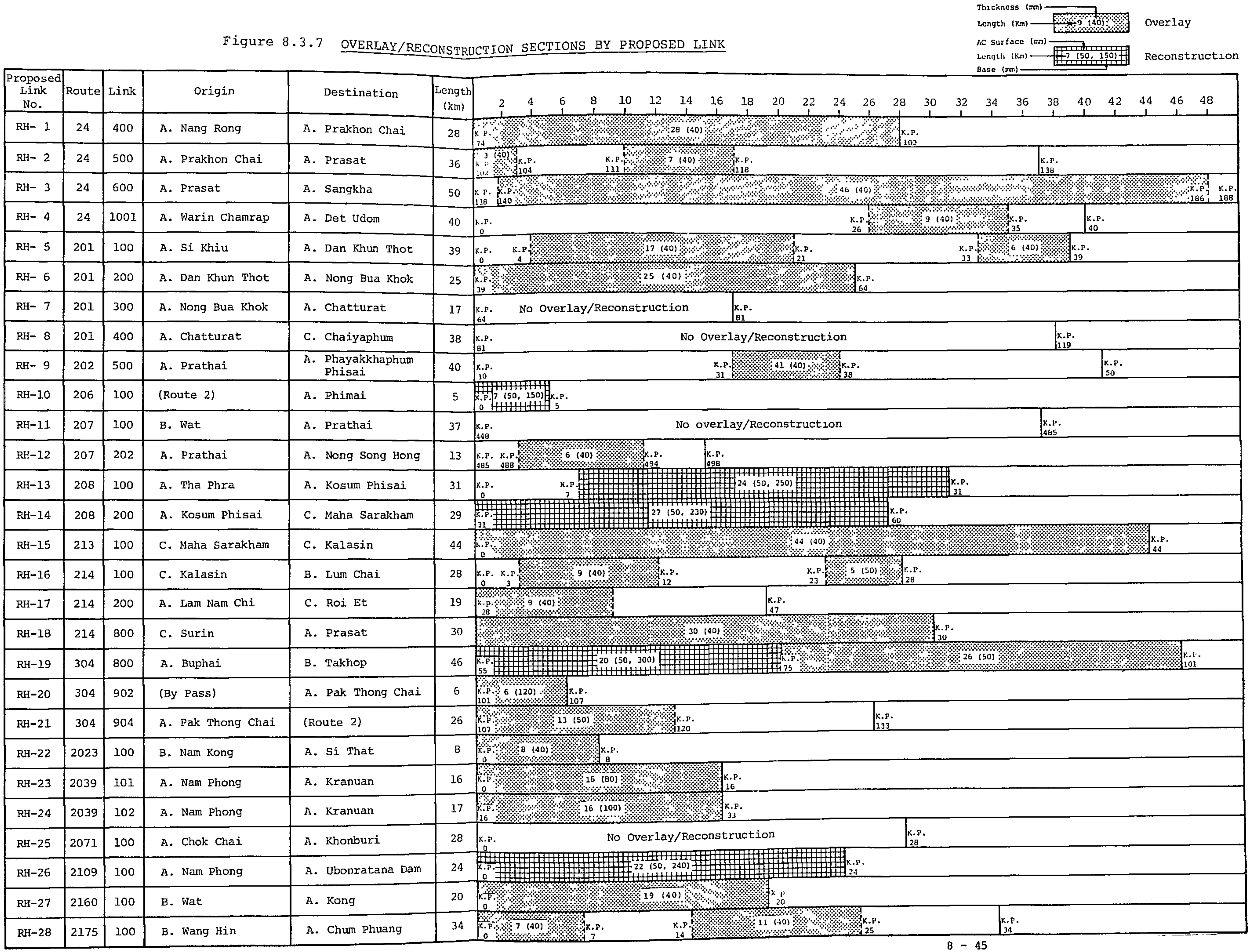
Link No.	Km.-Km.	Length (Km)	Calculated Thickness1/ (mm)	Planned Thickness2/ (mm)	Roughness1/ (mm/km)	Rehabilitation Measures
RH - 1	74 - 102	28	20	40	2,620	Overlay
RH - 2	102 - 104	2	14	40	1,680	Overlay
	110 - 118	8	3	40	6,520	Overlay
RH - 3	140 - 186	46	27	40	3,170	Overlay
RH - 4	26 - 35	9	7	40	2,990	Overlay
RH - 5	4 - 21	17	6	40	5,510	Overlay
	33 - 39	6	28	40	4,770	Overlay
RH - 6	39 - 64	25	32	40	4,100	Overlay
RH - 7*						
RH - 8*						
RH - 9	31 - 38	7	11	40	3,690	Overlay
RH - 10	0 - 5	5	70	50(150)		Reconstruction
RH - 11*						
RH - 12	488 - 494	6	8	40	4,070	Overlay
RH - 13	7 - 31	24	38	50(250)	4,350	Reconstruction
RH - 14	31 - 58	27	66	50(230)	5,030	Reconstruction
RH - 15	0 - 44	44	12	40	4,010	Overlay
RH - 16	3 - 12	9	19	40	3,770	Overlay
	23 - 28	5	42	50	3,970	Overlay
RH - 17	28 - 37	9	32	40	4,200	Overlay
RH - 18	0 - 30	30	35	40	4,240	Overlay
RH - 19	55 - 75	20	126	50(300)	5,330	Reconstruction
	75 - 101	26	58	50	3,310	Overlay
RH - 20	101 - 107	6	129	120	4,480	Overlay
RH - 21	107 - 120	13	43	50	2,560	Overlay
RH - 22	0 - 8	8	35	40	3,710	Overlay
RH - 23	0 - 16	16	72	80	4,400	Overlay
RH - 24	16 - 32	16	95	100	4,670	Overlay
RH - 25*						
RH - 26	0 - 22	22	39	50(240)	7,590	Reconstruction
RH - 27	0 - 16	16	29	40	4,160	Overlay
RH - 28	0 - 7	7	25	40	3,040	Overlay
	14 - 25	11	32	40	3,160	Overlay
Total		468				

Note: 1/ : Figures indicate the average of the section.

2/ : Figures indicate AC thickness for Overlay and AC surface and crushed rock base for Reconstruction.

* : No rehabilitation works are required within the design period.

Figure 8.3.7 OVERLAY/RECONSTRUCTION SECTIONS BY PROPOSED LINK



Proposed Link No.	Route	Link	Origin	Destination	Length (km)
RH- 1	24	400	A. Nang Rong	A. Prakhon Chai	28
RH- 2	24	500	A. Prakhon Chai	A. Prasat	36
RH- 3	24	600	A. Prasat	A. Sangkha	50
RH- 4	24	1001	A. Warin Chamrap	A. Det Udom	40
RH- 5	201	100	A. Si Khiu	A. Dan Khun Thot	39
RH- 6	201	200	A. Dan Khun Thot	A. Nong Bua Khok	25
RH- 7	201	300	A. Nong Bua Khok	A. Chatturat	17
RH- 8	201	400	A. Chatturat	C. Chaiyaphum	38
RH- 9	202	500	A. Prathai	A. Phayakkhaphum Phisai	40
RH-10	206	100	(Route 2)	A. Phimai	5
RH-11	207	100	B. Wat	A. Prathai	37
RH-12	207	202	A. Prathai	A. Nong Song Hong	13
RH-13	208	100	A. Tha Phra	A. Kosum Phisai	31
RH-14	208	200	A. Kosum Phisai	C. Maha Sarakham	29
RH-15	213	100	C. Maha Sarakham	C. Kalasin	44
RH-16	214	100	C. Kalasin	B. Lum Chai	28
RH-17	214	200	A. Lam Nam Chi	C. Roi Et	19
RH-18	214	800	C. Surin	A. Prasat	30
RH-19	304	800	A. Buphai	B. Takhop	46
RH-20	304	902	(By Pass)	A. Pak Thong Chai	6
RH-21	304	904	A. Pak Thong Chai	(Route 2)	26
RH-22	2023	100	B. Nam Kong	A. Si That	8
RH-23	2039	101	A. Nam Phong	A. Kranuan	16
RH-24	2039	102	A. Nam Phong	A. Kranuan	17
RH-25	2071	100	A. Chok Chai	A. Khonburi	28
RH-26	2109	100	A. Nam Phong	A. Ubonratana Dam	24
RH-27	2160	100	B. Wat	A. Kong	20
RH-28	2175	100	B. Wang Hin	A. Chum Phuang	34

Table 8.3.7 SUMMARY OF REHABILITATION COSTS

Link No.	Link Length (km)	Rehabilitation Costs		Remarks
		Financial (10^6B)	Economic (10^6B)	
RH - 1	28	22.5	20.3	Overlay
RH - 2	10	7.5	6.8	"
RH - 3	46	34.5	31.1	"
RH - 4	9	6.8	6.2	"
RH - 5	23	17.3	15.6	"
RH - 6	25	18.7	16.9	"
RH - 9	7	5.3	4.8	"
RH - 10	5	8.6	7.8	Reconstruction
RH - 12	6	4.5	4.1	Overlay
RH - 13	24	60.0	54.4	Reconstruction
RH - 14	27	65.9	59.8	"
RH - 15	44	33.0	29.8	Overlay
RH - 16	14	11.3	10.2	"
RH - 17	9	6.8	6.2	"
RH - 18	30	22.5	20.3	"
RH - 19	26	29.2	26.3	"
- 19	20	52.9	48.0	Reconstruction
RH - 20	6	15.7	14.2	Overlay
RH - 21	13	13.9	12.5	"
RH - 22	8	5.0	4.5	"
RH - 23	16	24.4	22.0	"
RH - 24	16	29.8	26.8	"
RH - 26	22	42.3	38.4	Reconstruction
RH - 27	16	10.0	9.0	Overlay
RH - 28	18	12.5	11.2	"
Total		560.9		

Figure 8.4.1 ROUGHNESS - VOCs RELATIONSHIPS

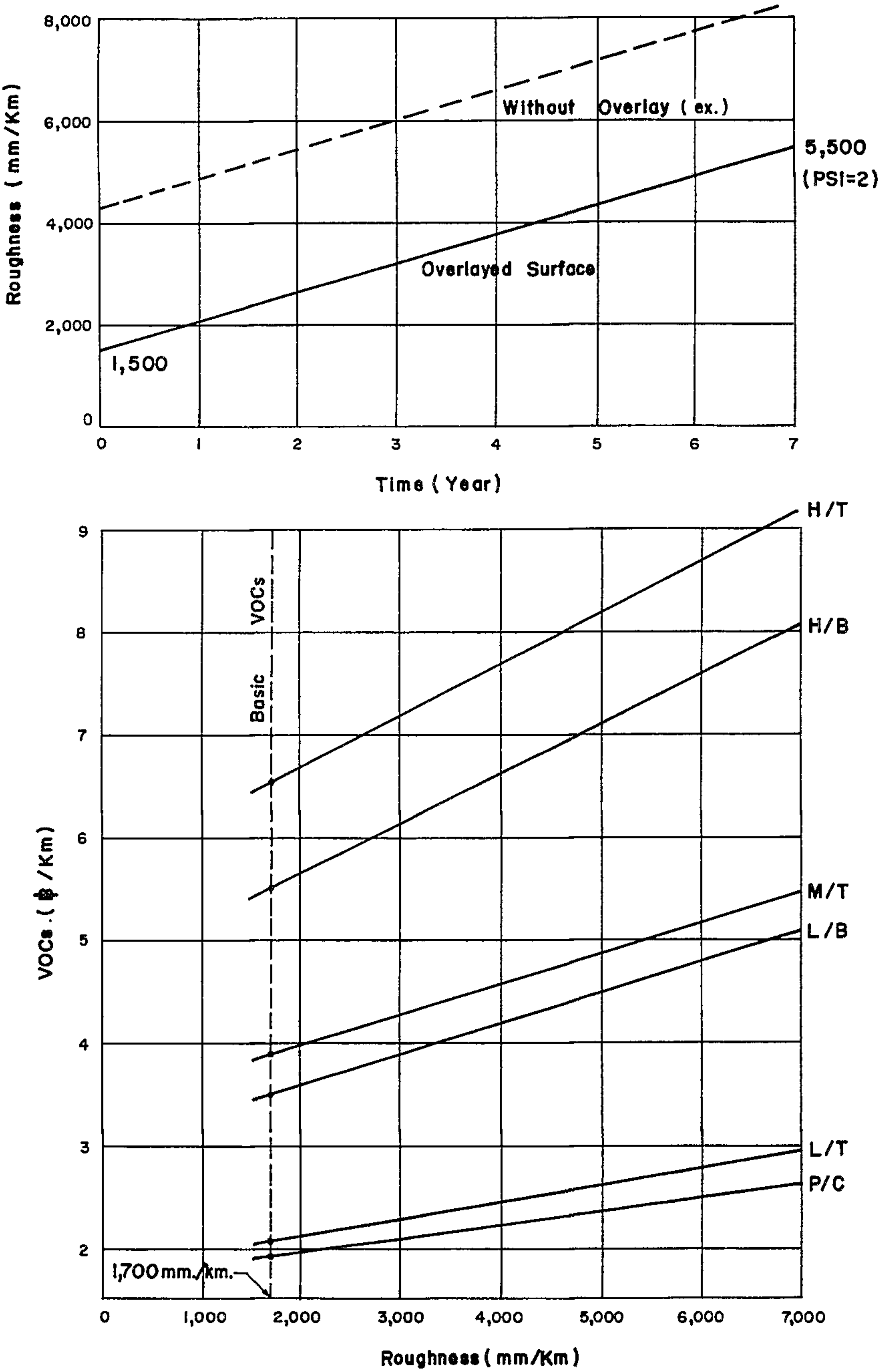


Table 8.5.1 SUMMARY RESULTS OF EVALUATION FOR REHABILITATION LINKS

Proposed Links								ADT (1989)	Length (Km)		Design Deflection (mm)	Pavement roughness (mm/km)	AC Overlay Thickness (mm)	Reconst. AC-Surface (mm) Base (mm)	Construction Cost (10^6 ฿)	IRR (%)
Link Number	Route	Link	Surface Type	Link Length (Km)	Origin	Destination	Proposed Length (Km)		Overlay	Reconstruction						
RH-1	24	400	AC	28	A. Nang Rong	A. Prakhon Chai	28	1386	28	-	0.899	2,620	40		22.5	13.3
RH-2	24	500	AC	36	A. Prakhon Chai	A. Prasat	36	1701	10	-	0.797	5,450	40		7.5	91.9
RH-3	24	600	AC	50	A. Prasat	A. Sangkha	50	880	46	-	1.194	3,170	40		34.5	11.0
RH-4	24	1001	DT	40	A. Warin Chamrap	A. Det Udom	40	1662	9	-	0.849	2,990	40		6.8	27.9
RH-5	201	100	DT	39	A. Sikhui	A. Dan Khun Thot	39	1474	23	-	0.895	5,320	40		17.3	69.7
RH-6	201	200	DT	25	A. Dan Khun Thot	A. Nong Bua Khok	25	1427	25	-	1.046	4,100	40		18.7	48.8
RH-7	201	300	DT	17	A. Nong Bua Khok	A. Chatturat	17	1776	**		0.510	5,560	**			
RH-8	201	400	DT	38	A. Chatturat	C. Chaiyaphum	38	1776	**		0.341	4,890	**			
RH-9	202	500	DT	40	A. Prathai	A. Phrayakkhamphum Phisai	40	849	7	-	1.005	3,690	40		5.3	20.3
RH-10	206	103	AC	5	A. Phimai By Pass		5	725	-	5	0.881			50 150	8.6	19.6
RH-11	207	100	DT	37	B. Wat	A. Prathai	37	695	**		0.783	4,430	**			
RH-12	207	202	DT	35	A. Prathai	A. Khok Chik	13	601	6	-	0.958	4,070	40		4.5	10.1
RH-13	208	100	DT	31	A. Tha Phra	A. Kosum Phisai	31	1912	-	24	1.126	4,350		50 250	60.0	9.9
RH-14	208	200	DT	29	A. Kosum Phisai	C. Maha Sarakham	29	1722	-	27	1.316	5,030		50 230	65.9	11.7
RH-15	213	100	DT	44	C. Maha Sarakham	A. Kalasin	44	1742	44	-	0.882	4,010	40		33.0	56.8
RH-16	214	100	DT	28	A. Kalasin	B. Lum Chai	28	1793	14	-	1.121	3,850	(40-9km 50-5km)		11.3	43.1
RH-17	214	200	DT	19	A. Lamnamchi	C. Roi Et	19	1118	9	-	1.166	4,200	40		6.8	34.5
RH-18	214	800	PM	30	C. Surin	A. Prasat	30	2249	30	-	1.035	4,240	40		22.5	82.8
RH-19	304	800	AC	46	A. Buphai	B. Takhop	46	2350	26	20	1.476	4,180	50	50 300	82.1	28.9
RH-20	304	902	AC	6	A. Pak Thong Chai By Pass		6	2720	6	-	1.564	4,480	120		15.7	25.7
RH-21	304	904	AC	26	A. Pak Thong Chai	(Route 2)	26	2720	13	-	1.030	2,560	50		13.9	20.7
RH-22	2023	100	PM	8	B. Nam Kong	A. Si That	8	3936	8	-	1.047	3,710	40		5.0	118.1
RH-23	2039	101	DT	16	A. Nam Phong	A. Kranuan	16	2016	16	-	1.339	4,400	80		24.4	34.5
RH-24	2039	102	DT	17	A. Nam Phong	A. Kranuan	17	2016	16	-	1.538	4,670	100		29.8	29.8
RH-25	2071	100	DT	28	A. Chokchai	A. Khonburi	28	1108	**		0.734	5,400	**			
RH-26	2109	100	DT	24	A. Nam Phong	A. Ubolratana Dam	24	959	-	22	1.409	7,590		50 240	42.3	22.7
RH-27	2160	100	DT	20	B. Wat	A. Kong	20	442	16	-	1.397	4,160	40		10.0	7.3
RH-28	2175	100	DT	34	B. Wang Hin	A. Chum Phuang	34	1104	18	-	1.214	3,110	40		12.5	13.1
						Total	774		370	98						

(**) Overlay/Reconstruction is not required

CHAPTER 9

PRIORITY RANKING AND PHASING

CHAPTER 9
PRIORITY RANKING AND PHASING

9.1 APPROACH

Listings of the proposed projects ranked by economic viability or social impacts are to be further scrutinized from an overall viewpoint taking also into account policies of the Thai Government.

In determining priority order of the projects for improvement and new construction, an attention is paid to the significance of social impact as well as the economic justification.

Priority or urgency of the proposed project for rehabilitation is judged primarily according to the degree of the existing deterioration, although the economic viability of the investment for rehabilitation is also assessed.

The projects given high priority ranking are classified into Stage I program, and the remained is considered to be included in Stage II program.

9.2 PRIORITY RANKING AND PROPOSED PHASING

9.2.1 Routes for Improvement and New Construction

First, priority of the projects was assessed from the viewpoint of economic viability. As a consequent, 15 routes were picked up to be included into a group of high priority projects. Next, for the remaining 18 routes, further screening was made paying special attention to the routes which have importance from the viewpoint of social impacts. And, 3 routes were chosen to be added into the priority project group. Eighteen routes thus selected were classified into Stage I program and the remained 15 routes were considered to be included into Stage II. The projects included in the Stage I are recommended to be proceeded with further feasibility studies for earliest implementation.

The process of phasing is illustrated in Figure 9.2.1 and a proposal of a phased project list is presented in Table 9.2.1 and shown in Figure 9.2.2.

9.2.2 Links for Rehabilitation

Out of the identified links of 774 km in total, sections of 468 km was proposed to be urgently rehabilitated. All of the proposed links are judged to be of higher priority in view of the degree of deterioration of the existing pavement. As listed up in Table 9.2.2, they are classified into the Stage I program which are expected to be implemented immediately, within the current five-year-plan period. Those included in Stage I program are shown also in Figure 9.2.3.

The remaining links, 306 km in total, which are judged not required overlay now, are considered to be included into Stage II program.

9.2.3 Proposed Phasing and Fund Requirement

A proposed phasing discussed in the above is summarized in the following table, together with approximate fund requirement:

Summary of Phased Program

Classification	Number of Project	Length (km)	Fund Requirement (Mn ฿)
Stage I			
Improvement and New construction	18 routes	666.9	1,269.8
Rehabilitation	25 links	468.0	560.9
(Overlay)	(20 links)	(370.0)	(331.2)
(Reconstruction)	(5 links)	(98.0)	(229.7)
Total of Stage I	-	-	1,830.7
Stage II			
Improvement and New Construction	15 routes	479.4	n.a.
Rehabilitation	19 links	306.0	n.a.

Figure 9.2.1 PROCESS OF PHASING

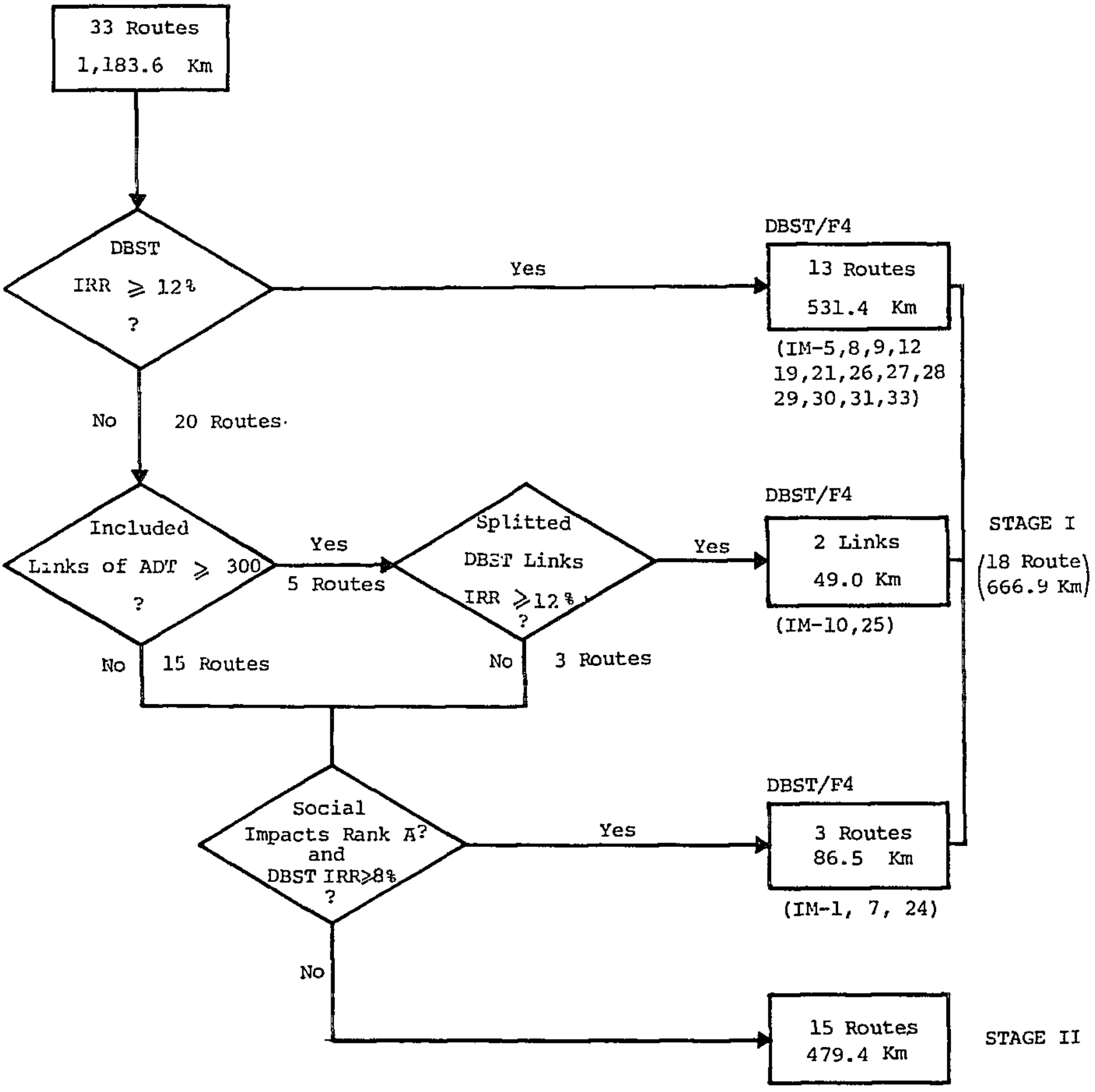


Table 9.2.1 PHASED PROGRAME (IMPROVEMENT AND NEW CONSTRUCTION)

1) STAGE I

Pro-posed Route	Origin	Destination	Length (Km)	Road Class	Surface[1] Type	Const.[2] Cost (Mn ฿)	IRR (%)	Social Impacts
IM-28	C. Buri Ram	Lam Chi River	42.0	F4	DBST	96.1	27.0	B
IM-33	J. R. 2	A. Chokchai	51.5	F4	DBST	108.6	21.6	A
IM-5	A. Nam Phong	J. R. 209	29.1	F4	DBST	61.5	20.0	C
IM-8	B. Huai Koeng	A. Kumphawapi	16.7	F4	DBST	27.4	18.1	C
IM-19	A. Selaphum	B. Kham Phon Sung	46.0	F4	DBST	95.3	17.1	B
IM-31	A. Lamplai Mat	B. Nong Ki	59.7	F4	DBST	93.1	15.1	C
IM-30	A. Huai Thalaeng	B. Ka Sang	51.0	F4	DBST	96.4	14.6	C
IM-21	A. T. Phut Phon	A. Khemarat	65.3	F4	DBST	112.4	14.3	C
IM-12	A. S. Daen Din	A. Song Dao	18.1	F4	DBST	35.9	12.5	A
IM-10[3]	A. Phen	K. A. Song Khom	26.0	F4	DBST	45.6	12.4	B
IM-26	B. Non Dang	A. Rattana Buri	39.5	F4	DBST	74.3	11.8	A
IM-25[3]	A. Maha Chana Chai	A. Kho Wang	23.0	F4	DBST	39.9	11.6	B
IM-29	A. Prakhon Chai	A. Krasang	48.0	F4	DBST	95.5	11.5	C
IM-27	B. Nong Khao	A. Chom Phra	31.1	F4	DBST	52.0	11.3	C
IM-9	A. Nong Han	A. Khumphawapi	33.4	F4	DBST	72.6	11.1	C
IM-24	B. Na Suang	B. Na Yia	14.5	F4	DBST	25.7	10.6	A
IM-1	A. Khong	J. R. 2180	48.0	F4	DBST	91.5	9.6	A
IM-7	B. Khok Lat	B. Tha Yom	24.0	F4	DBST	46.0	8.1	A
		Total of Stage I	666.9			1,269.8		

2) STAGE II

Pro-posed Route	Origin	Destination	Length (Km)	Road Class	Surface[1] Type	Const.[2] Cost (Mn ฿)	IRR (%)	Social Impacts	O.O.Y.[4] FYB = 12% DBST	F5/S.A.[5]	
										COST	IRR
IM-23	B. Don Chik	B. Nong Riang	44.8	F4	DBST	74.2	10.7	C	1988	38.5	13.9
IM-2	B. Waeo	K. A. Na Pho	9.4	F4	DBST	16.3	10.2	B	1991	8.8	12.7
IM-17	A. Kuchinarai	B. Nong Riang	30.4	F4	DBST	66.1	8.7	B	1991	40.6	12.2
IM-20	B. Na Hai	A, Kut Khao Pun	17.2	F4	DBST	32.9	8.4	B	1992	22.3	11.0
IM-18	C. Kalasin	B. K. Nong Bua	50.7	F4	DBST	98.2	7.5	B	1992	59.6	11.6
IM-3	J. R. 2301	A. Na Chuak	30.6	F4	DBST	57.8	7.4	B	1993	32.1	11.6
IM-13	B. Chuam	A. Na Wha	19.8	F4	DBST	37.5	6.6	B	1994	24.5	9.4
IM-4	A. Chonnabot	B. Kut Ru	35.3	F4	DBST	60.6	6.2	B	1994	33.7	9.8
IM-11	B. Thung Yai	K. A. Thung Fon	8.3	F4	DBST	18.8	5.1	A	1996	12.4	8.8
IM-15	A. R. Nakhon	B. Ku Ru Khu	40.1	F4	DBST	75.4	5.1	C	1996	45.2	8.9
IM-22	A. Khemarat	B. Hua Saphan	122.4	F4	DBST	217.1	4.5	A	1997	116.6	8.1
IM-32	B. Yok Kham	B. Soeng Sang	29.0	F4	DBST	49.5	4.5	C	1999	29.1	9.8
IM-6	B. Sok Chan	Ubolratana Dam	20.3	F4	DBST	62.4	4.0	A	1999	36.0	6.2
IM-14	J. R. 223	K. A. Tao Ngai	12.0	F4	DBST	27.7	3.7	A	1999	18.5	5.8
IM-16	J. R. 212	A. Whan Yai	9.1	F4	DBST	15.2	3.0	A	1999	7.6	8.6
IM-25[6]	A. Kho Wang	J. R. 2168	15.2							18.5	8.1
IM-10[6]	K. A. Song Khom	J. R. 212	22.1							23.5	6.4
		Total of Stage II	516.7								

Note:
1/ DBST : Double Bituminous Surface Treatment
2/ Excluding price contingency
3/ Section 1 (with ADT more than 300 in the 7th year)
4/ Optimum Opening Year : The year when the first year benefit exceeds 12% of total investment
5/ S.A. : Soil Aggregate Surfaced
6/ Section 2 (with ADT less than 300 in the 7th year)

Figure 9.2.2 PHASED PROGRAM FOR IMPROVEMENT AND NEW CONSTRUCTION

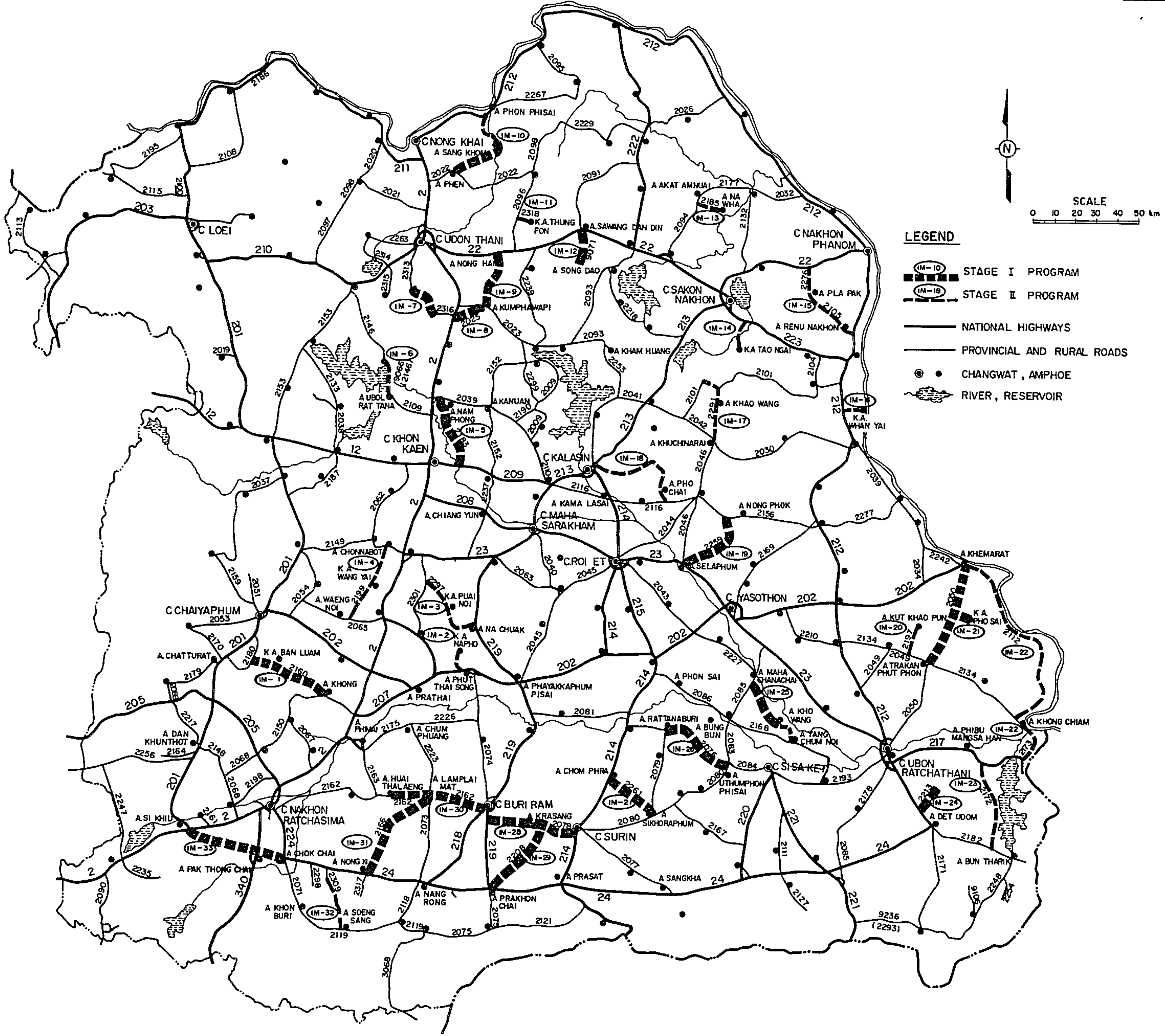
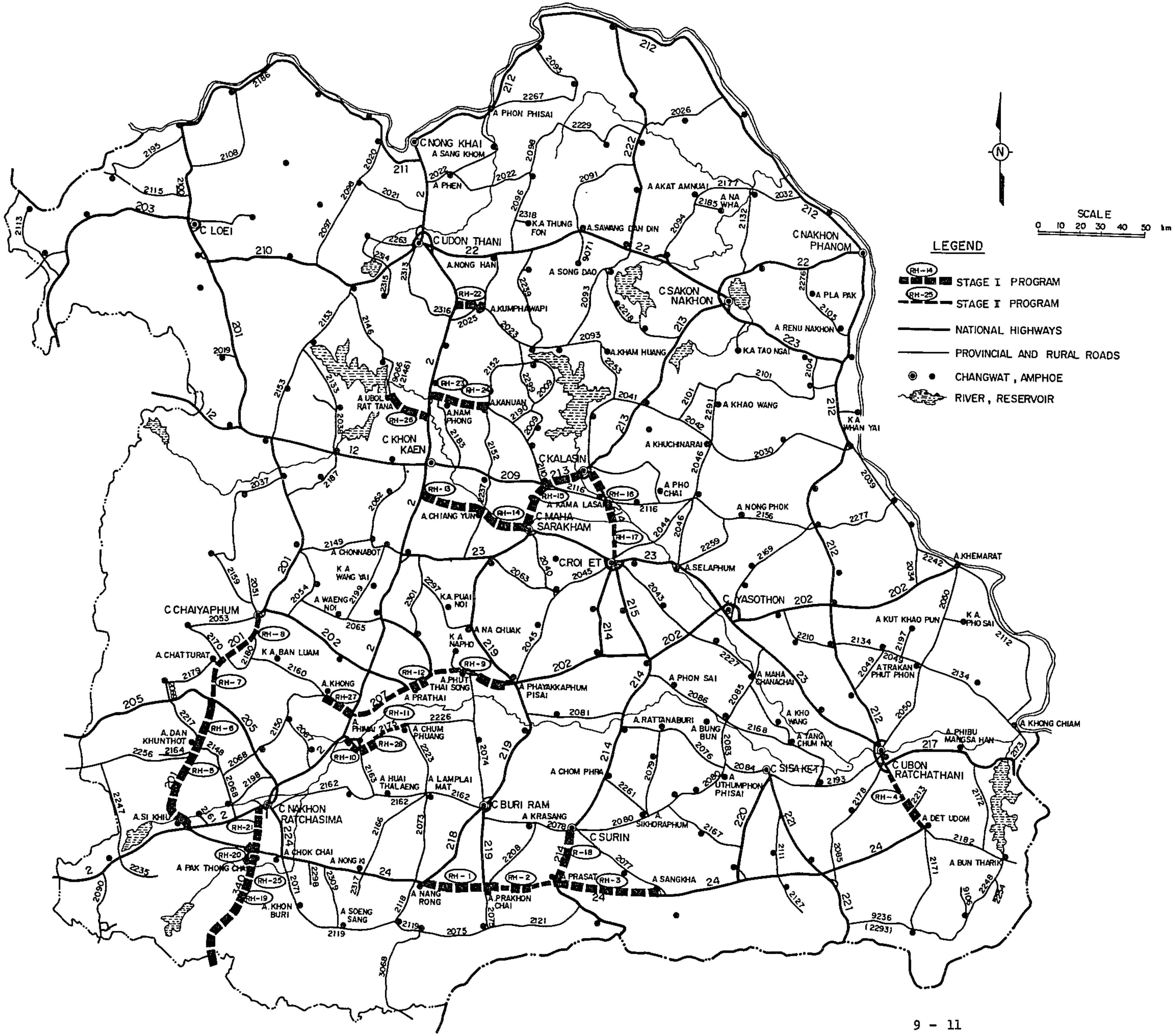


Table 9.2.2 STAGE I PROGRAM FOR REHABILITATION

Proposed Route	Proposed Link Length (Km)	Const. Cost (Mn ฿)		IRR (%)
		Overlay	Reconst.	
RH-22	8	5.0		118.1
RH-2	10	7.5		91.9
RH-18	30	22.5		82.8
RH-5	23	17.3		69.7
RH-15	44	33.0		56.8
RH-6	25	18.7		48.8
RH-16	14	11.3		43.1
RH-17	9	6.8		34.5
RH-23	16	24.4		34.5
RH-24	16	29.8		29.8
RH-19 (1)	26	29.2		28.9
(2)	20		52.9	
RH-4	9	6.8		27.9
RH-20	6	15.7		25.7
RH-26	22		42.3	22.7
RH-21	13	13.9		20.7
RH-9	7	5.3		20.3
RH-10	5		8.6	19.6
RH-1	28	22.5		13.3
RH-28	18	12.5		13.1
RH-14	27		65.9	11.7
RH-3	46	34.5		11.0
RH-12	6	4.5		10.1
RH-13	24		60.0	9.9
RH-27	16	10.0		7.3
Total	468	331.1	229.7	

Figure 9.2.3 PHASED PROGRAM FOR REHABILITATION



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