CHAPTER 3

IMPROVEMENT AND NEW CONSTRUCTION ROUTES

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3.1 INFLUENCE AREA

3.1.1 Delineation of Influence Area

The influence area of a rural road is defined as the area served, impacted or modified by the implementation of a road project in its geographical environment. Within the influence area, a road project is expected to improve the local economy by changing transportation costs, land use patterns, production prices and costs, marketing systems, etc. and also to induce better social services by improving accessibility to administrative centers, hospitals and schools. The project may even narrow the income disparity. The estimation of the area influenced by the road, therefore, is the first and critical task in a feasibility study of a rural road.

In past feasibility studies of rural roads, various definitions of the influence area were proposed as shown in the following examples:

i) Area delineated by the maximum distance from the road in any direction that a person can travel during one day using any available transportation means.[1]

ii) Area within one day's walk (approximately 32 km) on either side of the road.[2]

iii) Area within about 5.0 km on either side of the road which is not closer to any all-weather road.[3]

iv) Area delineated theoretically based on an analysis of transportation and production

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Sources: 1. "Criteria for Planning Rural Roads in Developing Countries", Report EEP-17, Institute in Engineering Economic Systems, August 1972 (case of Mexico), etc.
2. "Evaluating Construction Priorities of Farm to Market Roads in Developing Countries: A Case Study", The Journal of Developing Areas, April 1971 (case of Liberia).
3. "Socio-Economic Studies of Village Access Roads", IBRD, November 1974 (case of Thailand) and "Road Development Study in the Northern Region", JICA, June 1981 (case of Thailand).

costs.[1]

These examples show a wide variation in delineating the influence area of a road. Based on an interview survey done during field reconnaissances, however, a practical maximum of the walking distance for work or shopping is about 5 km in rural Thailand.

In accordance with this finding, the influence area was delineated as an area within about 5.0 km on either side of the road in the study. This is the same method as mentioned in iii), which was generally applied in previous studies in Thailand.

The actual area of influence, however, was defined by taking into account topographic features such as rivers, mountains, existing roads and other transportation modes.

The influence area may not extend beyond big rivers and steep mountains. In the case that the standards of existing roads passing near or across the study route is equal to or higher than that of the study route after its improvement, the influence area is shared mutually by the existing route and the study route. However, when existing roads of lower class are intersected by the study route, sharing of the influence area by the existing roads is not necessary, because transportation through these existing roads will be developed by improvement of the study route.

In other transportation modes such as rail, the influence area is shared mutually based on an analysis of the modal split.

The influence area of each study route was thus delineated and is shown in the Route Report concerned.

3.1.2 Population in the Influence Areas

The populations in the influence areas for the years 1988, 1994 and 2002 were projected following the method described below:

- Future population in the whole Kingdom was projected by adopting the population in 1983 and by increasing the average annual growth rate estimated by NSO.

- Future population by Region was estimated in the same manner as for the whole Kingdom. The population of the Region thus estimated was adjusted based on the population of the whole Kingdom as a control total.

- Future population by Changwat and Amphoe was estimated based on 1983 popula-

Source: 1. "The Economic of Road User Charges", IBRD Staff Occasional Paper No. 5, 1968, etc.

tion figures and on historical trends during the past four years, because NSO does not set forth their average annual growth rates. Changwat and Amphoe populations were thus estimated with adjustments based on Region and Changwat populations, respectively, as control totals.

- Present population in the influence area of each study route was estimated by summing up the populations of the related Tambons included within the influence areas concerned which was calculated from the population of the related Tambon in 1983 multiplied by the percentage of the area of the Tambon included in the influence area to the whole Tambon area. (See Appendix 3.1.1)

- Future population by influence area was estimated by employing the growth rate of population in the Amphoe where the Tambon is included. (See Appendix 3.1.1)

In the estimation of Changwat population for Mukdahan and Nakhon Phanom, only two years' data were available, since they were separated in 1982.

Estimation of Amphoe population was made based on the following principles:

- All of the time series data were examined by correlation coefficient and apparent errors were deleted.

- In the case of little correlation, the future population of the Amphoe concerned was assumed to be at the same level as the population in 1983.

- In the case of an Amphoe which was separated in 1983, combined data of the two separated Amphoes were used for projection and divided into two again in proportion to their proportions in 1983.

As mentioned above, the historical trend of Tambon population was not applied for the projection of future population by influence area. Because Tambons are rearranged year by year, the historical trend of the population on a Tambon basis is generally unreliable.

Where the population of the influence area shows a declining trend, it is assumed to be the same as the population in 1983, because the influence area will receive better road services than the area outside.

A summary of projected population by influence area concerned is shown in Table 3.1.1.

TABLE 3.1.1 POPULATION OF INFLUENCE AREA BY STUDY ROUTE

(Unit: persons)

Route No.		Year			
		1983	1988	1994	2002
IM - 1	A. Khong - J. R. 2180	33,300	33,600	33,900	34,300
			(0.20)	(0.15)	(0.12)
IM - 4	A. Chonnabot - B. Don Han	27,100	27,500	28,000	28,500
			(0.35)	(0.27)	(0.22)
IM - 5	A. Nam Phong - B. Nong Tun	40,400	43,100	46,000	49,700
			(1.29)	(1.10)	(0.96)
IM - 7	B. Lao - B. Tha Yom	31,000	32,800	34,800	37,300
			(1.15)	(1.00)	(0.87)
IM - 8	B. Huai Koeng - A. Kumphawapi	21,100	24,200	27,700	32,300
			(2.74)	(2.30)	(1.92)
IM - 9	A. Nong Han - A. Kumphawapi	29,300	31,100	33,200	35,700
			(1.23)	(1.06)	(0.92)
IM - 12	A. S. Daen Din - A. Song Dao	15,100	15,500	15,800	16,100
			(0.47)	(0.31)	(0.26)
IM - 19	A. Selaphum - B. Kham Phon Sung	48,400	51,000	53,900	57,500
			(1.08)	(0.93)	(0.81)
IM - 24	B. Na Suang - B. Na Yia	10,800	12,500	14,400	16,900
			(2.89)	(2.41)	(2.00)
IM - 25	A. Maha Chana Chai - A. Kho Wang	29,500	30,900	32,400	34,200
			(0.92)	(0.79)	(0.69)
IM - 26	B. Som Poi Noi - B. Muang Mak	37,300	38,900	40,700	42,800
			(0.85)	(0.73)	(0.63)
IM - 27	A. Chom Phra - B. Nong Khawao	37,400	40,000	43,000	46,600
			(1.37)	(1.19)	(1.03)
IM - 29	A. Prakhon Chai - A. Krasang	51,300	55,000	59,200	64,400
			(1.41)	(1.23)	(1.06)
IM - 31	B. Nongpha Ong - A. Nong Ki	51,800	57,100	63,200	70,900
			(1.98)	(1.70)	(1.45)
IM - 33	A. Si Khiu (J. R. 2) - A. Chok Chai	26,200	28,400	30,800	33,900
			(1.60)	(1.38)	(1.20)

Note: ( ): Average annual growth rate in %

3.1.3 Production in the Influence Areas

3.1.3.1 Features of Agriculture

The major farm products in the influence areas are composed of the following 11 crops:

1) Paddy
2) Maize
3) Sorghum
4) Soybeans*
5) Mungbeans*
6) Groundnuts
7) Cassava
8) Kenaf
9) Sugarcane
10) Cotton
11) Castor beans

Other crops such as chillis, shallots, onions, garlic and certain fruits are not included in the studies because the areas involved are negligible.

Crop production in the related Amphoes is of low productivity because of infertile land, soil salinity, drought due to uneven rainfall, occasional flooding and other factors. Production amounts by crop from 1980 to 1983 varied greatly because planted areas and crop yields also varied.

The cultivated areas in the related Amphoes are mostly occupied by paddy field. Rice is mainly cultivated under rainfed conditions except for certain portions of some Amphoes, and generally the ratio of irrigated fields to total paddy fields is very low in these Amphoes.

The crop density (the ratio of planted area to cultivated area) of the paddy and upland fields is less than 100% in related Amphoes mainly due to rainfed cultivation.

The crop patterns in the related Amphoes show that a second crop of paddy during the dry season between December and April is uncommon except in limited areas with irrigation facilities. The crop season of upland crops such as maize, sorghum and soybeans is also limited to the rainy season, while mungbeans are planted as a second crop before the main crop of maize and before and/or after rice. The crop calendars for each area are shown in the Route Report.

3.1.3.2 Land Use

Land use and land capability in the influence areas concerned were analyzed on the following maps, together with the field survey findings:

Note: *: Soybeans and mungbeans are included together in the analysis.

- Land Use Map by Changwat, 1 : 100,000, 1978–79, Department of Land Development.

- Land Capability Map by Changwat, 1 : 100,000, 1973–82, Department of Land Development.

- Soil Salinity Distribution by Changwat, 1 : 250,000, 1982–83, Department of Land Development.

- Layout Map of Cultivated Areas by Crop with Tambon Boundaries, 1983, Agricultural Extension Offices in related Amphoes.

The influence areas were divided into cultivated land for paddy and upland crops, unused cultivable land, forest and uncultivable land such as lakes, swamps, irrigation tanks, rocky land, rivers and urban areas by Tambon and Amphoe based on the above maps as shown in the Route Report. Areas heavily affected by salinity were also measured in the case of paddy fields as shown in Appendix 3.1.2.

Recently, the Royal Forestry Department has enforced a policy of forestry conservation and reforestation for preservation of forestry resources. Some of the forest lands remaining in the area also have a function as a water resource for cultivation. Therefore, the remaining forest lands were not considered as newly developed cultivated land.

Based on an analysis of areas by type of land, the cultivated lands by Tambon and Amphoe in the influence areas in 1983 were estimated as shown in Appendix 3.1.3.

A summary of land use by route is shown in Table 3.1.2.

The crop densities of rice and upland crops in each influence area were estimated based on the average crop densities of related Amphoes for the past 2 or 3 years as shown below. The planted areas by crop in the influence areas in 1983 were calculated by using these average crop densities.

3.1.3.3 Average Crop Yield and Crop Production

1) Average Crop Yield

Average crop yields by influence area were estimated as shown in Appendix 3.1.5 by taking the following data into consideration:

i) Average crop yields by related Amphoe from 1980 to 1983.

ii) Area ratios of related Amphoes by crop in the influence areas.

2) Crop Production

Estimated crop production for 1983 in the influence areas was calculated from planted areas and average yields by crop as shown in Appendix 3.1.6.

CROP DENSITY BY ROUTE

(Unit: %)

Route No.	Paddy	Upland Crop
IM - 1	83.4	77.0
IM - 4	62.0	92.9
IM - 5	72.5	78.0
IM - 7	79.7	51.0
IM - 8	80.1	91.1
IM - 9	68.4	71.8
IM - 12	98.0	88.0
IM - 19	83.6	87.6
IM - 24	99.0	51.8
IM - 25	95.1	85.9
IM - 26	96.7	70.0
IM - 27	94.0	39.0
IM - 29	86.9	-
IM - 31	98.3	46.0
IM - 33	71.8	55.9

TABLE 3.1.2 LAND USE BY STUDY ROUTE

(Unit: thousand rai (km^2))

Route No.	Total Land (A)	Cultivated Area			B/A %	Unused Cultivable Area			Uncultivable, Idle, Forestry & Other Land
		Paddy Field	Upland Field	Total (B)		Paddy	Upland	Total	
IM- 1	217.5 (348)	111.2	55.02	166.2 (265.9)	76				51.3 (82)
IM- 4	146.9 (235)	137.70	0.84	138.54 (221.7)	94				8.36 (13.4)
IM- 5	118.1 (189)	102.13	2.37	104.5 (167.2)	89				13.6 (21.8)
IM- 7	168.1 (269)	50.06	59.07	109.13 (174.6)	74				59.0 (94.4)
IM- 8	61.9 (99)	32.01	8.24	40.25 (64.4)	61				21.7 (34.6)
IM- 9	145.6 (233)	85.31	22.64	107.95 (172.7)	74				37.7 (60.2)
IM-12	102.5 (164)	48.06	37.24	85.30 (136.5)	83				17.2 (27.5)
IM-19	234.5 (375.2)	108.94	81.08	190.02 (304)	81				44.5 (71.2)
IM-24	63.8 (102)	53.44	4.63	58.07 (92.9)	91				5.7 (9.1)
IM-25	136.3 (218)	96.76	9.92	106.68 (170.7)	79				29.6 (47.4)
IM-26	145.0 (232)	111.51	3.73	115.24 (184.4)	79				29.8 (47.6)
IM-27	134.4 (215)	122.57	1.00	123.57 (197.7)	93				10.8 (17.3)
IM-29	249.4 (399)	180.01	-	180.01 (288)	72				69.4 (111.0)
IM-31	280.0 (448)	230.12	28.5	258.62 (413.8)	93				21.4 (34.2)
IM-33	232.5 (372)	37.87	69.47	107.34 (171.7)	46	13.17	78.3	91.47 (146.4)	33.7 (53.9)

3.2 TRAFFIC SURVEY AND FORECAST

3.2.1 Approach

3.2.1.1 Traffic Forecast Procedures

Based on the results of the analysis of regional characteristics, traffic surveys and projections of agricultural development, forecasts of future traffic volumes were made for the study routes. The forecasted traffic volume was given by vehicle type for the 1st, 7th and 15th years after the opening of the concerned routes, for both "with and without project".

The study flow of the traffic forecast is illustrated in Figure 3.2.1.

For the selection of a traffic forecast method to be employed, various methods adopted for DOH related studies were compared as shown in Appendix 3.2.1. Consequently, an application of the method used in the Phase I Study was determined after little modification.

The method employed was either the "Growth Rate Method" or the "Assignment Method", depending on the characteristics of the study route.

1) Growth Rate Method

The growth rate method was employed in the forecast of future traffic volumes where no diverted and little induced traffic is foreseen. This method was employed for all study routes except for IM-1 and 33.

Procedures of the method were as follows:

- Estimation of traffic volume (ADT) by vehicle type for the base year (1984) based on the results of the traffic count survey.

- Estimation of movements of passengers and freight in tons for 1984 by converting estimated ADT based on the occupancy rate and average load obtained from the O/D survey.

- Estimation of future passenger movements based on the future growth rate of population and GPP, and elasticities of transportation demand.

- Estimation of future freight movements by correlating with passenger movements for non-agricultural freight, and by applying the growth rates of agricultural production for agricultural freight.

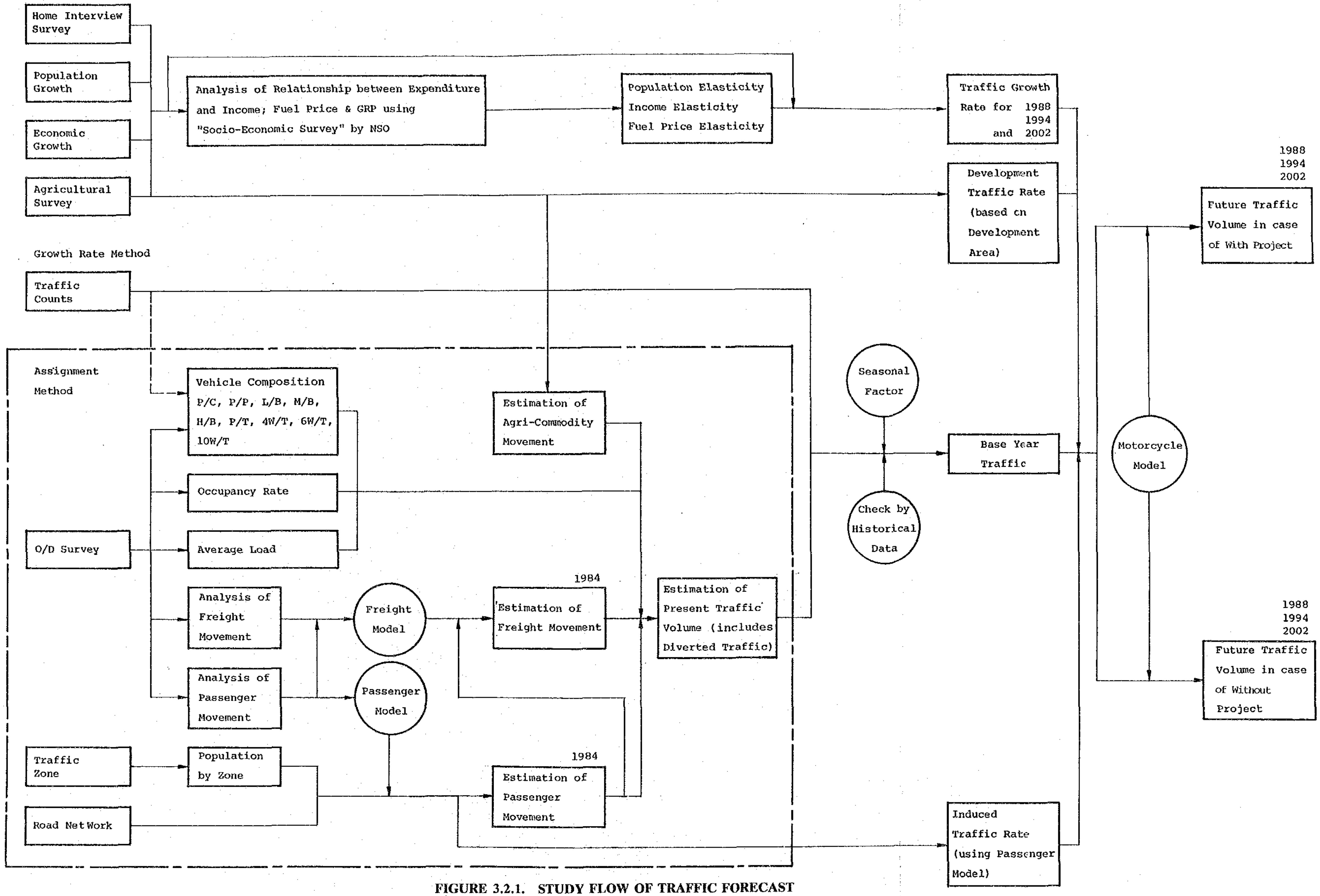


FIGURE 3.2.1. STUDY FLOW OF TRAFFIC FORECAST

- Forecast of future ADT by applying future occupancy rate and average load to estimated future passenger and freight movements by vehicle type and traffic composition.

2) Assignment Method

The assignment method was applied for new construction routes where both diverted and considerable induced traffic are foreseen, such as IM-1 and 33.

The procedures of the method were as follows:

- Traffic zoning and measurement of road link conditions including length.
- Estimation of passenger and freight movements by O/D pair for 1984 based on the present population and agricultural production in the traffic zone and O/D survey results.
- Forecast of future ADT by vehicle type based on the assigned traffic movement for 1984 by applying the same growth rates, occupancy rate, average load and traffic composition as mentioned in 1) above.

3.2.1.2 Type of Traffic and Vehicles

1) Type of Traffic

Traffic was classified into four types: normal, diverted, induced and developed, in estimating road user benefits.

Normal traffic is defined as traffic which takes place on an existing road, arising from a natural increase of population and economic activities independent of road improvement.

Diverted traffic is defined as traffic which changes its route to a study route owing to improvement or new construction.

Induced traffic is defined as extra traffic which is newly generated as a result of improvement of transport conditions such as a decrease in travel time and cost. In the estimation of induced traffic, only natural population growth is considered as a source of traffic; a population increase by migration is disregarded.

Developed traffic is defined as traffic which occurs in excess of the natural growth of population and economic activities caused by agricultural development attributable to road improvement.

2) Type of Vehicles

In the Region, the present traffic can be classified into ten types of vehicle by size and use.

Typical types of vehicles and their characteristics are shown below:

Motorcycle (M/C) - Two-wheel vehicle such as the Suzuki A100 or Honda Dt 100. The engine capacity is commonly 100 cc.

Passenger Car & Taxi (P/C) - Vehicle such as the Toyota Corolla or Corona with a 1600 cc petrol engine.

Pickup Truck for Passenger Use (P/P) - Vehicle such as the Toyota Hilux or Datsun Professional, mainly used for passenger trips. The engine capacity is 1600–2200 cc.

Light Bus (L/B) - A common model is the Isuzu Faster whose engine capacity is 2200 cc. It provides longitudinal bench seats and canopy. The seat and total capacities are approximately 10 and 20, respectively.

Medium Bus (M/B) - A common model is the Isuzu KS with a 3865 cc engine capacity. It provides longitudinal bench seats and a canopy. The seat and total capacities are approximately 16 and 30, respectively.

Heavy Bus (H/B) - A common model is the Mercedes-Benz with a 210 HP engine. The seat and total capacities are approximately 38–52 and 70, respectively.

Pickup Truck for Truck Use (P/T) - The models are the same as the pickup truck for passenger use but they are used mainly for freight transportation. The loading capacity is approximately 1 ton.

4-Wheel Truck (4/T) - Truck such as the Isuzu 250, with a 2775 cc diesel engine.

6-Wheel Truck (6/T) - Double-axle truck such as the Isuzu 100 HP with a 3268 cc diesel engine. The loading capacity is approximately 6 tons.

10-Wheel Truck (10/T) - Triple-axle truck such as the Isuzu KTM with a 5785cc diesel engine. The loading capacity is approximately 13 tons.

3.2.2 Traffic Surveys

Traffic surveys conducted included traffic counts, O/D surveys and home interview surveys.

Traffic counts and O/D surveys were conducted at 22 and 4 points, respectively. The locations are shown in Appendix 3.2.2.

Home interview surveys were conducted along each study route. The number of samples collected was about 70 per route for a total of 1062, of which 962 were valid.

1) Traffic Counts

Manual traffic counts by vehicle type and automatic counts for determination of base year traffic and for estimation of expansion factors were conducted as follows:

- Manual counts: 12 hours (6:00–18:00)
- Automatic counts: 24 hours

Traffic counts were made for the following ten types of vehicles:

Motorcycle, Passenger Car & Taxi, Light Bus, Medium Bus, Heavy Bus, Pickup Truck, 4-Wheel Truck, 6-Wheel Truck, 10-Wheel Truck and Other Vehicles with Engine.

2) O/D Surveys

O/D surveys, which include manual traffic counts and roadside interview surveys, were conducted as mentioned below to obtain the O/D patterns between traffic zones in the study route concerned and information required for the traffic forecast:

- Manual traffic counts: 12 hours (6:00–18:00)

- Automatic traffic counts: 2 hours

- Roadside interview surveys: 10 hours (6:00–16:00)

Traffic was classified into the same types as those mentioned in 1) above, except that pickup use was subdivided into passenger and truck use.

Information collected was as follows:

- Origin and destination of vehicle
- Type and characteristic of vehicle
- Number of passengers in passenger vehicle
- Frequency of trips
- Weight of commodities loaded
- Kind of commodities loaded

- Origin and destination of bus passengers
- Bus route

Survey forms used for the roadside interviews are shown in Appendix 3.2.3.

3) Home Interview Surveys

The home interview surveys were aimed mainly at obtaining data for the estimation of income elasticity related to transportation expenditures which was applied for the projection of traffic growth rates for passenger movements.

Main survey items were as follows:

- Household income
- Household expenditure for transportation
- Number of household members

During the home interview surveys, information necessary to assess social impact was also collected.

Survey forms used for the home interview surveys are shown in Appendix 3.2.4.

3.2.3 Traffic Forecast

3.2.3.1 Passenger and Freight Movements in Base Year (1984)

1) Growth Rate Method

Passenger and freight movements were derived by vehicle type based on historical traffic count data conducted by JICA and DOH, and by using average occupancy and load obtained from the O/D surveys. Adjustment for seasonal fluctuation was made by analyzing through year count data of DOH. The seasonal fluctuation factor in the Region was as follows:

$$ADT = \text{Counted traffic volume} \times 1.16$$

The average number of occupants and load by vehicle type obtained by O/D survey are shown below:

AVERAGE NUMBER OF OCCUPANTS

Vehicle Type		Number of Occupants (persons/vehicle)
Passenger Car	(P/C)	3.2
Pickup Truck for Passenger Use	(P/P)	3.3
Light Bus	(L/B)	9.5
Medium Bus	(M/B)	22.8
Heavy Bus	(H/B)	40.4

AVERAGE LOAD

Vehicle Type		Average Load of Loaded Truck (tons/vehicle)	Loaded Truck Ratio (%)	Average Load (tons/vehicle)
Pickup Truck for Freight Use	(P/T)	0.86	42	0.35
4-Wheel Truck	(4/T)	2.63	40	1.05
6-Wheel Truck	(6/T)	4.13	55	2.27
10-Wheel Truck	(10/T)	11.54	60	6.92

2) Assignment Method

a) Zoning

The influence area of each study route to which the assignment method was applied was divided into several traffic zones. Traffic zones were established by taking into consideration the road network, physical constraints such as rivers and mountains, and Tambon boundaries as shown in the Route Report.

Population by traffic zone was estimated based on Tambon statistics. The zone nodes were assumed at the places which were the most predominant in terms of socio-economic activities within each zone. Zone characteristics are shown in the Route Report.

b) Road Link

The study route and its related existing roads were divided into several road links which were assumed to be uniform throughout the link in characteristics such as surface condition and traffic volume. Assuming the opening year of the project is 1988, the related roads which have been committed to be improved or constructed by 1988 under the government programs were regarded as improved in both "with and without project". Dummy nodes were placed at the intersections of the road as illustrated in the Route Report.

Specific road characteristics, i.e., distance, surface condition, average travel speed and improvement plans under government programs, were surveyed through field reconnaissances, road inventory surveys and data available from DOH. For the sake of simplification, the road links were classified into one of 11 road grades considering surface condition, alignment and travel speed as shown in the table below. Link condition and length are shown in the Route Report.

ROAD GRADE

Grade	Surface Condition	Alignment	Traveling Speed (km/h)
1	AC	Good	85
2	AC	Fair	75
3	AC	Bad	65
4	DBST	Good	78
5	DBST	Fair	68
6	DBST	Bad	58
7	SA	Good	58
8	SA	Fair	48
9	SA	Bad	38
10	Earth	Fair	21
11	Earth	Bad	16

Note: AC : Asphaltic concrete
DBST: Double bituminous surface treatment
SA : Soil aggregate surfacing

c) Estimation of Passenger Movements

In accordance with the traffic zoning and road link network, passenger movements by O/D pair in the base year of 1984 were estimated.

In order to estimate the passenger movements, a mathematical model of gravity type, variables of which are population size in traffic zones and travel time between zones, was applied.

The model formula is as follows:

$$V_{ij} = Q_i \cdot k \cdot \frac{Q_j^a}{t_{ij}^b}$$

where, V_{ij} : Passenger movements between zone i and j (trip/day)
Q_i : Population size in origin zone i (1000 persons)
Q_j : Population size in destination zone j (1000 persons)

t_{ij} : Travel time between zone i and j (minutes)
a,b,k : Parameters

The model parameters, a, b and k, were determined by the least square method using traffic data studied by the study team in 1982 and 1984.

The items of a regression analysis were the number of trips by O/D pair obtained from the results of O/D surveys, present population size corresponding to traffic zones and actual travel time between the zones under the existing road network conditions.

In general, an O/D survey by roadside interview cannot detect all movements between O/D zones, because some traffic may move on other routes without passing the O/D station.

Furthermore, a pattern of traffic observed through O/D surveys is characterized depending on the specific functions and conditions of the road on which the survey station is located. Therefore, data obtained from O/D surveys were carefully checked to obtain reasonable input data for the estimation of model parameters. As a result, 43 data were selected.

The parameters derived from the regression analysis together with the correlation coefficients are shown below:

ESTIMATED MODEL PARAMETERS

Parameter			Correlation Coefficient
a	b	k	
0.421	1.082	193.1	0.91

d) Passenger Movements by Traffic Type

For the sake of VOC benefit calculations, passenger movements were estimated by type of traffic, normal and induced, as follows by applying the model formula above:

CALCULATION FORMULAS OF PASSENGER MOVEMENTS BY TYPE

(Passenger Traffic)

Type	Description	Calculation Formula*
Normal	Corresponds to the population with natural growth	$V_{ij}^{(N)} = \overline{Q}_i \cdot k \cdot \frac{\overline{Q}_j^a}{\overline{t}_{ij}^b}$
Induced	Corresponds to the difference in travel time between with and without project	$V_{ij}^{(I)} = \overline{Q}_i \cdot k \cdot \frac{\overline{Q}_j^a}{t_{ij}^b} - \overline{Q}_i \cdot k \cdot \frac{\overline{Q}_j^a}{\overline{t}_{ij}^b}$

Note: * : $V_{ij}^{(N)}$: Normal passenger movements between zone i and zone j

$V_{ij}^{(I)}$: Induced passenger movements between zone i and zone j

$\overline{Q}_{i \text{ or } j}$: Population in zone i for "without project"

$\overline{t}_{ij}$: Minimum travel time between zone i and zone j for "without project"

t_{ij} : Minimum travel time between zone i and zone j for "with project"

a,b,k : Model parameters

e) Assignment of Passenger Movements on Link

Passenger movements by traffic type were assigned on the road network by the all or nothing method which searched minimum paths by travel time as the sole yardstick.

In order to clarify the traffic types of normal, diverted and induced, 4 cases concerning a combination of passenger movements and road network were set up for link assignment as shown below:

CASE OF LINK ASSIGNMENT

Case	Passenger Movements	Road Network*	Type of Traffic on Road Link
1	$V_{ij}^{(N)}$	$\overline{W}$	Normal
2	$V_{ij}^{(N)}$	W	Normal + Diverted
3	$V_{ij}^{(I)}$	W	Induced
4**	$V_{ij}^{(I)}$	$\overline{W}$	Induced

Note: * : $\overline{W}$: without project

W : with project

** : Hypothetical case for use in benefit calculation

f) Estimation of Freight Movements

i) Non-agricultural Freight Traffic

Non-agricultural freight traffic movements were estimated on the basis of the relationship between passenger movements and tonnage of freight movements except for agricultural freight on the road links.

A model of the exponential type was established as shown below:

$$Z_i = a \cdot V_i^b$$

where, Z_i : Tonnage of non-agricultural freight movements on road i
V_i : Passenger movements on road link i
a,b : Model parameters

The actual data of V_i and Z_i, which were obtained from O/D surveys in 1982 and 1984 by the study team, were used for the estimation of the parameters shown below:

ESTIMATED PARAMETERS

Parameter		Correlation Coefficient
a	b	
0.00964	1.24	0.96

The movements for non-agricultural freight by traffic type for normal and induced traffic were also estimated based on the above equation by applying corresponding figures of passenger transportation movements by traffic type.

ii) Agricultural Freight Movements

The movements for agricultural freight was estimated based on the agricultural production volume estimated in Section 3.3.3 by applying the following equation:

$$F_{Tit} = F_{Nit} \cdot (F_{AAt}/F_{NAt} + 1)$$

where, F_{Tit} : Total freight movements in year t by link
F_{Nit} : Non-agricultural freight movements in year t by link
F_{AAt} : Average agricultural freight movements in year t by route
F_{NAt} : Weighted average of F_{Nit} by link length

The F_{Tit} and F_{Nit} in the base year are shown in the Route Report, together with agricultural freight movements as freight movements in the base year.

3) Base Year Traffic

Traffic volume by vehicle type and passenger and freight movements by study route in the base year thus estimated are shown in the Route Report.

3.2.3.2 Estimation of Future Passenger and Freight Movements

Future passenger and freight movements were estimated by multiplying estimated movements in the base year by growth rates established as mentioned below:

1) Growth Rates of Passenger Movements

The growth rates of passenger movements were calculated by the following equation:

$$Gi = GC \cdot EC + GPi \cdot EP$$

where,

Gi	:	Growth rate of passenger movements on route i
GC	:	Growth rate of average per capita GPP among related Changwats
GPi	:	Growth rate of population in the influence area by route
EC	:	Income elasticity of person trips
EP	:	Population elasticity of person trips

In the estimation of the growth rates of passenger movements, the following assumptions were applied:

GC	:	3.1% per annum
GPi	:	estimated in Section 3.1.2
EC	:	1.436
EP	:	1.00

Income elasticity of person trips (EC) was estimated based on the result of the home interview surveys.

The estimated growth rates of passenger movements by route are shown in the Route Report.

2) Growth Rates of Freight Movements

The growth rates of freight movements were estimated separately for non-agricultural and agricultural freight movements.

The growth rates of non-agricultural freight movements were estimated by applying the formula explained in 3.2.3.1, 2), f), and that of agricultural freight movements was estimated based on the agricultural production projection described in 3.3.3.

An average growth rate of the above two freight movements was calculated by weighting based on the proportion of the present non-agricultural and agricultural freight movements in tonnage quantified by the O/D survey.

The growth rates of freight movements by study route are shown in the Route Report.

3) Induced and Developed Traffic

a) Induced Traffic

In the case of the assignment method, the induced traffic was estimated as described in 3.2.3.1, 2), d). For the growth rate method cases, it was estimated by multiplying normal passenger and freight traffic by the ratio of induced traffic (15%) which is commonly used in DOH studies. However, for IM-7, an induced traffic ratio of 64% was applied based on the Phase I Study, because a large difference is expected in the road conditions between "with and without project".

b) Developed Traffic

Developed traffic was estimated by multiplying the normal plus induced traffic by the ratio of developed traffic.

The ratio of developed traffic for passenger movements was calculated by the following formula:

$$RDt = (AWt - A\overline{Wt}) / A\overline{Wt}$$

where,

RDt	:	Ratio of developed traffic
AWt	:	Cultivated area in "with project"
$A\overline{Wt}$	:	Cultivated area in "without project"
t	:	Year t

Furthermore, freight movements by increments of agricultural production were also taken into account. The ratio of developed traffic by study route is shown in the Route Report.

3.2.3.3 Estimation of Traffic Volume by Vehicle Type

1) Traffic Composition in Base Year

The forecasted traffic movements, both passenger and freight, were converted into traffic volumes by vehicle type by using the estimated traffic composition, the number of occupants and average loads previously obtained from traffic survey results.

Present traffic composition was adopted as the traffic composition in base year. Present traffic composition was obtained through an analysis of data of the roadside interview surveys, manual traffic counts and DOH traffic records. In case no existing composition was available, such as in the case of routes for which traffic volume was forecasted by applying the assignment method, the adopted traffic composition was that of a road with similar conditions and located near the study routes.

2) Change in Traffic Composition after Paving

By analyzing the data in DOH's 1982 "Annual Vehicle Kilometer Project", it was assumed for passenger vehicles that 12% of public vehicles will be converted to private vehicles in the case that laterite roads are paved.

For freight traffic, however, there will be no significant changes caused by paving.

3) Traffic Composition in Future

Traffic composition in 2002 was estimated based on the data of the DOH project mentioned above for "with project", and based on the results of traffic surveys by the JICA team for "without project". Furthermore, these traffic compositions were modified based on the growth ratios of private and public traffic in the same manner used in the calculation of growth rates of passenger movements, which were estimated by applying the income elasticities of 2.227 and 0.941, respectively.

Traffic compositions in 2002 for "with and without project" are shown below.

TRAFFIC COMPOSITION IN 2002

(Unit: %)

Traffic	Case	Composition				
		P/C	P/P	L/B	M/B	H/B
Passenger	With project	39.0	38.0	3.0	13.0	7.0
Traffic	With project	7.0	58.0	8.0	26.0	1.0
		P/C	4/T	6/T	10/T	
Freight	Without project	13.0	11.0	50.0	26.0	
Traffic	Without project			No change		

Traffic compositions for 1988 and 1994 were interpolated from those in the base year and 2002. Traffic compositions are shown in the Route Report.

4) Motorcycle Traffic

Motorcycle traffic was estimated by applying the following model derived from the results of the traffic survey:

$$MC = -500 + 145 \log_e ADT$$

where, MC : *Motorcycle traffic (vehicles/day)*
ADT : Average daily traffic (vehicles/day)

5) Forecasted ADT

A summary of forecasted ADT by study route in 1988, 1994 and 2002 is shown in Table 3.2.1. Details are given in the Route Report.

Exploration for natural gas is being planned close to IM-5. That plan, however, was not taken into consideration for future traffic projections, since pipelines for transportation of the products are included in the plan.

TABLE 3.2.1 ANNUAL AVERAGE DAILY TRAFFIC

(Unit: vehicles/day)

Route No.	Origin	Destination	1988	1994	2002
IM - 1	A. Khong	J. R. 2180	294	384	560
IM - 4	A. Chonnabot	B. Don Han	477	628	901
IM - 5	A. Nam Phong	B. Nong Tum	376	548	924
IM - 7	B. Lao (J. R. 210)	B. Tha Yom	126	173	264
IM - 8	B. Huai Koeng	A. Kumphawapi	297	390	565
IM - 9	A. Nong Han	A. Kumphawapi	280	368	536
IM - 12	A. Sawang Daen Din	A. Song Dao	275	341	466
IM - 19	A. Selaphum	B. Kham Phon Sung	235	303	431
IM - 24	B. Na Suang	B. Na Yia	287	445	789
IM - 25	A. Maha Chana Chai	A. Kho Wang	167	256	473
IM - 26	B. Som Poi Noi	B. Muang Mak	219	308	497
IM - 27	A. Chom Phra	B. Nong Khawao	262	368	577
IM - 29	A. Prakhon Chai	A. Krasang	302	475	907
IM - 31	B. Nong Pha Ong	A Nong Ki	317	472	805
IM - 33	A. Si Khiu (J. R. 2)	A. Chok Chai	1,453	1,940	2,696

3.3 AGRICULTURAL DEVELOPMENT BENEFITS

3.3.1 Approach

A similar approach to the Phase I Study was employed in the estimation of agricultural development benefits in this study. In view of the remarkably predominant share of the agricultural sector in the economy of the study area, development benefits attributed to road development are represented by the net added value of crop production between "with and without project" caused by accelerated promotion of agricultural guidance services, labor productivity and marketing conditions.

The increase in gross values of production in the study area was estimated considering the following factors:

i) Increase in planted area and newly developed land

ii) Increase in crop yield

iii) Increase in farmgate price

iv) Diversification of crop pattern into a commercially oriented one

A correlation between the direct effects mentioned above and the estimated agricultural development factors was drawn as shown in the form of the causation process in Figure 3.3.1.

The study flow employed in the projection of the agricultural development benefits was made up as shown in Figure 3.3.2 based on the causation process of agricultural benefits.

Agricultural development benefits in the study were calculated by the following formula:

$$P(\overline{w})_i^t = (1+a_i)^t PA_i \cdot (1+b_i)^t Y_i$$

$$P(w)_i^t = (1+c_i)^t PA_i \cdot (1+d_i)^t Y_i$$

$$NPV(\overline{w})_i^t = P(\overline{w})_i^t \cdot FP(\overline{w})_i - (i+a_i)^t PA_i \cdot PC(\overline{w})_i$$

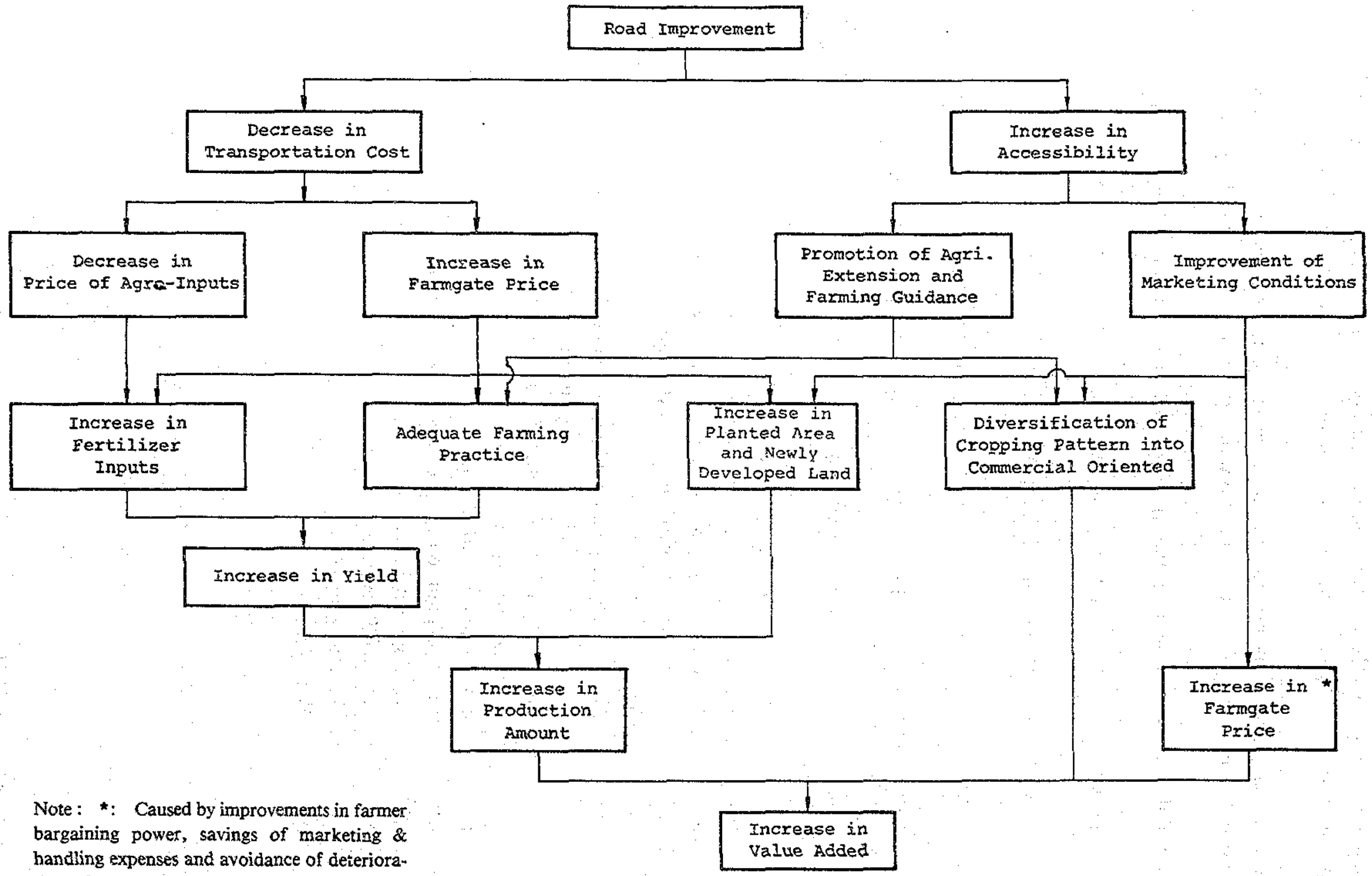
$$NPV(w)_i^t = P(w)_i \cdot FP(w)_i - (1+c_i)^t PA_i \cdot PC(w)_i - LPC \cdot NL(w)^{t*}$$

$$DB^t = {}_i NPV(w)_i^t - {}_i NPV(\overline{w})_i^t$$

where,

P_i^t	:	Production of i crop at year t
PA_i	:	Planted area of i crop at base year
a_i	:	Growth rate of planted area of i crop (without)
b_i	:	Growth rate of yield of i crop (without)
Y_i	:	Yield of i crop
c_i	:	Growth rate of planted area of i crop (with)
d_i	:	Growth rate of yield of i crop (with)
NPV_i^t	:	Net crop production value of i crop at year t
FP_i	:	Farmgate price of i crop
PC_i	:	Production cost of i crop
LPC	:	Land preparation cost for newly developed land
DB^t	:	Development benefit at year t
NL^t	:	New land developed at year t
$(\overline{w})$	:	Without project
(w)	:	With project

Note: *: In the case of IM-33



Note : *: Caused by improvements in farmer bargaining power, savings of marketing & handling expenses and avoidance of deterioration of crop quality.

FIGURE 3.3.1 CAUSATION PROCESS OF AGRICULTURAL BENEFITS

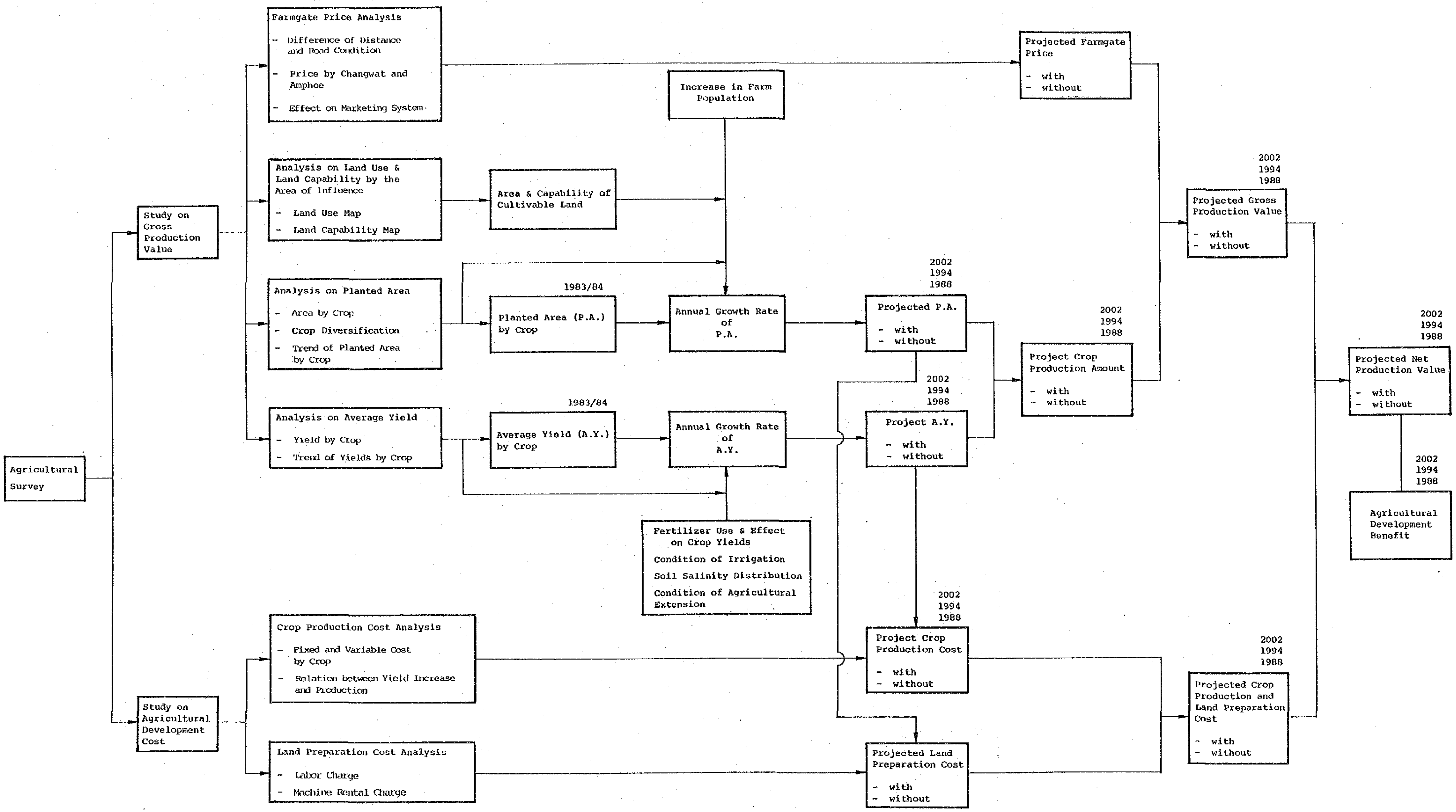


FIGURE 3.3.2 STUDY FLOW ON PROJECTION OF AGRICULTURAL DEVELOPMENT BENEFITS

3.3.2 Planted Area

The forecast for expansion of the planted area was derived from an increase in crop density and newly developed land.* Growth rates of the planted area in "without project" were estimated based on the past trend of Amphoe data and the growth of population in Amphoes. On the other hand, in the case of "with project", higher growth rates were estimated assuming that the expansion of planted area would be accelerated by promoting labor productivity caused by mechanization, transport time saving and development of marketing systems.

The growth rates were adjusted taking into account maximum crop densities under rainfed conditions and availability of unused cultivable areas.

Shares of each crop planted were determined based on the crop patterns in each influence area.

The crop calendar and estimated planted areas of each crop in "with and without project" are shown in the Route Report.

3.3.3 Crop Yields

The road improvement will provide the area not only with easy access to and from the agricultural extension offices but also with improved bargaining power and incentives to improve the productivity of farmers.

The yields of each crop by influence area in the base year of 1983–1984 were determined depending on the analysis of data at Amphoe level collected in the field surveys. Future yields in "without project" were estimated by the general tendency of crop yields in each Amphoe concerned, and an analysis of production costs at the agro-zone level.

Future yields in "with project" were estimated based on the following:

- Difference in fertilizer inputs by crop by improvement of road condition (data obtained by the home interview survey)

- *Effect of fertilizer on crop yield*

- Relationship between production costs and crop yields

The projected future average and total crop yields in "with and without project" are shown in the Route Report.

Note : *: In the case of IM-33

3.3.4 Farmgate Prices

Farmgate prices of crops in "without project" were set basically with reference to the data on farmgate prices in 1983 in each related Changwat prepared by MAC, and adjusted based on the results of surveys as shown in Appendix 3.3.1.

The financial prices were converted to economic prices using conversion factors which were derived from components of taxes and other transfer items. They are 1.3 for paddy, 1.08 for sugarcane, and 1.03 for maize, sorghum, beans, groundnuts, cassava, kenaf, cotton and castor beans. Economic farmgate prices by study route were estimated as shown in Appendix 3.3.2.

Improvement of roads will result in higher farmgate prices to farmers due to the following reasons:

i) Reduction in transportation costs

ii) Savings in marketing and handling costs

iii) Avoidance in deterioration of crop quality

iv) Raising of farmer bargaining power

The factors employed in the study for the increase in farmgate prices were limited to ii), iii) and iv) above. The reduction in transportation costs was considered in VOC saving studies.

The increase in farmgate prices in "with project" was estimated for each crop based on the length of each road and the level of improvement of the existing road.

The projected farmgate prices applied for each influence area in "with and without project" are shown in the Route Report.

3.3.5 Production and Land Preparation Costs

Financial production costs by agro-zone in "without project" were derived from MAC data. The costs consist of two components: variable costs such as labor, material and equipment, and fixed costs such as land rental depreciation.

Financial production costs were converted to economic production costs taking into account the components of financial production costs. The conversion factors to economic production costs are shown in Appendix 3.3.3.

With higher crop yields in "with project", production costs would be higher than those in "without project".

The improvement of road accessibility may help farmers to obtain less expensive agricultural inputs such as fertilizer, agro-chemicals and newly improved seeds of high yield varieties.

Economic production costs in both "with and without project" were estimated based on an analysis on the relationship between production cost components and increase in yield.

Land development costs for new cultivation fields at the minimum level including clearing bushes and trees, digging and burning roots, and initial plowing were estimated at 900 baht per rai, excluding erosion prevention work.

3.3.6 Net Production Value Added

Adopting an approach similar to the Phase I Study, the estimation of future agricultural development benefits was made in terms of the increase in net value added.

Development benefits of each project route were quantified from the difference in net production values in both "with and without project" in 1988, 1994 and 2002 as shown in Table 3.3.1.

TABLE 3.3.1 NET PRODUCTION VALUE ADDED

(Unit: thousand baht)

Route No.	Origin	Destination	1988	1994	2002
IM - 1	A. Khong	J. R. 2180	1,627	3,468	6,331
IM - 4	A. Chonnabot	B. Don Han	656	4,183	6,054
IM - 5	A. Nam Phong	B. Nong Tum	698	1,938	4,128
IM - 7	B. Lao (J. R. 210)	B. Tha Yom	2,952	6,200	8,147
IM - 8	B. Huai Koeng	A. Kumphawapi	406	974	1,855
IM - 9	A. Nong Han	A. Kumphawapi	1,282	3,778	5,314
IM - 12	A. Sawang Daen Din	A. Song Dao	1,405	1,912	2,514
IM - 19	A. Selaphum	B. Kham Phon Sung	2,785	4,375	6,633
IM - 24	B. Na Suang	B. Na Yia	311	1,075	2,057
IM - 25	A. Maha Chana Chai	A. Kho Wang	849	1,154	1,565
IM - 26	B. Som Poi Noi	B. Muang Mak	656	1,468	2,550
IM - 27	A. Chom Phra	B. Nong Khawao	776	2,433	4,534
IM - 29	A. Prakhon Chai	A. Krasang	1,782	5,667	11,762
IM - 31	B. Nong Pha Ong	A. Nong Ki	2,683	6,796	12,122
IM - 33	A. Si Khiu (J. R. 2)	A. Chok Chai	2,157	6,120	9,504

Details of crop production and net crop production value for each study route are shown in the Route Report.

3.4 ROAD USER BENEFITS

3.4.1 Approach

As in the Phase I Study, the method of calculating vehicle operating costs (VOC), shown in "Standardization of Vehicle Operating Costs for Thailand, 1977" (SVOCT), was also adopted in this study.

First, the basic cost of VOC components under ideal conditions on level tangent paved roads was calculated based on the latest data. Then VOC variations by road surface condition and travel speed were calculated. Finally, these VOCs on level tangent roads were converted to the actual costs on each subject road link depending on actual running frictions on the link such as curves, grades and speed changes. Road user benefits were quantified in terms of savings in VOC, valued at economic prices, between "with and without project".

3.4.2 Typical Vehicles

Vehicles were classified into motorcycle (M/C), passenger car (P/C), light bus (L/B), medium bus (M/B), heavy bus (H/B), pickup truck (P/T), 4-wheel truck (4/T), 6-wheel truck (6/T) and 10-wheel truck (10/T).

Basic characteristics of typical vehicles are shown in Table 3.4.1.

TABLE 3.4.1 CHARACTERISTICS OF TYPICAL VEHICLES

(Unit: baht)

Classification	Typical Vehicle	Share (%)	No. of Axles	No. of Tires	Engine Capacity (cc)	Selling Price (A)	Price less Taxes (B)	Cost of Tires & Tubes less Taxes* (C)	Economic Cost of Vehicle (B-C)
M/C	Suzuki A100	100	2	2	100	16,500	13,000	400	12,600
P/C	Toyota Corolla	60	2	4	1300	266,000	118,800	3,500	115,300
	Toyota Corona	40	2	4	1600	284,000	134,200	3,500	130,700
	Average	—	2	4	1420	273,200	125,000	3,500	121,500
L/B	Isuzu Faster	100	2	4	2200	154,000	127,800	3,600	124,200
M/B	Isuzu KS	100	2	6	3865	315,000	255,100	10,000	245,100
H/B	Mercedes Benz	100	2	6	210 HP	780,000	627,900	18,600	609,300
P/T	Toyota Hilux	100	2	4	2446	158,000	131,100	3,600	127,500
4/T	Isuzu 250 Diesel	100	2	4	2775	220,800	183,300	6,500	176,800
6/T	Isuzu 100 HP	100	2	6	3268	253,800	206,800	8,800	198,000
10/T	Isuzu KTM	100	3	10	5785	495,000	398,500	29,300	259,200

Note: *: The cost of tires and tubes includes the cost of one spare tire and tube, except for motorcycles.

3.4.3 VOC UNDER IDEAL CONDITIONS

1) Components of VOCs

Usually, road user costs include VOC and passenger time costs. In this study, passenger time costs were excluded but crew costs which depend on time were included. VOC consists of the following components:

i) Fuel
ii) Oil
iii) Tires and tubes
iv) Repair and maintenance
v) Depreciation and interest

vi) Overhead
vii) Crew

2) Ideal Conditions

The basic costs of each VOC component were calculated for ideal conditions, i.e., running constantly at benchmark speed or lifetime speed on a level tangent paved road of good surface condition without traffic frictions. The fuel, oil and repair and maintenance costs were calculated at the benchmark speed, which was 80 km/h for passenger cars and 72 km/h for other vehicles. The tire and tube, depreciation and interest, overhead and crew costs were calculated at the average lifetime speed, which was taken as 56 km/h.

3) Basic Cost Components

a) Fuel Costs

The unit cost of fuel was obtained from interviews with fuel distributing companies and related organizations.

The retail prices of premium gasoline, regular gasoline and diesel were calculated by averaging the pump prices at 7 points in the Region, at 12.02, 11.12 and 7.02 baht per liter, respectively. The taxes and oil fund included in these prices were 5.91, 5.50 and 1.38 baht per liter, respectively. Thus, the economic unit costs of fuel calculated were 6.11, 5.52 and 5.64 baht per liter, respectively, for premium gasoline, regular gasoline and diesel. The kind of fuel used by each vehicle type and fuel consumption rates were obtained from field surveys and interviews with manufacturing companies. The fuel consumption rates for typical vehicles except for motorcycles were adjusted based on data obtained from a related study in Japan.

Fuel costs by vehicle type, together with relevant data, are shown below:

FUEL COSTS

Classification	Type of Fuel Used (%)			Unit Cost of Fuel Used (baht/liter)	Fuel Consumption (km/liter)	Fuel Cost (baht/km)
	Premium	Regular	Diesel			
M/C	—	100	—	6.11	30.00	0.2037
P/C	65	30	5	5.91	11.34	0.5212
L/B	—	—	100	5.64	10.63	0.5308
M/B	—	—	100	5.64	9.18	0.6144
H/B	—	—	100	5.64	5.00	1.1271
P/T	5	20	75	5.64	10.63	0.5308
4/T	—	—	100	5.64	9.18	0.6144
6/T	—	—	100	5.64	6.12	0.9216
10/T	—	—	100	5.64	3.91	1.4407

b) Oil Costs

Although a wide variety of oils are used in Thailand, oils commonly used can be classified into two groups: the standard type such as SHELL X-100 or ESSO EXTRA and the high-class type such as SHELL SUPER PLUS or ESSO UNIFLO. The average price of these oils in the Region, 35.40 baht per liter, was used as the retail price of oil. Since the customs duty and business tax on oil were estimated to be 4.37 baht per liter, the economic cost of oil was estimated to be 31.13 baht per liter.

Oil costs by vehicle type, together with consumption rates, are shown below:

OIL COSTS

Classification	Consumption (km/liter)	Oil Cost (baht/km)
M/C	750	0.04151
P/C	1000	0.03113
L/B	920	0.03384
M/B	770	0.04043
H/B	450	0.06918
P/T	920	0.03384
4/T	770	0.04043
6/T	450	0.06918
10/T	450	0.06918

c) Tire and Tube Costs

Data on the unit prices of new tires and tubes and retread tires were obtained from interviews with major tire manufacturing companies and local distributors. The tax components included in the retail price are 7.7% as the business tax and 2.0% as the import duty on materials.

Tire and tube costs by vehicle type, together with relevant data, are shown below:

TIRE AND TUBE COSTS

Classification	Tire Size	New Tire and Tube: Retail Price (baht)	New Tire and Tube: Cost less Taxes (baht)	New Tire and Tube: Average Life (thousand km)	Retread Tire: Retail Price (baht)	Retread Tire: Cost less Taxes (baht)	Retread Tire: Average Life (thousand km)	No. of Retreads	Tire & Tube Cost (baht/km)
M/C	2.75×18 4 ply	225	203	30	-	-	-	-	0.0135
P/C	165 SR13	780	703	45	-	-	-	-	0.0625
L/B	6.0×14 5 ply	800	721	35	180	162	28	0.5	0.0655
M/B	7.5×16 12 ply	1.590	1.433	40	366	329	32	0.5	0.1712
H/B	9.0×20 14 ply	2,950	2,658	50	1,033	931	40	1.0	0.2393
P/T	6.0×14 8 ply	800	721	35	180	162	28	0.5	0.0655
4/T	7.5×15 10 ply	1,440	1,298	40	331	298	32	0.5	0.1034
6/T	7.0×16 10 ply	1,400	1,261	45	350	316	36	1.0	0.1168
10/T	9.0×20 12 ply	2,950	2,658	50	1,033	930	40	1.0	0.3987

d) Repair and Maintenance Costs

The figures for hours of labor given in SVOCT were basically used with minor adjustments. The percentages for spare parts costs were reviewed and adjusted based on Jan De Weille's "Quantification of Road User Savings".

The labor wage rate was estimated to be 101 baht per day based on information obtained from the Employment Service Division, Labour Department.

The calculated repair and maintenance costs are given below:

REPAIR AND MAINTENANCE COSTS

Classification	Economic Cost of Vehicle (thousand baht)	Spare Parts Cost (% of Economic Cost of Vehicle per thousand km)	Labor Cost (hour/thousand km)	Repair & Maintenance Cost (baht/km)
M/C	12.6	0.10	1.30	0.0290
P/C	121.5	0.11	1.65	0.1545
L/B	124.2	0.21	1.90	0.2848
M/B	245.1	0.21	1.90	0.5387
H/B	609.3	0.12	9.40	0.8498
P/T	127.5	0.12	1.65	0.1738
4/T	176.8	0.21	1.90	0.3953
6/T	198.0	0.21	7.64	0.5123
10/T	369.2	0.07	9.40	0.3771

e) Depreciation and Interest Costs

Depreciation and interest costs of typical vehicles were calculated using the following equation:

$$D = (P - L)\,CRF + L \cdot i$$

where, D : Depreciation and interest costs
P : Economic value of vehicle
L : Salvage value of vehicle
CRF : Capital recovery factor
i : Annual rate of interest, 12%

Depreciation and interest costs by vehicle type are shown in the following table:

DEPRECIATION AND INTEREST COSTS

Clas-sifi-cation	Economic Cost of Vehicle (thousand baht)	Salvage Value of Vehicle (thousand baht)	Service Life (years)	Capital Recovery Factor	Annual Distance Travelled (thousand km)	Depreciation and Interest Cost (baht/km)
M/C	12.6	-	6	0.2432	10	0.3064
P/C	121.5	20	10	0.1770	20	1.0183
L/B	124.2	10	7	0.2191	40	0.6556
M/B	245.1	10	7	0.2191	40	1.3178
H/B	609.3	50	9	0.1877	70	1.5854
P/T	127.5	15	10	0.1770	25	0.8685
4/T	176.8	10	8	0.2013	35	0.9936
6/T	198.0	45	10	0.1770	40	0.8120
10/T	369.2	50	10	0.1770	50	1.2500

f) Overhead Costs

The overhead costs were calculated for the following commercial vehicles: medium bus, heavy bus, 6-wheel truck and 10-wheel truck. It was estimated that the overhead costs at an average lifetime speed of 56 km/h were 7% of the economic cost of vehicle for heavy buses, 4% for 10-wheel trucks and 2.5% for medium buses and 6-wheel trucks.

Overhead costs by vehicle type are shown below:

OVERHEAD COSTS

Classification	Economic Cost of Vehicle (thousand baht)	Overhead Cost (% of Economic Cost of Vehicle per year)	Annual Distance Travelled (thousand km)	Overhead Cost (baht/km)
M/B	245.1	2.5	40	0.1532
H/B	609.3	7.0	70	0.6093
6/T	198.0	4.0	40	0.1980
10/T	369.2	2.5	50	0.1846

g) Crew Costs

Crew costs were estimated based on the actual wages paid to crews of commercial vehicles. Since light buses and 4-wheel trucks are usually operated by an owner, their crew costs were assumed to be half the wages of employed drivers.

Wage rates were estimated based on information obtained from Express Transport Organization (ETO) and other agencies.

Crew costs by vehicle type are shown below:

CREW COSTS

Classification	Driver		Conductor		Crew Cost at Life Time Speed (baht/km)
	No.	Wage (baht/h)	No.	Wage (baht/h)	
L/B	1	6			0.1071
M/B	1	11	1	7	0.3214
H/B	1	13	2	7	0.4821
4/T	1	9			0.1607
6/T	1	18			0.3214
10/T	1	22			0.3929

3.4.4 VOC ON ACTUAL ROAD LINKS

1) Factors Affecting Cost Variations

As the basic costs of VOC components were estimated under ideal conditions on level tangent paved roads, they were converted first to VOCs corresponding to each road class by surface type and travel speed on level tangent roads. Then these VOCs were modified to actual VOCs with additional costs affected by road geometry such as grades, curves and speed changes caused by traffic restrictions.

2) Road Classes

Based on field observations, road classes and average travel speeds on level tangent roads were determined as follows:

AVERAGE TRAVELLING SPEED BY ROAD CLASS (ON LEVEL TANGENT ROAD)

Classi-fication	Paved ①	Laterite Good ②	Laterite Fair ③	Laterite Poor ④	Earth ⑤
M/C	64	56	48	40	32
P/C	80	64	56	40	32
L/B	72	56	48	40	32
M/B	72	56	48	40	32
H/B	72	56	48	40	32
P/T	72	56	48	40	32
4/T	72	56	48	40	32
6/T	64	56	48	40	32
10/T	64	56	48	40	32

Note: *: ①～⑤ are road class indices.

3) Cost Variations by Speed and Surface Type

The conversion indices for variations due to speed and road surface were taken from T.P. O'Sullivan's "Road User Cost in Thailand: Technical Report No. 36" (RUCT) and from SVOCT.

For fuel, oil, tire and repair and maintenance costs, the conversion indices in RUCT were employed, while for depreciation and interest, overhead and crew costs, those in SVOCT were employed. The indices are shown in Appendix 3.4.1.

Thus converted VOCs on level tangent roads by five road classes at different speeds are summarized in Table 3.4.2 and their component costs are given in Appendix 3.4.2.

4) Additional Costs due to Road Geometry and Speed Change Cycle

a) Gradients and Curves

Additional costs due to gradients and curves were calculated by applying the coefficients given in SVOCT, as shown in Appendix 3.4.3.

b) Speed Change Cycle

Generally, VOCs are affected by deceleration and acceleration due to traffic frictions such as narrow bridges, villages, crossroads and other bottlenecks. In this study, the speed change cycle due to the following five frictions was considered:

REDUCED SPEEDS DUE TO TRAFFIC FRICTIONS

Traffic Friction	Reduced Speed	
	Unimproved	Improved
Village	24 km/h	40 km/h
Timber Bridge	stop	-
Narrow Concrete Bridge	16 km/h	-
Crossroad or Railway	stop	stop
Corner with Acute Angle	stop	stop

TABLE 3.4.2 TOTAL VEHICLE OPERATING COSTS ON LEVEL TANGENT ROADS

(Unit: baht/km)

VEHICLE TYPE	ROAD CLASS	SPEED (KPH) 10	16	24	32	40	48	56	64	72	80	88
M/C	1	0.6728	0.6370	0.6101	0.5856	0.5730	0.5676	0.5726	0.5838	0.5980	0.6141	0.6372
	2	0.7340	0.7435	0.7100	0.6793	0.6632	0.6534	0.6646	0.6773	0.6970	0.7190	-
	3	0.8498	0.8016	0.7625	0.7280	0.7081	0.6998	0.6980	0.6897	0.6940	-	-
	4	0.9380	0.8341	0.8350	0.7964	0.7643	0.7472	0.7403	0.7054	-	-	-
	5	1.0013	0.9417	0.8839	0.8427	0.8073	0.7863	0.7710	-	-	-	-
P/C	1	1.9470	1.8519	1.7757	1.7147	1.6797	1.6731	1.6914	1.7234	1.7632	1.8192	1.8826
	2	2.2614	2.1527	2.0631	1.9872	1.9436	1.9390	1.9632	2.0025	2.0641	2.1335	-
	3	2.4741	2.3423	2.2342	2.1451	2.0878	2.0667	2.0641	2.0413	2.0511	-	-
	4	2.7551	2.6040	2.4722	2.3613	2.2690	2.2192	2.2030	2.0920	-	-	-
	5	2.9622	2.7924	2.6422	2.5138	2.4079	2.3467	2.3031	-	-	-	-
L/B	1	3.7680	2.9930	2.3572	1.9916	1.7795	1.6446	1.5801	1.5250	1.5432	1.5744	1.6114
	2	4.4543	3.3717	2.7117	2.2617	2.0709	1.9252	1.8443	1.8168	1.8326	1.8630	-
	3	4.8023	3.6569	2.9531	2.4647	2.2296	2.0629	1.9591	1.9131	1.9265	-	-
	4	5.2656	4.0468	3.2647	2.7370	2.4418	2.2375	2.1222	2.0439	-	-	-
	5	5.6106	4.3234	3.5026	2.9370	2.5976	2.3696	2.2328	-	-	-	-
M/B	1	8.6794	6.5606	4.8970	4.0749	3.5633	3.2411	3.0233	2.9542	2.8761	2.8574	2.8650
	2	9.8342	7.5237	5.7298	4.8421	4.2408	3.8722	3.6508	3.5296	3.4961	3.4903	-
	3	10.5379	8.1513	6.2431	5.2430	4.6180	4.1405	3.8755	3.7131	3.6447	-	-
	4	11.4768	8.9836	6.9151	5.7874	5.1195	4.5033	4.1613	3.9439	-	-	-
	5	12.1751	9.5990	7.4216	6.1329	5.4912	4.7716	4.3787	-	-	-	-
H/B	1	14.6294	10.9873	8.2372	6.6275	5.6638	5.0603	4.7107	4.5761	4.5149	4.5732	4.7151
	2	16.8537	12.8516	9.8039	7.9730	6.8425	6.1743	5.8272	5.6473	5.6917	5.3080	-
	3	17.9472	13.8117	10.5625	8.5707	7.3776	6.5501	6.1671	5.9335	5.9653	-	-
	4	19.3912	15.0703	11.5727	9.3734	8.0574	7.0864	6.6009	6.3326	-	-	-
	5	20.4676	16.0002	12.3206	9.9625	8.5840	7.4615	6.9299	-	-	-	-
P/T	1	3.7227	3.0337	2.3955	2.0279	1.8077	1.6637	1.5860	1.5037	1.5264	1.5405	1.5659
	2	4.5311	3.4443	2.7797	2.3066	2.1173	1.9615	1.8572	1.8103	1.8107	1.8257	-
	3	4.9247	3.7603	3.0437	2.5257	2.2805	2.0974	1.9621	1.8769	1.8845	-	-
	4	5.4517	4.1959	3.3850	2.8216	2.4970	2.2689	2.1167	2.0045	-	-	-
	5	5.8435	4.5095	3.6466	3.0388	2.6594	2.3961	2.2191	-	-	-	-
4/T	1	5.4212	4.2734	3.3360	2.8058	2.4937	2.2907	2.1884	2.0941	2.1133	2.1332	2.1692
	2	6.4169	4.8076	3.8345	3.1829	2.9059	2.6390	2.5619	2.5069	2.5106	2.5371	-
	3	6.9214	5.2193	4.1848	3.4754	3.1318	2.8830	2.7217	2.6467	2.6367	-	-
	4	7.5944	5.7825	4.6340	3.8677	3.4325	3.1289	2.9496	2.8213	-	-	-
	5	8.0951	6.1896	4.9774	4.1562	3.6543	3.3128	3.1045	-	-	-	-
6/T	1	8.2164	6.2187	4.7000	3.8003	3.2692	2.9458	2.7731	2.7219	2.7303	2.8074	2.9409
	2	9.6129	7.3898	5.6843	4.6310	4.0003	3.6365	3.4659	3.3959	3.4741	3.5863	-
	3	10.2557	7.9542	6.1253	4.9332	4.3127	3.8615	3.6745	3.5806	3.6585	-	-
	4	11.1027	8.6923	6.7156	5.4558	4.7063	4.1856	3.9435	3.8337	-	-	-
	5	11.7352	9.2361	7.1504	5.8023	5.0131	4.4107	4.1458	-	-	-	-
10/T	1	11.0623	8.4257	6.3697	5.2135	4.5347	4.1285	3.8981	3.8572	3.8865	4.0227	4.2524
	2	13.0769	10.1197	7.7989	6.4462	5.6416	5.1393	4.9693	4.9112	5.0538	5.2543	-
	3	13.9849	10.9254	8.4293	6.9523	6.0868	5.5045	5.2466	5.1388	5.2643	-	-
	4	15.1883	11.9833	9.2762	7.6352	6.6552	5.9551	5.6035	5.4565	-	-	-
	5	16.0393	12.7634	9.8995	8.1374	7.0963	6.2703	5.8731	-	-	-	-

ROAD CLASS : PAVED = 1 LATERITE (GOOD) = 2 LATERITE (FAIR) = 3 LATERITE (POOR) = 4 EARTH = 5

The coefficients for speed change cycle were taken from SVOCT which are shown in Appendix 3.4.3 and additional costs per traffic friction were estimated for each vehicle type.

5) Road User Costs on Each Link

Based on the VOCs on level tangent roads of five classes and the coefficient due to road geometrics and speed change cycle, actual VOCs were estimated for each road link.

Data used in calculating VOCs on actual road links are shown in the Route Report.

3.4.5 VOC SAVINGS

The savings were estimated as the difference of total VOC in the related road network in "with and without project". They were calculated by vehicle traffic type and then summed up.

Whole savings were counted for normal traffic for both passengers and freight, while one half of savings were counted for induced traffic. Savings for developed traffic were not counted, since the benefits due to developed traffic were considered to be included in the benefits of agricultural development.

Vehicle operating cost savings by study route are summarized in Table 3.4.3.

TABLE 3.4.3 VEHICLE OPERATING COST SAVINGS

(Unit: thousand baht)

Route No.	Origin	Destination	1988	1994	2002
IM - 1	A. Khong	J. R. 2180	9,573	12,766	18,900
IM - 4	A. Chonnabot	B. Don Han	5,449	7,474	11,410
IM - 5	A. Nam Phong	B. Nong Tum	6,237	9,068	14,781
IM - 7	B. Lao (J. R. 210)	B. Tha Yom	3,098	3,912	5,349
IM - 8	B. Huai Koeng	A. Kumphawapi	1,902	2,683	4,269
IM - 9	A. Nong Han	A. Kumphawapi	7,061	9,721	14,811
IM - 12	A. Sawang Daen Din	A. Song Dao	3,428	4,464	6,377
IM - 19	A. Selaphum	B. Kham Phon Sung	10,382	13,829	20,367
IM - 24	B. Na Suang	B. Na Yia	2,133	3,409	6,275
IM - 25	A. Maha Chana Chai	A. Kho Wang	4,203	5,343	7,444
IM - 26	B. Som Poi Noi	B. Muang Mak	3,997	5,576	8,634
IM - 27	A. Chom Phra	B. Nong Khawao	2,379	3,487	5,867
IM - 29	A. Prakhon Chai	A. Krasang	10,567	15,077	24,683
IM - 31	B. Nong Pha Ong	A. Nong Ki	9,903	14,263	23,219
IM - 33	A. Si Khiu (J. R. 2)	A. Chok Chai	29,476	41,694	66,473

3.5 ENGINEERING

Engineering studies were composed of:

- Field surveys
- Preliminary design
- Construction and maintenance costs estimates

Field surveys covering road inventory and topographic surveys and soils, boring and materials testing were performed. Preliminary design was made based on the results of these surveys and available data.

3.5.1 Field Surveys

3.5.1.1 Inventory Survey and Field Reconnaissance

An inventory survey was conducted for existing routes and field reconnaissance for new construction routes, totaling 500 km in length covering all study routes.

An inventory survey with an accuracy of pre-feasibility study level was done in the Phase I Study. Therefore, importance in the inventory survey was put on confirming the following matters as well as reviewing the performance in Phase I Study in order to improve the accuracy at the feasibility study level:

- Location, type and dimension of bridge and culvert structures
- Structures and obstacles which may cause roadside friction
- Boundary of villages
- Catchment area and drainage facilities
- Flooded areas
- Road surface conditions

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

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

For new construction sections in IM-1, 9 and 33, detailed reconnaissance was carried out to study the new alignment and to clarify control points.

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

The principal check points in the reconnaissance were:

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

The conditions of the existing roads are summarized in Table 3.5.1 and details for each study route are shown in the Route Report.

3.5.1.2 Topographic Survey

For partial or whole sections of IM-1, 4, 5, 8, 9, 25, 26, 27, 31 and 33, topographic maps prepared by DOH were fully utilized in the study. For the remaining 5 study routes (IM-7, 12, 19, 24 and 29) of about 150 km in length, topographic surveys consisting of center line, profile, and cross section surveys, were carried out by the study team.

TABLE 3.5.1 CONDITION OF EXISTING ROADS

Route No.	Length (km)	Terrain	Road Condition			Number of Bridges	Overflow Length (km)
			Alignment	Width (m)	Surface		
IM- 1	46.8	Flat/Rolling	Fair/Bad	6.5	Laterite Earth	T-2	3.1
IM- 4	24.0	Flat	Fair	6.5	Laterite	T-1	2.0
IM- 5	28.0	Flat/Rolling	Fair	6.9	Laterite	C-7,T-2	0.9
IM- 7	40.7	Flat/Rolling	Fair	6.0	Laterite	C-3,T-2	0.5
IM- 8	14.2	Flat	Fair	6.9	Laterite	T-1	-
IM- 9	34.3	Flat	Fair	7.7	Laterite	T-13	1.3
IM-12	19.1	Flat/Rolling	Fair	7.3	Laterite	C-1,T-4	0.7
IM-19	46.3	Flat/Rolling	Fair	7.0	Laterite	C-18,T-1	-
IM-24	13.6	Flat	Fair	6.7	Laterite	T-2	0.5
IM-25	24.5	Flat	Fair	6.0	Laterite	C-1	8.2
IM-26	28.4	Flat	Fair	6.0	Laterite	C-3	0.6
IM-27	31.1	Flat	Fair	7.0	Laterite	T-1	-
IM-29	47.1	Flat	Fair	7.5	Laterite	C-4,T-7	8.0
IM-31	52.6	Flat	Fair	7.5	Laterite	C-1,T-2	-

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

The results of the topographic surveys were drawn at the following scales and are shown in the Route Report at the reduced scale of 1/25,000:

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

3.5.1.3 Material Source Survey and Soil Tests

Prior to carrying out soil sampling, data concerning the qualities and locations of materials for selected fill, subbase and base such as laterite, sand and gravel/crushed stone were collected at the Material and Research Division of DOH and at DOH Division Engineer Offices.

Since data of laterite and granular materials for all of the study routes had been collected by DOH, sampling for these materials was omitted. In IM-19, however, soil sampling for five laterite sources was carried out to test soil stabilization with cement. Because that study route is far from any gravel/crushed stone source, the employment of a laterite base stabilized with cement may be required from the economic point of view.

Soil samplings for subgrade were made at about 7-km intervals, for a total of 74, on all the study routes for the following laboratory tests:

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

The items tested for soil stabilization with cement were as follows:

- Classification
- Sieve analysis
- Plasticity
- Determination of optimum moisture content of cement mixed samples: mixing ratio of cement ranged from 3% to 5%
- Unconfined compression test

- CBR test on the most appropriate mixed sample

An alternative cost analysis on the base materials for IM-19 proved that the unit rate of cement stabilized base was more expensive than that of aggregate base. Thus, an aggregate base was finally employed for IM-19.

All these laboratory tests were carried out by the Material and Research Division of DOH. The locations and test results are shown in the Route Report.

3.5.1.4 Boring Survey

A boring survey was carried out at 5 points to verify the subsoil conditions at the sites of existing bridges with comparatively long total span lengths which are to be replaced with reinforced concrete bridges.

BORING SITES

Route No.	Number of Borings	Location
IM - 5	1	17+900
IM - 19	3	10+900, 12+800, 33+000
IM - 29	1	29+200

Boring was composed of drilling a borehole with the standard penetration test (SPT) at the sites and collecting soil samples for laboratory tests.

Laboratory tests on the following items were carried out for representative samples of each stratum:

- Moisture content
- Unit weight
- Atterberg limits
- Sieve analysis

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

3.5.2 Preliminary Design

3.5.2.1 Design Standard

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

National Highways: Roads which are of primary importance to the economic development, administration and defence of the Kingdom.

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

Based on these definitions, IM-33, which was planned as an extension of National Highway Route 24, was categorized as a national highway and all the other study routes which were planned for the development of local areas categorized as provincial highways.

DOH has minimum design standards for national highways called the P and S standards. The P standard is subclassified into four road classes from P_D to P_3 according to the projected ADT. Criteria for classification are as follows:

- Class P_D: 7th-year ADT is above 8,000 or is justified by economic feasibility calculations
- Class P_1 to P_3: 15th-year ADT is as follows: $P_1 = 4{,}000 - 8{,}000$, $P_2 = 2{,}000 - 4{,}000$, $P_3 =$ below 2,000

For IM-33, the P standard was applied because Route 24, into which IM-33 will be incorporated in future, was constructed based on this standard. Since the projected ADT of IM-33 in 15 years after opening is 2,696 as shown in Table 3.2.1, the P_2 standard was adopted.

For provincial highways, DOH also has a minimum design standard called the F standard. This standard is subdivided into seven road classes from F_D to F_6 according to the projected ADT. Criteria for classification are as follows:

- Class F_D: 7th-year ADT is above 8,000 or is justified by economic feasibility calculations
- Class F_1 to F_3: 15th-year ADT is as follows: $F_1 = 4{,}000 - 8{,}000$, $F_2 = 2{,}000 - 4{,}000$, $F_3 = 1{,}000 - 2{,}000$
- Class F_4: ADT of more than 300 in 7th year and less than 1,000 in 15th year
- Class F_5: ADT of less than 300 in 7th year and more than 300 in 15th year
- Class F_6: a projected ADT of less than 300 in 15th year

As shown in Table 3.2.1, projected ADTs of all study routes except IM-7 and 25 are more than 300 in the 7th year after opening and less than 1,000 in the 15th year. The F_4 standard was, therefore, adopted for these routes.

ADTs in the 7th year of IM-7 and 25 were forecasted at less than 300. However, the F_4 standard was applied to these routes instead of F_5, because existing roads, at present, already satisfy the F_5 standard.

Design standards applied to each route are summarized below.

APPLICATION OF DESIGN STANDARD

Standard	Route No.	ADT	
		7th Year	15th Year
P_2	IM-33	1,940	2,696
F_4	IM-1, 4, 5, 8, 9 12, 19, 24, 26, 27, 29 and 31	303-628	431-924
F_4*	IM-7 and 25	173-256	264-473

Note: *: Exception

3.5.2.2 Geometric Design

1) Design Speed

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

DESIGN SPEED

Terrain Condition	Design Speed (km/h)	
	P_2 (IM-33)	F_4 (other study routes)
Flat and Moderately Rolling	80-100	60-80
Rolling and Hilly	60-80	45-60
Mountainous	50-60	30-45

In addition, 40 km/h was applied as the design speed on the sections passing through densely populated areas on all routes.

2) Geometric Design Criteria

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

GEOMETRIC DESIGN CRITERIA

Description	Design Speed (km/h)							
	100	90	80	70	60	50	40	30
Minimum Radius & Curvature (m)	350	270	210	160	120	80	50	30
Minimum Stopping Sight Distance (m)	160	135	115	90	70	60	45	30
Maximum Gradient (%)	6	7	8	9	10	10	12	12

3) Alignment

In principle, the alignments of the study routes were designed to follow the existing alignments as much as possible.

Improvement was considered only for existing poor alignments which do not satisfy the geometric design criteria. IM-5 has numerous sharp curves which cross over small canals at right angles. These curves were improved so as to satisfy the design criteria. In sections where the roads pass through densely populated areas, even if sharp horizontal curves which do not fulfill the geometric design criteria exist, no improvement was designed when removing of houses is required.

New roads were designed for the whole section of IM-33 and for some sections of IM-1 and 9. IM-33 has no existing road which parallels the planned route. Since some short sections of IM-1 do not exist at all or are in poor condition, these were planned as new roads. The section where IM-9 approaches Route 2023 is close to the Lampao River and is often damaged by flooding. For this section, a new route was designed at a distance from the river to avoid flood damage.

No bypasses were planned. Based on traffic observation during road inventory surveys, minimal traffic passes through the villages without stopping. Most traffic stops in the center of villages for such purposes as picking up local passengers, distributing daily necessities and collecting agricultural products.

The length of the sections designed as new road are shown below:

LENGTH OF NEW ROAD

Route No.	Length (km)	
	Total	New Road Section
IM - 1	46.8	6.8
IM - 9	34.3	0.2
IM - 33	51.4	51.4

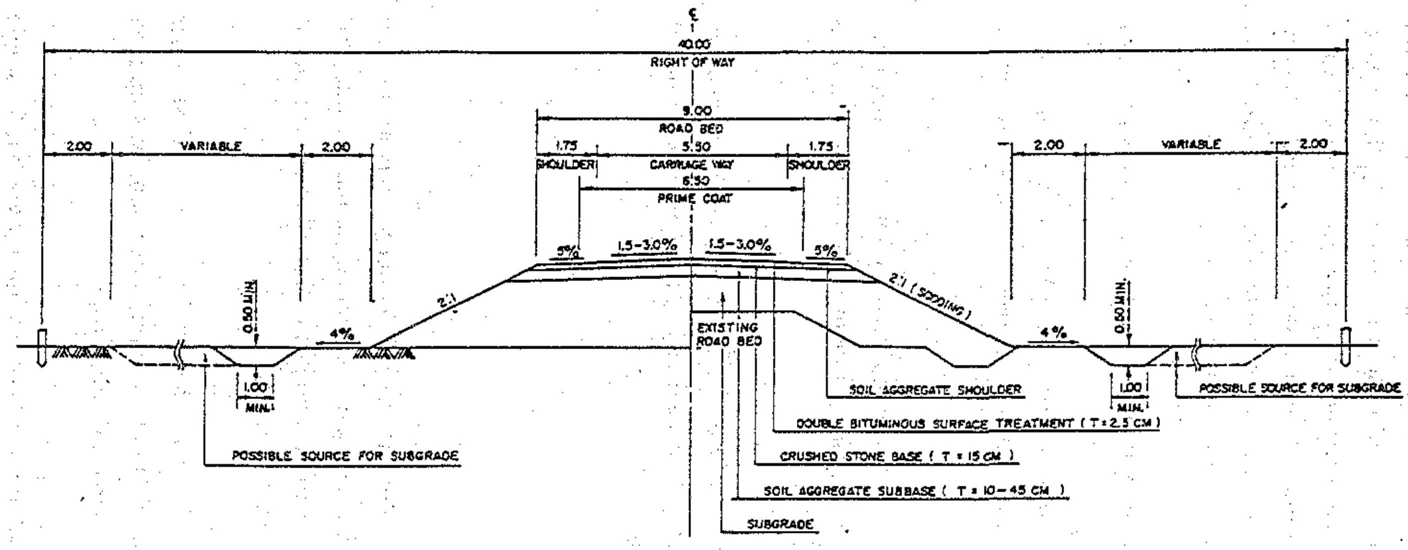
4) Typical Cross Sections

Typical cross sections of P_2 and F_4 standards are shown in Figure 3.5.1.

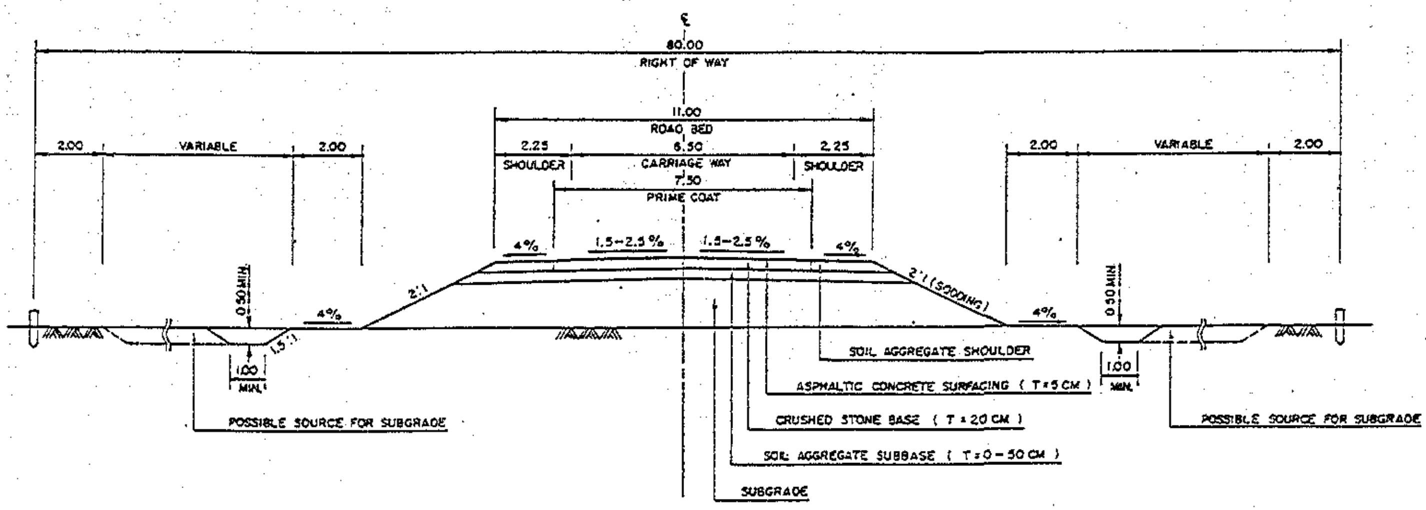
Typical cross sections in DOH standards were applied without change.

The components which are not instructed in DOH's typical cross sections, such as the embankment and cut slopes, the minimum depth of the side borrow ditch and the width of berms between the toe of the embankment slope and the side borrow ditch were determined through a study of typical sections of recent DOH highway projects. Their specifications are as follows:

- The gradient of the embankment slope is 2:1.
- The gradient of the cut slope is 1.5:1 in principle, but variable depending on the cut depths and soil conditions.
- In the embankment section, 2-m side berms are provided between the toe of embankment slopes and the side borrow ditches.
- The minimum sizes of the side borrow ditch specified are 80 cm in depth and 100 cm in bottom width.
- The minimum gradient of the side slope of the side borrow ditch is 1.5:1.



PROVINCIAL HIGHWAY (CLASS F4)



PRIMARY HIGHWAY (CLASS P2)

FIGURE 3.5.1 TYPICAL CROSS SECTIONS

3.5.2.3 Earthwork Design

The required minimum height of the road formation is determined mainly in consideration of the influence of the surrounding water level on the road structures, especially on the pavement structures. In this study, the minimum height of road formation was designed to be 70 cm above the surrounding high water level estimated during the road inventory survey. Clearing and grubbing were planned within about 15 m on either side of the proposed road center line excluding the formation width of the existing road concerned.

Roadway excavation was executed only for approach sections of existing permanent bridges.

Since the side borrow method is common and economical for embankment construction in Thailand, this method was therefore applied in embankment construction on all sections of the study routes.

Since CBR of subgrade soils obtained from the soil test conducted by DOH's laboratory show rather high values on most of the study routes, embankment with selected materials was not applied for any study routes at this stage.

Replacement of existing subgrade which was extremely deteriorated and softened because of its high natural moisture content or other factors was considered by assuming quantities of such deteriorated materials on each study route.

3.5.2.4 Pavement Design

1) General

There are commonly two types of flexible pavement: asphalt concrete pavement and bituminous surface treatment. In Thailand, asphalt concrete pavement is mainly adopted for national highways which have relatively heavy traffic, and bituminous surface treatment for provincial highways which have comparatively less traffic.

As mentioned previously, IM-33 is classified as a P_2 class national highway and all other routes as F_4 class provincial highways. Therefore, asphalt concrete pavement was applied only for IM-33 and bituminous surface treatment for all other routes.

Bituminous surface treatment adopted in Thailand is classified into two types: single bituminous surface treatment (SBST) and double bituminous surface treatment (DBST). In principle, the application of SBST or DBST has to be decided based on the expected traffic level. However, DBST was employed in the study because of the following advantages:

- It provides a smoother surface texture, and makes the surface more impermeable.

- It provides a heavier bituminous surface on a base course consisting of poorer material.
- Furthermore, experience shows that the production of single size cover aggregate for SBST is rather difficult.

In Thailand, the following two design methods are mainly adopted for flexible pavement:

a) DOH method: Technical Note No. 12/2520 of the Material and Research Division of DOH. This method is mainly based on the Asphalt Institute Ms-1, "Thickness Design, Full Depth Asphalt Pavement Structures for Highways and Streets".

b) Road Note 31 method: Overseas Unit, Transport and Road Research Laboratory, United Kingdom, Road Note 31, "A Guide to the Structural Design of Bitumen-Surface Roads in Tropical and Sub-Tropical Countries".

Characteristics of these two design methods are summarized below:

i) The DOH method is applicable mainly for design of asphalt concrete pavement because the required thickness of pavement structure is calculated in terms of full depth asphalt concrete. It is necessary, therefore, to apply conversion factors to estimate the thickness of the base and the subbase. On the other hand, the Road Note 31 method is prepared mainly for design of low cost road with double bituminous surface treatment.

ii) In the Road Note 31 method, the thickness of the base is fixed at 150 mm or 200 mm and only the thickness of the subbase can be directly determined through the design procedures. On the other hand, in the DOH method, the thicknesses of both base and subbase can be determined arbitrarily.

iii) For overlay, the Road Note 31 method recommends fixed thickness of overlay, 50 mm of asphalt concrete or DBST with 75 mm of crushed stone base, for a half million standard axles or more. In the DOH method, methods to determine the thickness of overlay by calculation are given.

Based on the characteristics mentioned above, the DOH method was applied for the pavement design of IM-33 classified as a P_2 class road and the Road Note 31 method for all other study routes classified as F_4 class roads. For reference, the pavement thickness of IM-8 was estimated by the above two methods and compared as an example.

The design period of the pavement was assumed to be 7 years and overlay or resurfacing was planned at the beginning of the 8th year after opening, based on DOH standards. The advantages of stage construction are as follows:

i) Partially deteriorated spots can be repaired and reinforced during the first stage, and thus pavement performance in the second stage can be improved more effectively.

ii) By surveying the actual traffic on the road during the first stage, a more accurate analysis of traffic can lead to a more adequate pavement design for the second stage.

2) Pavement Design by DOH Method (IM-33)

a) Number of Heavy Trucks (NHT)

The number of heavy trucks (NHT), medium trucks and heavy buses on design lanes was estimated as follows because IM-33 is a two lane road:

NHT = Average ADT of Heavy Trucks × 50%

b) Average Gross Weight of Heavy Trucks (AGW)

Based on the O/D survey results the average gross weights of heavy trucks were estimated as follows:

AVERAGE GROSS WEIGHT OF HEAVY TRUCKS

Type of Vehicle	Average Gross Weight (t)
Heavy Truck	15.13
Medium Truck	7.70
Heavy Bus	9.42

Note: Refer to Table 4.3.2 in Chapter 4.

The AGW of heavy trucks on the design lane were calculated by multiplying the above average gross weight by the component number of NHT by vehicle type and then totalled.

c) Design Traffic Number (DTN)

Assuming that a single axle load limit is 8,200 kg, the initial traffic number (ITN) was estimated based on a traffic analysis chart (Fig. 3.5.2) using AGW and NHT previously estimated.

Using the annual growth rate of ADT, the ITN adjustment factor was calculated by the following formula:

$$\text{Factor} = \frac{(i+r)^n - 1}{20 \cdot r}$$

where, r : Annual growth rate of ADT
n : Design period

DTNs for the design periods of 7 and 15 years were obtained by multiplying ITN by the ITN adjustment factor.

d) Design CBR

Design CBR can be determined based on the standard deviation of tested CBR values derived from the following equation:

$$Se = \frac{R}{d}$$

where, Se : Estimated standard deviation
R : Range of values, i.e., the difference between the greatest and smallest values
d : Factor (see the table below)

FACTOR FOR ESTIMATING STANDARD DEVIATION

Number of Value n	Factor (d)
2	1.1284
3	1.6926
4	2.0588
5	2.3259
6	2.5344
7	2.7044
8	2.8472
9	2.9700
10	3.0775

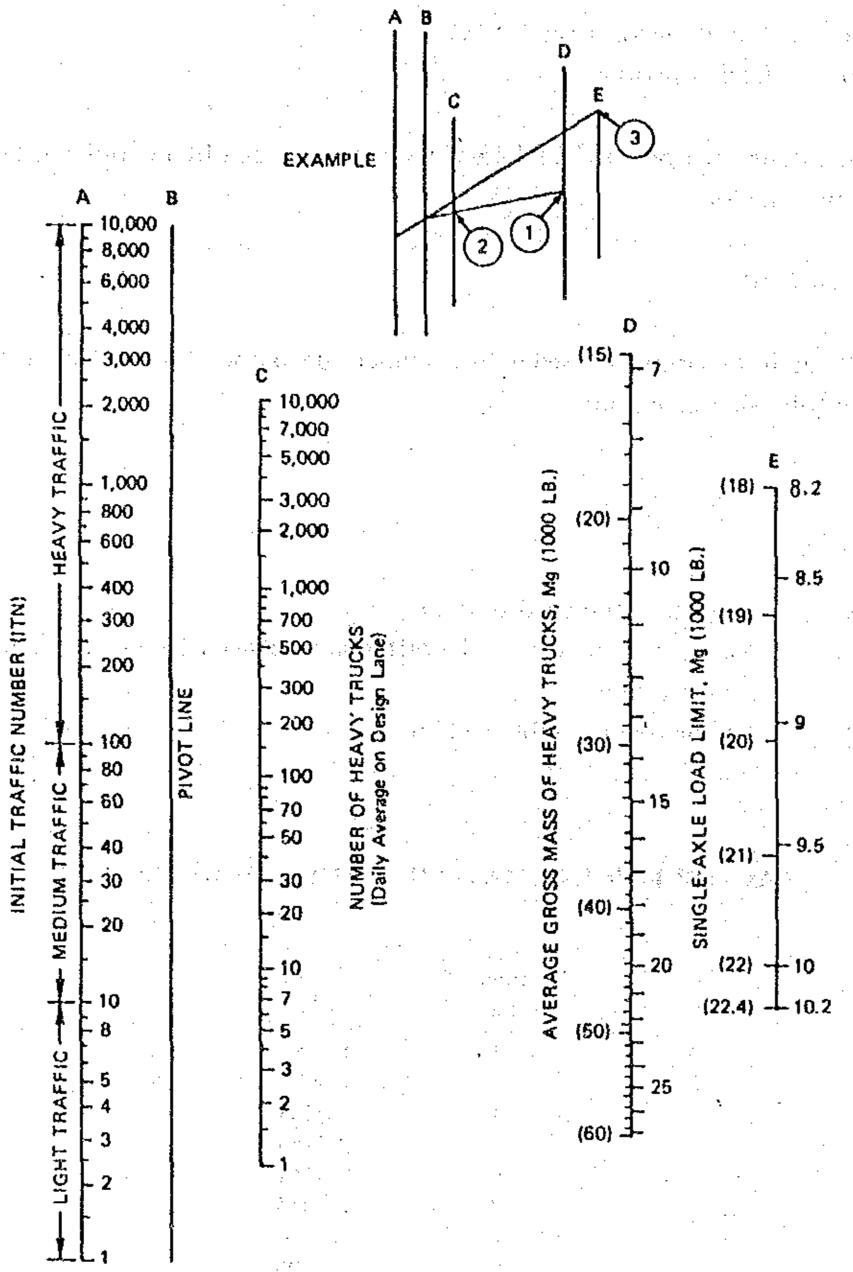


FIGURE 3.5.2 TRAFFIC ANALYSIS CHART

The Material and Research Division of DOH uses the 30th percentile CBR value as the design CBR. Using the standard deviation calculated by this equation, the 30th percentile CBR value (the design CBR) is estimated by the following equation:

$$\text{Design CBR} = \text{CBRm} - 0.524\ \text{Se}$$

where,	CBRm	:	Mean value of tested CBR value
	0.524	:	Factor for estimating 30th percentile value
	Se	:	Standard deviation corresponding to number of CBR tests

e) Pavement Thickness

By applying the calculated DTN and subgrade design CBR on the thickness design chart (Fig. 3.5.3), the required thickness of full-depth asphalt concrete layer was obtained.

The Asphalt Institute recommends the application of a substitution ratio (S_r) in conversion from asphalt concrete layer to untreated granular base and subbase. The recommended S_r is:

- High quality granular material (crushed stone)... Sr = 2.0
- Low quality granular material (good quality laterite)... Sr = 3.3

The thickness of the asphalt concrete surface was designed to be 5 cm based on the thickness usually applied in Thailand. The thickness of the base and the subbase were calculated based on the thickness which deducted 5 cm from the estimated full depth of the asphalt concrete by using the above substitution ratios.

f) Overlay Thickness

The overlay thickness of asphalt concrete was obtained by deducting the estimated thickness of the 7-year design period from that of the 15-year design period with a certain substitution ratio considering deterioration during 7 years.

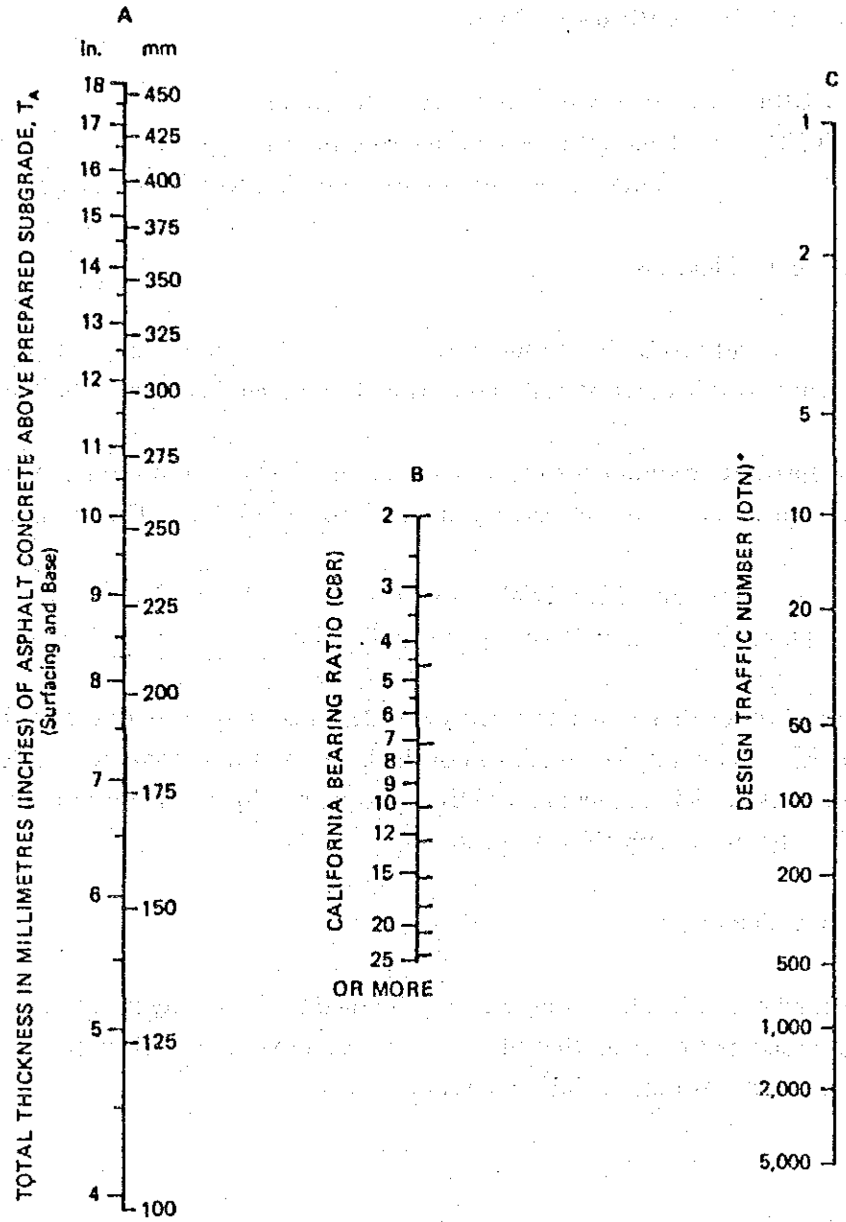


FIGURE 3.5.3 THICKNESS DESIGN CHART

3) Pavement Design by Road Note 31 Method (All study routes except IM-33)

a) Number of Heavy Trucks (NHT)

From the results of traffic forecast, NHT on the design lane from 1988 to 1994 was calculated for each study route.

b) ESA Conversion Factor (Equivalent to Standard Axles at 8,200 kg)

ESA conversion factors were estimated as follows:

ESA CONVERSION FACTOR

Heavy Truck	Medium Truck	Heavy Bus
1.24	0.76	0.50

Note: Refer to Table 4.3.2 in Chapter 4

c) Cumulative Number of ESA

The cumulative number of ESA during the design period of 7 years on the design lane was calculated by using the above ESA conversion factors and NHT from 1988 to 1994.

d) Design CBR

Design CBR was calculated through the same procedure described in design by the DOH method.

e) Pavement Thickness

Applying the calculated cumulative number of ESA and design CBR to the thickness design chart (Fig. 3.5.4), the required thickness of the subbase was estimated as the base with a fixed thickness of 15 cm.

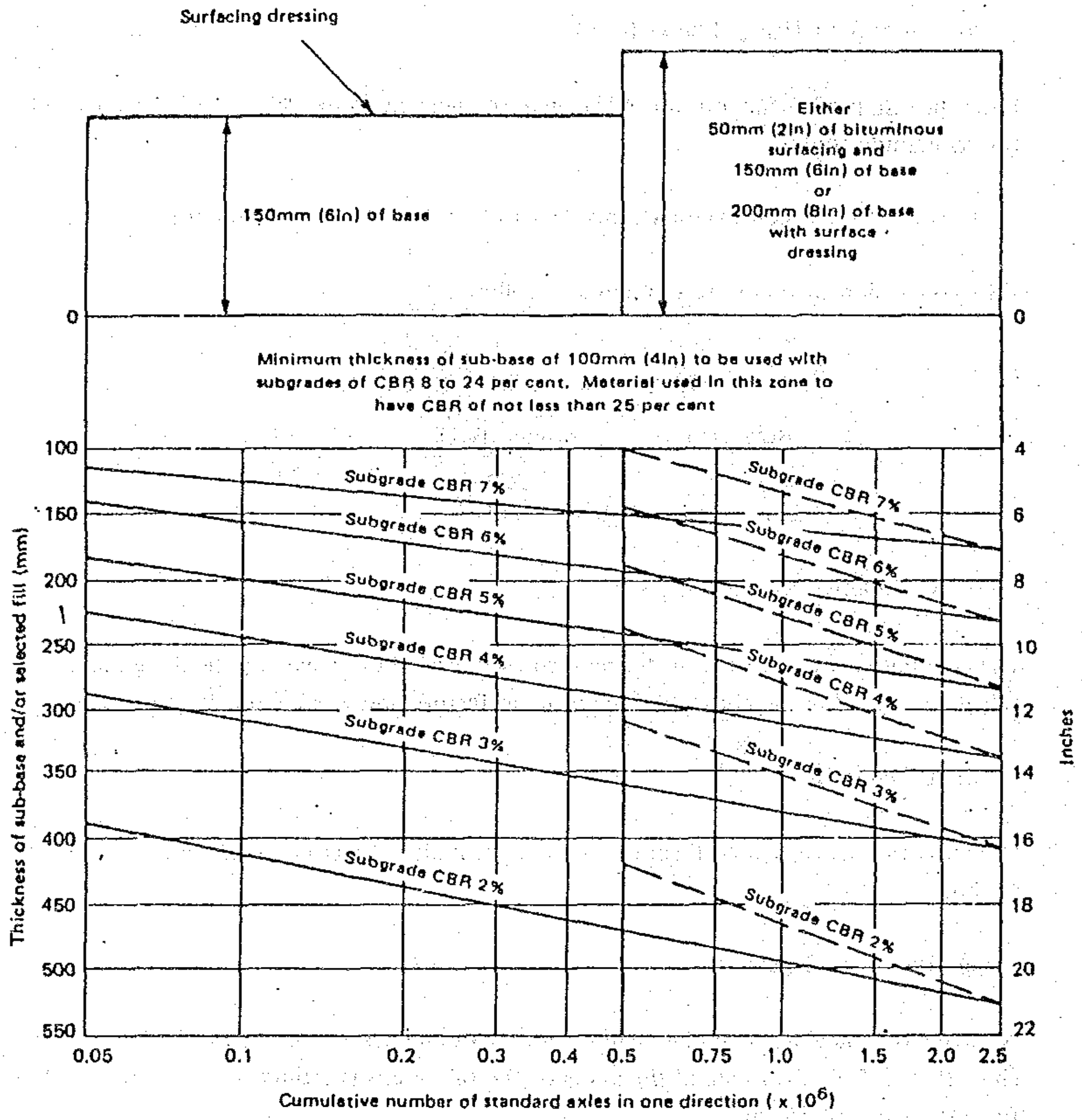


FIGURE 3.5.4 PAVEMENT DESIGN CHART (ROAD NOTE 31)

f) Overlay Thickness

In this method, an overlay consisting of 50 mm of asphalt concrete or at least DBST with 75 mm of crushed stone base is recommended for a half million standard axles or more. However, the forecasted traffic shows that no study route exceeds a half million standard axles within 15 years after opening. Thus, only resurfacing was planned at the beginning of the 8th year after opening.

The designed pavement structures of each study route are shown in Table 3.5.2.

4) Shoulder Design

Shoulders were designed of the same thickness as that of the base determined by the design of pavement structure based on DOH standards. Materials with CBR greater than 30% and PI between 4 and 15 were employed for the shoulders.

3.5.2.5 Drainage Design

Appropriate drainage facilities are indispensable for maintaining roads in all-weather condition. The existing roads have very poor drainage facilities in number and in capacity. Substantial improvement of drainage facilities was required for all the study routes.

In the study, the location, type and size of required drainage facilities were determined based on the design discharge calculated by appropriate formulas corresponding to the extent of the catchment area.

TABLE 3.5.2 DESIGNED PAVEMENT STRUCTURE

Study Route No.	Link Code	Length (km)	Road Class	Structures of 7 years Design Period (mm) Surface	Base	Subbase	Resurfacing or Overlay Thickness (mm)
IM - 1	1	11.9	F4	DBST	150	150	DBST*
	2	8.9	F4	DBST	150	200	DBST
	3	10.2	F4	DBST	150	150	DBST
	4	15.8	F4	DBST	150	150	DBST
IM - 4	-	13.7	F4	DBST	150	100	DBST
IM - 5	1	15.5	F4	DBST	150	250	DBST
	2	12.5	F4	DBST	150	400	DBST
IM - 7	-	40.7	F4	DBST	150	100	DBST
IM - 8	-	13.7	F4	DBST	150	100	DBST
IM - 9	1	20.6	F4	DBST	150	150	DBST
	2	13.7	F4	DBST	150	100	DBST
IM - 12	1	21.2	F4	DBST	150	100	DBST
	2	18.3	F4	DBST	150	100	DBST
IM - 19	1	24.7	F4	DBST	150	100	DBST
	2	21.6	F4	DBST	150	100	DBST
IM - 24	-	13.6	F4	DBST	150	250	DBST
IM - 25	-	24.5	F4	DBST	150	100	DBST
IM - 26	1	18.1	F4	DBST	150	100	DBST
	2	10.3	F4	DBST	150	100	DBST
IM - 27	1	15.4	F4	DBST	150	100	DBST
	2	15.7	F4	DBST	150	100	DBST
IM - 29	1	27.3	F4	DBST	150	100	DBST
	2	19.8	F4	DBST	150	100	DBST
IM - 31	1	24.5	F4	DBST	150	150	DBST
	2	28.1	F4	DBST	150	150	DBST
IM - 33	1	20.5	P2	AC=50	200	170	AC=45
	2	16.7	P2	AC=50	200	370	AC=35
	3	14.2	P2	AC=50	200	120	AC=40

Note: *: Resurfacing by DBST

1) Pipe Culverts

Pipe culverts ranging between 80 cm and 150 cm in diameter were applied because of easy maintenance and availability. Standard drawings of pipe culverts are shown in Figure 3.5.5.

In flat areas, the locations of pipe culverts were determined through the inventory survey, with the following standard intervals:

STANDARD INTERVALS OF PIPE CULVERTS IN FLAT AREA

Description	Standard Interval (m)
Paddy Area Flood Section	200
Others	500

In rolling areas, pipe culverts were installed at the selected sag points based on the results of topographic surveys and as-build plans of the existing roads prepared by DOH.

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

2) Box Culverts

Reinforced concrete box culverts (2.4 m × 2.4 m) with head wall and aprons were adopted as the standard type. In case that a bigger flow capacity was required, a double cell culvert of this standard size was used. Standard drawings of box culverts are shown in Figure 3.5.6.

Existing box culverts were planned to be extended by adding new box culverts of the same type and size.

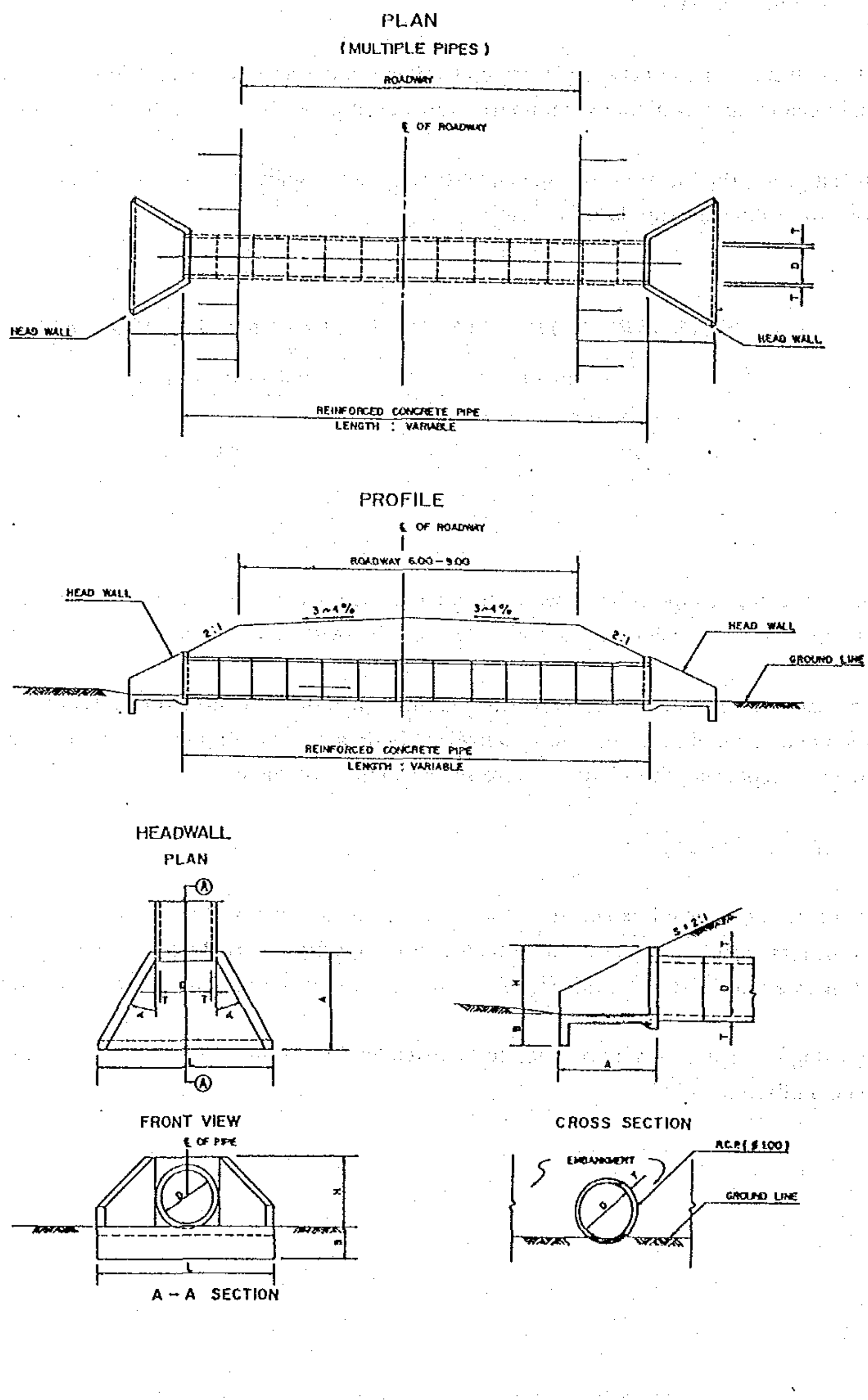


FIGURE 3.5.5 TYPICAL DESIGN OF PIPE CULVERTS

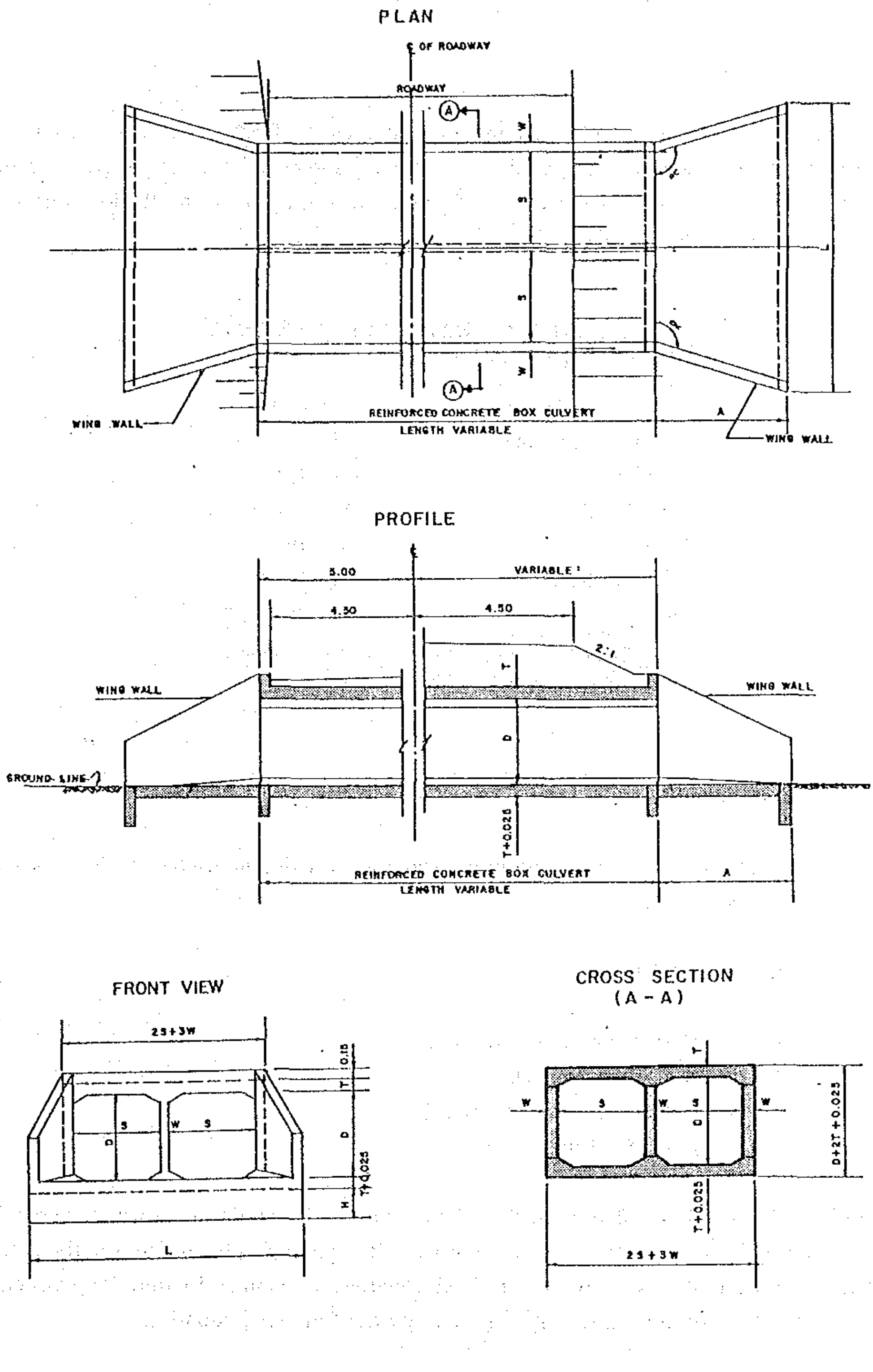


FIGURE 3.5.6 TYPICAL DESIGN OF BOX CULVERTS

3) Discharge Computation

a) Rainfall Intensity

Rainfall intensity was determined based on a rainfall intensity duration curve for a frequency of 10, 20, 50 and 100 years, prepared by PRI Study[1] and established by the study team. Rainfall intensity-duration curves from the 6 observatory stations in the Region were applied to the study routes as follows:

APPLICATION OF RAINFALL INTENSITY-DURATION CURVES

Observatory Station	Route No.
Nakhon Ratchasima	IM - 1, 31, 33
Khon Kaen	IM - 4, 5
Udon Thani	IM - 7, 8, 9, 12
Roi Et	IM - 19
Ubon Ratchatani	IM - 24, 25
Surin	IM - 26, 27, 29

Note: Rainfall intensity-duration curves by station are shown in Appendix 3.5.1.

b) Rational Formula

The following rational formula was adopted to compute the design discharge where the catchment area is less than 25 km^2:

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

where,

Q : Design discharge (M^3/sec)
C : Run-off coefficient
I : Rainfall intensity (mm/hr)
A : Catchment area (km^2)

Coefficient of run-off was determined by the graph used by DOH as shown in Appendix 3.5.2, which corresponds to the rainfall intensity and the topographic features in the catchment area. The rainfall intensity was determined from the rainfall intensity-duration-frequency curve and the time of concentration computed by the following equation:

Source: 1. Feasibility Study and Detailed Engineering Design for Provincial Road Improvement, 1981.

$$Tc = \left(\frac{0.87\ L^3}{H} \right)^{0,385}$$

where, Tc : Time of concentration (hours)

L : Stream length (km)

H : Stream fall (m)

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

c) Snyder's Equation

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

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

where, Q : Design discharge (m^3/sec)

q_p : Peak discharge ($l/sec/km^2$)

α : Reduction of point rainfall intensity for large catchment areas

i : Rainfall intensity (mm/h)

ϕ : Infiltration capacity (mm/h)

tr : Critical duration of rainfall (hours)

A : Catchment area (km^2)

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

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

where, k_p : peak discharge coefficient

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

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

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

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

In Snyder's equation, α is derived from the curves developed by the U.S. Weather Bureau and k_p and ϕ are taken from Ven Te Chow's "Handbook of Applied Hydrology". These are shown in Appendices 3.5.3, 3.5.4, 3.5.5 and 3.5.6.

4) Capacity Computation

The flow capacity of box culverts and bridges was computed by Manning's formula:

$$Q = A \cdot V$$
$$V = \frac{1}{n} R^{2/3} \cdot I^{1/2}$$

where,
- Q : Flow capacity (m^3/sec)
- A : Cross sectional area of drainage structure (m^2)
- V : Mean velocity (m/sec)
- n : Manning's roughness coefficient: 0.02 for box culverts and 0.05 for waterway at bridge sites
- R : Hydraulic radius (m)
- I : Slope of the drainage facility

3.5.2.6 Bridge Design

1) General

The number and length of required bridges, replacement of existing timber bridges and new construction are shown in Table 3.5.3 by study route.

Since none of the existing timber bridges with widths ranging from 3.5 to 5.6 m have enough bearing capacity to design loading of HS-20, they were planned to be replaced by permanent concrete bridges or concrete box culverts.

New bridges were planned at selected sites as required.

For sites with concrete permanent bridges narrower than the width specified in DOH standards, new bridges with widths of 4.5 m were planned in parallel to them for reasons of economy.

2) Superstructure

The length of bridges was determined through the hydrological analysis of discharge and flow capacity as described in 3.5.2.5.

All new bridges were designed as reinforced concrete structures and their widths were determined according to the following DOH design standards:

TABLE 3.5.3 NUMBER AND LENGTH OF REQUIRED BRIDGES

Route No.	Replacement		New Construction		Total	
	Number	Length (m)	Number	Length (m)	Number	Length (m)
IM - 1	2	45.0	1	10.0	3	55.0
IM - 4	-	-	-	-	-	-
IM - 5	2	45.0	-	-	2	45.0
			4	38.0	4	38.0
IM - 7	2	35.0	-	-	2	35.0
			2	45.0	2	45.0
IM - 8	1	10.0	-	-	1	10.0
IM - 9	11	187.0	-	-	11	187.0
IM -12	4	40.0	-	-	4	40.0
			1	28.0	1	28.0
IM -19	-	-	-	-	-	-
			16	402.0	16	402.0
IM -24	2	50.0	-	-	2	50.0
IM -25	-	-	-	-	-	-
IM -26	-	-	-	-	-	-
IM -27	1	20.0	-	-	1	20.0
IM -29	7	160.0	-	-	7	160.0
			4	102.0	4	102.0
IM -31	2	42.0	-	-	2	42.0
IM -33	-	-	3	52.0	3	52.0

WIDTH OF NEW BRIDGES

Road Class	Bridge Width (m)		
	Carriageway	Shoulder	Total (curb to curb)
P_2 (IM-33)	6.5	2.25×2	11.0
F_4 (all other routes)	5.5	1.75×2	9.0
New Bridge beside Existing Narrow Concrete Bridge	2.75	1.75×1	4.5

A sidewalk of 1 m in width is included within the shoulder width.

3) Substructure

Since a common type of substructure applied in the Region is a pile bent pier and an abutment with concrete piles, it was also employed in the study. The length of concrete pile was determined to be 15 m based on an analysis of the boring results.

Standard drawings of reinforced concrete bridges adoptd are shown in Figure 3.5.7.

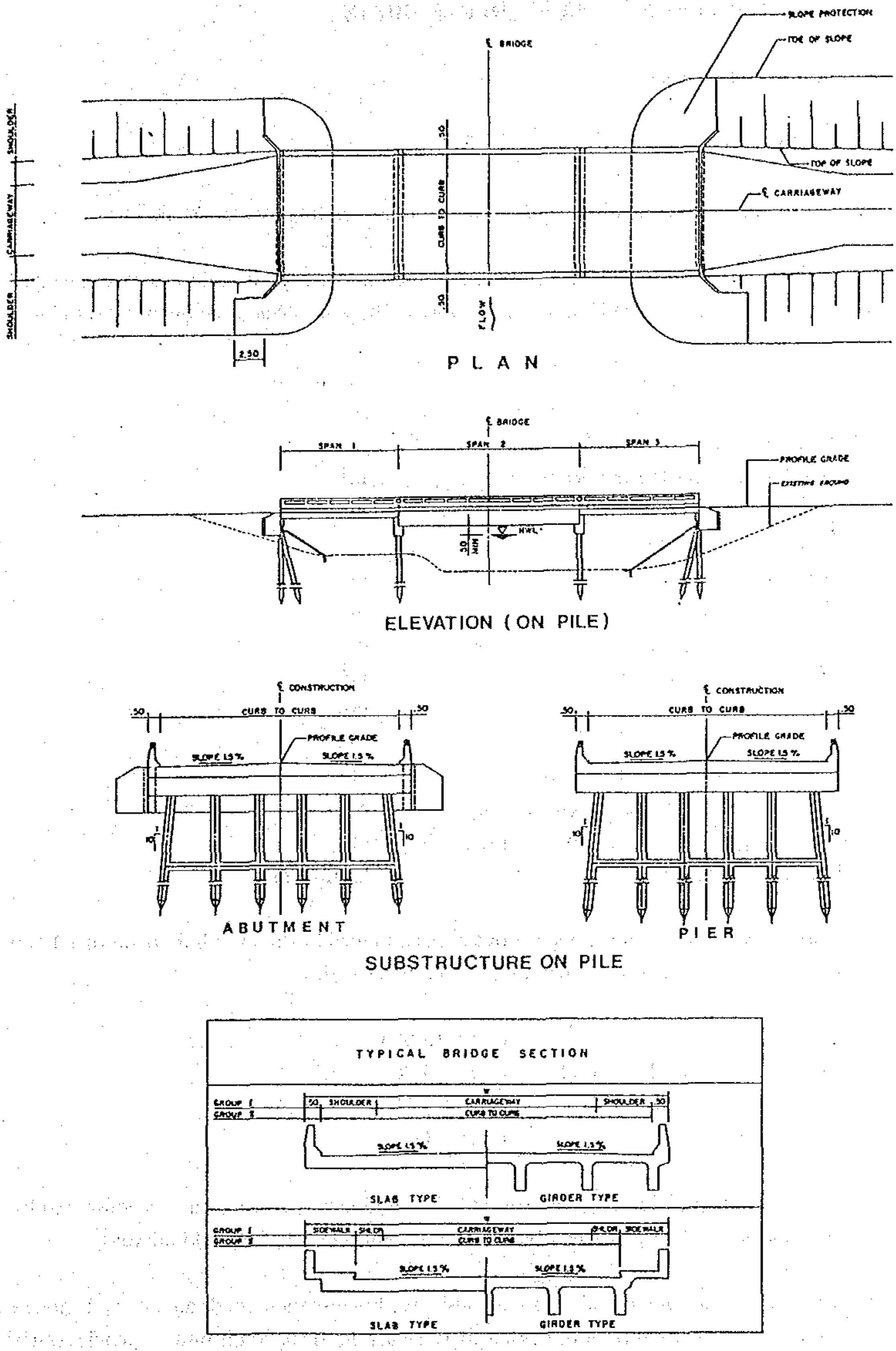


FIGURE 3.5.7 TYPICAL DESIGN OF BRIDGES

3.6 CONSTRUCTION AND MAINTENANCE COSTS

3.6.1 Construction Costs

3.6.1.1 Quantity

DOH has standard specifications and payment items for highway construction.

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

Clearing and grubbing	ha
Roadway excavation (unclassified)	m^3
Embankment (common soil)	m^3
Embankment (selected material)	m^3
Replacement of soft spots	m^3
Subbase (soil aggregate)	m^3
Aggregate base	m^3
Cement stabilized base	m^3
Shoulder (soil aggregate)	m^3
Asphaltic prime/tack coat	m^2
DBST	m^2
AC surfacing	ton
RC pipe culvert (D = 1.0 m equivalent)	m
RC box culvert (2.4×2.4 m equivalent)	m
RC bridge (W = 9.0 m, L = 10 m equivalent)	m
Miscellaneous works	lump sum

The quantities by work item mentioned above were computed based on as-built plans of 1:1,000 and the preliminary design drawings of the following scales:

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

The area of land acquisition required for widening and new construction was computed by developed and less developed lands based on data collected during field surveys.

Land acquisition along DOH roads was not considered because these roads already had enough right-of-way width. The width of right-of-way to be acquired for roads under agencies other than DOH was considered to be 30 m in principle and 20m especially for sections within

TABLE 3.6.2 SUMMARY OF CONSTRUCTION QUANTITIES

Item	Unit	1M-1	1M-4	1M-5	1M-7	1M-8	1M-9	1M-12	1M-19	1M-24	1M-25	1M-26	1M-27	1M-29	1M-31	1M-33
EARTHWORK																
Clearing & Grubbing	ha	115	55	65	97	33	85	44	108	32	82	69	72	109	120	154
Roadway Excavation (unclassified)	m^3	0	0	6,500	0	0	0	1,700	20,700	0	800	2,800	0	7,200	22,600	0
Embankment (common soil)	m^3	397,000	91,500	203,200	227,800	84,200	330,000	151,100	394,300	111,400	230,900	208,400	259,000	449,500	115,300	560,700
Embankment (selected material)	m^3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Replacement of Soft Spots	m^3	3,500	1,300	2,800	3,800	1,700	3,400	2,100	3,700	1,100	3,100	3,600	4,000	3,900	4,400	0
SUBBASE & BASE COURSES																
Subbase (soil aggregate)	m^3	70,200	22,600	77,800	38,300	13,300	41,900	18,000	43,500	32,000	23,000	26,700	29,300	44,300	74,100	137,200
Aggregate Base	m^3	45,600	23,400	27,300	39,700	13,800	33,500	18,700	0	13,300	23,900	27,600	30,300	45,900	51,300	77,200
Cement Stabilized Base	m^3	0	0	0	0	0	0	0	45,200	0	0	0	0	0	0	0
Shoulder (soil aggregate)	m^3	17,500	9,000	10,500	15,300	5,300	12,800	7,200	17,400	5,100	9,200	10,700	11,700	17,600	19,700	36,000
SURFACE COURSES																
Asphaltic Prime/Tack Coat	m^2	304,300	156,000	182,100	264,600	92,300	223,000	124,200	301,000	88,400	159,300	184,700	202,200	306,200	342,000	385,600
DBST	m^2	257,500	132,000	154,100	223,900	78,100	188,700	105,100	254,700	74,800	134,800	156,300	171,100	259,100	289,400	0
AC Surfacing	t	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39,300
STRUCTURES																
RC Pipe Culvert (D = 1.0m equivalent)	m	2,088	1,119	2,452	882	391	1,489	785	1,237	600	1,886	1,603	1,861	2,814	3,374	2,302
RC Box Culvert (2.4m × 2.4m equivalent)	m	96	51	8	69	0	216	0	32	0	0	81	0	31	72	626
RC Bridge (W = 9.0m L = 10m equivalent)	m	55	0	102	67	10	187	60	281	50	0	0	20	231	42	52
LAND ACQUISITION																
Highly Developed Land	ha	37	0	8	33	0	48	25	0	0	34	0	0	18	0	270
Less Developed Land	ha	2	0	0	2	0	4	4	0	0	4	0	0	1	0	141

Note: *: Hauling distance is 50 km.

villages.

The quantities by work item and land area by study route are summarized in Table 3.6.1.

3.6.1.2 Unit Cost

1) Financial Unit Cost

The unit costs as of 1984 were derived from both actual contract unit costs in similar construction projects in the Region and preliminary unit costs estimated by the study team.

Due consideration was paid to the hauling charge of construction materials from the source to the construction site. Materials such as bitumen, cement and reinforcing steel bars were assumed to be transported to the project site from Bangkok.

The selected material for embankment and laterite for subbase course and shoulders were assumed to be procured within a certain distance from construction sites depending on the results of soil and material tests.

The number of rock quarries available for base, DBST, asphaltic concrete and structures is limited by the study routes. The shortest routes for hauling rock materials were examined on the basis of the existing road network connecting the study route and the material source.

Haulage distances were categorized into the following groups:

HAULAGE DISTANCE

Haulage Distance	Study Route
50 km	IM-24, 27 & 29
100 km	IM-5, 7, 12, 19, 26, 31 & 33
150 km	IM-1, 4, 8, 9 & 25

As a result, the unit costs to be employed were modified and estimated on the above assumptions and considerations, and are summarized in Table 3.6.2.

2) Economic Unit Costs

Economic unit cost to be used for economic evaluation was computed by deducting the tax component of each work item from the financial unit cost.

The percentage of tax components included in the unit cost are shown in Table 3.6.2. These were determined based on previous studies of similar type construction in Thailand, under the assumption that the construction would be performed by local contractors.

TABLE 3.6.2 UNIT COSTS OF MAJOR WORK ITEMS

(Unit: baht)

Item	Unit	Unit Cost	% of Economic Cost	
EARTHWORK				83
Clearrng & Grubbing	ha	10,000	83.5	
Roadway Excavation (unclassified)	m^3	19	83.1	
Embankment (common soil)	m^3	38	83.4	
Embankment (selected material)	m^3	70	83.0	
Replacement of Soft Spots	m^3	88	83.1	
SUBBASE & BASE COURSES				83
Subbase (soil aggregate)	m^3	112	83.5	
Aggregate Base	m^3	320*	82.9	
Cement Stabilized Base	m^3	390	83.0	
Shoulder (soil aggregate)	m^3	120	82.5	
SURFACE COURSES				85
Asphaltic Prime/Tack Coat	m^2	12	85.9	
DBST	m^2	38*	84.9	
AC Surfacing	t	750	84.2	
STRUCTURES				83
RC Pipe Culvert (D=1.0 m equivalent)	m	2,000	83.0	
RC Box Culvert (2.4m x 2.4m equivalent)	m	18,800	82.5	
RC Bridge (W=9.0 m L=10 m equivalent)	m	46,500	82.8	
LAND ACQUISITION				100
Highly Developed Land	ha	50,000		
Less Developed Land	ha	15,000		
Subtotal (a)				
Miscellaneous Works (a) x 7%				83

Note: * : Hauling distance is 50 km.

3) Foreign and Local Currency Portions of Unit Costs

The percentages of foreign and local currency portions of the unit cost to the financial cost by work item are shown in Table 3.6.3. These were determined based on studies for costs of construction materials, equipment and vehicles to be imported in the unit cost by each work item.

TABLE 3.6.3 FOREIGN AND LOCAL CURRENCY PORTIONS OF UNIT COSTS

(Unit: %)

Work Item	Foreign		Local	
Clearing and Grubbing	48.4		51.6	
Roadway Excavation (unclassified)	49.8		50.2	
Embankment (common soil)	48.4	(49)	51.6	(51)
Embankment (selected material)	49.8		50.2	
Replacement of Soft Spots	49.8		50.2	
Subbase (soil aggregate)	44.8		55.2	
Aggregate Base	45.4	(46)	54.6	(54)
Shoulder (soil aggregate)	47.1		52.9	
Cement stabilized base	54.9	55	45.1	45
Asphaltic Prime/Tack Coat	58.7		41.2	
DBST	56.5	(56)	43.5	(44)
AC Surfacing	56.0		44.0	
RC Pipe Culvert (D=1.0 m equivalent)	50.0	(50)	50.0	(50)
RC Box Culvert (2.4 m x 2.4 m equivalent)	49.9	(50)	50.1	(50)
RC Bridge (W=7.0 m, L=10 m equivalent)	48.9		51.1	
Subtotal (a)				
Miscellaneous Works (a) x 7%		51		49

Note: ( ): Average

3.6.1.3 Construction Costs

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

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

The financial and economic construction costs for each study route are summarized in Table 3.6.4. The breakdown is shown in the Route Report.

3.6.2 Road Maintenance Costs

Road maintenance is categorized into the following 4 groups by DOH for the sake of simplicity in administration and budgetary methods:

- Routine maintenance
- Periodic maintenance
- Special maintenance and minor betterment
- Emergency rehabilitation

Road maintenance is executed by the organizations at the subdistrict, field district and field division levels with road maintenance equipment rented under DOH's Revolving Fund System.

The standard frequency and capacity of routine maintenance operation teams specified by DOH are as follows: (See Table 3.6.5)

TABLE 3.6.4 SUMMARY OF COSTS

(thousand baht)

Route No.	Road Class	Length (km)	Financial Cost	Economic Cost
IM- 1	F4	46.8	90,643	76,022
IM- 4	F4	24.0	36,433	30,463
IM- 5	F4	28.0	61,886	51,725
IM- 7	F4	40.7	65,041	54,647
IM- 8	F4	14.2	22,274	18,621
IM- 9	F4	34.3	80,463	67,569
IM-12	F4	19.1	35,211	29,633
IM-19	F4	46.3	91,998	76,824
IM-24	F4	13.6	26,580	22,196
IM-25	F4	24.5	46,933	39,497
IM-26	F4	28.4	47,336	39,558
IM-27	F4	31.1	50,333	42,064
IM-29	F4	47.1	92,690	77,553
IM-31	F4	52.6	79,741	66,668
IM-33	P2	51.4	176,345	150,063
TOTAL		502.1	1,003,907	843,103

TABLE 3.6.5 FREQUENCY OF ROUTINE MAINTENANCE

Surface Type and Traffic Desity		Routine Maintenance					
		Patching and Repair		Grading of Shoulder		Grading of Surface	
Surface Type	ADT	Fre quency (no./ year)	Capa- city (km/ day)	Fre- quency (no./ year)	Capa- city (km/ day)	Fre- quency (no./ year)	Capa- city (km/ day)
Concrete	No limit	4	4	-	-	-	-
Asphaltic Concrete	6,000	4	4	13	14	-	-
and	3,000-6,000	4	4	7	14	-	-
Standard P.M.	3,000	4	4	3	14	-	-
Under Standard	3,000	4	2	7	14	-	-
Penetration	1,500-3,000	4	2	3	14	-	-
Macadam	1,500	4	2	3	14	-	-
Single Surface	1,500	4	2	3	14	-	-
and	750-1,500	4	2	3	14	-	-
Double Surface Treatment	750	4	1	3	14	-	-
Soil Aggregate	750	4	3	-	-	26	7
	400-750	4	3	-	-	13	7
	150-400	4	3	-	-	7	7
	150	4	3	-	-	3	7

In many feasibility study reports submitted to DOH recently, formulas to estimate the road maintenance cost as a function of ADT were proposed. However, there are considerable differences among the results obtained from them.

Therefore, DOH budgetary allocatable maintenance costs were introduced in the study in accordance with the procedures given in the Feasibility Study Handbook for Improvement and New Construction Road Projects (FSH), compiled by the DOH Programming Section with the assistance of the Australian Development Assistance Bureau.

1) Routine Maintenance

Routine maintenance costs by study route were calculated by employing the maintenance allocation factors and the rates of maintenance cost of specified highways estimated by DOH.

Rates of maintenance cost of specified highways (as of 1984):

-Unimproved road (laterite) : 7,700 baht/km/yr
-Improved road (bitumen) : 8,200 baht/km/yr

In the Road Feasibility Study Project Report (October 1982), an addition of administrative costs to the above was suggested and this addition (administration factor: 1.4) was made in the study because routine maintenance work is being executed in the form of direct labor by DOH.

2) Periodic Maintenance Costs

Special periodic maintenance is usually not required on unimproved roads. On improved roads, overlay or resurfacing at intervals specified in the Revolving Fund System is required as periodic maintenance costs. The costs for periodic maintenance are described in 3.6.3.

3) Special Maintenance and Minor Betterment

In the study routes, it was assumed that no special maintenance or minor betterment during the design life would be required judging from the projected future traffic level. As a result no special maintenance costs were taken into account.

4) Emergency Rehabilitation

Costs equivalent to 15% of estimated routine maintenance costs were provided for emergency rehabilitation considering the possibility of emergencies and disasters.

5) Economic Maintenance Costs

The economic maintenance costs were derived from the following formula:

Specified Maintenance Cost (see 1) above) × Ka or Kb × 1.4 × (1+0.15) × 0.85

where,	Ka	:	Road characteristics factor of unimproved road: the figure is between 1.10 and 1.81.
	Kb	:	Road characteristics factor of improved road: the figure is between 1.14 and 1.33.
	1.4	:	Administration factor
	0.15	:	Emergency rehabilitation cost factor
	0.85	:	Economic maintenance cost factor to financial maintenance cost

Formulas and factors to calculate Ka and Kb are given in FSH.

Economic maintenance costs for each study route thus estimated are shown in the Route Report.

3.6.3 Overlay and Resurfacing Costs

According to DOH standards, overlay or resurfacing should be planned at the beginning of the 8th year after opening of roads which have been improved or newly constructed, and in the Revolving Fund System, periodic maintenance intervals are specified as follows:

PERIODIC MAINTENANCE SYSTEM

Surface Type	ADT	Period (years)
AC, DBST, SBST	1500	5
	750-1500	6
	750	7

As mentioned in 3.5.2.4, the Road Note 31 method was applied for the design of DBST on study routes classified as F_4 class roads. In this method, an overlay consisting of 50 mm of asphalt concrete or at least 75 mm of crushed stone base with double surface treatment is recommended when 500,000 standard axles pass. However, standard axles passes exceeding 500,000 are foreseen for none of the study routes during the 15 years after opening. Only resurfacing by DBST, therefore, was planned at the beginning of the 8th year after opening.

IM-33 is classified as a P_2 class road which requires an asphaltic concrete surface. The DOH method was applied in its design as mentioned above. In this method, the overlay thickness of asphaltic concrete was determined by deducting the estimated thickness of the 7-year design period from that of the 15-year design period. The estimated thickness of segments 1, 2 and 3 is 4.5 cm, 4.0 cm and 3.5 cm, respectively.

Unit costs of resurfacing by DBST and overlay by asphaltic concrete and the total costs on each route are shown in Tables 3.6.6 and 3.6.7, respectively.

TABLE 3.6.6 UNIT COST OF RESURFACING AND OVERLAY

(Unit: baht/m^2)

Surface Type	Route No.	Reconditioning	Prime Coating	DBST and AC	Misc. (%)	Total
DBST	IM - 1, 4, 8, 9, 25	21.0	12.0	40.0	5.0	78.0
	IM - 5, 7, 12, 19, 26, 31	21.0	12.0	39.0	5.0	77.0
	IM - 24, 27, 29	21.0	12.0	38.0	5.0	76.0
AC	IM - 33-(1)	21.0	12.0	80	8.0	121.0
	-(2)	21.0	12.0	71	7.0	111.0
	-(3)	21.0	12.0	62	7.0	102.0

TABLE 3.6.7 COST OF RESURFACING AND OVERLAY

Route No.	Route Length (km)	Width (m)	Unit Cost (baht/m^2)	Resurfacing and Overlay Cost (thousand baht)
IM-1	46.8	5.5	78.0	20,077.2
4	24.0	5.5	78.0	10.296.0
5	28.0	5.5	77.0	11,858.0
7	40.7	5.5	77.0	17,236.5
8	14.2	5.5	78.0	6,091.8
9	34.3	5.5	78.0	14,714.7
12	19.1	5.5	77.0	8,088.9
19	46.3	5.5	77.0	19,608.1
24	13.6	5.5	76.0	5,684.8
25	24.5	5.5	78.0	10,510.5
26	28.4	5.5	77.0	12,027.4
27	31.1	5.5	76.0	12,999.8
29	47.1	5.5	76.0	19.687.8
31	52.6	5.5	77.0	22,276.1
33-(1)	20.5	6.5	121.0	16,123.3
-(2)	16.7	6.5	111.0	12,049.1
-(3)	14.2	6.5	102.0	9,414.6
33-(Total)	51.4	6.5	—	37,587.0

3.6.4 Residual Value

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

Earthworks : $RV = 100\ (1 - 0.0067 \times 15) = 90\%$
Pavement : $RV = 100\ (1 - 0.0333 \times 15) = 50\%$
Major Structure : $RV = 100\ (1 - 0.0333 \times 15) = 50\%$

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

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

3.6.5 Preliminary Work Program and Cost Disbursement Schedule

In general, it is preferable that the road length to be improved as a project be less than 50 km and that the period of construction time be less than 2 years, taking into account a contractor's capability to supply construction equipment, the labor force required and financial preparation, as well as the project life cycle considering the feedback of project results and fluctuation of monetary value.

In the Region, since the 3 months from August to October are the rainy season, no major work can be executed in this period.

The critical works are as follows:

- Earth works
- Pavement works including subbase, base and surface works
- Long-span bridge works

The longest bridge in the study routes is 60 m in length on IM-19. The net construction period for this bridge is as follows:

NET CONSTRUCTION PERIOD

Work Item	Period (months)
Production of Piles	3.0
Piling	1.0
Coping	1.0
Superstructure	6.0
Total	11.0

The second longest bridge in the study route is 30 m in length and its net construction period was estimated at about 8.0 months based on the above analysis.

It is assumed that asphaltic concrete surfacing will be performed in accordance with the following schedule if a 40^{t}/hr AC plant is employed:

Asphalt concrete of 5 cm in thickness: 763^{t}/km
Daily output: 200 tons
Monthly working day ratio: 65%
30 days/month × 0.65 × 200^{ton}/day = $3{,}900^{ton}$/month
$3{,}900^{ton}$/month ÷ 763^{ton}/km = 5.0 km

In this study, the following assumptions were made in connection with the period of construction time:

REQUIRED CONSTRUCTION PERIOD

Work Item	Monthly Performance or Required Period
General Preparation	2.0 months
Required Time between General Preparation and Pavement Works	4.0 months for AC
	2.0 months for DBST
Major Works before Pavement Works	
Earthworks	40,000 m³ for improvement
	60,000 m³ for new construction
Pavement Works	5.0 km
Bridge Works	11.0 months/60 m total span length
Other Works after Pavement Works	2.0 months
Rainy Season	3.0 months/year

Based on the above assumptions, the construction and cost disbursement schedules were established as summarized in Table 3.6.8.

TABLE 3.6.8 CONSTRUCTION AND COST DISBURSEMENT SCHEDULES

Route	Nomenclature			Construction Schedule (months)			Disbursement Schedule (million baht)			
No.	Length (km)	Surface Type	Longest Bridge (m)	1986	1987	Total	Base Year	1986 %	1987 %	Total
IM-1	46.8	DBST	30	12	12	24	90.6	50	50	110.6
4	24.0	"	-	2	12	14	36.4	25	75	45.3
5	28.0	"	30	6	12	18	61.9	30	70	76.8
7	40.7	"	21	8	12	20	65.0	40	60	80.1
8	14.2	"	10	-	12	12	22.2	-	100	28.1
9	34.3	"	30	9	12	21	80.4	40	60	99.0
12	19.1	"	28	2	12	14	35.2	15	85	44.2
19	46.3	"	60	12	12	24	92.0	50	50	112.2
24	13.6	"	30	-	12	12	26.6	-	100	33.8
25	24.5	"	-	6	12	18	47.0	30	70	58.3
26	28.4	"	-	6	12	18	47.3	35	65	58.4
27	31.1	"	20	7	12	19	50.3	35	65	62.2
29	47.1	"	36	12	12	24	92.7	50	50	113.1
31	52.6	"	24	12	12	24	79.7	50	50	97.3
33	51.4	AC	20	12	12	24	176.3	50	50	215.9

ASSUMPTION: ANNUAL RISE IN PRICES

Currency	1984 (base year)	1985	1986	1987
Local	100	110.0	121.0	133.1
Foreign	100	106.5	113.4	120.8

3.7 ASSESSMENT OF SOCIAL IMPACT

3.7.1 SOCIAL BENEFITS

Impacts caused by the improvement of roads cannot be limited only to savings in VOC and increases in agricultural production.

The following positive impacts may also be expected:

- Better accessibility to general government services including security
- Improved educational levels
- Improved medical care
- Alleviation of income disparity with other areas
- More job opportunities and subsequent higher incomes
- Reduction in prices of consumer goods in rural areas
- Creation of jobs during construction
- Better environment such as less dust

These impacts are difficult to quantify. Nevertheless, they are too important to be ignored. Indeed the Fifth National Social and Economic Development Plan stresses equitable development and states as one of the major goals of the Plan the alleviation of income disparity and of disparity in the provision of social services between urban and rural areas.

Therefore, an attempt was made to include such impacts in the evaluation process of the improvement projects of the study routes. The first four positive impacts listed above were selected for this purpose as social benefits.

3.7.2 General Approach

The general methodology for estimating the first three social benefits is by means of the quantification of increased value-added in the provision of such social services. Benefits of more social services due to increased accessibility are directly attributable to road improvement projects. These benefits were estimated by following standard national accounts procedures, whereby the total benefits were assumed to equal the value-added of the increased services to the population concerned. The increase in value-added equals wages and salaries paid for these services and overhead costs associated with them. This standard national accounts method cannot be an entirely accurate measure of the value of such services or social benefits since these sectors are mostly government-controlled and thus far from the conditions of a perfectly competitive market. Nevertheless, this method still provides a better measure of value relative to the value of other goods and services than arbitrary evaluation methods. This method has been used in several studies in recent years, such as the Ruwu Road Development Program Study in Indonesia.

Evaluation of the fourth item, alleviation of income disparity, is somewhat different. The increase in income due to expanded agricultural production has already been calculated in monetary terms. The stipulation here is that a given amount to the poor is more valuable than the same amount to the rich.

A weighting function with regard to income level, therefore, was assumed and applied.

These quantified social benefits were then combined for each route, and the ranking was done based on the amount of social benefits per unit construction cost.

3.7.3 Better Accessibility to General Government Services

Improved accessibility to cities and towns such as Amphoe centers would induce the additional use and purchase of services provided there by the population in the influence areas. This would occur for services provided by both private and government sectors. Previously prevalent feelings of isolation in these areas would be alleviated and the process of integrating remote communities into the mainstream of Thai society would be expedited.

Increased transactions in the private sector have to be paid for out of increased income in the influence area, and their values are included in the increased income. However, if the increased demand for government services results in an increase in services provided by the government in terms of more personnel and supplies, these costs are a net increase in value-added attributable to the area.

The amount of additional passenger traffic generated by the reduction in travel time was estimated as described in Section 3.2.3. In the absence of evidence to the contrary, it was assumed that trips to and from government services would increase by the same percentage, A%. For the given population of an influence area, P, this would mean that the government would have to handle an increase in service demand corresponding to the number of people of $P \times A/100/(1+A/100)$. The last term, $1/(1+A/100)$, indicates that the population before the road improvement benefits much less from government services due to less accessibility and resulting suppressed trip making.

If the ratio of the number of government employees to population is Rg, then the additional number of government employees required is $Rg \times P \times A/100 \times (1-A/100)$. Therefore, the net value-added of additional government services due to better accessibility, Vg, can be expressed as:

$$Vg = Rg \times P \times A/100 \; / \; (1+A/100) \times Sg \times Og$$

where, Sg : Average annual salary for a government employee
Og : Average overhead cost ratio per government employee

In 1979 the total number of government employees in the Region was 225,800 whereas the population was 15.99 million, according to the Statistical Summary of Thailand 1981. An Rg value of 0.0141 was adopted.

3.7.4 Improved Educational Levels

The provision of educational facilities has traditionally been given a high priority in Thailand.

As a result, schools, particularly primary schools, are located in every corner of the country, so that all children can attend a school within walking distance. The survey done by the study team showed that schools are numerous and well distributed.

Despite such good accessibility, school attendance statistics in rural Thailand, particularly in the Region, often show a drastic reduction after the fourth grade, indicating school attendance has little to do with accessibility.

However, increased contacts with the outside world would certainly induce the concerned population to put a higher priority on education. It was assumed that the school attendance level would reach half the regional average level by 1994. This rather conservative assumption was made because of the lack of data concerning the number of school-age children.

Since a breakdown by age group of population in the influence areas was not available, the ratio of primary school enrollment to population was used instead. The annual value-added of extra educational services in terms of additional teachers and supplies, Ve, is:

$$Ve = 0.5\,(Re - \frac{E}{P}) \times P \times Te \times Se \times Oe$$

where,

P	:	the population in the influence area
E	:	the primary school enrollment in the influence area
Re	:	the average regional primary school enrollment/population ratio
Te	:	the average regional teacher/student ratio
Se	:	the average annual salary for a teacher
Oe	:	the average school overhead cost ratio per teacher

Since enrollment data for secondary school students living within the influence areas was also unavailable, only primary school enrollment, therefore, was taken into consideration.

In recent years in Thailand the ratio of the number of teachers to the number of students has increased greatly because of the remarkable decline in the birth rate. As a result, in many schools the number of students has declined, although the number of teachers has remained constant, or even increased to absorb newly graduated teachers. Given this situation, additional teachers may not be employed following road improvement.

The above formulation should be interpreted as the value of increased educational levels.

The number of primary school students in the Region in 1979 was 2.75 million out of a total population of 15.99 million, giving an Re value of 0.172. In the same year the teacher/student ratio for all schools in the Region was 0.035. The value of Te was set at 0.035 considering these factors.

3.7.5 Improved Medical Care

In the same way as for general government services, the demand for medical services would increase after accessibility improved.

The rate of increase of demand for medical services would probably be higher than the increase in the general passenger traffic. The income elasticity of expenditures on medical care calculated from household expenditure data for villages in the Region shown in the Report of the Socio-Economic Survey of 1975–1976 published by the National Statistical Office was 2.68, whereas that of expenditures on transport (local travel, travel out of area and vehicle operation) for villages in the Region was 1.99 (See Table 3.7.1). It was assumed therefore that the increase in demand for medical services would be 1.35 times as large as the increase in passenger traffic.

TABLE 3.7.1 AVERAGE MONTHLY EXPENDITURES PER HOUSEHOLD FOR DECILE GROUPS OF HOUSEHOLDS RANKED BY MONTHLY PER CAPITA CONSUMPTION EXPENDITURES, VILLAGES

(Unit: baht)

Per Capita Consumption Expenditure Class	Average Monthly Consumption Expenditure	Transport (local, out of area, vehicle operation)	Medical Care Medicines	Medical Care Services
Average	1,403	51	57	30
< 125	776	14	21	5
125-147	961	20	28	10
148-169	1,038	23	34	13
170-190	1,145	31	36	11
191-214	1,262	36	53	27
215-239	1,343	41	58	28
240-275	1,461	49	67	42
276-326	1,671	56	63	30
327-425	1,897	86	92	58
426 <	2,489	158	118	81

Source: Report, Socio-Economic Survey 1975-76, Northeastern Region, National Statistical Office, Office of Prime Minister.

The additional annual net value-added in medical care services, Vm, is:

$$Vm = Rm \times P \times A/100 \; / \; (1 + A/100) \times 1.35 \times Sm \times Om$$

where, Rm : Regional average number of doctors and nurses per population
P : Population in the influence area

A : Increase in passenger traffic in percent
Sm : Average annual salary for doctors and nurses
Om : Average overhead cost ratio per hospital personnel

The number of medical personnel per population was calculated by Amphoe hospitals as shown in Table 3.7.2. The ratio was found to be 1.40×10^{-4} medical personnel per population.

TABLE 3.7.2 AMPHOE POPULATION AND NUMBER OF MEDICAL PERSONNEL IN AMPHOE HOSPITALS

Changwat	Amphoe	1983 Population	Doctors	Nurses	Total
Nakhon Ratchasima	Khong	75,010	1	11	12
Khon Kaen	Chonnabot	46,969	2	9	11
	Nam Phong	93,300	2	11	13
Udon Thani	Kumphawapi	130,621	5	21	26
	Nong Han	127,209	3	11	14
Sakon Nakorn	Sawang Daen Din	139,692	4	21	25
	Song Dao	22,297	1	7	8
Roi Et	Selaphum	113,480	2	5	7
	Nong Phok	46,647	1	5	6
Ubon Ratchathani	Det Udon	180,153	5	16	21
Yasothon	Maha Chana Chai	54,158	2	9	11
Si Sa Ket	Yang Chum Noi	31,753	-	9	9
	Uthumphon Phisai	131,529	2	11	13
Surin	Rattanaburi	111,737	4	11	15
	Chom Phra	54,071	1	11	12
	Si Khoraphum	122,705	3	11	14
Buri Ram	Prakhon Chai	145,161	4	13	17
	Krasang	76,594	2	10	12
	Nong Ki	54,416	2	9	11
	Lam Plai Mat	116,824	6	11	17
Nakhon Ratchasima	Pak Thong Chai	116,879	3	16	19
	Si Khiu	99,317	3	11	14
	Khon Buri	77,817	2	11	13
	Total	2,168,339	60	260	320

3.7.6 Alleviation of Income Disparity

This criterion is purely "social" in that it implies that the value of a certain amount of monetary gain depends upon who benefits from it. It is "economic" in that it follows the economic axiom of diminishing marginal return.

In other words, the elasticity of utility of income with respect to income is negative. In the study, the social value of income gain, Vi, is a function of the income level of recipient expressed in ratio to the regional average income level as follows:

$$Vi = ACI \times \left(\frac{CI}{PxRACI}\right)^{e}$$

where,

ACI	:	Additional crop income in the influence area due to the improvement
RACI	:	Regional average crop income per person
CI	:	Total crop income in the influence area
P	:	Population in the influence area
e	:	Elasticity taking a negative value

In actuality, road improvement would expand the job market for the rural poor working outside the area, mostly as agricultural workers, and would result in a higher total per capita income. The results of the most recent household surveys, however, show no evidence of increase in non-farm income in villages in the Region despite significant rural road improvements since the time of the last surveys in 1975.[1]

It was therefore decided to consider only crop income to represent total income.

The value of the elasticity, e, was assumed to be −1. This means that an additional income of a certain amount obtained by a person with an income level half the average is twice the value as the same amount for an average person. Conversely an additional income for a person with an income level twice the average is only half as valuable as the amount for an average person. An elasticity of −0.5 was also tested. Table 3.7.3 shows a comparison of revalued additional income among the study routes.

3.7.7 Estimation of Cost of Social Services

It was decided that the cost of providing general government services would be represented by the cost of an Amphoe office. A typical Amphoe office would consist of the following:

ORGANIZATION OF AMPHOE OFFICE

Position	Civil Service Grade Level	Number of Persons
District Officer	7 to 6	1
Section Chief	5 to 4	10
Staff	2	50
Janitor & Other	1	4

Source: 1. Preliminary Report, Socio-Economic Survey 1979-80. Northeastern Region, National Statistical Office, Office of Prime Minister.

Using the current civil servant salary schedule, the average annual salary for these government employees would be in the order of 37,000 baht per year.

The allocation of operational funds to Amphoe offices is quite limited. A figure of 10% of the direct personnel salary was assumed to be operational funds.

The average cost of general government services is therefore assumed to be 40,700 baht per year per government employee. Table 3.7.4 shows the resulting estimates for this benefit.

It was assumed that the average salary of primary school teachers would be at the level of Level 3, Step 5. Again, assuming 10% overhead, the average cost of primary school education was calculated at 46,700 baht per year per teacher. Table 3.7.5 shows the resulting estimates for this benefit.

The average number of doctors and nurses per Amphoe level hospital in or adjacent to the study areas were found to be 2.7 and 11.4, respectively. The salary scales of doctors and nurses would be at Levels 6 and 4, respectively, on average. Assuming an overhead rate of 20%, the cost of medical services provision was calculated at 69,500 baht per year per medical personnel. Table 3.7.6 shows resulting estimates for this benefit.

TABLE 3.7.3 INCOME GAIN WEIGHTED BY PER CAPITA INCOME LEVEL

Route No.	P 1944 Inflence Area Population	C 1994 Crop Prod.Value with Project (million baht)	CI 1994 Crop Prod.Value without Project (million baht)	ACI 1994 Prod.Value Gain (million baht)	F 1994 Per Capita Prod.Value (baht)	G Ratio to Regional Average	H Weighted Value e = -1.0	I Weighted Value e = -0.5	Vi Weighted Value e = -1.0	Vi Weighted Value e = -0.5
IM- 1	33,930	151.12	144.19	6.93	4,250	1.557	0.642	0.801	4.45	5.55
IM- 4	27,980	102.79	91.70	11.09	3,277	1.200	0.833	0.913	9.24	10.13
IM- 5	46,030	93.02	89.02	4.00	1,934	0.708	1.412	1.180	5.65	4.72
IM- 7	34,800	143.74	133.84	9.90	3,846	1.409	0.710	0.842	7.03	8.34
IM- 8	27,740	52.95	51.20	1.75	1,846	0.676	1.479	1.216	2.59	2.13
IM- 9	33,180	114.94	107.20	7.74	3,231	1.184	0.845	0.919	6.54	7.11
IM-12	15,770	108.52	106.22	2.30	6,736	2.467	0.405	0.637	0.93	1.47
IM-19	53,940	211.54	205.02	6.52	4,463	1.635	0.612	0.782	3.99	5.10
IM-24	14,420	59.95	58.08	1.87	4,028	1,475	0.678	0.823	1.26	1.54
IM-25	32,380	114.94	113.36	1.58	3,501	1.282	0.780	0.883	1.23	1.40
IM-26	40,680	120.20	117.55	2.65	2,890	1.059	0.663	0.972	1.67	2.58
IM-27	42,970	117.66	113.48	4.18	2,641	0.967	1.034	1.017	4.32	4.25
IM-29	59,170	178.69	166.18	12.51	2,809	1.029	0.972	0.986	12.16	12.34
IM-31	63,160	267.23	255.99	11.24	4,053	1.485	0.673	0.821	7.57	9.23
IM-33	30,810	105.72	90.94	14.78	2,952	1.081	0.925	0.962	13.67	14.22

Note: Calculations were done as follows:

ACI = C − CI

F = CI/P

G = F/RACI (RACI = 2730 baht/person: Northeast average for 1994)

H = G^e

Vi = ACI × H

TABLE 3.7.4 ESTIMATION OF ACCESSIBILITY TO GENERAL SERVICES BENEFIT

Route No.	P 1994 Influence Area Population	A Traffic Increase (%)	Vg 1994 Better Accessibility Benefit (million baht)
IM - 1	33,930	93.0	9.38
IM - 4	27,980	15.0	2.09
IM - 5	46,030	15.0	3.60
IM - 7	34,800	64.0	7.79
IM - 8	27,740	15.0	2.08
IM - 9	33,180	15.0	2.48
IM - 12	15,770	15.0	1.18
IM - 19	53,980	15.0	4.04
IM - 24	14,420	15.0	1.08
IM - 25	32,380	15.0	2.42
IM - 26	40,680	15.0	3.04
IM - 27	42,970	15.0	3.22
IM - 29	59,170	15.0	4.43
IM - 31	63,160	15.0	4.73
IM - 33	30,810	102.5	8.95

Note: 1. Traffic increase for roads other than IM-1, IM-7 and IM-33 was assumed to be 15% by adopting figures developed through DOH experience.

2. Calculations were done by the following formula:

$$Vg = Rg \times P \times A/100 \times E \times Sg \times Og$$

where,

E : $1/(1+A/100)$
Rg : 0.0141 govt. employees/population (1979)
Sg : 37,000 baht/employee/year
Og : 1.1

TABLE 3.7.5 ESTIMATION OF EDUCATION IMPROVEMENT BENEFITS

A Route No.	B 1983 Influence Area Population	C Primary School Enrollment	D Primary School Teachers	E Enrollment Ratio to Population	F Teacher/ Student Ratio	G Enrollment/ Regional Average Ratio	P 1994 Influence Area Population	Ve 1994 Education Improvement Benefit (million baht/year)
IM- 1	33,295	4,108	197	0.123	0.0480	.049	33,930	1.36
IM- 4	27,055	3,242	140	0.120	0.0432	.052	27,980	1.19
IM- 5	40,422	2,344	122	0.058	0.0520	.114	46,030	4.29
IM- 7	30,951	2,560	128	0.083	0.0500	.089	34,800	2.53
IM- 8	21,139	1,109	47	0.052	0.0424	.120	27,740	2.72
IM- 9	29,293	3,603	183	0.123	0.0508	.049	33,180	1.33
IM-12	15,120	3,062	136	0.203	0.0444	.031	15,770	-
IM-19	48,350	2,829	130	0.059	0.0460	.113	53,940	4.98
IM-24	10,837	1,615	70	0.149	0.0433	.023	14,420	0.27
IM-25	29,498	1,688	102	0.057	0.0604	.115	32,380	3.04
IM-26	37,320	1,851	105	0.050	0.0567	.122	40,680	4.06
IM-27	37,397	2,312	108	0.062	0.0467	.110	42,970	3.86
IM-29	51,271	6,583	250	0.128	0.0380	.044	59,170	2.13
IM-31	51,781	3,906	175	0.075	0.0448	.097	63,160	5.01
IM-33	26,210	1,370	67	0.052	0.0489	.120	30,810	3.02

Note: Calculations were as follows:

E = C/B
F = D/C
G = Re − E
Ve = $0.5G \times P \times Te \times Se \times Oe$

where, Re : 0.172 students/population (based on 1979 data)
Te : 0.035 teacher/student ratio
Se : 42,450 baht/teacher/year
Oe : 1.10

TABLE 3.7.6 ESTIMATION OF MEDICAL CARE BENEFIT

Route No.	P 1994 Influence Area Population	A Traffic Increase (%)	Vm 1994 Medical Care Benefit (million baht)
IM - 1	33,930	93.0	0.215
IM - 4	27,980	15.0	0.048
IM - 5	46,030	15.0	0.079
IM - 7	34,800	64.0	0.178
IM - 8	27,740	15.0	0.048
IM - 9	33,180	15.0	0.057
IM - 12	15,770	15.0	0.027
IM - 19	53,980	15.0	0.092
IM - 24	14,420	15.0	0.025
IM - 25	32,380	15.0	0.055
IM - 26	40,680	15.0	0.070
IM - 27	42,970	15.0	0.074
IM - 29	59,170	15.0	0.101
IM - 31	63,160	15.0	0.108
IM - 33	30,810	102.5	0.205

Note: Calculations were done by the following formula:

$$Vm = Rm \times P \times \frac{A}{100} \times E \times 1.35 \times Sm \times Om$$

where,
- E : $1/(1+A/100)$
- Rm : 1.40×10^{-4} medical personnel/population
- Sm : 57,900 baht/medical personnel/year
- Om : 1.2

3.8 EVALUATION AND RANKING

3.8.1 Approach

The evaluation of a rural road development project involves engineering, economic and social considerations. Any project must be sound in all engineering aspects both in design and construction. Beyond ensuring this soundness, the evaluation should be based on economic and social worth. An attempt was made in the study to explicitly integrate these evaluations.

3.8.2 Economic Evaluation

The economic viability of the study routes was evaluated by using the conventional cost/benefit analysis.

1) Economic Benefits

Economic benefits taken into account in the evaluation include:

- Savings in VOCs as described in 3.4.5.
- Increase in net value added of agricultural production attributable to the project as described in 3.3.6.
- Savings in road maintenance costs on the study and related roads as described in 3.6.3.

2) Economic Costs

Economic costs consist of:

- Economic project costs which include direct construction cost, physical contingencies, engineering and supervision and land acquisition costs as described in 3.6.1.
- Cost of overlay at the beginning of the 8th year after opening to traffic as described in 3.6.3.
- Residual value of the study route at the end of the evaluation period of 15 years. Calculations are shown in 3.6.4. This cost is a negative value.

3) Results of Evaluation

The calculated economic evaluation indicators and ranking by IRR are summarized in Tables 3.8.1 and 3.8.2 and computations are shown in the Route Report.

4) Sensitivity Analysis

Sensitivity analyses were carried out for the cases of a 15% increase in the construction cost and a 15% decrease in the total benefit for all study routes. The changes in IRR are shown in Table 3.8.3 and changes in other economic evaluation indicators are shown in the Route Report.

3.8.3 Ranking by Social Benefits

The first three social benefits, general government services accessibility, education and medical care, were estimated in real monetary terms and added together to yield a total amount. In order to find the effectiveness of each study route, the total of the three benefits was then

TABLE 3.8.1 SUMMARY OF ECONOMIC EVALUATION

Route No.	Construction Cost (million baht)	NPV (thousand baht)	B/C Ratio	IRR (%)	FYRR (%)	Optimum Opening Year
IM - 1	76.0	16,127	1.18	14.1	11.23	1988
IM - 4	30.5	34,987	1.94	22.2	15.8	1988
IM - 5	51.7	13,268	1.22	14.6	10.5	1988
IM - 7	54.6	-4,656	0.93	11.1	8.4	1990*
IM - 8	18.6	2,567	1.12	13.5	10.0	1988
IM - 9	67.6	7,266	1.09	13.1	9.5	1988
IM - 12	29.6	7,852	1.23	14.9	12.8	1988
IM - 19	76.8	28,814	1.31	15.7	13.0	1988
IM - 24	22.2	4,531	1.18	14.2	8.9	1988
IM - 25	39.5	-3,334	0.93	11.0	9.8	1989*
IM - 26	39.6	-1,375	0.97	11.6	9.0	1990*
IM - 27	42.1	-12,168	0.76	8.8	5.8	1993*
IM - 29	77.6	44,136	1.47	17.1	12.0	1988
IM - 31	66.7	55,144	1.66	19.2	14.4	1988
IM - 33	150.1	131,211	1.74	19.7	15.5	1988

Note: *: At FYRR of 10%

TABLE 3.8.2 RANKING BY IRR

Rank	Route No.	Origin	Destination	Length (km)	IRR (%)
1	IM - 1	A. Khong	J. R. 2180	24.0	22.2
2	IM - 4	A. Chonnabot	B. Don Han	51.4	19.7
3	IM - 5	A. Nam Phong	B. Nong Tum	52.6	19.2
4	IM - 7	B. Lao (J. R. 210)	B. Tha Yom	47.1	17.1
5	IM - 8	B. Huai Koeng	A. Kumphawapi	46.3	15.7
6	IM - 9	A. Nong Han	A. Kumphawapi	19.1	14.9
7	IM - 12	A. Sawang Daen Din	A. Song Dao	28.0	14.6
8	IM - 19	A. Selaphum	B. Kham Phon Sung	13.6	14.2
9	IM - 24	B. Na Suang	B. Na Yia	46.8	14.1
10	IM - 25	A. Maha Chana Chai	A. Kho Wang	14.2	13.5
11	IM - 26	B. Som Poi Noi	B. Muang Mak	34.3	13.1
12	IM - 27	A. Chom Phra	B. Nong Khawao	28.4	11.6
13	IM - 29	A. Prakhon Chai	A. Krasang	40.7	11.1
14	IM - 31	B. Nong Pha Ong	A. Nong Ki	24.5	11.0
15	IM - 33	A. Si Khiu (J. R. 2)	A. Chok Chai	31.1	8.8

TABLE 3.8.3 SENSITIVITY TESTS OF IRR

Route No.	Origin	Destination	Length (km)	IRR (%)		
				Base	Case 1*	Case 2*
IM - 1	A. Khong	J. R. 2180	46.8	14.1	12.3	12.0
IM - 4	A. Chonnabot	B. Don Han	24.0	22.2	19.8	19.4
IM - 5	A. Nam Phong	B. Nong Tum	28.0	14.6	12.7	12.4
IM - 7	B. Lao (J. R. 210)	B. Tha Yom	40.7	11.1	9.4	9.1
IM - 8	B. Huai Koeng	A. Kumphawapi	14.2	13.5	11.6	11.3
IM - 9	A. Nong Han	A. Kumphawapi	34.3	12.1	11.4	11.1
IM - 12	A. Sawang Daen Din	A. Song Dao	19.1	14.9	12.9	12.6
IM - 19	A. Selaphum	B. Kham Phon Sung	46.3	15.7	13.7	13.4
IM - 24	B. Na Suang	B. Na Yia	13.6	14.2	12.3	12.0
IM - 25	A. Maha Chana Chai	A. Kho Wang	24.5	11.0	9.3	9.1
IM - 26	B. Som Poi Noi	B. Muang Mak	28.4	11.6	9.9	9.6
IM - 27	A. Chom Phra	B. Nong Khawao	31.1	8.8	7.3	7.1
IM - 29	A. Prakhon Chai	A. Krasang	47.1	17.1	15.2	14.9
IM - 31	B. Nong Pha Ong	A. Nong Ki	52.6	19.2	17.1	16.7
IM - 33	A. Si Khiu (J. R. 2)	A. Chok Chai	51.4	19.7	17.5	17.2

Note : *: Case 1. Costs are 15% more while benefits are unchanged.
Case 2. Costs are unchanged while benefits are 15% less.

divided by the total construction cost. A ranking of the study roads was made in the ascending order of this B/C ratio.

The last measure, the weighted social value of additional income, is not expressed in real monetary terms and cannot be added together with the first three. A separate ranking of the roads by B/C ratio of this aspect was also prepared.

In order to rank the study routes, the four social benefit measures were combined and the B/C ratios calculated.

The three kinds of rankings described above are shown in Table 3.8.4.

3.8.4 Overall Ranking

The ranking of study routes in terms of EIRR and by the B/C ratio of social benefits was presented in Sections 3.8.2 and 3.8.3 above. The overall ranking was determined on the basis of these two factors.

The range of accuracy of IRR thus far calculated was considered around 10% of the values presented, whereas the accuracy of social benefits would most likely be much lower. Therefore, if any two routes have IRRs within 10% of each other, the route with a higher position in social benefit ranking was given a higher priority, provided that the difference in social B/C ratio was more than 50%. Otherwise, the ranking by IRR was kept. However, if both IRRs and the social benefit ranking were close to each other, the one with a lower total construction cost was given a higher position in the overall ranking.

Table 3.8.5 summarizes the relevant factors and the final overall ranking.

TABLE 3.8.4 RANKING BY SOCIAL BENEFITS

A Route No.	B Construction Cost (million baht)	C General Accessibility Benefit (million baht)	D Education Benefit (million baht)	E Medical Care Benefit (million baht)	F Total of C, D and E (million baht)	G Benefit/ Cost Ratio ($x10^{-2}$)	H Ranking by G	I Weighted Prod.Value Gain/Cost ($x10^{-2}$)	J Ranking by I	K Combined Ratio ($x10^{-2}$)	L Overall Ranking
IM- 1	76.0	9.38	1.36	0.215	10.96	11.65	9	4.72	10	16.37	12
IM- 4	30.5	2.09	1.19	0.048	3.33	10.93	10	30.33	1	41.26	1
IM- 5	51.7	3.60	4.29	0.079	7.97	15.42	5	10.92	6	26.34	5
IM- 7	54.6	7.79	2.53	0.178	10.50	19.23	2	12.87	5	32.10	3
IM- 8	18.6	2.08	2.72	0.048	4.85	26.05	1	13.90	3	39.95	2
IM- 9	67.6	2.48	1.33	0.057	3.87	5.72	14	9.67	8	15.39	13
IM-12	29.6	1.18	-	0.027	1.21	4.08	15	3.15	15	7.23	15
IM-19	76.8	4.04	4.98	0.092	9.11	11.86	8	5.19	12	17.05	11
IM-24	22.2	1.08	0.27	0.025	1.38	6.22	13	5.71	11	11.93	14
IM-25	39.5	2.42	3.04	0.055	5.52	13.97	7	3.11	14	17.08	10
IM-26	39.6	3.04	4.06	0.070	7.17	18.13	3	4.22	13	22.35	8
IM-27	42.1	3.22	3.86	0.074	7.15	17.00	4	10.27	7	27.27	4
IM-29	77.6	4.43	2.13	0.101	6.66	8.58	11	15.67	2	24.25	7
IM-31	66.7	4.73	5.01	0.108	9.85	14.77	6	11.35	4	26.12	6
IM-33	150.1	8.95	3.02	0.205	12.18	8.11	12	9.11	9	17.22	9

TABLE 3.8.5 OVERALL RANKING OF STUDY ROUTES

Route No.	Construction Cost (million baht)	Economic IRR (%)	Ranking by IRR	One Year Social Benefit/Cost Ratio	Ranking by Social B/C	Overall Ranking
IM - 4	30.5	22.2	1	0.413	1	1
IM - 33	150.1	19.7	2	0.172	9	3
IM - 31	66.7	19.2	3	0.261	6	2
IM - 29	77.6	17.1	4	0.243	7	4
IM - 19	76.8	15.7	5	0.171	11	6
IM - 12	29.6	14.9	6	0.072	15	10
IM - 5	51.7	14.6	7	0.263	5	3
IM - 24	22.2	14.2	8	0.119	14	8
IM - 1	76.0	14.1	9	0.164	12	9
IM - 8	18.6	13.5	10	0.400	2	7
IM - 9	67.6	13.1	11	0.154	13	11
IM - 26	39.6	11.6	12	0.224	8	12
IM - 7	54.6	11.1	13	0.321	3	13
IM - 25	39.5	11.0	14	0.171	10	14
IM - 27	42.1	8.8	15	0.273	4	15

3.8.5 Recommended Implementation

It is concluded that, considering the overall ranking and possible schedule of the improvement of the study routes with due consideration to the prevailing opportunity cost of capital, study routes which have an IRR greater than 12% are worth improving with the opening year of 1988. The following 11 study routes were selected in accordance with the above criteria:

IM - 1, 4, 5, 8, 9, 12, 19, 24, 29, 31 and 33.

With regard to the remaining 4 study routes with IRRs less than 12%, IM - 7, 25, 26 and 27, the optimum opening years were calculated as follows:

IM - 7 : 1990
IM - 25 : 1989
IM - 26 : 1990
IM - 27 : 1993

CHAPTER 4

REHABILITATION ROUTES

CHAPTER 4
REHABILITATION ROUTES

The main objectives of the study on rehabilitation routes were:

- To clarify engineering problems on rehabilitation design by analyzing existing pavement conditions of the case study sections selected.

- To analyze VOC savings from rehabilitation works by measuring fuel consumption of vehicles on pavement surfaces of varying roughness by a JICA road inspection car.

4.1 IDENTIFICATION OF CASE STUDY SECTIONS

Identification of the case study sections was made based on the results of field reconnaissance conducted with DOH staff. Sections which satisfy the following conditions were selected:

- Sections with surface conditions varying from good to poor
- Sections with little variation in traffic volume
- Sections nearly level and tangent
- Sections not recently rehabilitated
- Sections not within residential areas

The case study sections identified are shown below and the present conditions of each section are illustrated in Appendix 4.1.1.

CASE STUDY SECTIONS FOR REHABILITATION

Route No.	Surface Type	Total Length (km)	Case Study Section		Conditions in Study Section (length: km)				
			Length (km)	Km Post	Very Good	Good	Fair	Poor	Very Poor
RT - 224	AC	29	10	10-20	-	2	2	4	2
RH - 21	AC	13	13	120-133	7	5	-	1	-
RH - 22	PM	8	8	0-8	-	-	8	-	-
RH - 5	PM	39	19	20-39	-	7	2	8	2
RH - 12	DBST/SBST	35	10	488-498	-	6	1	3	-
RH - 16	,,	28	10	{ 7-12 13-18	-	5	-	5	-
RH - 25	,,	28	10	7-17	-	1	3	3	3
RH - 27	,,	20	10	9-19	-	3	-	7	-
		200	90		7	29	16	31	7

4.2 ENGINEERING SURVEYS

Engineering surveys performed included two major surveys: a surface condition survey for assessing the serviceability of pavements and a structural deterioration survey for evaluating the deteriorated situation of pavement structures.

4.2.1 Surface Condition Survey

4.2.1.1 PSI by Visual Assessment

PSI was estimated by assessing deficiencies on the pavement surface visually. In the study, PSI was assessed by applying the items and form defined in the "HRB Report"[1] as given in Appendix 4.2.1. PSI was assessed by the following rating panel:

Japanese engineer	1
Thai engineer	1
Thai technician	1

Vehicle and Running Speed Employed:

JICA Inspection Car, Toyota Cressida 2000
5 - 6 km/h

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

Unit Length for Assessment:
150-m long sections

Prior to operation of the assessment based on detailed rating items given in the HRB Report, training was carried out according to the general assessment method employed in the ASSHTO road test which has 5 ranking rates, from very poor to very good, in order to give a unified rating standard.

The results of the assessment are shown in Appendix 4.2.2.

4.2.1.2 PSI by Measurement

In a PSI assessed visually, individual differences are inevitable. For this reason, a formula to express PSI by visual assessment in terms of irregularity of surface, rate of cracking and rut depth was established by AASHTO.

In Japan, the following formula [1] for PSI assessment was established based on the AASHTO formula:

$$PSI = 4.53 - 0.518 \log\sigma - 0.371 \sqrt{C} - 0.471D^2$$

where, σ : Standard deviation of longitudinal irregularity in mm

C : Rate of cracking

$$= \frac{\text{areas with cracked surface} + \text{areas with patched surface}}{\text{total area surveyed}} \times 100\ (\%)$$

D : Mean rut depth in cm

In order to introduce an appropriate formula which can be applied for assessing pavement in Thailand, the following items were measured for the whole length of the case study sections in the same manner as in Japan:

- Surface irregularities measured along a line parallel with the road center line keeping 80 cm to 100 cm inside the edge line of the pavement by using a profilometer. (See Appendix 4.2.3)

- Rating of cracking estimated by sketching the areas of cracked surfaces, patched surfaces and potholes. (See Appendix 4.2.3)

Source: 1. Road Repair and Maintenance Manual, Japan Road Association

- Rut depth measured directly in wheel paths. (See Appendix 4.2.3)

4.2.1.3 Roughness by MRM

Roughness was measured for the whole length of the case study sections by a Mays Ride Meter (MRM) installed in the JICA road inspection car for evaluation and comparison of the surface conditions.

The MRM measures the displacement of the rear axle of the vehicle corresponding to irregularites in the pavement surface. The roughness measured is given in a graphical oscillation chart and its summation expressed as figures.

The running speed was 60 km/h and the roughness was recorded for each 150-m long section as shown in Appendix 4.2.2.

4.2.2 Structual Deterioration Survey

Structural deterioration surveys, including a deflection survey, a field CBR test and laboratory soil and asphalt concrete tests, were carried out to evaluate the structural deterioration of the existing pavement within the case study sections.

4.2.2.1 Deflection by Benkelman Beam

Deflection is a basic factor for rehabilitation design and an essential yardstick for the evaluation of deterioration of existing pavement structures.

Deflection was measured at the point of maximum deflection and its forward offset points of 30, 60, 100 and 200 cm as well as the distance measured from the maximum deflection point to the point where deflection comes to zero.

Deflection was measured at intervals of 50 m. However, since serviceability surveys were carried out for every 150-m long section, deflection values measured at three points within a unit length of the serviceability survey were averaged for a correlation analysis among these survey results. The average deflection values of 150-m long sections are shown in Appendix 4.2.2.

4.2.2.2 Field CBR, Laboratory Soil Test, and Stiffness Test of Asphalt Concrete

The field CBR test was carried out to measure field CBR of each layer consisting of a pavement structure, base course, subbase course and subgrade. The field CBR values were used for correlation analysis with their CBR values estimated by the surveyed deflections.

The field CBR test was conducted according to the method specified in ASTM Designation: D 1883-73 at the 8 spots shown below:

SPOTS FOR FIELD CBR TEST

Route No.	Surface Type	Station Tested	
RT - 224	AC	11+500 (L),	16+000 (L)
RH - 5	PM	21+500 (R),	36+200 (L)
RH - 12	DBST/SBST	492+600 (R),	493+450 (L)
RH - 25	DBST/SBST	9+450 (R),	11+950 (R)

Sampling was carried out at 2 sites in each case study section, for a total of 16. In addition, 8 samples were collected at the same places that the field CBR tests were done.

For the sampled materials, the following tests were carried out:

- Natural moisture content
- Consistency
- Particle size distribution
- Specific gravity
- Compaction under condition of natural moisture content
- CBR under condition of natural moisture content

Samples of existing asphalt concrete surface were collected at the same places that the field CBR tests were done in RT-224 to estimate the stiffness of the existing asphalt concrete surface by the Shell method.

Tests conducted were as follows:

- Abson extraction
- Penetration
- Softening point
- Unit weight (concentration of mineral aggregate percent by volume: Cv)

$$Cv = \frac{\text{volume of mineral aggregate}}{\text{volume of (mineral aggregate + asphalt)}}$$

Sampling of either soil or asphalt concrete was done by the study team and testing of these samples was conducted by the Material and Research Division of DOH.

The results of soil and CBR tests and of the stiffness of the existing asphalt concrete are shown in Appendices 4.2.4 and 4.2.5, respectively.

4.2.3 Fuel Consumption Survey

A survey on fuel consumption was carried out by the JICA inspection car on the case study sections with a total length of 90 km and on an additional 28 km in the periphery of Bangkok.

Fuel consumption and road roughness were measured for every 1-km section at a cruising speed of 60 km/h. In order to find the relationship between fuel consumption and running speed, fuel consumption was measured at speeds of 20, 40, 60 and 80 kp/h on some sections.

The results of the fuel consumption survey are shown in Appendix 4.2.6.

4.3 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 of flexible pavement, 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.

Since loads imposed by light weight cars do not have a significant effect on the structural damage of pavement, only heavy vehicles, such as medium and heavy trucks and buses, were taken into consideration in the analysis of pavement design.

With regard to the analysis of the number of times that wheel loads are applied, an estimation of the future traffic volume during the design period was required.

4.3.1 Future Traffic Volume

DOH has determined traffic growth rates to estimate future traffic volume for each paved road. These DOH growth rates were applied without modification to estimate future traffic volume of heavy trucks for each case study section.

The growth rates of case study sections are shown in Table 4.3.1 and future ADT by vehicle type calculated by using these growth rates are shown in Appendix 4.3.1.

TABLE 4.3.1 TRAFFIC GROWTH RATE

(Unit: %)

Route No.	Year	Heavy Vehicles
RT - 224	1981 - 1987	5.20
(224-0100)*	1988 - 2001	3.80
RH - 21	1982 - 1987	5.20
(304-0904)	1988 - 2001	3.80
RH - 22	1982 - 1987	4.50
(2023-0100)	1988 - 2001	3.60
RH - 5	1982 - 1987	5.00
(201-0102)	1988 - 2001	4.00
RH - 12	1982 - 1987	5.00
(207-0202)	1988 - 2001	4.00
RH - 16	1982 - 1987	5.20
(214-0100)	1988 - 2001	3.80
RH - 25	1982 - 1987	5.00
(2071-0100)	1988 - 2001	4.00
RH - 27	1982 - 1987	4.50
(2160-0100)	1988 - 2001	3.60

Note: *: Link no.

4.3.2 Cumulative Number of ESA

1) Gross Vehicle Weight Distribution

Surveys on the gross vehicle weight distributions of 6- and 10-wheel trucks were conducted at 7 locations in the region by DOH in 1980. In this study, an interview with drivers on actual loading weights of 6- and 10-wheel trucks and buses was conducted at 4 O/D survey points.

These survey locations are shown in Appendix 4.3.2 and their results in Appendix 4.3.3.

The gross vehicle weight distributions were calculated based on the above two survey results.

2) ESA Conversion Factors

The share of front axle and rear axle load against the gross vehicle weight was surveyed on 6- and 10-wheel trucks by DOH as shown in Appendix 4.3.4. The share of axle load for heavy buses, however, was assumed to be the same as that of 6-wheel trucks because there was no data available.

The equivalent factors to ESA, which were established in the AASHTO Road Test and which were employed in the study, are shown in Appendix 4.3.5.

ESA conversion factors for 6- and 10-wheel trucks and buses were calculated as shown in Table 4.3.2 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

6-Wheel Truck	10-Wheel Truck	Heavy Bus
0.76	1.24	0.50

3) Cumulative Number of ESA

Based on the ESA conversion factors, traffic volumes of heavy trucks and cumulative numbers of ESA were calculated for each case study section as shown in Appendix 4.3.1.

TABLE 4.3.2 (1) ESA CONVERSION FACTORS

6-Wheel Truck

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	45.0	0.378
5	1.95	3.05	0.0036	0.015	0.0186	1.310	0.024
6	2.16	3.84	0.0048	0.038	0.0428	2.357	0.101
7	2.38	4.62	0.0065	0.085	0.0915	4.060	0.371
8	2.56	5.44	0.0082	0.183	0.1912	5.500	1.052
9	2.75	6.25	0.0103	0.335	0.3453	5.893	2.035
10	2.90	7.10	0.0125	0.55	0.5625	7.464	4.199
11	3.08	7.92	0.0157	0.87	0.8857	5.762	5.103
12	3.24	8.76	0.0190	1.35	1.369	7.857	10.756
13	3.45	9.55	0.025	2.00	2.025	4.190	8.485
14	4.64	10.36	0.030	2.90	2.93	5.762	16.883
15	3.77	11.23	0.035	4.15	4.185	2.357	9.864
16	3.87	12.13	0.040	6.00	6.04	1.964	11.863
17	4.01	12.99	0.045	8.30	8.345	0.393	3.280
18	4.14	13.86	0.053	11.10	11.153	0.131	1.461
19	4.33	14.67	0.064	14.20	14.264	0	0
20	4.52	15.48	0.078	18.20	18.278	0	0
Total						100	75.855
Factor							0.76

Note: Locations of Survey (D1—D7 and J1—J4) are shown in Appendix 4.3.2.
Surveyed by JICA team (1984) and DOH (1980).
Average gross weight is 7.70 tons.

TABLE 4.3.2 (2) ESA CONVERSION FACTORS

10-Wheel Truck

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	40.0	1.080
9	2.98	6.02	0.0138	0.027	0.041	0.496	0.020
10	3.08	6.92	0.0158	0.044	0.060	0.451	0.027
11	3.18	7.82	0.0178	0.067	0.085	0.586	0.050
12	3.24	8.76	0.0188	0.103	0.122	0.676	0.082
13	3.32	9.68	0.0205	0.153	0.174	1.036	0.180
14	3.36	10.64	0.022	0.22	0.242	1.081	0.262
15	3.41	11.59	0.023	0.31	0.333	1.396	0.465
16	3.42	12.58	0.023	0.43	0.453	1.937	0.877
17	3.45	13.55	0.024	0.6	0.624	3.334	2.080
18	3.46	14.54	0.024	0.82	0.844	7.071	5.968
19	3.48	15.52	0.025	1.1	1.125	10.855	12.212
20	3.48	16.52	0.025	1.41	1.435	11.260	16.158
21	3.51	17.49	0.026	1.8	1.826	6.442	11.763
22	3.52	18.48	0.026	2.35	2.376	1.712	4.068
23	3.54	19.46	0.0265	3.0	3.027	2.117	6.408
24	3.55	20.45	0.027	3.8	3.827	1.712	6.552
25	3.60	21.40	0.029	4.6	4.629	1.892	8.758
26	3.64	22.36	0.03	5.7	5.73	2.252	12.904
27	3.73	23.27	0.033	6.8	6.833	1.577	10.776
28	3.81	24.19	0.036	8.0	8.036	0.901	7.240
29	3.86	25.14	0.039	9.4	9.439	0.631	5.956
30	3.90	26.10	0.04	11.2	11.24	0.225	2.529
31	3.94	27.06	0.043	13.0	13.043	0.135	1.761
32	3.97	28.03	0.054	16.2	16.254	0.045	0.731
33	4.03	28.97	0.060	19.0	19.060	0.045	0.858
34	4.08	29.92	0.065	22.0	22.065	0	0
35	4.17	30.83	0.070	25.0	25.070	0	0
36	4.25	31.75	0.075	28.5	28.575	0.135	3.858
Total						100	123.623
Factor							1.24

Note: Locations of Survey (D1—D7 and J1—J4) are shown in Appendix 4.3.2.
Surveyed by JICA Team (1984) and DOH (1980).
Average gross weight is 15.13 tons.

TABLE 4.3.2 (3) ESA CONVERSION FACTORS

Heavy Bus

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		
5	1.95	3.05	0.0036	0.015	0.0186		
6	2.16	3.84	0.0048	0.038	0.0428		
7	2.38	4.62	0.0065	0.085	0.0915	0.746	0.068
8	2.56	5.44	0.0082	0.183	0.1912	26.866	5.137
9	2.75	6.25	0.0103	0.335	0.3453	31.344	10.823
10	2.90	7.10	0.0125	0.55	0.5625	17.910	10.074
11	3.08	7.92	0.0157	0.87	0.8857	17.910	15.863
12	3.24	8.76	0.0190	1.35	1.369	4.478	6.130
13	3.45	9.55	0.025	2.00	2.025	0.746	1.511
14	4.64	10.36	0.030	2.90	2.93		
15	3.77	11.23	0.035	4.15	4.185		
16	3.87	12.13	0.040	6.00	6.04		
17	4.01	12.99	0.045	8.30	8.345		
18	4.14	13.86	0.053	11.10	11.153		
19	4.33	14.67	0.064	14.20	14.264		
20	4.52	15.48	0.078	18.20	18.278		
Total						100	49.606
Factor							0.50

Note: Locations of Survey (J1—J4) are shown in Appendix 4.2.2.
Surveyed by JICA Team (1984).
Average gross weight is 9.42 tons.