4.4 DESIGN STANDARDS

4.4.1 Road Design Standards

(1) Design Speed

The design speed for the Project Road is recommended to be 80 km/hr. due to the following reasons:

a. The Project Road is characterized as an Intra-Urban Primary Distributor.

b. The Project Road would be directly connected to the Toll Expressway at both ends of this Road which has a design speed of 100 km/hr. From this viewpoint, the design speed of the Project Road should be less than that of the Toll Expressway.

c. The design speed of the East-West Highway Supporting Road was designed to be 80 km/hr. This road is characterized to be the same as the Project Road.

(2) Design Vehicles

For the purpose of geometric design, a semi-trailer is selected as the "design vehicle" due to the characteristics of the Project Road.

(3) Geometric Design Standard

The Malaysian design standard is developed originally for roads in the rural areas. In this study, a comparative analysis between the Malaysian design standard, AASHTO and the Japanese Standard was made. As a result, it is concluded that the Malaysian design standard is applicable for not only roads in rural areas but also for those in urban areas. The geometric design standard recommended for the Project Road is shown in Table 4.1.

Table 4.1 DESIGN STANDARD

Items	Unit	Description
Recommended Group	–	04 – 06
Design Vehicles	–	All type of vehicles
Design Speed	Km.p.h.	80
Carriageway width	m	3.75 each lane
Central Reservation	m	3.50 each lane
Shoulder Width		
–Right shoulder	m	0.5
–Left shoulder	m	2.0
Maximum Gradient	%	4
Critical Grade Length	m	330
Stopping Sight Distance	m	105
Passing Sight Distance	m	540
Minimum Radius	m	210
Transition Curves Length	m	72
Vertical Curves (crest)	–	25.5
Vertical Curves (Sag)	–	22.5

4.4.2 Bridge Design Standards

(1) Specifications

The standard specifications for bridges and other structures are based on the specifications of the British Standard Institution and/or the Public Works Department (JKR).

They are as follows:

1) Loads

a. Live Load

Design HA loading or Design HA loading combined with design HB loading of 45 unit.

b. Longitudinal Force on Bridges

Girder Span	HA Loading	HB Loading
below 3 meters	10 tons	–
above 3 meters	10 tons plus ½ ton for each 0.3 meter of span over 3 meters but not exceeding 25 tons	45 tons for all spans

c. Wind Load

On unloaded structures	150 kg/m²
On loaded structures	45 kg/m²

d. Temperature Effect

Coefficient of expansion being 0.0000065 per degree Fahrenheit.

e. Effect of Earthquakes

Not considered.

(2) Navigation Opening

The navigation opening for passage of ships is an important design criteria for the bridge across the Prai River. The following cases of navigation opening used in this study is decided upon after discussion with the two shipyards, i.e. Hong Leong–Lürssen Shipyard and PPC Bagan Dalam Dockyard, with confirmation from the Technical Committee.

Case A	:	Minimum Clearance width	60 meters
		Vertical clearance height	25 meters above HHW
Case B	:	Minimum clearance width	60 meters
		Vertical clearance height	16 meters above HHW

Case C :	Minimum clearance width	60 meters
	Vertical clearance height	3.5 meters above HHW

4.4.3 Intersection Design Standards

(1) At-grade intersection

The At-grade intersection design standards are adopted from "A Policy on Design of Highways and Arterial Streets" (AASHTO).

(2) Interchange

The interchange design standards are adopted from "A Policy on Geometric Design of Rural Highways". The design speed of ramp is adopted to be 40 km/hr.

4.4.4 Pavement Design Standards

Asphalt concrete pavement design standards are based on the "Manual for Design and Construction of Asphalt Pavement, 1980 (Japan Road Association)" while "Asphalt Institute of U.S.A." and "Shell Pavement Design Manual" are also referred to.

4.4.5 Drainage Criteria

The Malaysian Drainage Standard, contained in the "Urban Drainage Design Standards and Procedures for Peninsular Malaysia" is adopted as the basic data.

4.5 ALTERNATIVE ROUTE STUDY

4.5.1 Route Location Policy

The Project Road is defined as an Intra-Urban Primary Distributor in the Butterworth Metropolitan Area. Considering the present conditions and future developments of the area influenced by the Project Road, the following route location policy is set up:

a. The horizontal alignment shall be set taking into account smooth-flowing traffic flow, utilizing the existing right-of-way, minimizing the cost of the Prai River Bridge, minimizing the demolition of land and properties and preserving the environment in the affected areas as much as possible.

b. Connections with the existing roads shall be limited because the Project Road is serving longer-distance travel as well as freight traffic coming in and out of the North Butterworth Container

Wharf and the existing Butterworth port. However, minor roads will be connected to the service road of the Project Road where only turning to and from the service road is allowed and crossing is prohibited. In this connection, U-turns will be allowed only at limited median openings.

c. At-grade or grade-separated intersections using signal control system shall be provided in the intersections with the main roads.

4.5.2 Proposed Route Alternatives

It is possible to classify the study area into three (3) areas or sections having different characteristics as shown in Fig. 4.5. The route location of the Project Road is studied by each section as follows:

(1) A–B Section

Topographically, the corridor of this section is of flat terrain which is mainly a residential and industrial area. (Refer to Fig. 4.6 and Photo 1).

Taking into account the crossing of the Prai River, the connection with the Ferry Terminal and the existing Butterworth Port and the linkage with the Prai Industrial Estate and the planned and on-going housing schemes, the following three (3) alternative routes are preliminarily proposed to determine the optimum route:

1) Route 'A'

Route 'A' is the Improvement of the existing Jalan Prai and Jalan Chain Ferry from a two lane carriageway to a four lane carriageway. (Refer to Photo 1)

2) Route 'B'

Route 'B' is the improvement of the existing Jalan Prai (Refer to Photo 2) which passes over the Prai River between the Malayan Railway Bridge and the PPC Bagan Dalam Dockyard (Refer to Photo 3) and is connected to the front of the ferry terminal (Refer to Photo 4). Due to the two dockyards located along the Prai River, three alternative type of bridges namely high level bridge, medium level bridge, low level bridge and underwater tunnel are proposed as alternative mean to cross the Prai River.

3) Route 'C'

Route 'C' is directly connected to the North Butterworth Container Wharf and the C.B.D. of Butterworth to the southern part of the Toll Expressway. A part of this route is the improvement of the existing Jalan Presusahaan in the Prai Industrial Estate. And the other part will pass through the Prai Industrial Estate, Malayan Railway yard and across the Prai River and Railway bridge to the viaduct. (Refer to Photo 1).

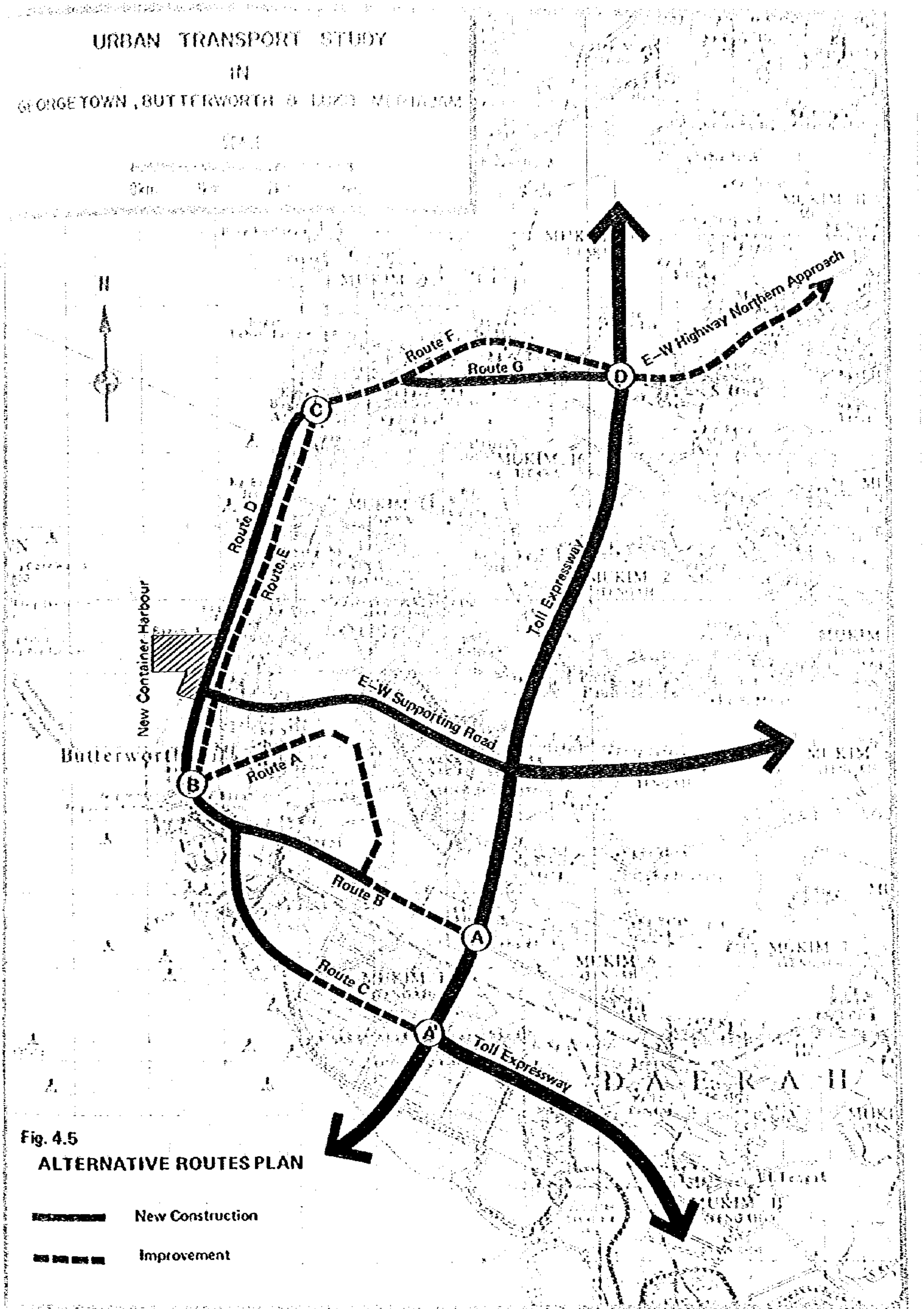


Fig. 4.5
ALTERNATIVE ROUTES PLAN

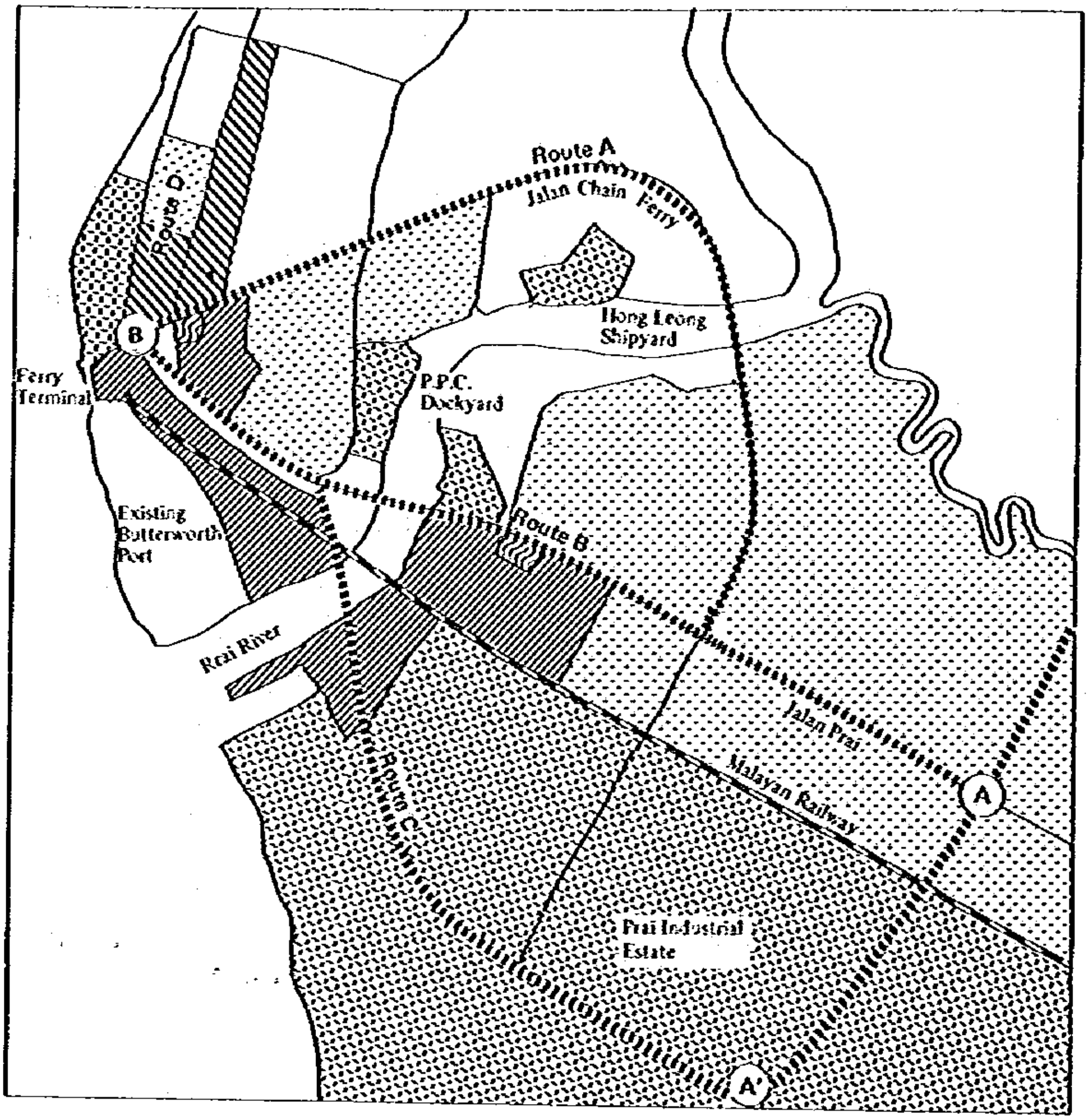


Fig. 4.6 PROPOSED ALTERNATIVE ROUTE (A-B SECTION) WITH PRESENT LAND USE

Photo 1

A–B Section

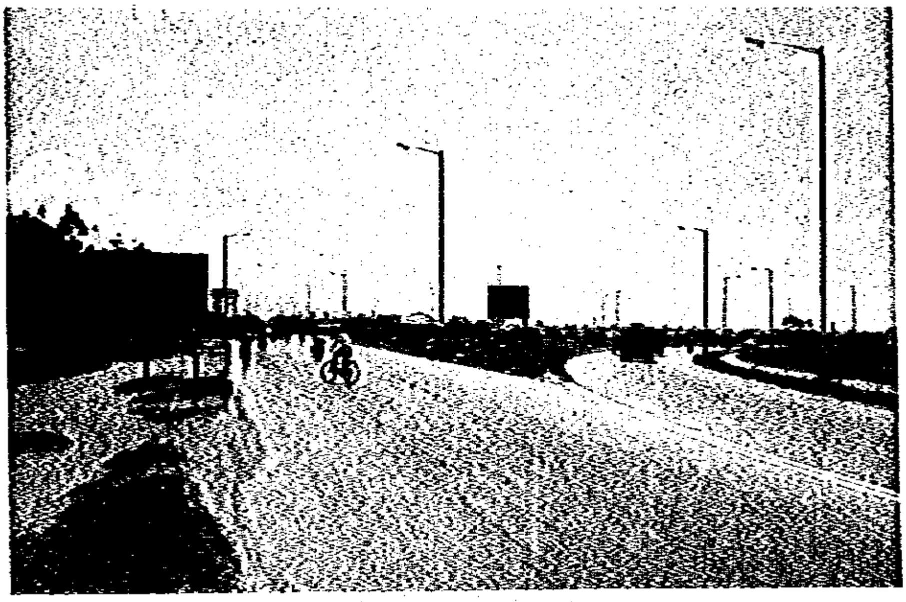
Route A ··········

Route B •——•-•

Route C ··········

Along the existing port

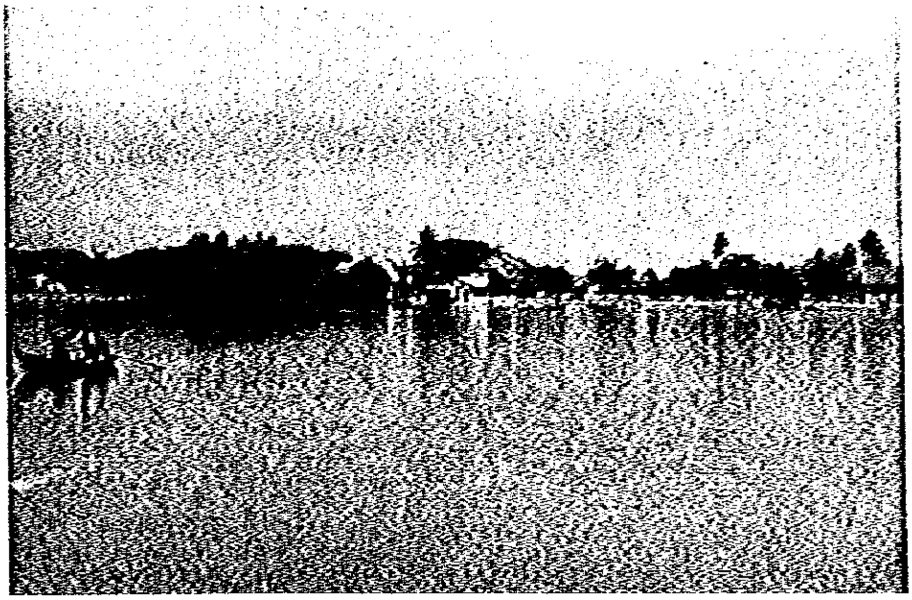
Photo 2



A–B Section Route B, C

Flyover for the Prai Roundabout

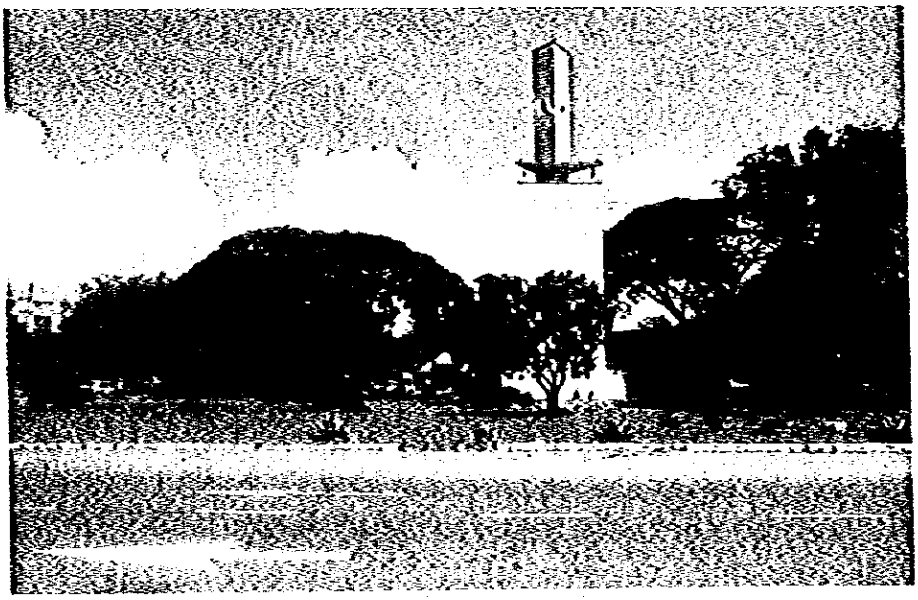
Photo 3



A–B Section Route B

Bridge Site on the Prai River

Photo 4



A–B Section Route B, C

Viaduct over the intersection in front of the Ferry Terminal

(2) B–C Section

Along this section, there are some development plans i.e. the North Butterworth Container Wharf planned by the PPC, East-West Highway Supporting Road planned by the HPU and some housing plans by private developers (Refer to Photo 5). Taking these plans into account, the three alternative routes are located, that is, Route 'D', Route 'E' and a combined route of Route 'D' and 'E'. (Refer to Fig. 4.7 and Photo 5, 6).

1) Route 'D'

Route 'D' is planned to pass through the existing seashore (Refer to Photo 7, 8 and directly connect to the North Butterworth Container Wharf and the East-West Highway Supporting Road. Some approach road which connects to Jalan Bagan Ajam will be required.

Basically, the alignment of this route will follow that of the road already proposed by the M.P.S.P.

2) Route 'E'

This route will be the improvement of Jalan Bagan Luar and Jalan Bagan Ajam. Since there are many buildings along the existing road the land acquisition is expected to be relatively difficult and compensation will also be very high.

3) Combined Route D and E

This alternative consists half the length of Route 'D' in its southern portion and half the length of Route 'E' in its northern portion.

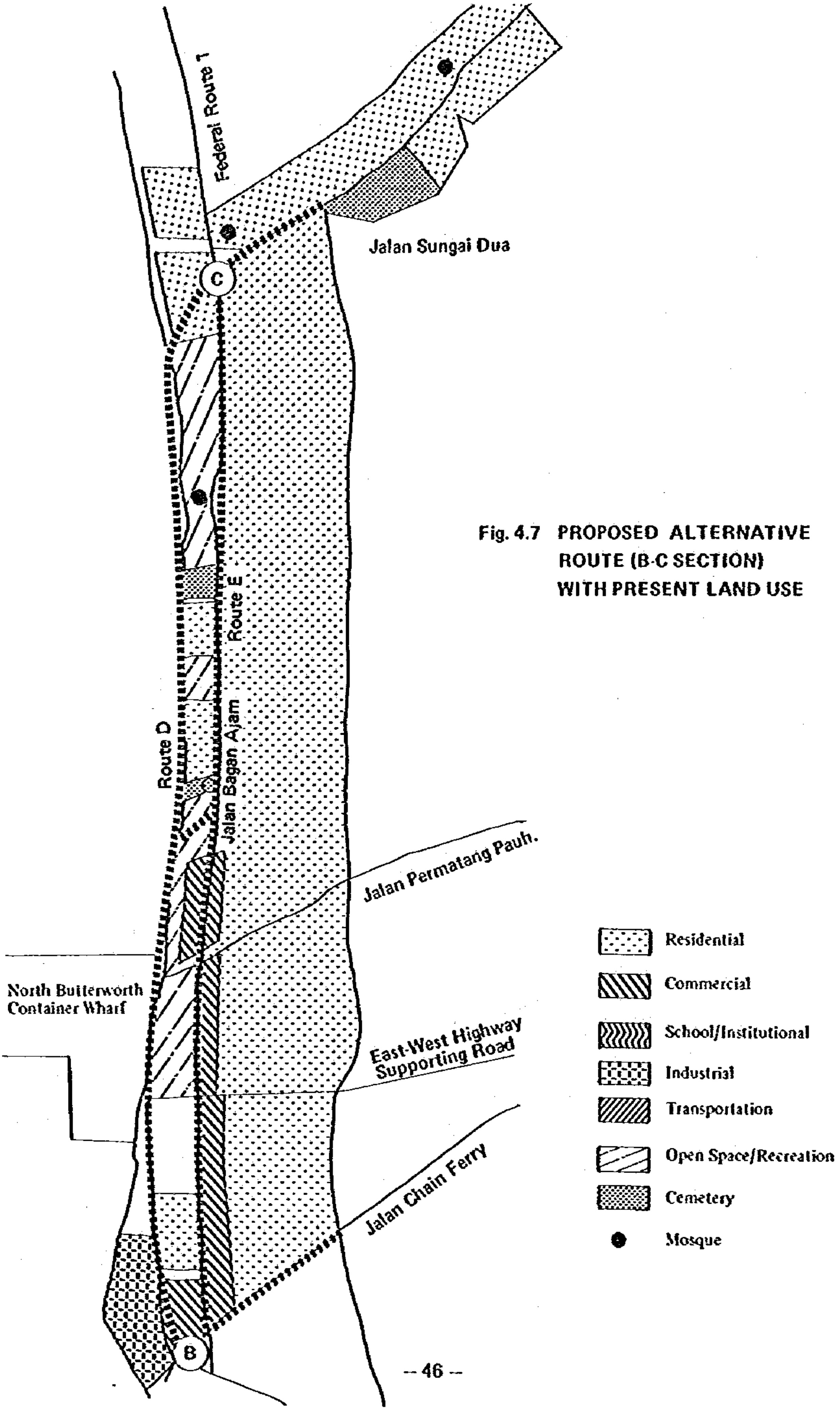
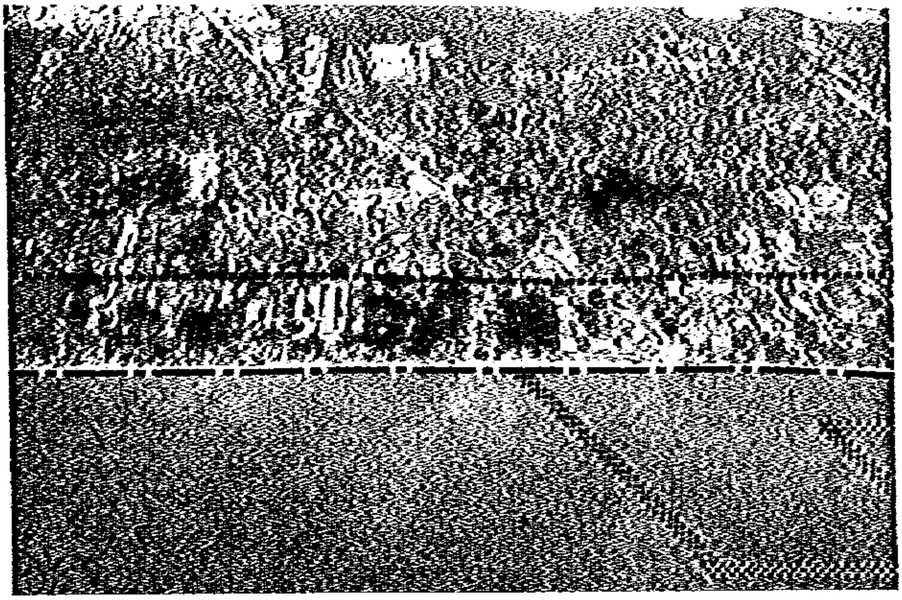


Fig. 4.7 PROPOSED ALTERNATIVE ROUTE (B-C SECTION) WITH PRESENT LAND USE

Photo 5



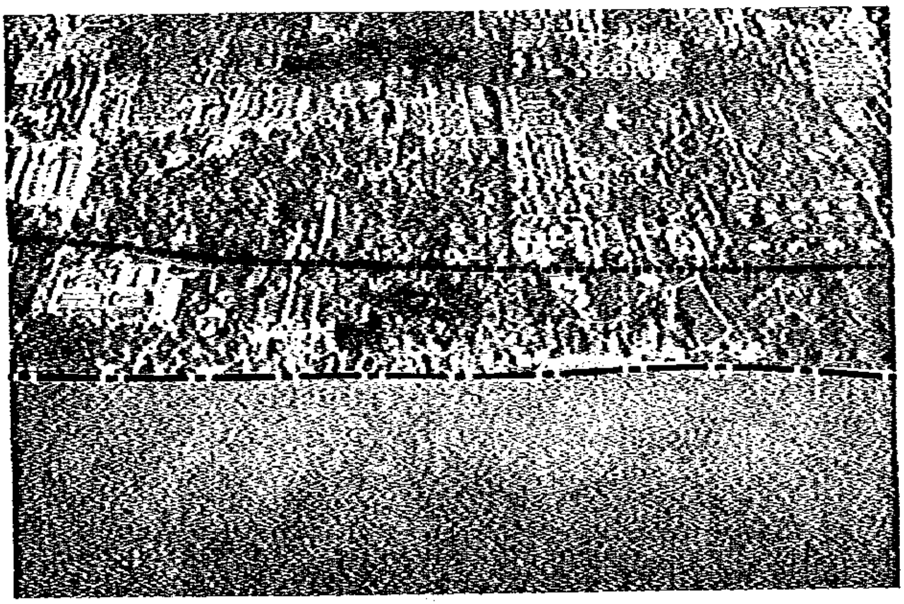
B–C Section

Route D

Route E

Butterworth North Seashore Line

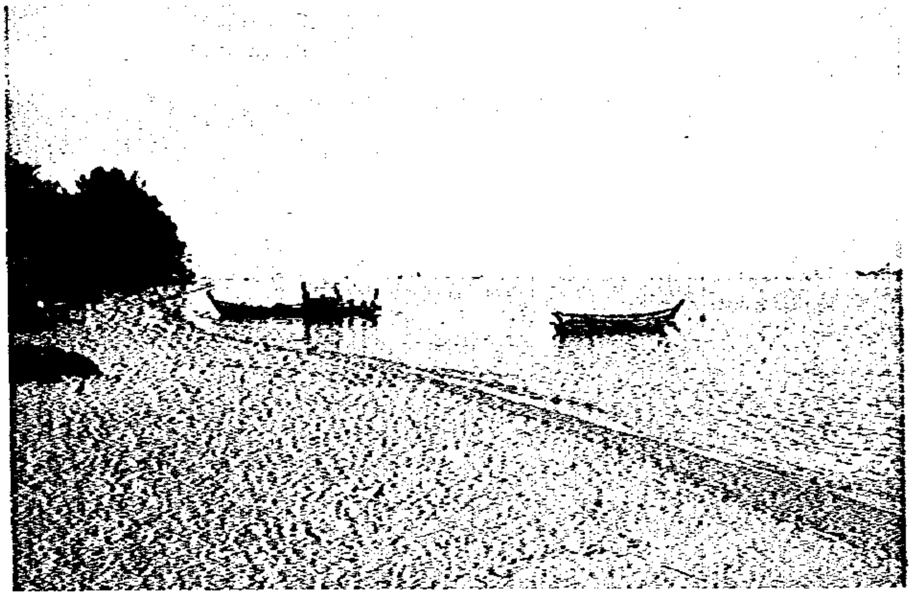
Photo 6



B–C Section

Butterworth North Seashore Line

Photo 7



B–C Section

Proposed Site of North Butterworth Container Wharf

Photo 8

B–C Section

Kg. Bagan Ajam Seashore

(3) C–D Section

Along Jalan Sungai Dua, there exists a Chinese cemetery, some mosques, a high density housing area, padi fields and the water supply pipes for Penang Island and Butterworth Town.

Taking into account the above-mentioned matters, the two alternative routes are located, that is, Route 'F' and Route 'G'. (Refer to Fig. 4.8 and Photo 9, 10).

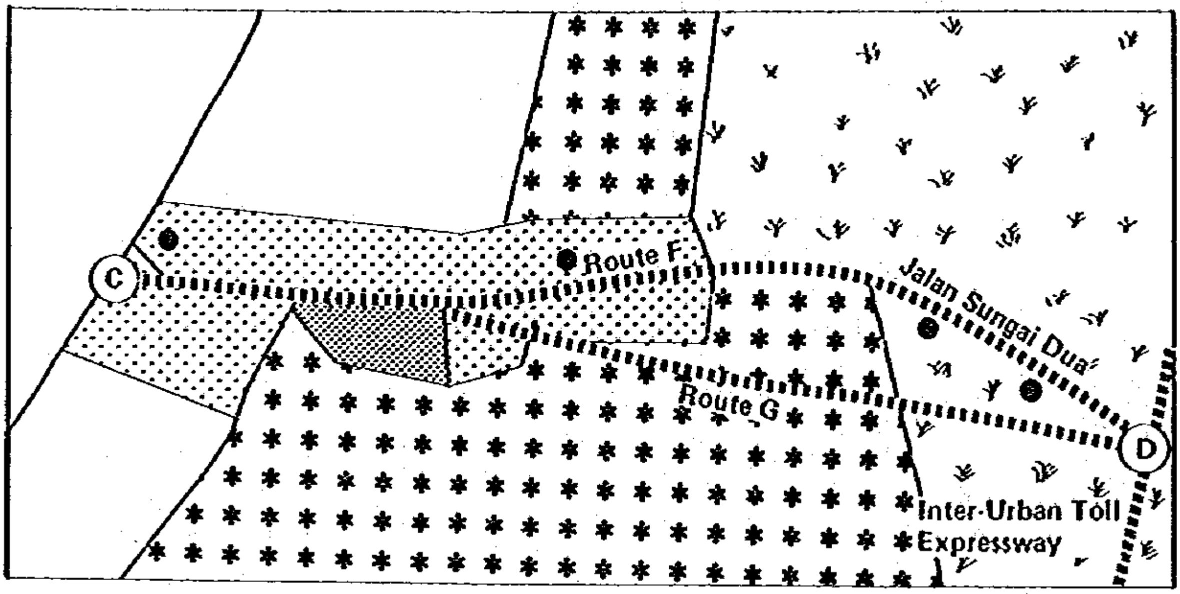
1) Route 'F'

Basically, this route is the improvement of the existing Jalan Sungai Dua and will be connected to the Inter-Urban Toll Expressway which is planned by the Highway Authority. The water pipes mentioned earlier which are located on both sides of the road, are very big and it has been concluded, after a discussion with the Penang Water Authority, that removing the ϕ 54" water pipe is relatively difficult. Therefore, ϕ 54" water pipeline will remain and it will be located under the shoulder of Route 'F'.

2) Route 'G'

There are many houses located along Puyu Village and the existing road here is very narrow. As such, Route 'G' will pass through a padi field and a coconut plantation area, avoiding the widening of the narrow road and the demolishing of the houses.

All the above-mentioned alternative routes (Refer to Fig. 4.5) were discussed at both the Technical Committee Meeting and the Steering Committee Meeting.



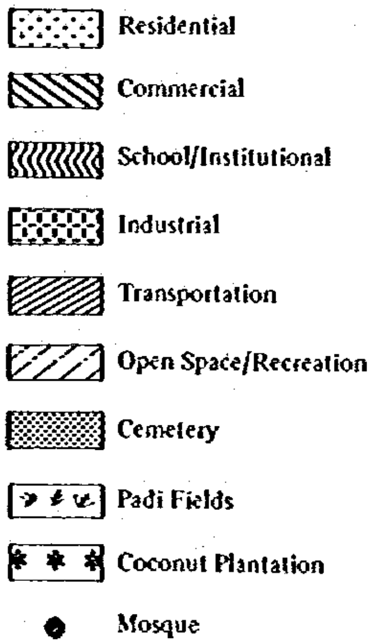
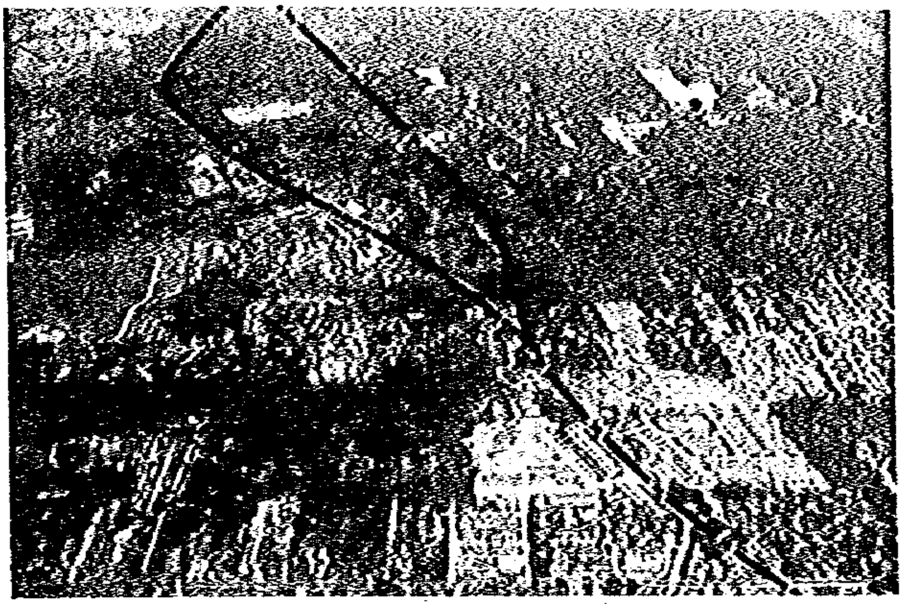


Fig. 4.8 PROPOSED ALTERNATIVE ROUTE (C-D SECTION) WITH PRESENT LAND USE

Photo 9



C–D Section

Route F ··········· (Jalan Sungai Dua)

Route G ·——·—·—

Along the existing Jalan Sungai Dua

Photo 10

C–D Section

Proposed Interchange Site at Jalan Sungai Dua

4.5.3 Screening of Alternative Routes

(1) General

All the alternative routes mentioned earlier, three (3) alternatives in the A–B section, three (3) in the B–C section and two (2) in the C–D section, are evaluated in this section. The evaluation of these alternatives is made from the technical, environmental and economical (minimum construction cost) viewpoints.

The comparison of the alternative routes are described below:

(2) Comparison of the Alternative Routes

1) Route 'A', Route 'B' and Route 'C'

a. Economic Aspect

Construction costs of Route 'A', Route 'B' and Route 'C' are estimated to be M$25,944,000, M$46,568,000 and M$57,856,000 respectively. Judging from these figures, Route 'A' is obviously the least expensive route to construct.

b. Technical Aspect

Route 'A' is comparatively more difficult to implement than Route 'B' due to the disturbance to the traffic flow during the construction period. In Route 'C', it is comparatively difficult to construct the viaduct structure over the Malayan Railway and its yard.

Route 'A' is not expected to have smooth traffic flow since the route passes through the urbanized areas. However, Route 'B' and Route 'C' are expected to have smooth traffic flow.

Route 'B' and Route 'C' have more suitable alignment than Route 'A' in terms of configuration of network patterns.

It is additionally required to construct a new bridge with the same level as the existing Prai River Bridge in Route 'A'. But in Route 'B' a new high level or medium level bridge on the Prai River is required to be constructed. In Route 'C' a viaduct over Malayawata Steel, Malayan Railway as well as the Prai River Bridge is required to be constructed. In order to ensure a smooth traffic flow in Route 'A', it is necessary to construct large scale fly-over structures at the Prai Roundabout and the Ferry Terminal Roundabout.

c. Socio-Environmental Aspect

From the viewpoint of a possible disruption of the existing community, it is anticipated that Route 'A' will cause disruption to the existing community since it will affect many houses along Jalan Chain Ferry. Route 'B' and Route 'C' are expected however to have very little disruption on the community.

Route 'A' is anticipated to affect the Butterworth Market as well as the commercial buildings along Jalan Chain Ferry. Route 'C' is expected to affect the areas of Malayawata Steel and the Malayan Railway. The socio-environmental impact of Route 'B', however, is not significant.

Table 4.2 shows the comparison of these alternative routes.

Table 4.2 COMPARISON OF ALTERNATIVE ROUTES (A–B SECTION)

Items		Route 'A'	Route 'B'	Route 'C'
Outline	Length	6.000 km	4.610 km	5.200 km
	Plan	Improvement of the Existing Federal Route 1	New Construction & Improvement of Jalan Prai	New Construction & Improvement of Jalan Perusahaan
	Land Use	Developed Area	Developed Area for Residential and Transportation	Developed Area of Industry and Transportation
Technical Aspect	Construction Condition	Comparatively difficult	Easy	Comparatively difficult
	Traffic Flow	Not Smooth	Smooth	Smooth
	Network Pattern	Not Suitable	Suitable	Suitable
	Major Structures	Two Large-scale Fly-over Structures and a Low level Bridge	High Level or Medium Level Bridge on Prai River	High Level or Medium Level Bridge on Prai River with viaduct Structure over Malayawata Steel and Malayan Railway
Socio-Environment Aspect	Disruption of Community	Anticipated	Small	Small
	Impacts on Existing Urban facility	Markets, commercial Buildings and Houses affected	Insignificant	Malayawata Steel and Malayan Railway affected
	Impacts on Urban Environment	Some problems	Insignificant	Insignificant
Construction Cost	Construction Cost	M$18,767,000	M$44,374,000	M$54,482,000
	Land Acquisition & Compensation	M$ 7,177,000	M$ 4,194,000	M$ 3,374,000
	Total	M$25,944,000	M$48,568,000	M$57,856,000

2) Route 'D', Route 'E' and Combined Route 'D' and 'E'

a. Economic Aspect

The construction cost of Route 'D', Route 'E' and combined Route 'D' and 'E' is estimated to be M$38,886,000, M$64,186,000 and M$38,130,000 respectively, showing that Route 'D' and combined Routes 'D' and 'E' are cheaper than Route 'E'.

b. Technical Aspect

Route 'E' passes through along the existing Jalan Bagan Ajam where many houses, commercial buildings and institutional buildings exist, therefore, problems in land acquisition can be anticipated. On the other hand Route 'D', passing through a seashore area, will have a smaller land acquisition problem. The combined Route 'D' and 'E' passes through along the seashore area and the existing Jalan Bagan Ajam; therefore, the land acquisition in this combined route is expected to be comparatively easy.

From the viewpoint of ensuring a smooth traffic flow, Route 'D' is the best. This is because it can be segregated functionally according to long-distance, short-distance and community and freight traffic.

From the viewpoint of providing on alternate road which is important in Road Planning in terms of ensuring space for emergency or security vehicles, Route 'D' is also superior to Route 'E' and combined Route 'D' and 'E'.

c. Socio-Environmental Aspect

From the viewpoint of disruption of community, Route 'E' is expected to affect many houses along Jalan Bagan Ajam. Many commercial buildings and institutional building would also be affected by Route 'E'.

The combined Route 'D' and 'E' requires the removal of many houses along Jalan Bagan Ajam. On the other hand, Route 'D' requires the removal of only few houses.

The comparison of these alternative routes in the B–C Section is shown in Table 4.3.

Table 4.3 COMPARISON OF ALTERNATIVE ROUTES (B-C SECTION)

	Items	Route 'D'	Route 'E'	Combined Route 'D' and 'E'
Outline	Length	5.535 km	5.150 km	5.385 km
	Plan	New Construction	Improvement of Jalan Bagan Ajam	New Construction and Improvement of Jalan Bagan Ajam
	Land Use	Seashore Area for Open Space and Recreation	Developed Area for Residence and Commerce	Developed Area for Residence and Commerce
Technical Aspect	Construction Condition	Easy	Easy	Easy
	Traffic Flow	Smooth	Not Smooth	Comparatively smooth
	Network Pattern	Alternative of Federal Route 1	No Alternative of Federal Route 1	Partial Alternative of Federal Route 1
Socio-Environmental Aspect	Disruption of Community	Small	Anticipated	Not significant, but anticipated
	Impacts on Existing Urban Facility	Insignificant	Many shops and houses are affected	Some houses are affected
	Impacts on Urban Environment	Park and Open Space along seashore area are affected	Anticipated	Anticipated
Construction Cost	Construction Cost	M$30,751,000	M$19,362,000	M$22,183,000
	Land Acquisition & Compensation	M$ 8,135,000	M$44,824,000	M$15,947,000
	Total	M$38,886,000	M$64,186,000	M$38,130,000

3) Route 'F' and 'G'

a. Economic Aspect

Construction costs of Route 'F' and Route 'G' are estimated to be M$16,239,000 and M$11,748,000 respectively. Considering these costs, it is clear that Route 'G' is cheaper than Route 'F'.

b. Technical Aspect

Two water pipelines of 24" diameter and 54" diameter have been located along the existing Jalan Sungai Dua on both sides. For Route 'F' to be constructed, the 24" diameter water pipe will have to be removed, but Route G will not need to remove it.

Many small houses are located along the existing Jalan Sungai Dua in Sungai Puyu, but there are comparatively few houses along Route 'G'. Therefore, land acquisition of Route 'F' is more difficult than that of Route 'G'.

3) Environmental Aspect

From the environmental aspects, Route 'G' is slightly better than Route 'F' because Route 'F' passes through the center of the existing community, but Route 'G' passes through a coconut plantation and padi field.

The comparison of these alternative routes in the C–D Section is shown in Table 4.4.

Table 4.4 COMPARISON OF ALTERNATIVE ROUTE (C–D SECTION)

Items		Route 'F'	Route 'G'
Outline	Length	4.450 km	4.350 km
	Plan	Improvement of Jalan Sungai Dua	New Construction
	Land Use	Kampong Area	Agricultural Area for Padi and Coconut
Technical Aspect	Construction Condition	2 Water pipes (24 inches and 54 inches) are affected	Easy
	Traffic Flow	Smooth	Smooth
	Network Pattern	–	–
Socio-Environmental Aspect	Disruption of Community	Anticipated	Small
	Impacts on Existing Urban Facility	Small houses in Kampong Area are affected	Insignificant
	Impacts on Urban Environment	Anticipated	Small
Construction Cost	Construction Cost	M$10,806,000	M$8,883,000
	Land Acquisition & Compensation	M$ 5,433,000	M$2,865,000
	Total	M$16,239,000	M$11,748,000

(3) Results of Screening

From the results of the comparative analysis mentioned above, the following conclusions can be made:

a. Route 'B' seems to be a better route than the others. However, it is still required that Route 'A' be examined in the economic evaluation because construction cost of Route 'A' is clearly cheaper than that of the others. Although Route 'C' is the most expensive route, it may be generating more benefits than the others. The selection of these three alternatives, therefore, is left to the economic evaluation.

b. The comparative analysis shows that Route 'E' is clearly not recommendable in terms of construction cost and environmental aspects. Regarding the other alternative routes, the difference in construction cost between Route 'D' and combined Route 'D' and 'E' is only M$0.7 million (the former route is higher than the latter one), but, the former route may cause less social and environment problems and may prepare an alternative to the Federal Route 1. Considering the above, it is recommended that route 'D' is better than the combined Route 'D' and 'E'. However, the choice of these two alternatives is left to the economic evaluation in the later stage.

c. It is recommended that Route 'G' be selected as it has a lower construction cost, small environmental problems and does not entail any shifting of the 24' diameter water pipe.

Fig. 4.9 shows the remaining alternative routes which will be further evaluated for a final choice of route for the Project Road in the economic evaluation section in Chapter 7.

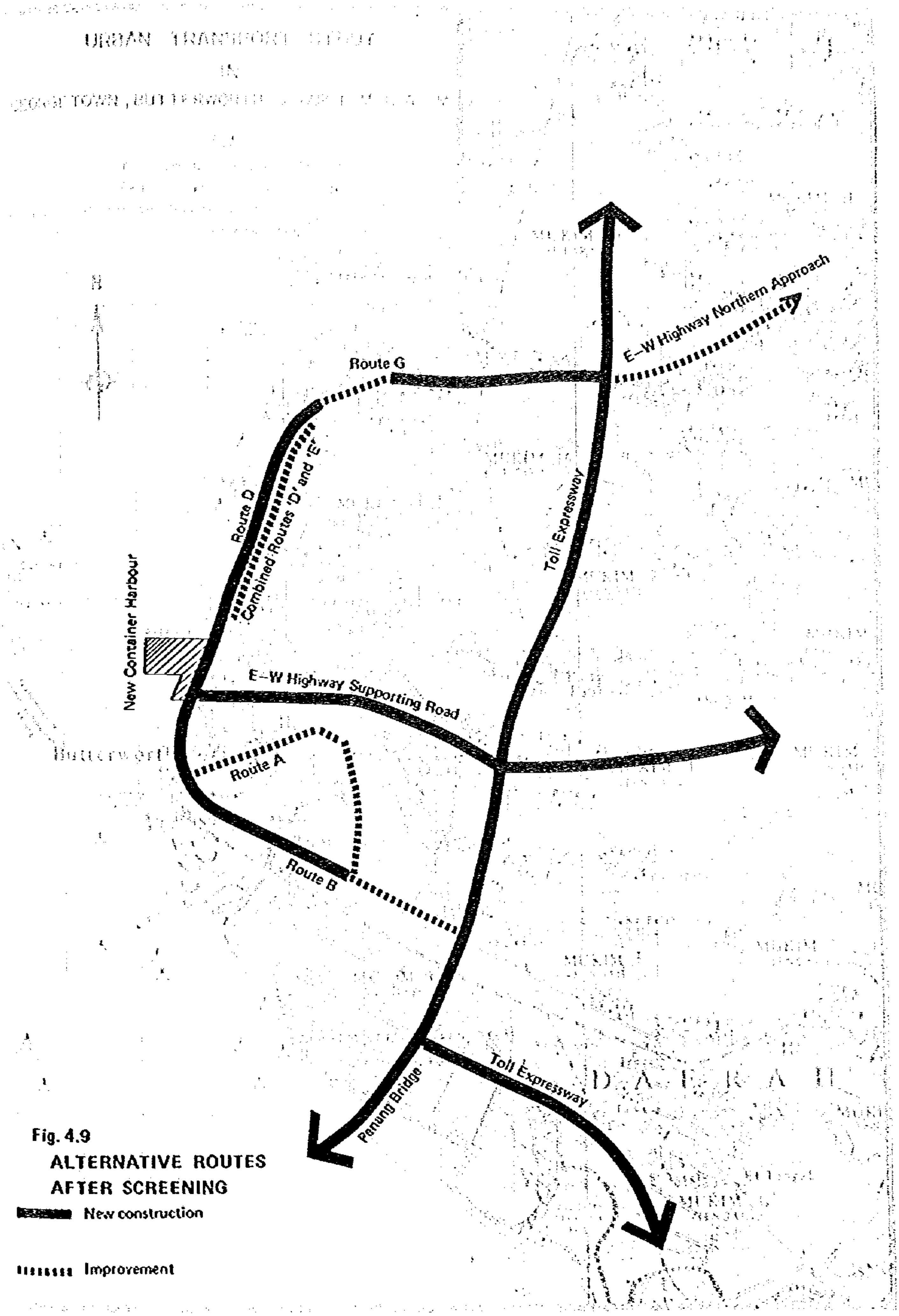


Fig. 4.9
ALTERNATIVE ROUTES AFTER SCREENING

New construction

Improvement

4.6 STUDY OF ALTERNATIVE STRUCTURES FOR THE PRAI RIVER

4.6.1 General

Based on the field investigations conducted, the design criteria established and the alternative routes selected, the alternative structures for the Prai River will be established in this section.

Among the alternative routes, a structure on Route 'A' can be constructed parallel and with a navigation clearance height of equallevel as the existing one. Therefore, it is not included in this section. However, in Route 'B' and Route 'C' new alternative structures for the Prai River have to be established.

4.6.2 Alternative Structures for the Prai River

The most critical condition in the design of the Prai River crossing structure on Route 'B' and Route 'C' is the navigation opening. This can be either:

a. A clearance height of 25.0 meters
b. A clearance height of 16.0 meters
c. A clearance height of 3.5 meters

With this critical condition, the structure types for the Prai River can either be as follows:

a. Bridge Type
b. Tunnel Type

For the bridge type, either one of the following types of bridge may be constructed:

a. Fixed Type of Bridge
b. Movable Type of Bridge

Table 4.5 shows the alternative structure plans in which the abovementioned alternatives are summarized.

Table 4.5 ALTERNATIVE STRUCTURE PLANS

Navigation and Compensation Need \ Structure Type	Fixed	Movable
Free passage for all ships and no specific compensation need	High Level Bridge (1) High Level Bridge (2) Underwater Tunnel	Medium Level Bridge Low Level Bridge
Limit passage of some or most of ships and compensation is necessary for the Hong Leong-Shipyard and the PPC Dockyard	Medium Level Bridge Low Level Bridge	

Note: a. High level bridge refers to bridge with a clearance height of 25 meters
b. Medium level bridge refers to bridge with a clearance height of 16 meters
c. Low level bridge refers to bridge with a clearance height of 3.5 meters

Based on the alternative plans mentioned above, the initial structure plans on Route 'B' and Route 'C' for the Prai River are designed and are shown in Table 4.6.

4.6.3 Screening of Alternative Structures

The alternative structure plans for the Prai River are analyzed comparatively from various viewpoints. The alternative plans are shown in Table 4.7.

The following conclusions can be derived from Table 4.7.

a. From the viewpoint of the function at the Project Road (mentioned in Section 4.3), the fixed type bridge is clearly better than the movable one.

b. The underwater tunnel plan is eliminated because of its extremely expensive construction and maintenance cost.

c. Judging from minimum cost criteria, the high level bridge (type 2) and the medium level bridge are selected.

Table 4.6 SUMMARY OF ALTERNATIVE PLANS

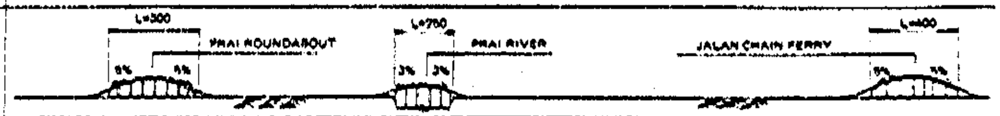
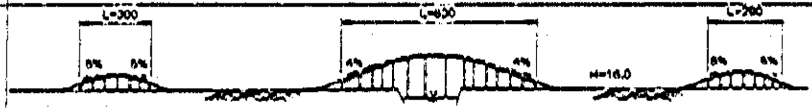
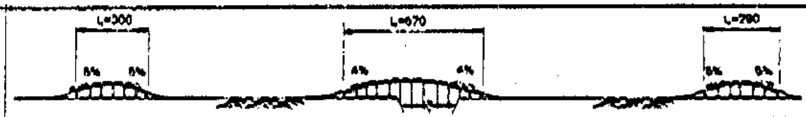
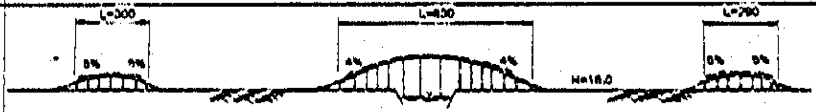
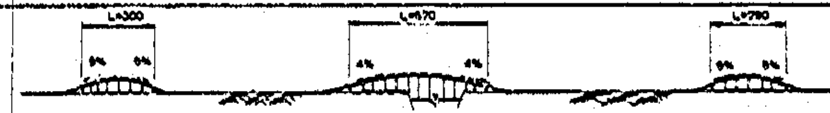
Route	Alternative Plan		Navigation	Compensation Need	Longitudinal Profile of Structure
Route A			Same to Existing Bridge	No Need	
Route B	B-1	High Level Bridge (1)	30 30 / 38	No Need	
	B-2	High Level Bridge (2)	30 30 / 38	No Need	
	B-3	Under water Tunnel		No Need	
	B-4	Medium Level Bridge	30 30 / 16	Need for Hong Leong-Lumsen Shipyard	
	B-5	Low Level Bridge	30 30 / 4.7	Need for Hong Leong-Lumsen Shipyard and Bagan Dalam Dockyard	
	B-6	Medium Level Bridge (Movable)	30 30 / 16	No Need	
	B-7	Low Level Bridge (Movable)	30 30 / 4.7	No Need	
Route C	C-1	High Level Bridge	30 30 / 38	No Need	
	C-2	Medium Level Bridge	16	Need for Hong Leong-Lumsen Shipyard	

Table 4.7 COMPARISON OF ALTERNATIVE STRUCTURE PLANS

Alternative Plans			Construction Cost (M$'000)	Shifting of Shipyard	Other Viewpoints
Route 'B'	B–1	High Level Bridge (1)	51,681	Not necessary to shift shipyards	–
	B–2	High Level Bridge (2)	40,839	–do–	–
	B–3	Underwater Tunnel	128,036	–do–	Technically possible, but rather hard to construct Maintenance and operating costs of tunnel are required
	B–4	Medium Level Bridge	45,660	Shifting of Hong Leong Shipyard is necessary	–
	B–5	Low Level Bridge	52,656	Shifting of both H.L. and PPC Dockyard is necessary	–
	B–6	Medium Level Bridge (Movable)	38,917	Not necessary to shift Shipyards	Necessity to control traffic on the bridge while the ship is passing through the bridge Maintenance and operating costs of bridge are additionally required
	B–7	Low Level Bridge (Movable)	33,078	–do–	–do–
Route 'C'	C–1	High Level Bridge	51,717	–do–	–
	C–2	Medium Level Bridge	52,867	Shifting of Hong Leong Shipyard is necessary	–

Note: Construction Costs are the total costs of the Prai Roundabout Fly-over Bridge, the structures for the Prai River and the Chain Ferry Fly-over Bridge, and also includes the compensation costs for the shipyards.

4.7 PRELIMINARY DESIGN

4.7.1 General

The design of the Project Road is made based on the alternatives selected and the topographic maps. The scale of each design is shown in Table 4.8.

Table 4.8 SCALE USED IN THE DESIGN OF THE PROJECT ROAD

Items		Scale	Remarks
Road Design	Plan	1 : 3,000	Topographical Map
	Profile	H=1 : 3,000 V=1 : 500	
	Cross-Section	1 : 200	
Typical Cross-Section		1 : 100	
Intersection Design		1 : 500	
Bridge Design		1 : 500	Survey Map

The map of scale 1 to 3,000 used in the design is enlarged to map of scale 4 chain to 1 inch with supplementary surveys conducted.

4.7.2 Alignment

(1) Horizontal Alignment

a. Following the result of the route location study, the horizontal alignment is designed on the topographical map of scale 1 : 3,000.

b. The alignment of the improved existing road is almost the same as that of the existing alignment, but parts of the road with small radii have been improved.

c. The part across the Prai River is designed to be a straight line which will decrease the construction cost for the long span bridge.

(2) Vertical Alignment

a. Taking into account the critical grade length, the maximum gradient of the Prai River bridge is adopted to be 4.00%.

b. Taking into account the drainage system, the minimum gradient is adopted to be 0.3%, but the part where there will be improvement of the existing road and seashore area the gradient is adopted to be 0.00%. In this section the drainage itself will be a slope.

c. The minimum vertical clearance is adopted to be 4.75 meters.

d. Taking into account the need for resurfacing, the proposed height of improvement of the existing road is established.

e. From the viewpoint of construction cost and wave height, the proposed height of the seashore area is estimated to be 2.5 meters.

f. The proposed height of the project road through the coconut plantation and padi field in Route G should be 1.0 meter over the existing ground level in order to protect the pavement from corrosion by the water.

4.7.3 Cross-Section

(1) Cross-Section Planning Policy

1) Basic standard to be used

On the basis of "A Guide to Typical Standards Used in Highway Design Unit JKR/J(Rb) 0005/80", the typical corss-section is made, paying attentions to the characteristics of traffic condition, land use, environmental and economic aspects.

2) Number of Lanes

On the basis of the results of traffic assignment and design capacity, the following number of lanes are proposed and are shown in Table 4.9.

Table 4.9 DESIGN CAPACITY

Item	Number of Lane	Capacity (P.C.U./day)	Level of Service	Design Capacity (P.C.U./day)
Highway Section	4-lane	72,800	0.75	54,600
	6-lane	109,200	0.75	81,900

Note: The level of service for the Project Road is employed as level IV.

3) Carriageway Width

The carriageway width of one lane is adopted to be 3.75 meters, the reason being:

a. The Project Road would be connected to the Toll Expressway and the East-West Highway Supporting Road. The carriageway widths of these roads are 3.75 meters. The Project Road, therefore, is planned to be of the same width in order to be compatible with these related roads.

b. Taking into account the traffic characteristics on the Project Road, a lot of freight traffic are expected to pass through on this Road, thus it is desirable to have a wider carriageway.

4) Central Reservation Width

The central reservation comprises a median strip and a right side shoulder. The central reservation width is adopted to be 4.5 meters in this study in order that trees can be planted to maintain a good environment.

5) Shoulder Width

A shoulder is the portion of the roadway which is continuous with the road for accommodating vehicles that need to stop during emergency. It also functions as a lateral support of the base and surface courses.

According to the JKR standards, the shoulder width of group 04 and 05 are 2.5 meters and 3.0 respectively. However, the width of shoulder is adopted to be 2.0 meters in the study. By reducing the Right-of-Way width, construction cost can be minimized. Within this shoulder width, it is possible to accommodate light vehicles such as motor-cycles and bicycles.

6) Service Road Width

It is recommended that a service road should basically be constructed along the Project Road. The service road should have a width of 6.0 meters and should be a two-way street. In this study, however, a service road is not designed.

7) Buffer Zone

It is desirable to provide a buffer zone along the Project Road. An environmental study has been carried out and necessary buffer zones are prepared.

8) Right of Way

The width of the right-of-way is adopted to be 30.0 meters, 40 meters and 58.50 meters according to the number of lanes and locations (See Table 4.10).

(2) Cross-Section

Based on the elements of cross-section components applicable to the Project Road mentioned in Section 4.4, the typical cross-section is presented in Table 4.10.

It is proposed that two alternative plans of cross-section be applied to the Project Road.

1) Plan 1

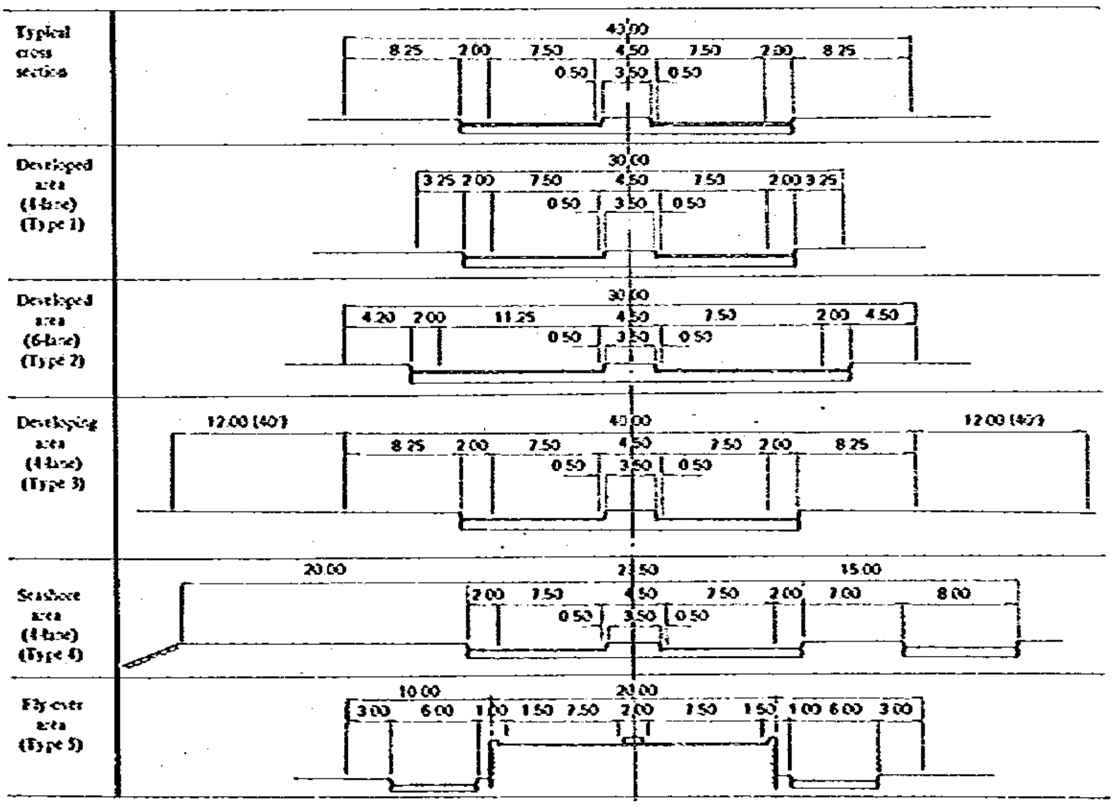
A six (6)–lane road from the Toll Expressway to the Prai Roundabout and a four (4)–lane road for the other parts of the Project Road.

2) Plan 2

A six (6)–lane road for the Toll Expressway to the North Butterworth Container Wharf and a four (4)–lane road for the other parts of the Project Road.

Fig. 4.10 and Table 4.10 shows plan 1 being applied to the Project Road.

Table 4.10 TYPE OF CROSS-SECTION



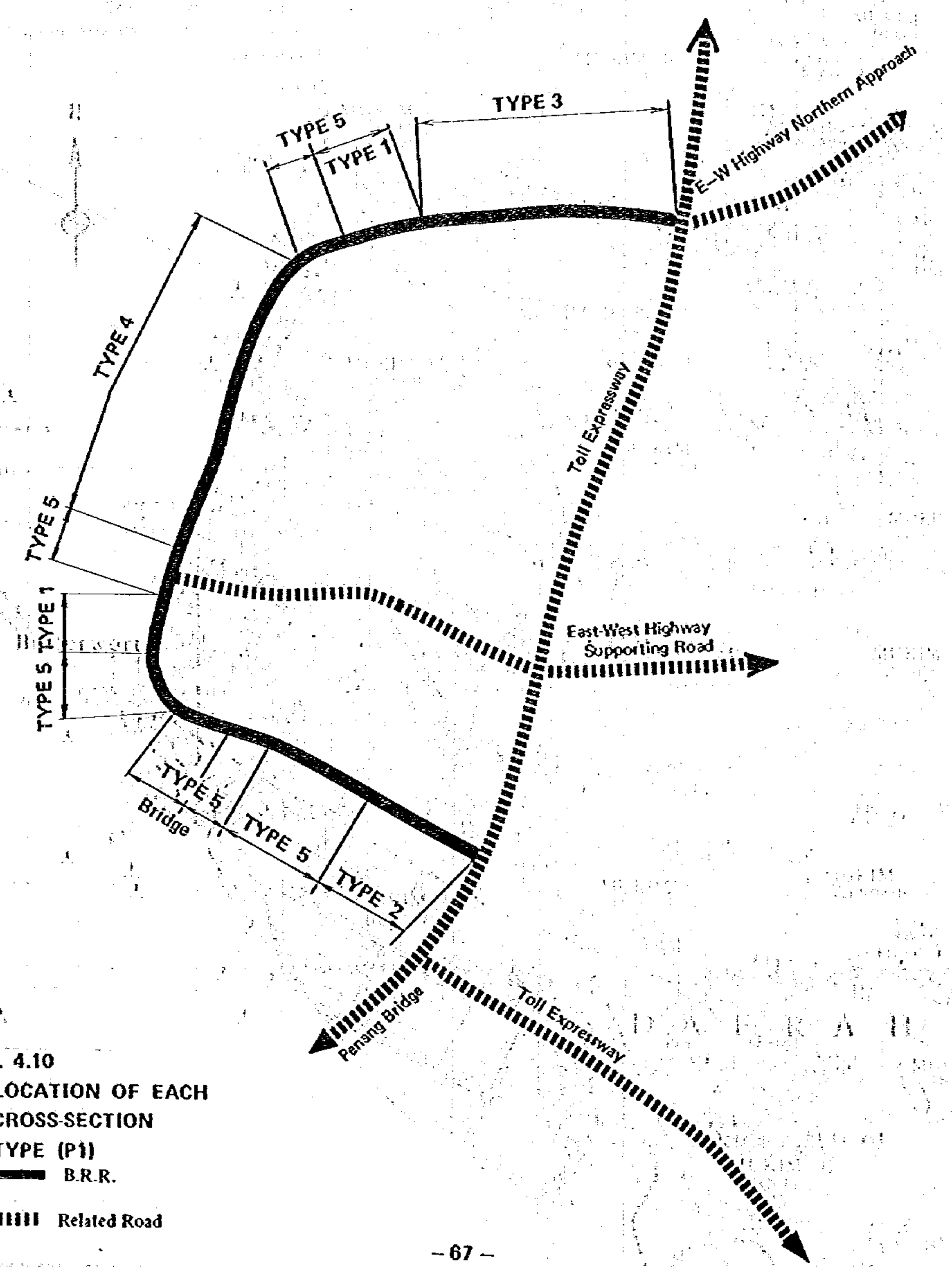


Fig. 4.10
LOCATION OF EACH CROSS-SECTION TYPE (P1)

B.R.R.

Related Road

4.7.4 Intersection Design

(1) General

The Project Road is a primary distributor in an intra-urban area so the operating speed should be higher than that of the existing road and has to be able to provide a smooth traffic flow. Generally, the type of intersections of the Project Road in relation to the other roads are shown in Table 4.11.

Table 4.11 TYPE OF INTERSECTION

Intersection of Butterworth Ring Road	At-grade intersection		Grade Separation	Remarks
	Non-signalized	Signalized		
to Inter-Urban Primary Distributor	X	X	O	
to Intra-Urban Primary Distributor	X	X	O	
to District Distributor	X	O	X	
to Local and Access Road	X	X	X	access control
to Approach Road	X	O	X	

Note: O – to establish intersections
X – not to establish intersections

(2) Location of Intersection

The location and type of intersection are shown in Fig. 4.11. Five (5) grade separated intersections namely intersection A, B, C, D and H and five (5) at-grade intersections namely E, F, G, I and J are located along the Project Road.

(3) Interchange

Four (4) interchanges have been planned on the Inter-urban Toll Expressway as interchanges K, L, M and N. These interchanges were planned to be full service interchanges by the Highway Authority of Malaysia.

(4) Intersection Design

Based on the turning movement traffic volume (see Appendix C) the following intersections are designed.

1) A-intersection (Refer to Fig. 4.11)

A-intersection is situated between the Project Road and Jalan

Chain Ferry. From the viewpoint of road hierarchy and the results of the calculation of the Phase Rate at signalized intersections, this intersection is planned to be a grade separated intersection.

2) B-intersection

B-intersection is situated between the Project Road and the existing port. From the viewpoints of traffic control of the incoming and outgoing traffic flow of the existing port, the results of the calculations of the Phase Rate at signalized intersection, and in addition to the discussion with the JKR, MPSP, PPC, this intersection is planned to be a grade separated intersection.

3) C-intersection

C-intersection is situated in front of the Ferry Terminal. From the viewpoint of traffic control of the incoming and outgoing traffic from the Ferry Terminal and from the results of the discussion with JKR, MPSP, PPC, this intersection is planned to be a grade separated intersection.

4) D-intersection

D-intersection is situated between the Project Road and the E–W Highway Supporting Road and both roads are classified to be primary distributors. From the viewpoint of road hierarchy and the results of the calculation of the Phase Rate in the signalized intersection, this intersection is planned to be a grade separated intersection.

5) H-intersection

H-intersection is situated between the Project Road and Jalan Bagan Ajam. As a result of the calculation of Phase Rate on signalized intersection, this intersections is planned to be a grade separated intersection.

6) E, F, G, I and J intersection

These intersections are situated between the Project Road and the local distributors and the traffic volumes at these intersections are not very large. As a result of the calculations of the Phase Rate on signalized intersections, these intersections are planned to be at-grade intersections.

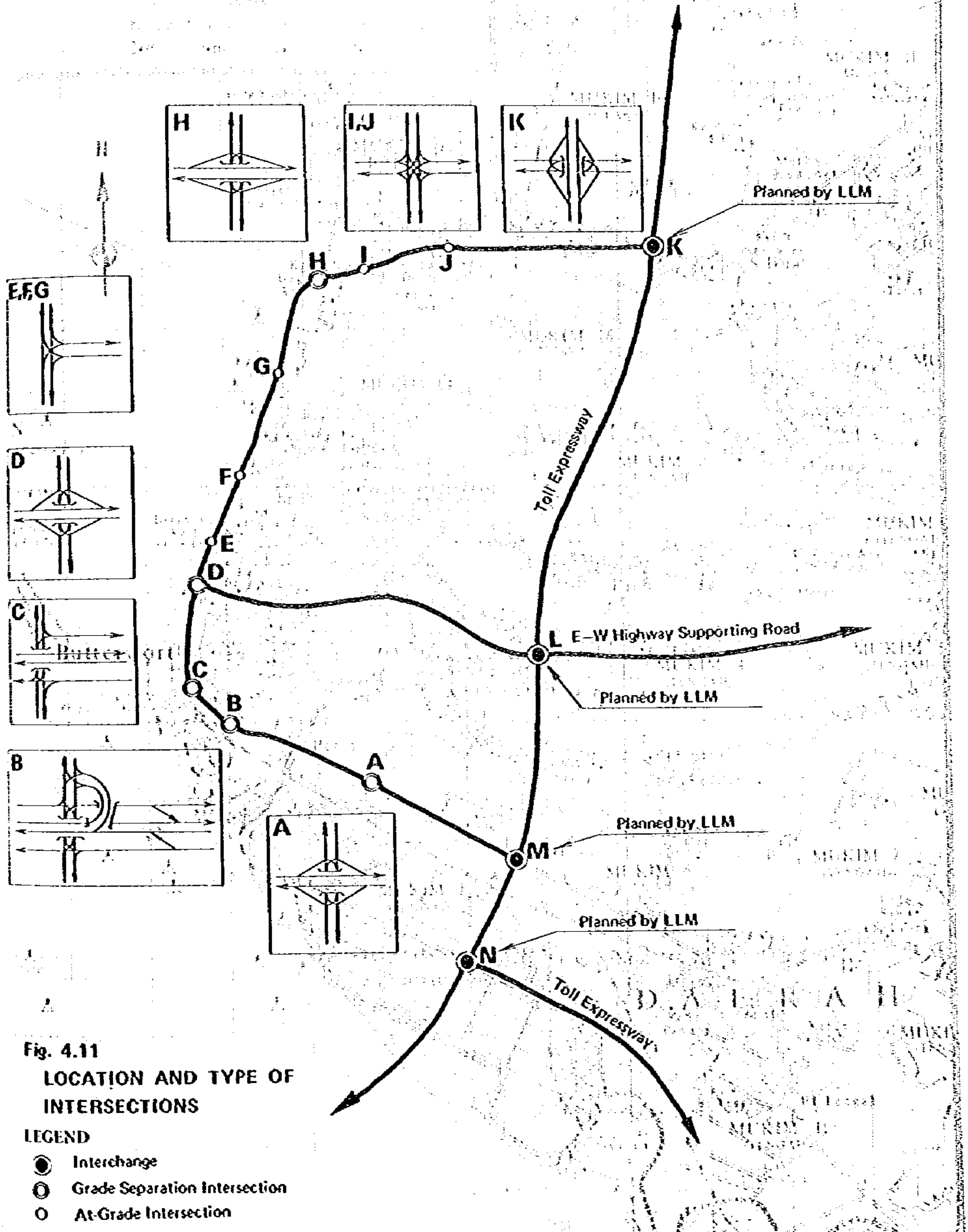


Fig. 4.11
LOCATION AND TYPE OF INTERSECTIONS

LEGEND

- Interchange
- Grade Separation Intersection
- At-Grade Intersection

4.7.5 Maximum Embankment Height

(1) Calculation of Circular Slip Safety Factor

On the approach to the bridge and the approach to the overpass, a study on the circular slip of the embankment is made.

Soil condition is as in the Geotechnical Investigation data.

The allowable safety factory for circular slip is $F_s = 1.2$. The water level used in this calculation is the water level in the borehole.

The results of calculation are indicated in Table 4.12.

Table 4.12 CIRCULAR SLIP SAFETY FACTOR

Examination – Site	BH–No.	Fill – height (m)	Safety Factor	Check
Prai River	BH–1	7.00	$F=1.07<F_s=1.2$	Out
		6.00	$F=1.29>F_s=1.2$	Safe
FerryTerminal	BH–3	7.00	$F=1.02<F_s=1.2$	Out
		6.00	$F=1.30>F_s=1.2$	Safe
Bagan Ajam	BH–6	7.00	$F=1.42>F_s=1.2$	Safe

As a result the calculation of circular slip, it is satisfactory to consider the fill height at Prai River, Ferry Terminal as 6.00 m and that at Bagan Ajam as 7.00 m.

(2) Calculation of Consolidation Settlement

Consolidation settlement is calculated using three different embankment heights such as 2.0 meters, 4.0 meters and 6.0 meters.

The results of calculation are indicated in Table 4.13.

Table 4.13 CONSOLIDATION SETTLEMENT

Site	BH–No.	Fill Height (m)	Depth (cm)				
			S1	S2	S3	S2	S1
Prai River	BH–1	6.00	15	50	60	50	15
		4.00	–	36	41	36	–
		2.00	–	15	20	15	–
Ferry Terminal	BH–3	6.00	20	97	120	97	20
		4.00	–	35	66	35	–
		2.00	–	12	20	12	–
Bagan Ajam	BH–6	7.00	22	70	80	70	22
		6.00	20	59	72	59	20
		4.00	–	34	51	34	–
		2.00	–	18	29	18	–

As a result of the calculation, the depths of consolidation settlement of heights 6.0 m, 4.0 m and 2.0 m are about 70 cm, 40 cm and 20 cm respectively.

(3) Conclusion

From the viewpoint of circulation slip, if the embankment height is taken to be 6.0 m, the consulidation settlement is very great, up to 120 cm in depth. In such a case, some kind of improvement to the soil foundation should be made to prevent such sinking. However, if a height of 4.0 m is used, the consolidation settlement is only about 40 cm. Assuming a 80% sinking, only 8 cm will remain. This is the allowable value for road construction. Hence a maximum of 4.0 m is adopted for the embankment in this study.

4.7.6 Design of Revetment

(1) General

Revetments constructed in the coastal area may be roughly divided into the following three types of structures:

a. Sloping faced type revetment.
b. Vertical faced type revetment.
c. Composite type revetment.

The three types of structure can be described as follows:

1) Sloping faced type revetment

The sloping faced type of revetment is often constructed on soft ground as the surcharge per unit area is small on account of the wide base of the structure. However, a large volume of sand filling is required. It is a favourable structure when sufficient sand filling is easily available. A sufficient space is also required for the wide base of the structure. The structure is stable against wave pressure. The construction cost is relatively low.

2) Vertical faced type revetment

The vertical faced type of revetment is a favourable structure for a strong foundation as the surcharge is concentrated on the narrow base width. It is also suitable in cases where sufficient space is not available.

3) Composite type revetment

The composite type of revetment is adopted when it is desirable to take advantage of both the sloping faced type and the vertical faced type of structure. It is particularly a favourable type of structure to be constructed in locations of deep waters.

(2) Structure of Revetment

The type of revetment to be constructed will be determined on the basis of the following conditions:

1) Hydrological conditions

With favourable hydrological conditions as mentioned in Chapter 4, the water area is relatively calm. The structure will not be subject to the attack of violent wave forces and it will not be necessary to use stones of large dimensions as armour stones. The location of the structure will be largely in shallow waters. As the location will be around the breaking point at low tide, it will be necessary to provide against scouring at the legs of the revetment.

2) Soil conditions

The slope of the sea bottom is a gradual slope (of roughly the same water depth of −0.3 m to +0.30 m to a distance of 500 – 1,000 m off-shore). In all the area, the surface layer is a clay layer (C = 2.5 t/m² thickness 10 m). A layer of ooze is accumulated to a thickness of approximately 0.5 m on the surface layer.

3) Construction material

Granite of good quality can be produced from the mountain area. In the case where concrete is used, fine aggregate is not easily available. Refined mountain sand mixed with clay is used as a substitute for the purpose. The present daily production is 1,700 t/day. The demand will increase with further construction works in the future, bringing about greater shortage of supply.

4) Construction hardness

As the structure will be constructed in a location of slightly greater depth from the shoreline, foundation work will be carried out as submarine works. It will be desirable to select a type of structure with advantage in submarine works.

5) Construction Cost

As mentioned above, a large volume reclamation filling will be available from the mountain area. A plan to make full use of the available material will be most desirable from the economic point of view.

(3) Recommendation

From the above various conditions of the proposed site, a stone pitching, sloping faced revetment is recommended as the most favourable type of structure. It will be provided against the soft surface layer of clay. The volume of concrete required will be small, the cost of which is relatively high. A structure with a gradual slope will give the inhabitants in the area some seashore as shown in Fig. 4.12.

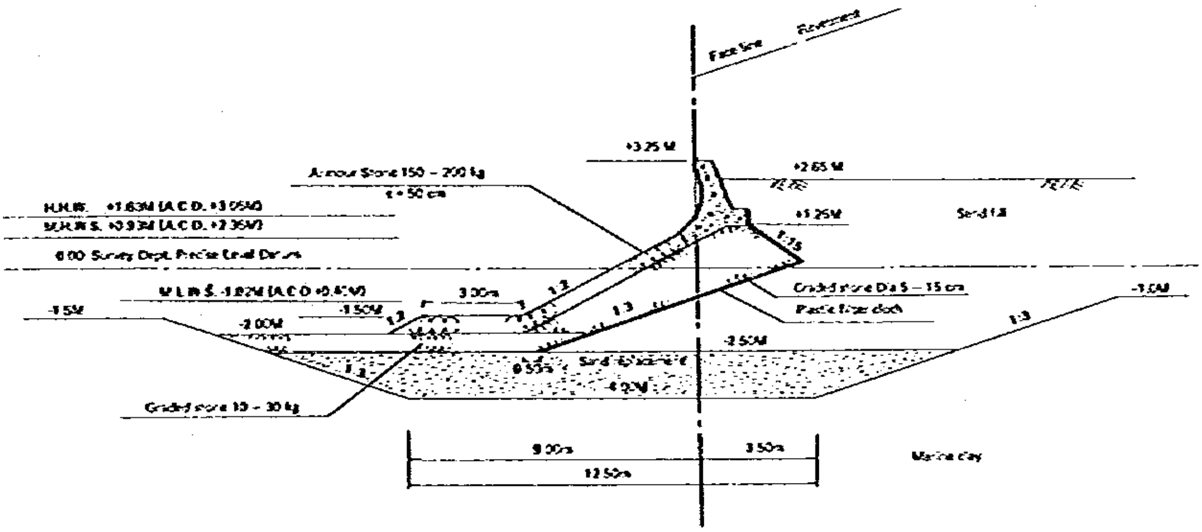


Fig. 4.12 REVETMENT OF COASTAL ROAD

4.7.7 Proposed Height of Seashore Area

(1) General

The cross-section and proposed height is examined according to the following:

a. Height of overtopping waves.
b. Environmental aspect.
c. Construction Cost.

(2) Alternative Plan

Taking into account the above three criteria, three alternative plans are prepared, namely, case A, Case B and case C. (Refer to Fig. 4.13, 4.14 and 4.15).

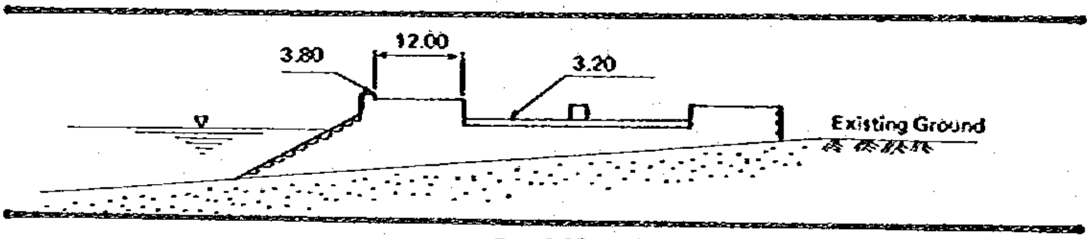


Fig. 4.13 CASE A

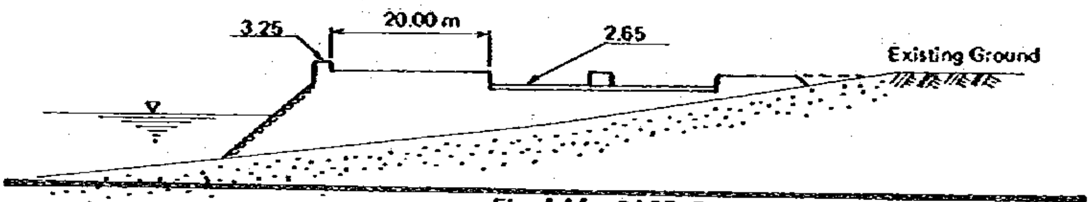


Fig. 4.14 CASE B

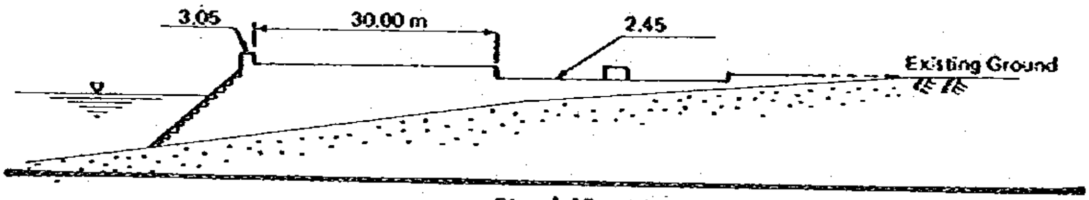


Fig. 4.15 CASE C

(3) Height of Overtopping Waves

The height of overtopping waves are calculated in three alternative plans. The detailed calculation is indicated in Technical Report 02 "Hydrological Study".

The result of the calculation is shown in Table 4.14.

Table 4.14 CROWN ELEVATION

Case	Elevation (m)
Case A	3.8
Case B	3.25
Case C	3.05

(4) Environmental Aspect

From the viewpoint of aesthetics, it is desirable to have the proposed height of the road lower than the existing ground level. However, since the high water level and the existing ground height is 1.6 m and 2.8 m respectively, it is very difficult to have the road lower than the existing ground level.

In the consideration of open space along the road, the wider the open space, the better it is. With the open space in all the three alternative plans, it is possible to introduce walking space, fishing space and so on.

(5) Construction Cost

The construction cost of case A, B and C is calculated to be M$3,000, M$2,800 and M$2,830 per meter respectively. The construction cost of case B is the lowest of all the three cases.

(6) Conclusion

Although all the three alternative plans are technically feasible, case B is recommended. Case B has the lowest construction cost while still maintaining an acceptable level of environmental condition. Hence the proposed seashore area will have a height of 2.65 meters above sea level and an open space width of 20.0 meters.

4.7.8 Pavement Design

(1) Type of Pavement

There are basically two common types of pavement namely asphalt concrete pavement and cement concrete pavement.

The asphalt concrete pavement is suggested for the Project Road. The reasons are as follows:

1) Lower Construction Cost

There is a limited supply of sand needed for the cement concrete pavement. Moreover, sand is expensive, causing the construction cost of the cement concrete pavement higher than that of the asphalt concrete pavement. For example, the construction cost of asphalt concrete pavement and cement concrete pavement are M$31.7 per square meter and M$46.5 per square meter respectively.

Table 4.15 COMPARISON OF CONSTRUCTION COST BETWEEN CEMENT CONCRETE PAVEMENT AND ASPHALT CONCRETE PAVEMENT

(per m^2)

Type of Pavement Course	Cement Concrete Pavement			Asphalt Concrete Pavement		
	Quantity	Unit Cost	Cost	Quantity	Unit Cost	Cost
Surface Course	$0.25m^3$	M$141.3	M$35.3	$0.10m^3$	M$205.8	M$20.58
Base Course	$0.20m^3$	M$28.0	M$7.0	$0.25m^3$	M$27.6	M$6.9
Sub-Base Course	$0.20m^3$	M$20.8	M$4.2	$0.20m^3$	M$20.8	M$4.2
Total			M$46.5			M$31.68

2) Availability of Construction Material

The materials for the base course and the sub-base course of the asphalt concrete pavement can be obtained from the site of the Outer Ring Road, but fine aggregates such as sand is not as easily available. As the cement concrete pavement requires more fine aggregates per square area as compared to the asphalt concrete pavement, the former may face a problem of shortage of materials. Moreover, reinforced concrete is required for the cement concrete pavement and reinforcement materials are scarce and expensive in Malaysia. Therefore, the construction of the asphalt concrete pavement will be much easier than the cement concrete pavement for the reasons mentioned.

3) Technical know-how

The asphalt concrete pavement type has been in use in Malaysia for a long time and therefore, the technical know-how required in its construction is easily obtainable.

4) Easy maintenance

In the urban area, it is often necessary to re-construct services like water supply, drainage and other road facilities. When this need arises, asphalt concrete pavement stands out superior over the cement concrete pavement because such facilities are easier to concrete pavement. The asphalt concrete pavement can also be easily resurfaced when it is weathered.

(2) Design of Pavement

1) Premises for design

a. From the Geotechnical Investigation, the C.B.R. values of the sub-grade is found to be about 5.0%.

b. The traffic counting survey shows that the percentage of lorries and buses is about 10%.

c. The maximum daily traffic volume in the year 2000 is estimated to be 54,000 P.C.U. per day. (Jalan Prai).

d. The lifetime adopted for asphalt concrete pavement is 20 years.

e. Proposed thickness of individual course is shown in Fig. 4.16.

2) Cross-Section of Pavement

The following cross-section is recommended (See Fig. 4.16).

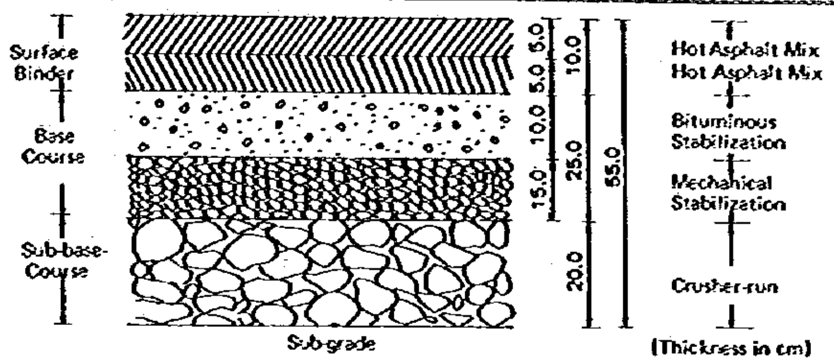


Fig. 4.16 CROSS-SECTION OF PAVEMENT

(3) Examination of thickness

1) The thickness of each course is shown in Fig. 4.17.

Surface	(1.0)	5.0	55.0
Binder	(1.0)	5.0	
Bitumen Stabilized Course	(0.8)	10.0	
Mechanically Stabilized Course	(0.35)	15.0	
Crusher-run	(0.25)	20.0	

Fig. 4.17 THE THICKNESS OF EACH COURSE (CM)

2) Road classification by volume of traffic

The maximum daily traffic volume in the target year is projected to be 54,000 P.C.U./day. The percentage of heavy traffic is estimated to be 10%. Therefore, the one way daily volume of heavy traffic is computed as 2,700 V/D (54,000 x 0.5 x 0.10). The road hence is classified as "Class C" road.

3) Thickness of T_A and H

With a C.B.R. of the subgrade as 5.0% (Refer to the Technical Report No. 1 "Geotechnical Study"), the thickness of T_A and H for "Class C" road should be 28.0 cm and 47.0 cm respectively by road engineering standards. For the proposed pavement as shown in Fig. 4.18, the T_A and H values can be calculated as:

$T_A = 5.0 \times 1.0 + 5.0 \times 1.0 + 10.0 \times 0.8 + 15.0 \times 0.35$
$+ 20.0 \times 0.25 = 28.25 \text{ cm} > 28.0 \text{ cm}$. . . . . (1)

$H = 55.0 \text{ cm} > 47.0 \text{ cm}$ . . . . (2)

The above computation shows that the proposed pavement structure is suitable for withstanding the load from the estimated high volume of traffic in the target year.

4.8 PRELIMINARY BRIDGE DESIGN

4.8.1 Study of Superstructure

(1) Main Span of Superstructure

1) Alternative Types of Structure

The following material types of structure may be employed for the Prai River Bridge:

a. Steel Bridge
b. Prestressed Concrete Bridge
c. Reinforced Concrete Bridge

Among these three types of structure, the steel bridge or the prestress concrete bridge is more suitable for the Prai River Bridge. This is because the reinforced concrete bridge is suitable only for short span bridge. In both the steel and the prestressed concrete bridges, the following alternative types of structure are suggested considering having to provide a wide navigation span for the bridge.

Table 4.16 ALTERNATIVE STRUCTURE TYPES OF MAIN SPAN

Navigation Span Length	Structure Type
40 m	(1) Posttensioned Concrete T–Shaped Girder
70 m	(2) Posttensioned Concrete Box Girder (Cantilever girder erection)
	(3) Steel Arch (Langer Girder)
100–120m	(4) Posttensioned Concrete Box Girder (Cantilever girder erection)
	(5) Steel Arch (Tied Arch)
140–160m	(6) Posttensioned Concrete Box Girder (Cantilever girder erection)
	(7) Cable Stayed Concrete Girder

2) Comparison of Alternative Structure Types

The alternative structure types are evaluated from the following viewpoints:

a. Construction cost.
b. Implementation
c. Maintenance
d. Aesthetics
e. Driving comfort

The results of the comparative analysis of each alternative structure type are shown in Tables 4.17 and 4.18.

3) Conclusion

As a results of the comparative analysis, the following conclusions can be made:

a. From the viewpoint of minimizing construction cost, the Post-tensioned Concrete T-Shaped girder bridge is the cheapest bridge among the alternatives. The second best is the Post-tensioned Concrete Box Girder with 70 meters center span.

b. From the aspect of implementation, the steel type is superior to the others as it needs lesser number of piers in the Prai River, a shorter period for implementation etc. However, considering the construction capability of the local constructors, concrete type may be more suitable than the others.

c. From the aspect of maintenance, the Concrete bridges are clearly superior to Steel bridge.

d. From the aspect of aesthetics, the Steel Tied Arch Bridge and the P.C. Box Girder Bridge with a 140 meters center span are superior to the others.

As a results of the comparative analysis, the Posttensioned Concrete Box Girder Bridge with a 70 meters center span is recommended due to its relatively lower construction cost and lesser problems from the other standpoints.

Table 4.17 COMPARISON OF ALTERNATIVE STRUCTURE TYPES (1)

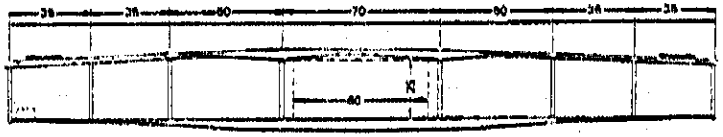
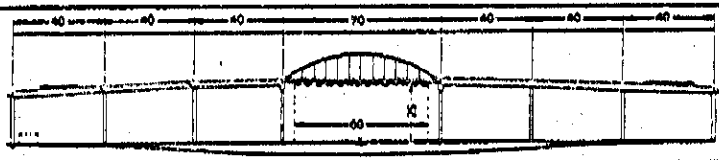
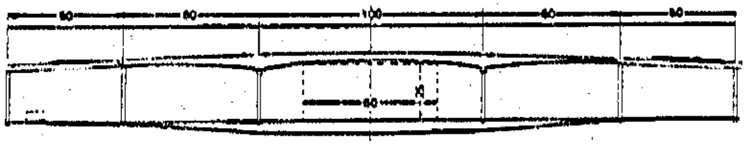
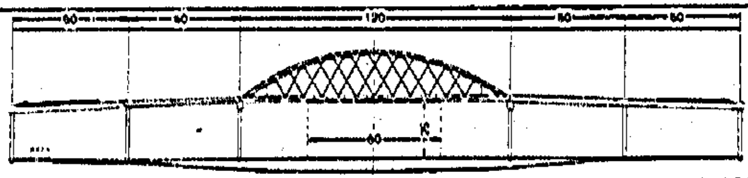
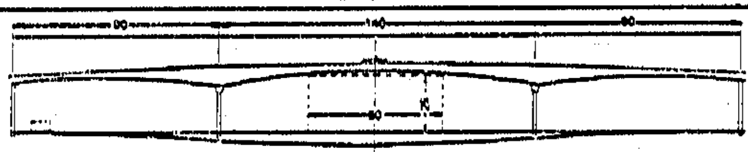
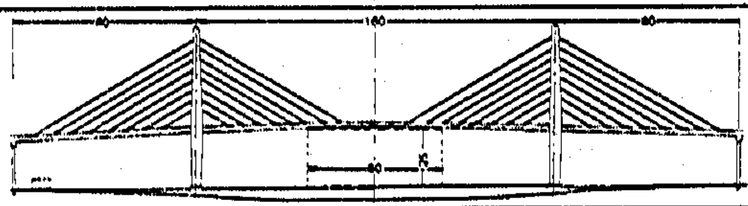
ITEM / ALTERNATIVES	PROFILE	UNIT COST (M$/m²) / TOTAL COST (M$'000): High Level	Medium Level
1. Posttensioned Concrete T-Shaped Girder		2,002 (1,160)	1,869 (1,099)
		29,634 (15,691)	17,426 (9,504)
2. Posttensioned Concrete Box Girder		2,269 (1,338)	2,146 (1,282)
		30,787 (16,339)	18,623 (10,171)
3. Steel Langer Girder		3,057 (2,029)	2,913 (1,964)
		31,159 (16,827)	19,082 (11,196)
4. Posttensioned Concrete Box Girder		2,795 (1,583)	2,691 (1,532)
		33,493 (17,674)	20,438 (11,041)
5. Steel Tied Arch		3,572 (2,483)	3,463 (2,429)
		32,835 (18,460)	20,679 (12,292)
6. Posttensioned Concrete Box Girder		3,155 (1,762)	3,104 (1,739)
		38,645 (20,575)	26,056 (14,178)
7. Cable Stayed Concrete Girder		3,593 (2,148)	3,515 (2,108)
		41,168 (22,802)	26,442 (14,234)

Table 4.18 COMPARISON OF ALTERNATIVE STRUCTURE TYPES (2)

Item / Alternatives	Engineering Considerations: Construction	Maintenance	Aesthetics	Driving Comfort
1. Posttensioned Concrete T–Shaped Girder	• Mass production of main girder is possible • Machinery for erection of girder is of relatively small scale and widely used for other projects. • Largest number of piers in the river. • Construction period is relatively short.	• Almost free	• Profile is monotonous and is not impressive	• Expansion joint that is set at each pier a discomfort for motorist
2. Posttensioned Concrete Box Girder	• Machinery for erection of girder is of relatively small scale which cannot be used for other projects. • Relatively large number of piers in the river. • Construction period is relatively long.	• Almost free	• Profile is a relatively flat arch that gives a neat appearance	• No special problems
3. Steel Langer Girder	• Erection of main bridge is easy and operated in short period	• Re-painting necessity once in every five to seven years	• Arch has a light accent but is not impressive	• This type causes a light vibration to motorist
4. Posttensioned Concrete Box Girder	• This type is given a medium evaluation between Alternative 2 and 6	• Almost free	• Same as in Alternative 2	• No special problems
5. Steel Tied Arch	• Using barges, main bridge can be erected easily and in short period • Relatively small number of piers in the river	• Re-painting necessity once in every five to seven years	• Arch presents a forceful and dynamic outlook • Diagonal rope hangers give a modern appear- ance	• No special problems
6. Posttensioned Concrete Box Girder	• Machinery for erection of girder is of relatively large scale, and cannot be used for other projects • Construction of foundation is relatively easy • Construction period is long	• Almost free	• Flat arch through the river gives a graceful and strong appearance	• No special problems
7. Cable Stayed Concrete Girder	• High technical necessity for construction • Construction of foundation is relatively easy • Construction period is long	• Almost free	• This type is of too strong design to with the surroundings	• Diagonal cables obstruct the view of the motorist

(2) Approach and Fly-Over Span of Superstructure

In order to establish the economical span length of the approach bridge, the span length ranging from 20 meters to 50 meters is examined in this study.

Among the structure types, the following types of bridge are applicable:

a. Pretensioned Girder Bridge
b. Posttensioned Hollow Slab
c. Posttensioned Concrete T-Shaped Girder
d. Posttensioned Box Girder

Fig. 4.18 shows the relationship between span length and cost per sq. meter. According to this figure, the most economical span length can be concluded to be between 30 meters to 35 meters. Therefore, the Posttensioned Concrete Hollow Slab is recommended for the approach span of the superstructure.

4.8.2 Study of Foundation

(1) Choice of Foundation Type

The foundation for the structures will have to be extended down to the older alluvial soils beneath. Piles will have to be used for the following reasons:

a. The foundations will have a relatively great depth, 40 to 50 meters. It may be too deep for both the open caisson and pneumatic caisson to be sunk.

b. The soils in which the piles are embedded have a N-Value of 25 at the most. Since the bearing resistance at the base of the foundation will be relatively small, the working vertical load on the foundation will have to depend on the skin friction around the surface of the foundation in relatively high component.

c. The caisson including the well foundation which has generally larger scale base and depends on the bearing resistance at the base in higher component than the pile, will be inferior to the pile in function.

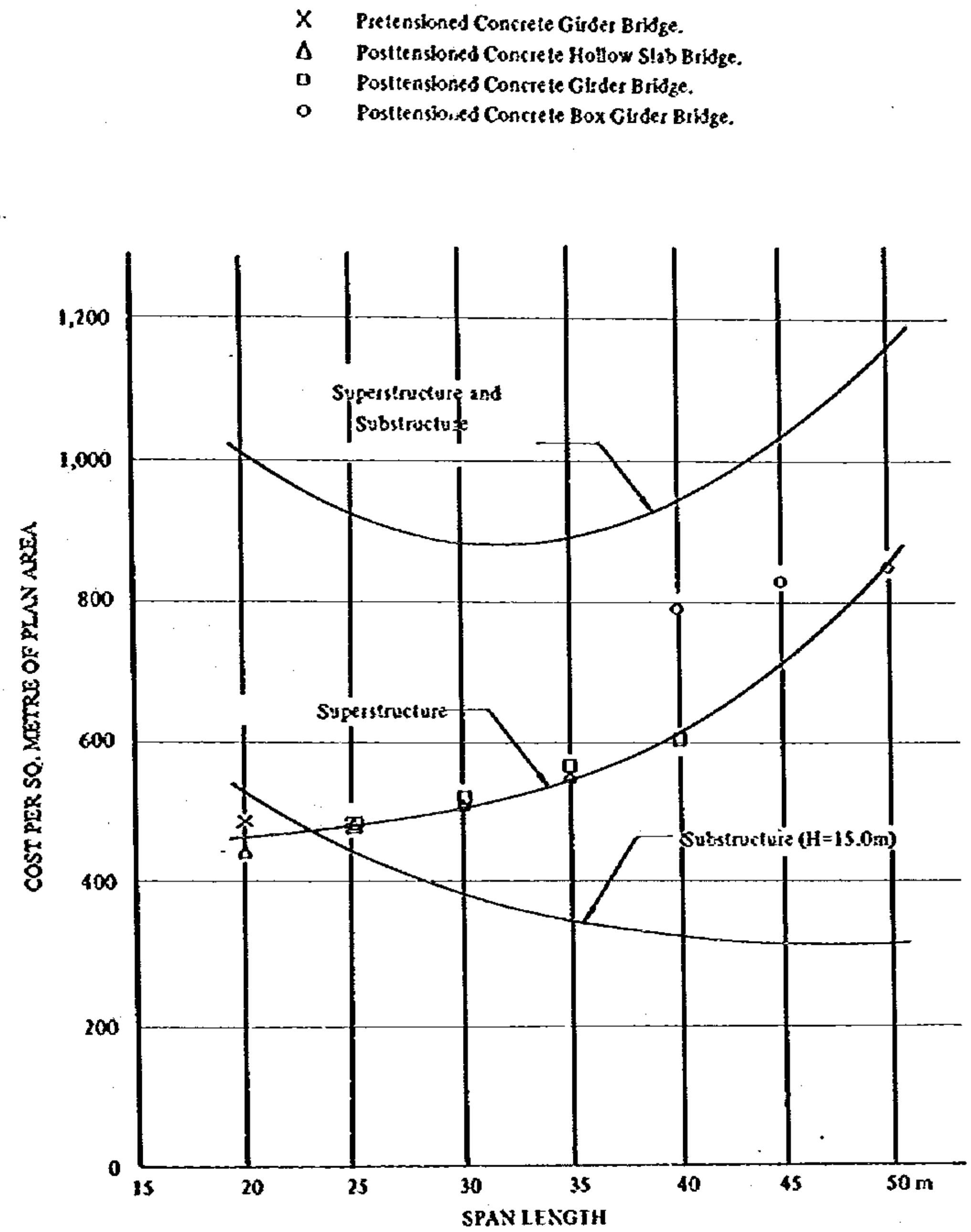


Fig. 4.18 GRAPH OF ECONOMIC SPAN LENGTH

(2) Types of Piles

In general, piles are divided into three main types, depending on their effect on the soil. They are displacement piles, small displacement piles and non-displacement piles.

1) Displacement Piles

Generally, these are applied to driven piles with the bottom end closed by a shoe or plug. driven piles have the following advantages:

a. Easy to construct.
b. Possible to check the bearing capacity of the soils.
c. Has largest bearing capacity as compared to the other types with the same diameter.

The major disadvantage of this type of pile is the great amount of noise and vibration created during construction. These include precast prestressed concrete piles, precast reinforced concrete piles and timber piles. Timber piles, however, are uncommon and rarely used in modern construction. However prestressed concrete piles have several advantages over normal reinforced concrete piles. The stresses set up can be resisted by smaller cross-sections when handling and hence, economy in materials may be achieved. The smaller cross-section may permit greater penetration. The tensile stresses caused by the action of stress waves when driving can be reduced by prestress. The reduction of tensile cracks will give greater durability to the pile.

2) Small Displacement Piles

These include open-ended rolled steel piles (driven) and screw piles. However, screw piles are uncommon nowadays for the reasons that steel or prestressed concrete piles are generally more economical and permit the work of construction to be carried out more rapidly.

Steel piles are generally used without shoes. However, if the piles are to be subjected to exceptionally hard driving, they may be strengthened at the bottom end by welding plates to increase the thickness of steel.

Open-ended steel piles are superior in penetration to the other driven piles with the bottom end closed. However, these are slightly inferior to the others in terms of compactive effect on the soils.

3) Non-Displacement Piles

These are applied to bored cast-in-place piles. These are formed by boring or other method of excavation, the borehole may be lined with a casing or tube that is either left in place or extracted as the hole is filled.

Generally, bored cast-in-place piles have the following advantages and disadvantages.

Advantages:

a. Possible to have piles in large diameter ranging from 80 to 600 centimetres.
b. Easy to vary the pile length when unexpected situations occur.
c. Almost possible to avoid noise and vibration when under construction.

Disadvantages:

a. Inferior to the driven piles in terms of compactive effect on the soils.
b. Smallest in bearing capacity as compared to the other types with the same diametre.
c. Impossible to check the bearing capacity of soils.
d. Need the equipment for disposing mud and muddy water.
e. Difficult in disposing slime that may reduce the efficiency of the piles.

Bored cast-in-place piles, generally, will be carried out by the following threee methods:

a. Earth Drilled Method
b. Benoto's Method
c. Reverse Circulation Drilled Method

Earth Drilled Method, generally, is considered to be the most economical among three types. However, it will be unsuitable for the sites that are relevant to the project for the reason that the bearing capacity of the machinery of this method will be 35 meters deep at the most.

Benoto's Method has the advantage that the borehole will be protected completely from a breakdown because it is carried out with all casing. However, this method needs the largest scall machinery, therefore, it will be unsuitable for construction in the river.

Reverse Circulation Drilled Method has the advantage of constructing the piles with no casing. However, it means a difficulty in the supervision of construction.

(3) Recommendation

Driven piles, either of precast prestressed concrete piles (bottom end closed) or open-ended rolled steel piles are recommended to be used for the following main reasons:

These types will be constructed more easily and in a shorter period than bored cast-in-place piles, and will give a larger bearing capacity and a more certain security for the bearing capacity designed. Moreover, there will be no problem in disposing the mud and muddy water.

Precast prestressed concrete piles is recommended for the following reasons:

a. More economical than steel piles.

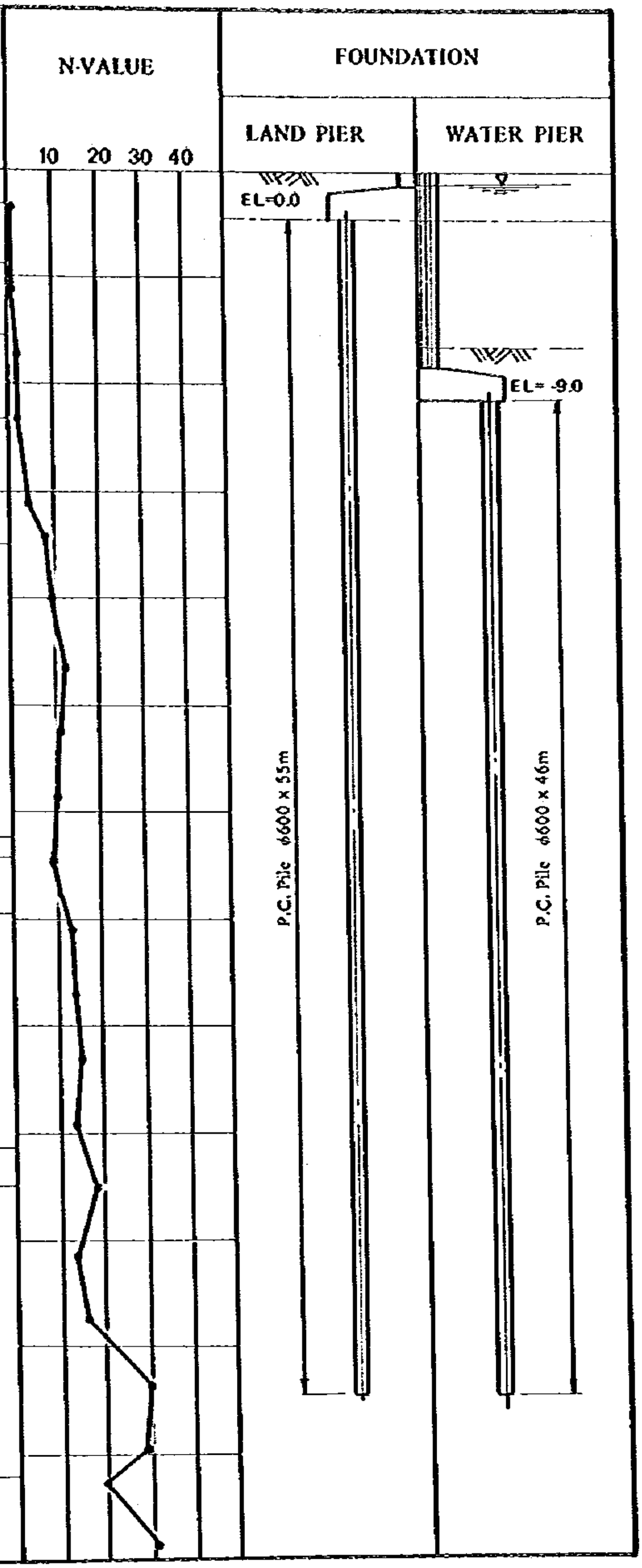
b. Produced in large quantities in Malaysia, hence it will have a lower component of foreign costs than steel piles.

c. Almost free from corrosion.

The recommended type of foundation is shown in Table 4.19.

Table 4.19 RECOMMENDED FOUNDATION

DEPTH (m)	TYPE OF SOIL	CONDITION
EL= 0.0	Sand with Shell	Very Loose
5	Silty Clay	Very Soft
10	Silty Clay with Sand	Very Soft
	Silty Clay	Soft
15	Silty Sand	Loose
20, 25, 30	Silty with Gravel	Medium to Loose
	Sandy Clay	
	Silty Clay	Stiff
35, 40, 45	Sand with Gravel	Medium
	Silty Clay	
50, 55, 60	Sand with Clay and Gravel	Medium
	Sandy Clay	Very Stiff to Hard



4.9 ENVIRONMENTAL CONSIDERATIONS

4.9.1 Objectives of the Study

The objectives of the environmental study is to minimise the unexpected environmental and social conflicts which will probably be generated by the Project Road.

The study consists of three major objectives which are:

a. To establish environmental indicators and preliminary analysis.

b. To assess the roadside environment in terms of environment protection.

c. To set planning and designing measures in order to mitigate foreseeable environmental disturbances.

4.9.2 Establishment of Environmental Indicators and Preliminary Analysis

The following environmental indicators are established and they are classified into two categories, physical indicators and social and economical indicators.

1) Physical Indicators

   a. Biology and ecology (flora, fauna and aquatic)

   b. Topography and geology (land scape and soil condition)

   c. Hydrography (drainage, underground water and floods)

   d. Meteorology (climate and weather)

   e. Traffic nuisance (noise, air pollution, vibration and other nuisance factors)

   f. Traffic accident

   g. Construction nuisance

2) Social and Economical Indicators

   a. Transport mobility and accessibility

   b. Land use potentiality

   c. Population distribution

   d. Tourism and recreation

   e. Historical and cultural sites

   f. Urban townscape

   g. Community cohesion

   h. Resident displacement

i. Agricultural and industrial production

j. Land price

k. Prices of commodities

The following corridors of the Project Road are taken into consideration in the analysis:

a. Prai Corridor

b. Southern Butterworth Corridor

c. Northern Butterworth Corridor

d. Sungai Dua Corridor

e. Other Study Areas

The environmental analysis is made for the following two time periods:

a. During Construction

b. After Opening of the Project Road

The preliminary qualitative analysis for the foreseeable effects of the Project Road on the above environmental indicators is carried out and the foreseeable magnitude matrix composed of environmental indicators and individual components is obtained as shown in Table 4.20. In this analysis, the magnitude is classified into three grades.

The result of this preliminary analysis shows that the Project Road will have favourable effects on transport mobility and accessibility, land use potentiality, townscape and land price. On the other hand, there will be adverse effects of traffic nuisance, construction nuisance, community cohesion, resident displacement and agricultural production.

These foreseeable effects and the probable mitigation measures for the adverse effects are discussed in Section 4.9.3 and 4.9.4.

Table 4.20 MAGNITUDE MATRIX

Category	Environmental Indicator	During Construction					After Opening				
		Prai	B'worth South	B'worth North	Sungai Dua	Other Area	Prai	B'worth South	B'worth North	Sungai Dua	Other Area
Physical	Biology and ecology										
	Topography and geology										
	Hydrography										
	Meteorology										
	Traffic nuisance	−	−	−			−	−	−	−	
	Traffic accident	−	−	−			+	+	+	+	
	Construction nuisance	−	−	−	−						
Social and economical	Transport mobility and accessibility	−	−	−			+	+	+	+	+
	Land use potentiality						+	+	+	+	+
	Population distribution								+	+	
	Tourism and recreation								+		
	Historical and cultural sites										
	Townscape	−	−						+	+	
	Community cohesion		−					−			
	People displacement	−					−	−	−		
	Shifting of Shipyards	−					−			−	
	Agricultural Production				−					−	
	Industrial Production						+	+			
	Land price						+	+	+	+	
	Prices of commodities										

(+) Favourable effect ( ) No change (−) Adverse effect

4.9.3 Favourable Effects

(1) Transport Mobility and Accessibility

At present, the Federal Route 1 exists along the Project Road but it does not function effectively due to the partially narrow carriageway width. Therefore, the Project Road is expected to enhance and strengthen the function of the road network system in Butterworth.

Moreover, the establishment of the Project Road will improve traffic services in the corridors, and reduce traffic congestion within the urbanized area. Accordingly, transport mobility and accessibility of the corridors along the Project Road will be improved because travel time and cost will be reduced.

(2) Land Use Potentiality

The improvement on mobility and accessibility will undoubtedly enhance land use potentiality and land value as it is generally contended that the value of land will increase in proportion with mobility and accessibility.

(3) Townscape

Road is a very important townscape component. The Project Road will not only handle the expected high volume of future traffic in the area but will also change the townscape to a more comfortable and orderly urban environment.

Moreover, the provision of an open space along the seashore in the plan will provide an easily accessible place for both active and passive recreation to the inhabitants of Butterworth.

(4) Land Price

As mentioned earlier, the improvement in accessibility will definitely induce enhancement in land use potentiality. There will be an increase in demand due to favourable conditions of location and thus there will occur an increase in the land value of the surrounding areas of the Project Road.

4.9.4 Measures for an Improved Environmental Quality

(1) Effects on Biological, Ecological and Hydrographical Conditions

There will be no critical effect on the topographical, geological, ecological and meteorological conditions as the surrounding area of the Project Road is already a stable and developed or developing area.

(2) Traffic Nuisance

The surrounding communities may be constantly inconvenienced by noise, air pollution, vibration and other nuisances caused by the Project Road.

1) Measures

However, traffic nuisance cannot completely be shut out for the time being, and adequate measures such as the provision of a buffer zone and tree planting should be provided especially in residential areas and near schools.

Therefore, an 8.25- meter sidewalk and 4.0 meter median strip for the residential area have been proposed as the basic requirements in the cross-section recommended. (See Fig. 4.19). This ample provision of space will ensure adequate planting in reducing traffic noise, pollution and glare.

(3) Construction Nuisance

The surrounding communities may be inconvenienced during the construction stage, by noise, gas, fumes, dust and dirt caused by the unstable and abnormal conditions incidental to construction activities. Moreover, the migratory workers having to stay on site during the construction may place a strain on the existing services and facilities, and aggravate public health in the area.

1) Measures

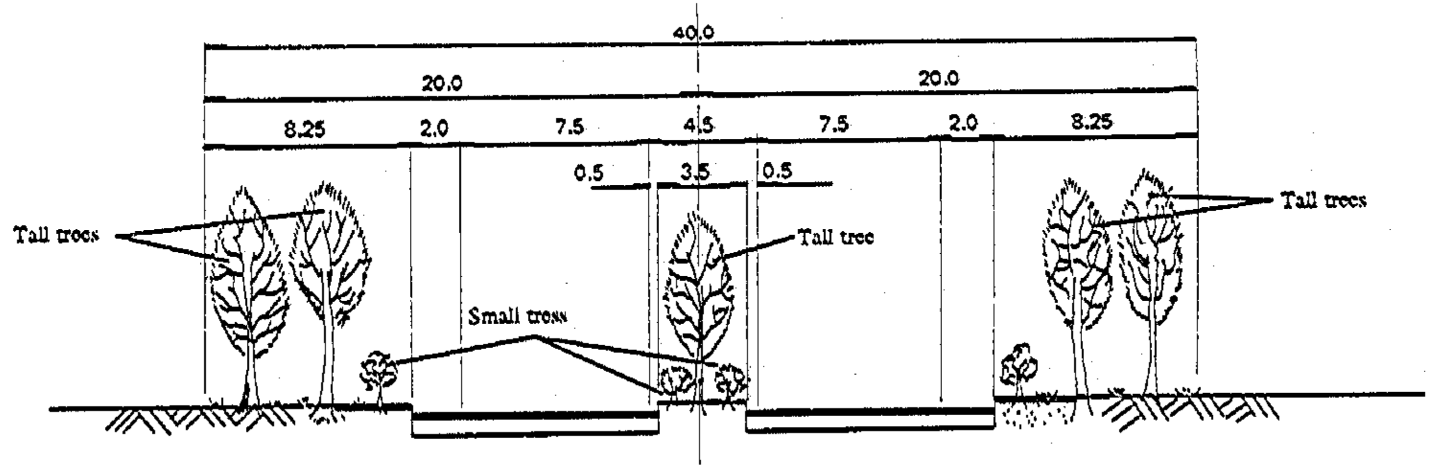
Nuisance and inconvenience during construction can be significantly reduced by the introduction of proper construction management and supervision and the adoption of proper construction equipment and methods. Against the latter problem, the Government and the contractors should collaborate in providing the necessary extra services and facilities.

(4) Resident Displacement

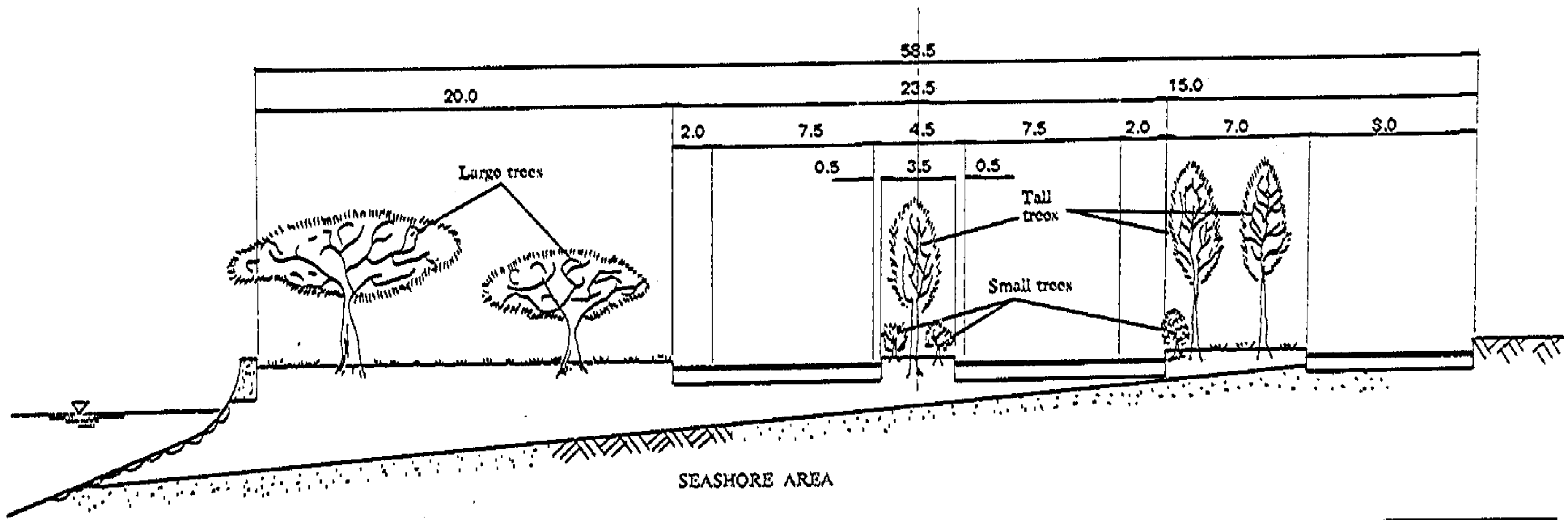
The existing residential development along the proposed alignment will have to be removed in accordance with the right-of-way acquisition of the Project Road. Total number of approximately 490 houses including 250 houses in the squatter area will be displaced.

1) Measures

The displaced families will be sufficiently compensated by resettlement to an acceptable area and/or by adequate monetary compensation. The squatter families affected by the project roads will be offered better opportunities and improved quality of life in the resettlement projects of the Government.



RESIDENTIAL AREA



SEASHORE AREA

Fig. 4.19 TYPICAL CROSS-SECTION FOR ENVIRONMENT PROTECTION

5 . TRAFFIC ASSIGNMENT TO ALTERNATIVES

5.1 GENERAL

5.1.1 Procedure

The procedure for traffic assignment to the alternatives of the Project Road is shown in Fig. 5.1.

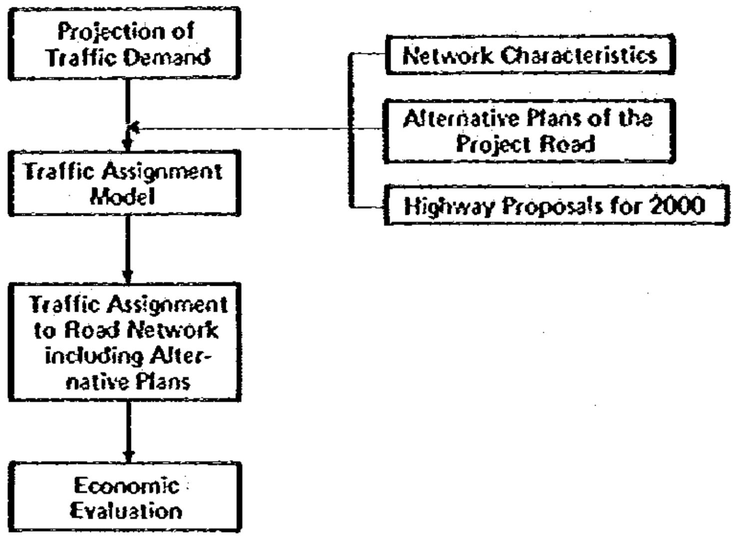


Fig. 5.1 PROCEDURE FOR TRAFFIC ASSIGNMENT

5.1.2 Highway Network

(1) Committed Projects

Prior to the formulation of the highway network, the committed highway projects in the study area are identified as follows:

a. Toll Expressway (Alor Star – Chankat Jering Highway).

b. Penang Bridge which connects Province Wellesley and Penang Island.

c. East-West Highway Supporting Road.

d. Prai Barrage Approach Road.

(2) Alternatives of the Project Road

Six (6) alternative routes of the Project Road selected from the alternative route study which were made in the engineering study, are shown in Fig. 5.2.

a. Route I : The route passes through routes A, D and E combination and route G.

b. Route II : The route passes through route A, D and G.

c. Route III : The route passes through routes B, D and E combination and route G.

d. Route IV : The route passes through routes B, D and G.

e. Route V : The route passes through routes C, D and E combination and route G.

f. Route VI : The route passes through routes C, D and G.

(3) Highway Networks

The highway networks incorporated with the committed projects and the alternatives of the Project Road are formulated in this study.

5.2 TRAFFIC ASSIGNMENT MODEL

(1) Traffic Assignment Model

In order to calculate the traffic volume on the Project Road, the following traffic assignment model is used.

a. For each link of the network to which vehicles are assigned, the relationship between traffic volume and travel time is established. In this relationship, travel time increases with the increase in traffic volume. When the traffic volume exceeds the rated capacity, the travel time increases sharply which limits the further rise of traffic volume.

b. It is assumed that an O–D pair traffic volume is assigned on route of minimum travel time (or cost).

c. Vehicular O–D traffic volume is first divided into 2 categories (motor-cars and motor-cycles). A 20% of the volume is first assigned to the road network and the resultant travel time is computed for each link. The next step is to assign a further 20% of the traffic volume to the network and a new set of resultant travel time is computed for all the links. This process is repeated until all the volume has been assigned and the final travel time calculated.

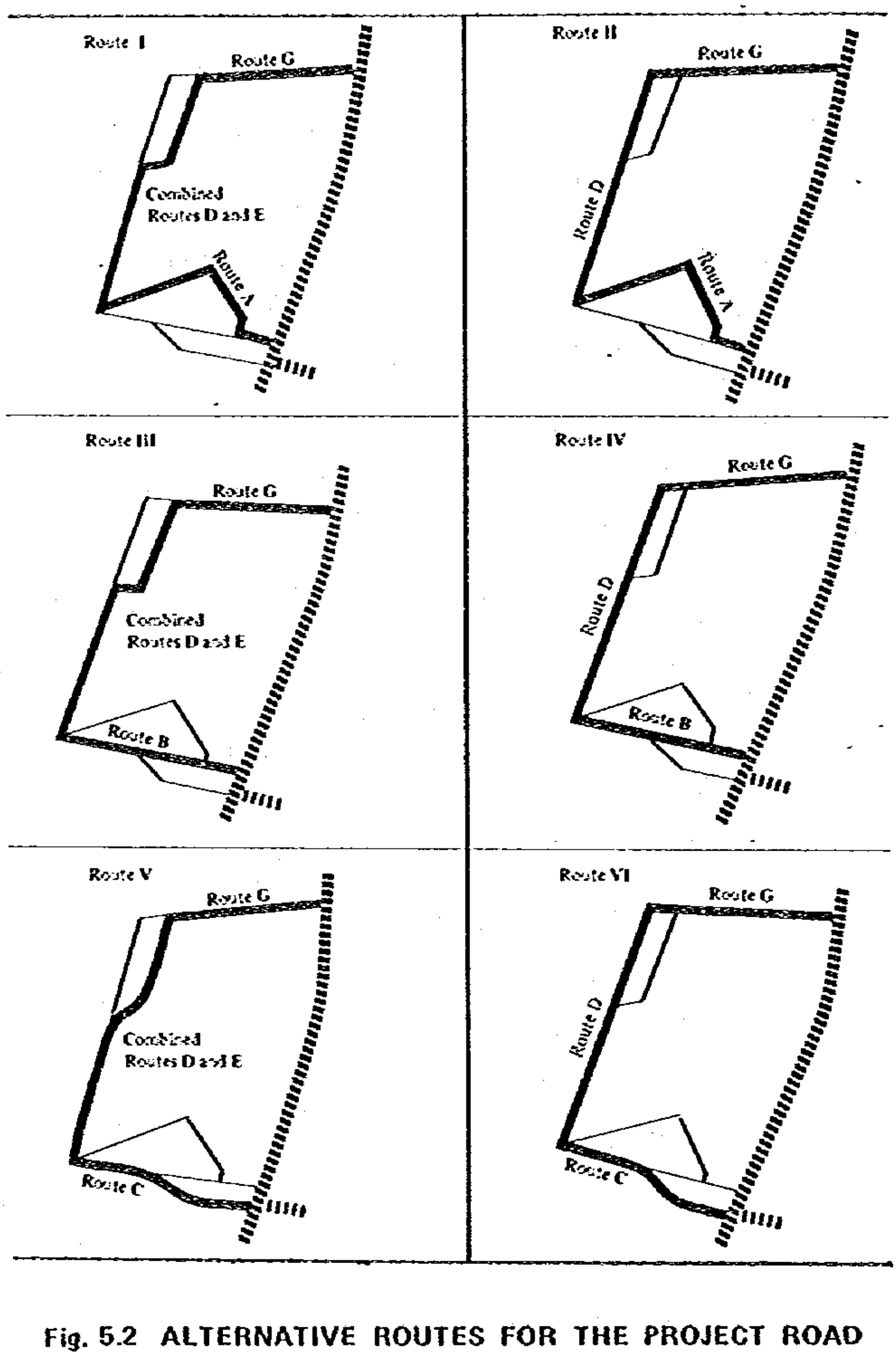


Fig. 5.2 ALTERNATIVE ROUTES FOR THE PROJECT ROAD

(2) Highway Network Data

Based on the highway network discussed in Section 5.1.2, the highway network data which comprises the highway type and the type of Q–V formula are prepared in order to compute traffic volume. Each link of the highway network is classified using the classification of highway type as shown in Table 5.1 and is prepared for the Q–V type as shown in Fig. 5.3.

Table 5.1 CLASSIFICATION OF ROAD TYPE

Class	Number of lane	2–lane			4–lane		6–lane
	Effective width of carriageway in feet	20'	22'	24'	44'	48'	72'
A	Urban Motorway	–	–	–	–	4–A	6–A
B	All purpose road with no standing vehicles permitted and negligible across traffic	$2–B_3$	$2–B_1$	$2–B_2$	$4–B_1$	$4–B_2$	6–B
C	All purpose street with no restrictions at junctions	$2–C_3$	$2–C_1$	$2–C_2$	$4–C_1$	$4–C_2$	–
D	All purpose street restricted by junctions	$2–D_3$	$2–D_1$	$2–D_2$	$4–D_1$	$4–D_2$	–

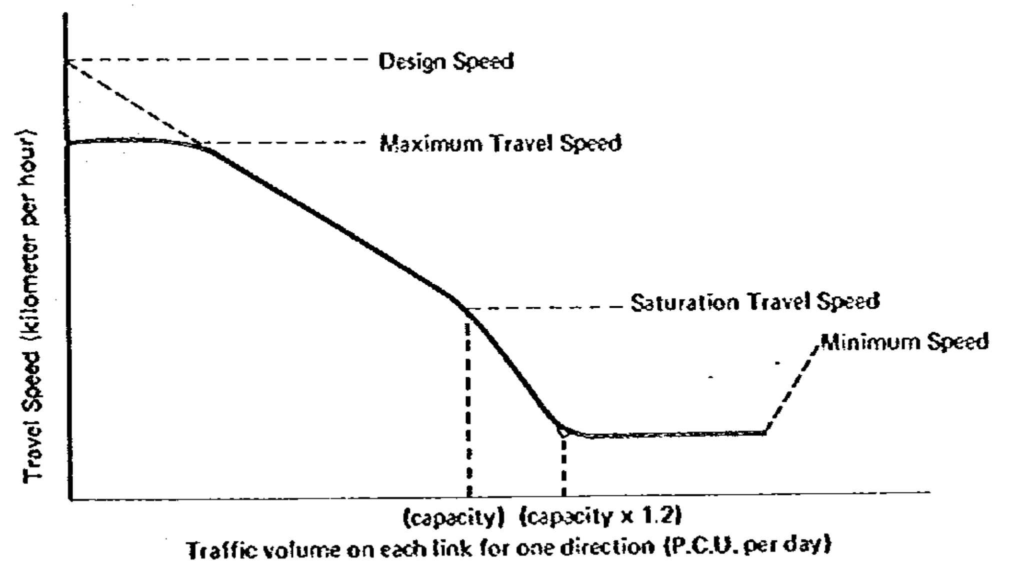


Fig. 5.3 Q–V FORMULA

Table 5.2 TRAVEL SPEED AND CAPACITY BY ROAD TYPE

(Unit: kms/Hr.)

No. of Lane	Type of Road	Maximum Travel Speed	Saturation Travel Speed	Minimum Travel Speed	Travel Capacity/ day (P.C.U.)
6	6–A	60	20	10	81,000
	6–B	60	20	10	65,000
4	$4-A_0$	50	15	7	55,900
	$4-B_0$	50	15	7	45,000
	$4-B_1$	50	15	7	40,900
	$4-C_0$	40	15	7	36,700
	$4-C_1$	40	12	7	31,700
	$4-D_0$	40	12	7	28,400
	$4-D_1$	40	12	7	25,000
2	$2-B_0$	40	15	5	25,000
	$2-B_1$	40	15	5	22,600
	$2-B_2$	35	12	5	20,100
	$2-C_0$	40	15	5	20,100
	$2-C_1$	35	12	5	16,700
	$2-C_2$	30	12	5	12,500
	$2-D_0$	35	12	5	15,100
	$2-D_1$	30	12	5	10,800
	$2-D_2$	30	10	5	6,700

5.3 RESULTS OF TRAFFIC ASSIGNMENT

5.3.1 Traffic Volume on the Project Road

Regarding to Route IV having mainly four (4) – lanes, it is estimated that the daily vehicle kilometer in 1990 and 2000 is expected to be 404 thousand P.C.U. kms and 538 thousand P.C.U. kms, respectively. The daily traffic volume on the Project Road in 1985 and 2000 is expected to be 92 thousand P.C.U. and 136 thousand P.C.U., respectively.

The average annual growth rate during 1985 – 2000 will be about 4.0 per cent per annum. (See Table 5.3)

Table 5.3 DAILY TRAFFIC VOLUME ON THE PROJECT ROAD

Alternative Route	Year	Traffic Volume ('000 P.C.U.)	Vehicle Kilometer ('000 P.C.U.–kms)
Route III with 4-lane and full access inter-change	1990	95.9	381.2
	2000	146.9	539.5
Route IV with 4-lane and full access inter-change	1990	91.7	403.6
	2000	135.7	538.4

Fig. 5.4 illustrates the flow of the daily traffic volume on road network. From this figure, the following observations can be obtained:

a. The assigned traffic volume on the Project Road is comparatively large; especially, that on the Prai River Bridge where in the year 2000 it is expected to be 54.4 thousand P.C.U.

b. The projected traffic volume of the southern section (Section 1) is larger than that of the northern section (Section 2).

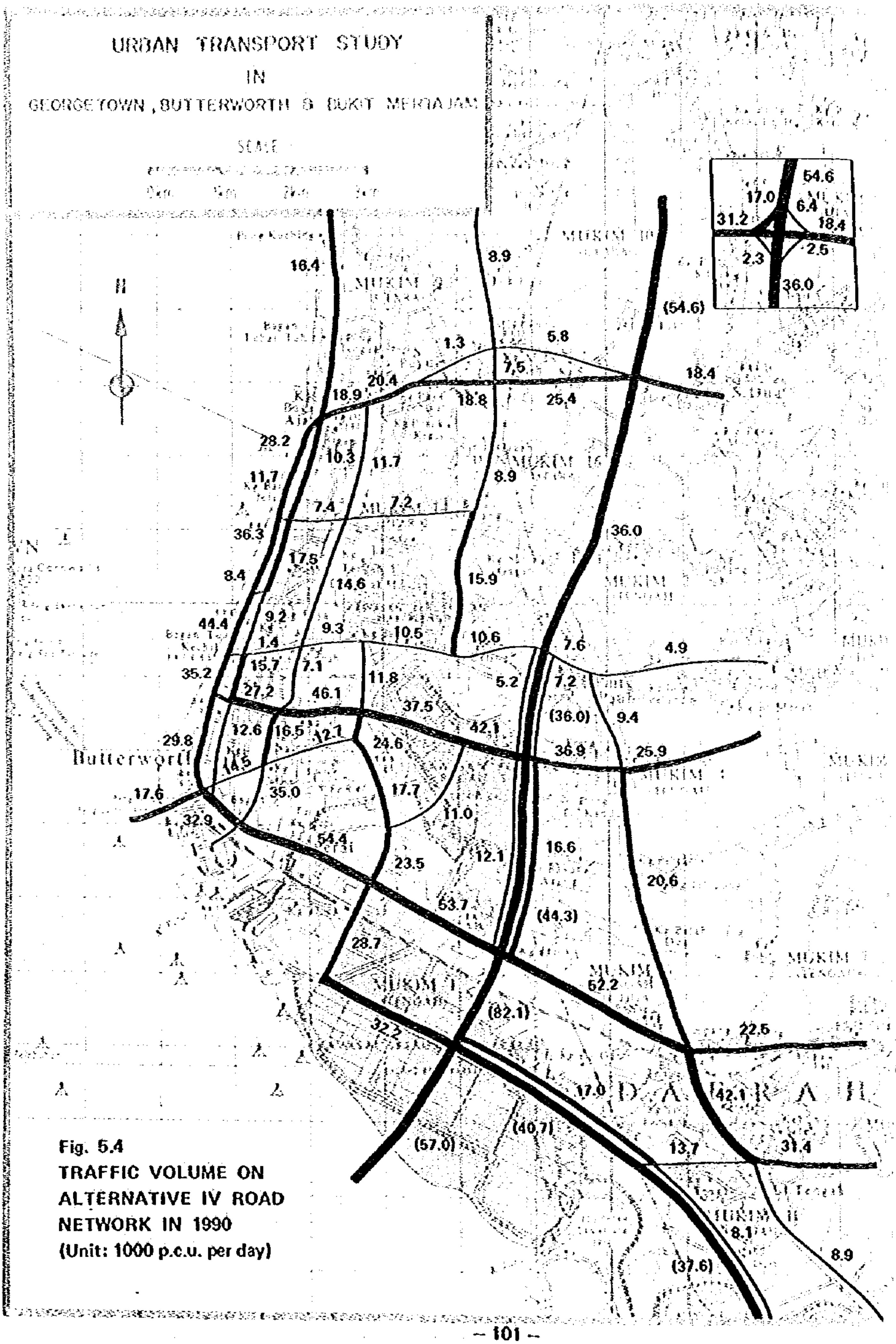


Fig. 5.4
TRAFFIC VOLUME ON ALTERNATIVE IV ROAD NETWORK IN 1990
(Unit: 1000 p.c.u. per day)

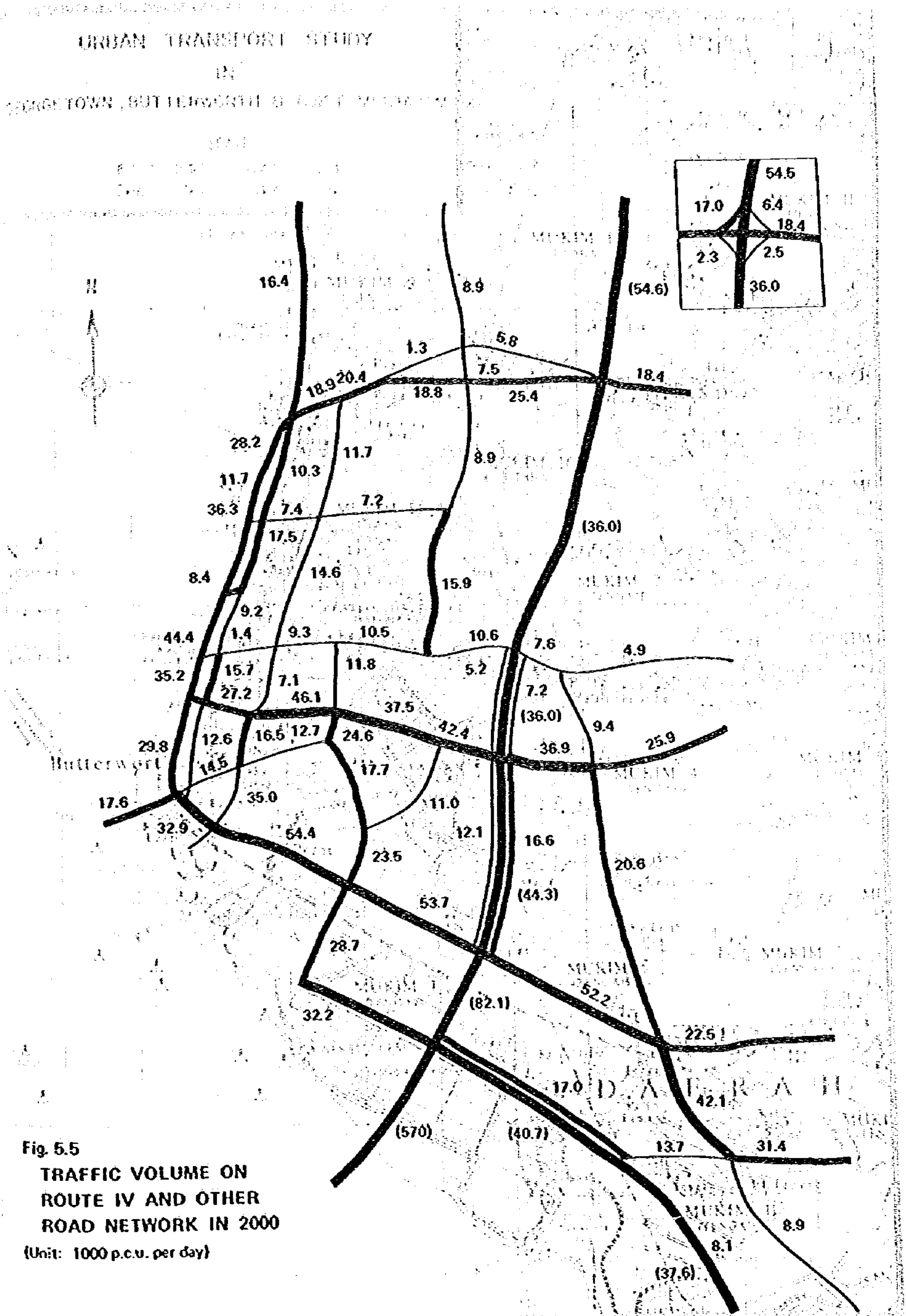


Fig. 5.5
TRAFFIC VOLUME ON ROUTE IV AND OTHER ROAD NETWORK IN 2000
(Unit: 1000 p.c.u. per day)

5.3.2 Comparison of Alternative Routes

Table 5.4 shows the congestion rates of alternative routes. Judging from the congestion rates, Route IV is clearly superior to the other alternative routes, especially in reducing the congestion rate in the C.B.D. of Butterworth.

Regarding Route I or Route II (passing along the existing Federal Route 1), its congestion rate is outstandingly higher than the other alternative routes.

Table 5.4 CONGESTION RATE BY ALTERNATIVE PLANS

Items		Alternative Route						Base Case
		Route I	Route II	Route III	Route IV	Route V	Route VI	
C.B.D.	Road Capacity	526.9	526.9	539.6	539.6	639.6	539.6	398.1
	Congestion Rate	0.68	0.68	0.59	0.59	0.61	0.61	0.95
Area affected by the Project road	Road Capacity	1894.5	2011.6	1863.5	1980.6	1801.6	1918.7	1371.6
	Congestion Rate	0.69	0.67	0.62	0.59	0.63	0.61	0.90
Study Area	Road Capacity	7533.3	7650.4	7602.4	7719.6	7543.9	7661.0	7010.5
	Congestion Rate	0.64	0.63	0.62	0.61	0.62	0.61	0.69

Note:

$$\text{Congestion Rate} = \frac{\text{Running vehicle-kilometers of traffic volume through the area excluding internal trips of the area}}{\text{Total of traffic capacity of roads in the area including the B.R.R. (road lengths x road capacities)}}$$

5.3.3 Effects of the Project Road

(1) Reduction of Congestion Rate and Increase of Travel Speed

Compared with the base case where the Project Road will not be constructed, the Route III or IV are verified in being effective in decreasing the traffic congestion as well as increasing the travel speed as shown in Fig. 5.6.

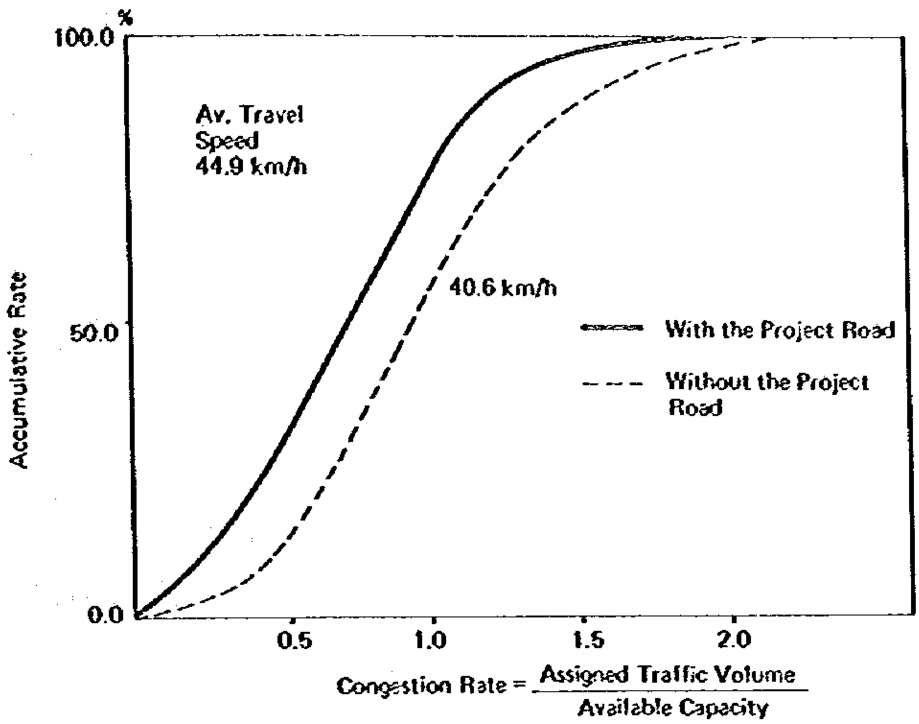


Fig. 5.6 DISTRIBUTION OF CONGESTION RATE ON ALL LINKS (YEAR 2000)

(2) Improvement of Accessibility

The construction of the Project Road will improve the accessibility to each zone in terms of convenience of travel. The accessibility is calculated by the following formula and is shown in Fig. 5.7.

$$Ai = \sum_{j=1}^{n} (Pj \times tij) / \sum_{j=1}^{n} Pj$$

where Ai : accessibility of zone i

Pj : population of zone j

tij : travel time between zone i and zone j

With the construction of the Project Road, 23 out of the 50 traffic zones will have "relatively good" or "good" accessibility. In other words, 46% of the traffic zones will have good accessibility as compared to only 23% without the Project Road.

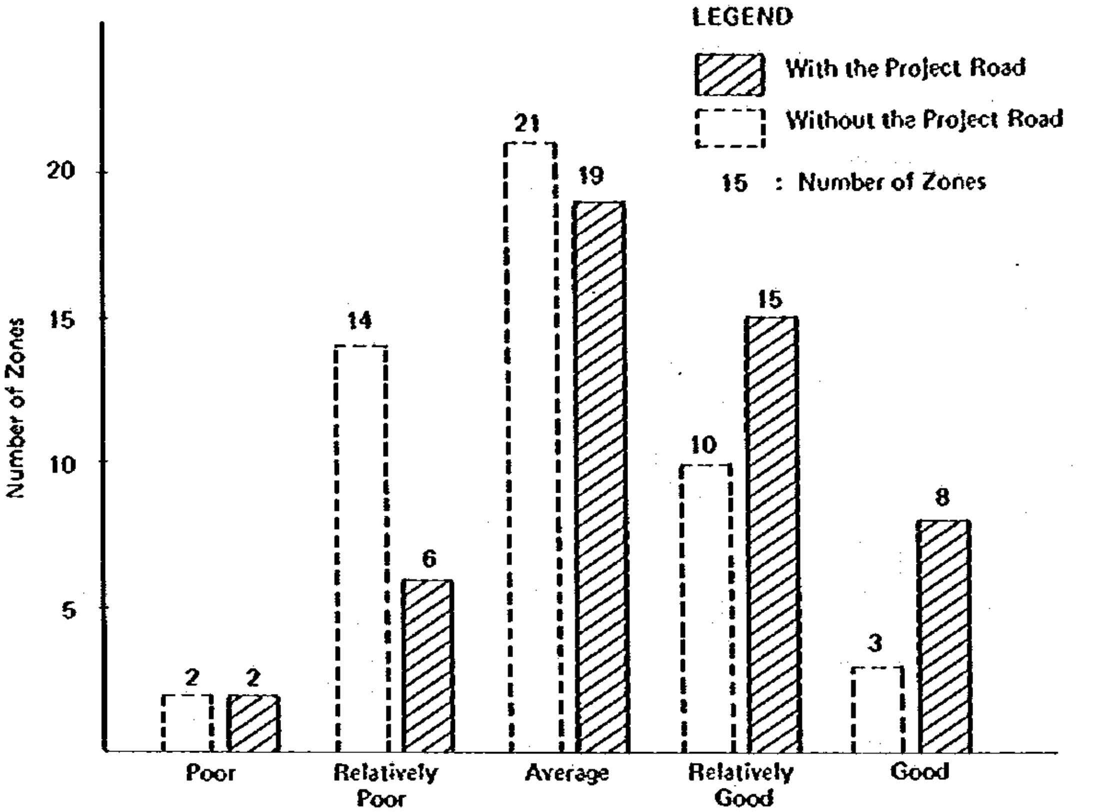


Fig. 5.7 DISTRIBUTION OF ACCESSIBILITY BY ROAD NETWORK

6. ESTIMATION OF THE PROJECT COST

6.1 GENERAL

The project cost is calculated using the same framework as Stage I of the Phase II Study (the Outer Ring Road Project in Penang) which was conducted in 1980, with reference to the Interim Report of the Feasibility Study of the East-West Highway, Draft Final Report of the Inter-Urban Toll Expressway, Penang Bridge Report and the North Coastal Road Report. The project cost presented in this report is expressed in 1981 prices.

6.1.1 Procedure for Cost Estimation

The cost estimation process is shown in Fig. 6.1.

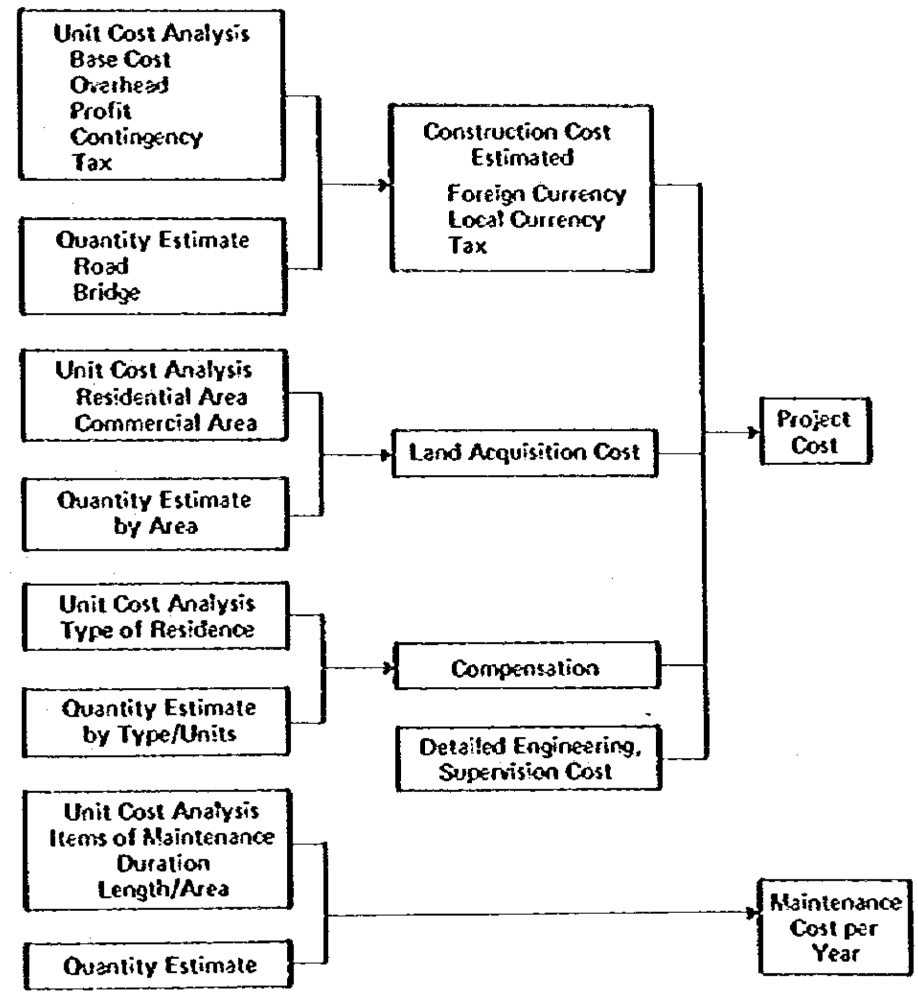


Fig. 6.1 PROCEDURE FOR COST ESTIMATION

.1.2 Components of the Project Cost

(1) Conditions

The project cost is calculated with the following conditions:

a. The construction cost is to be presented in Malaysian dollars. (Ringgit) (M$)

b. Cost estimates are to be carried out based on 1981 prices.

c. The construction cost is to be split into Foreign currency, Local currency and Tax.

(2) Base Cost

Base cost consists of:

a. The cost of labour.

b. The equipment and material for construction.

c. Other necessary items.

(3) Construction Cost

Construction cost consists of:

a. Base cost

b. Overhead cost

c. Profits of contractor

d. Contingency

e. Tax

(4) Foreign Currency

Foreign currency is incurred on:

a. Costs of imported machineries (CIF price), and materials such as steel products and others.

b. A portion of the detailed engineering and supervision service fees.

c. A portion of the overhead, profit and contingency costs.

(5) Local Currency

Local currency is incurred on:

a. The purchase of domestic products such as cement, soil, sand etc.

b. A portion of the detailed engineering and supervision service fees.

c. Labour cost and transport cost.

d. Cost of land acquisition and compensation.

(6) Land Acquisition Cost and Compensation

The land acquisition cost and compensation comprises of:

a. Land acquisition cost

b. Compensation
   - Houses
   - Dockyard

The cost belongs to the category of local currency.

(7) Other Cost

The following cost is also included in this study:

a. Detailed Engineering

b. Construction Supervision

6.2 UNIT COST ANALYSIS

6.2.1 Components of Unit Cost

The unit cost itself is also split into three parts, as foreign currency, local currency and tax. The foreign currency and local currency includes four components, namely base cost, overheads, profit of contractor and contingency. The percentage distribution of the above components is assumed and is shown in Table 6.1.

Table 6.1 PERCENTAGE OF COST COMPONENTS

Item	Percentage (%)
Base Cost	100
Overheads	10
Profit of contractor	10
Contingency	5

6.2.2 Labour Cost

Based on data collected, the unit labour cost is set up and is shown in Table 6.2.

Table 6.2 LABOUR COST

(In M$ at 1981 prices)

Items	Unit Cost per 8 hours day
1 General Labourer	20.0
2 Concrete Labourer	23.0
3 Mason	22.0
4 Mason's Labourer	20.0
5 Carpenter	30.0
6 Carpenter's Labourer	20.0
7 Steel Bender and Fixer	23.0
8 Pneumatic Tool Operator	22.0
9 Fitter	35.0
10 Welder	30.0
11 Painter	23.0
12 Truck Driver	30.0
13 Earth Moving Equipment Operator	35.0

6.2.3 Cost of Construction Material

The cost of major materials for construction is derived after discussion with the State JKR and other related government and private offices.

The cost list of the major materials is shown in Table 6.3.

6.2.4 Construction Equipment

The unit cost of various plants in Malaysia was analysed recently. Based on this information, the cost performances of the plants which are considered suitable for the Project Road construction in its size and capacity range are described as follows:

a. Service life of plant – 8 years.

b. Working hours per annum – 2,160 hrs.

c. Interest per capital outlay – 8%

d. Spare parts cost per annum – 5% of initial cost of plant.

e. Maintenance and repairs – 5% of the initial cost of plant.

f. Average plant efficiency – 70%

6.2.5 Result of Unit Cost Analysis

The result of unit cost analysis is shown in Table 6.4. This unit cost consists of base cost, overhead, profits of contractor and contingency.

Table 6.3 COST LIST OF MAJOR MATERIALS

(In M$ at 1981 prices)

Material	Description	Unit	Market Cost
Soil	Red Earth	m^3	0.7
Sand	25 – 5	m^3	20.9
	40 – 5	m^3	20.9
Crushed Stone	Granite dust	m^3	12.0
	∅ 20	m^3	30.1
	∅ 40	m^3	23.5
	∅ 150 200	m^3	17.0
Concrete	1 : 3 : 6	m^3	141.3
	1 : 2 : 4	m^3	182.0
	1 : 1½ : 3	m^3	234.0
Cement	Poltland	50 kg.	9.3
Asphalt	Grade (80 – 100)	T	491.8
	Cut Back Bitumen	T	609.8
P.C Pile (class Y)	∅ 150	1.83 m	34.5
	∅ 300	1.83 m	48.5
	∅ 450	1.52 m	70.0
	∅ 600	1.52 m	98.5
	∅ 900	1.52 m	187.5
	∅ 1050	1.52 m	237.0
	∅ 1200	1.52 m	294.0
	∅ 1350	1.52 m	361.0
	∅ 1500	1.52 m	430.0
Steel Bar	∅ 9	t	924.0
	∅ 13	t	938.0
	∅ 16 – 25	t	829.0
	∅ 32	t	827.0
Wood Pile	∅ 100	4 m	98.0
Steel Angle	V Type	t	1,015
	H Type	t	1,403
	L Type	t	1,137
Steel Pipe	∅ 240	m	80.0
Frame Work	Wood	m^2	10.8
Guard Rail	Steel	m	60.3
Lamp Post	Steel (10 m)	Vol.	406.8
	Steel (10 m)	Vol.	447.5
Kerb	Concrete	m	13.0
Gas Oil	Diesoline	liter	0.403
	Fuel oil	liter	0.46
	Petrol	liter	1.02

Table 6.4 RESULTS OF UNIT COST ANALYSIS
(In M$ at 1981 prices)

Items	Sub-Item	Class	Unit	Unit Cost			
				F.C.	L.C.	Tax	Total
Site clearing	Residential	–	m^2	1.90	1.26	0.16	3.32
	Field	–	m^2	0.26	0.17	0.02	0.45
Excavation	Soil	Common	m^3	1.24	0.89	0.11	2.24
Waste	- do -	- do -	m^3	1.74	1.89	0.29	3.92
Embankment	- do -	- do -	m^3	3.85	1.46	0.51	5.82
Slope		Grass	m^2	0	5.25	0.30	5.55
Turfing	Sidewalk	Tree	m^2	1.26	4.94	0.32	6.52
	Open Space	Grass	m^2	0	5.25	0.30	5.55
Drainage	Roadside	0.5 x 1.0	m	46.78	90.58	5.65	143.01
	Pipe Culvert	D = 600	m	46.21	77.71	5.23	129.15
	Box Culvert	2.0 x 3.0	m	489.60	577.43	58.50	1,125.53
		3.0 x 3.0	m	612.00	721.79	73.12	1,406.91
	Water Pipe	D = 24'	m	239.30	91.33	14.59	345.22
Wall	Masonry	Stone	m^2	26.21	64.03	6.26	96.50
	Revetment	Stone	m	818.70	1,169.70	132.70	2,121.10
Pavement	Carriageway	Asphalt	m^2	17.49	12.76	1.43	31.68
	Shoulder	Asphalt	m^2	13.64	9.13	1.10	23.87
	Service Road	Asphalt	m^2	13.64	9.13	1.10	23.87
	Sidewalk	Block	m^2	5.49	7.61	0.62	13.72
	Overlay	Asphalt	m^2	11.00	8.00	1.00	20.00
Facility	Kerb	Concrete	m	8.54	14.52	1.16	24.22
	Central Spilt	Concrete	m	20.86	43.86	3.28	68.00
	Guard Rail	Steel	m	44.11	3.22	6.23	53.56
	Lighting	Steel	m	40.00	19.00	7.00	66.00
	Lane-Marks	Paint	m	0.50	0.60	0.05	1.15
Intersection	At-Grade		Vol	32,976	64,506	2,922	100,404
	Interchange	Diamond	Vol	357,359	303,075	46,703	707,137
		Loop	Vol	1,629,159	1,467,567	164,643	3,261,369
Approach Road			m	462.46	498.20	48.71	1,009.37

Note: F.C. : Foreign Currency
L.C. : Local Currency

6.3 CONSTRUCTION QUANTITIES ESTIMATE

6.3.1 General

On the basis of the preliminary design on the map using a scale of 1 to 3,000, the construction quantities are estimated.

Highway construction quantities are estimated by each segment. The segments of the road are shown in Fig. 6.2 and bridge construction quantities are estimated by main bridge and other bridges.

6.3.2 Construction Quantities

The road construction quantities are calculated by each segment as shown in Tables 6.5 and 6.6 and the bridge construction quantities are shown in Table 6.7.

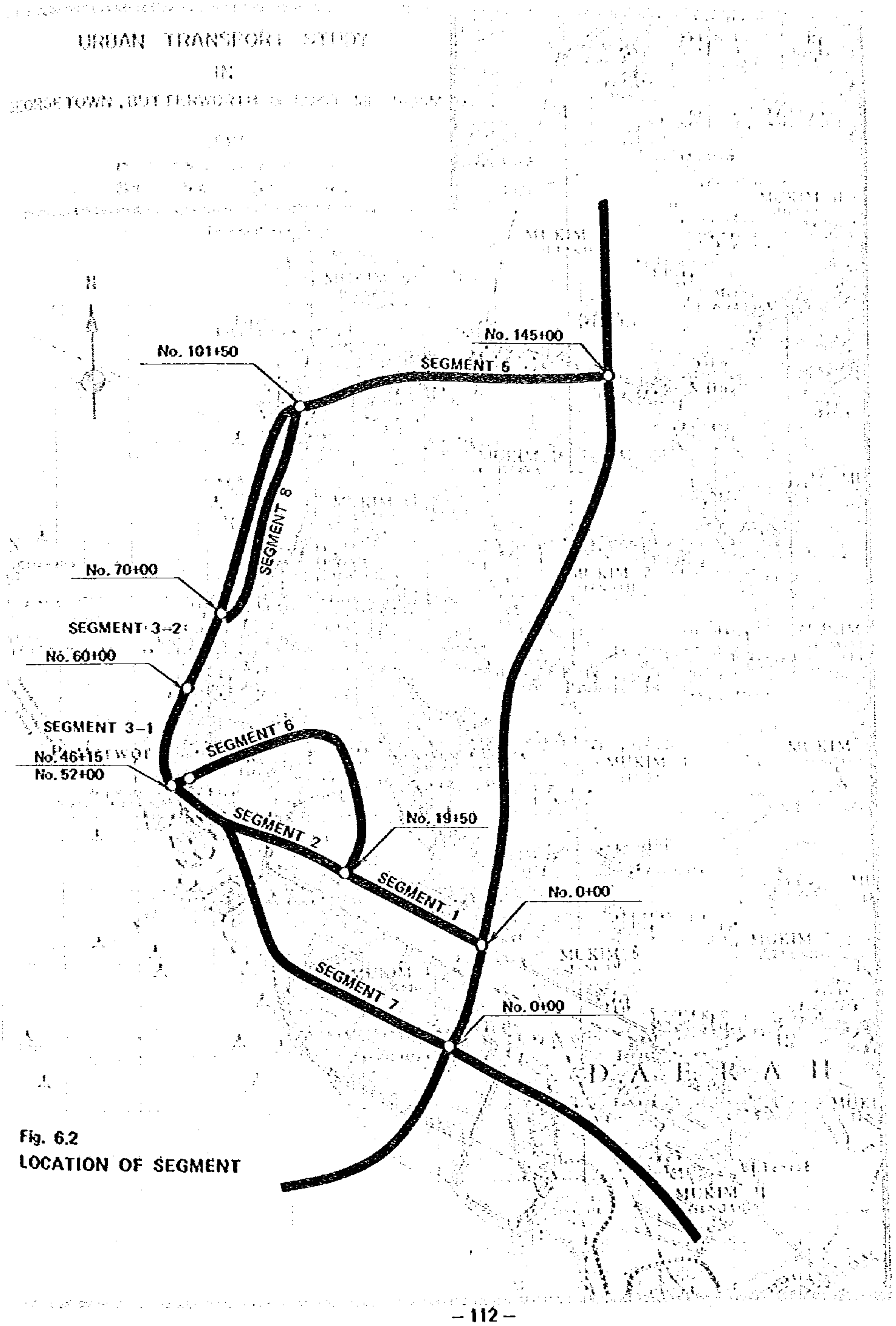


Fig. 6.2
LOCATION OF SEGMENT

Table 6.5 CONSTRUCTION QUANTITY BY SEGMENT (ROAD)
(4—lane)

Item	Sub-Item	Class	Unit	Quantity							
				Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8
Site Clearing	Residential		m^2	0	27,400	45,300	8,720	20,000	39,244	46,100	31,600
	Field		m^2	0	0	0	56,000	69,384	0	0	0
Excavation	Soil	Common	m^3	11,486	2,126	14,106	2,080	110,409	20,073	14,900	19,459
Waste	Soil	Common	m^3	7,701	0	0	0	0	9,146	4,600	12,860
Embankment	Soil	Common	m^3	3,785	7,003	116,800	367,920	139,115	10,926	10,300	6,599
Slope	Grass		m^2	0	0	0	0	11,200	0	0	0
Turfing	Sidewalk	Grass & Tree	m^2	12,853	14,630	37,222	79,417	4,208	25,292	21,500	1,300
	Open Space	Grass	m^2	0	0	0	0	0	0	0	0
Drainage	Roadside	1.0 x 1.0	m	3,760	4,080	4,470	6,300	8,700	7,700	7,200	6,420
	Pipe Culvert	D = 600	m	400	520	720	945	800	840	600	600
	Box Culvert	3.0 x 3.0	m	0	0	50	100	0	0	0	0
		5.0 x 5.0	m	0	0	0	50	0	0	0	0
	Transfer	D = 24"	m	0	0	0	0	0	0	0	0
Wall	Mooring		Vol.	0	0	0	1	0	0	0	0
	Masonry	H = 4.0	m^2	894	1,705	2,571	895	894	3,748	2,600	2,348
	Revetment	Stone	m	0	0	1,200	2,950	0	0	0	0
Pavement	Carriageway	Asphalt	m^2	17,230	7,245	36,100	51,820	63,193	29,586	29,800	30,934
	Shoulder	Asphalt	m^2	2,593	0	4,560	8,520	10,695	6,765	2,900	10,980
	Service Road	Asphalt	m^2	3,720	25,080	13,980	20,760	3,720	7,360	16,300	7,020
	Sidewalk	Concrete Block	m^2	12,853	14,630	9,922	7,917	4,208	25,292	21,500	20,633
	Overlay	Asphalt	m^2	16,515	1,755	0	0	10,453	37,599	26,500	20,123
Additional Facility	Kerb	Concrete	m	4,220	4,680	5,740	8,970	9,020	8,080	7,500	6,960
	Central Reserved	Concrete	m	1,800	500	1,980	3,000	4,200	3,390	2,400	285
	Guard Rail	Steel	m	320	610	920	320	320	1,340	900	840
	Lighting	Steel	m	3,010	2,665	1,785	3,150	400	1,450	3,300	3,550
	Lane-Marks	Paint	m	1,950	2,600	2,390	3,150	4,350	4,150	5,200	3,085
Intersection	At-Grade	Signal	No.	0.5	1	2.5	2.5	2.5	3	2.5	2.5
	Interchange	Diamond Type	Vol.	0	0	0	0	1.0	0	0	0
Bridge	L < 50 m	Concrete	m^2	0	0	0	0	0	0	0	0
	L > 50 m	Concrete	m^2	150	2,165	405	150	150	600	0	270
Approach Road			m	0	0	150	300	0	0	0	0

Table 6.6 CONSTRUCTION QUANTITY BY SEGMENT (ROAD)
(6-lane)

Item	Sub-Item	Class	Unit	Quantity			
				Segment 1	Segment 2	Segment 3-1	Segment 6
Site Clearing	Residential		m^2	600	50,015	52,500	55,244
	Field		m^2	0	0	0	0
Excavation	Soil	Common	m^3	18,219	8,502	13,125	31,319.8
Waste	Soil	Common	m^3	13,189	0	0	17,846.9
Embankment	Soil	Common	m^3	5,030	14,647	22,500	13,472.9
Slope	Grass	-	m^2	0	0	0	0
Turfing	Sidewalk	Grass & Tree	m^2	12,853	15,645	0	25,292.6
	Open Space	Grass	m^2	0	0	0	0
Drainage	Roadside	1.0 x 1.0	m	3,760	4,370	0	7,700
	Pipe Culvert	D = 600	m	500	650	4,470	1,050
	Box Culvert	3.0 x 3.0	m	0	0	0	0
		5.0 x 5.0	m	0	0	0	0
	Transfer	D = 24"	m	0	0	0	0
Wall	Mooring		Vol.	0	0	0	0
	Masonry	H = 4.0	m^2	894	2,405	1,200	3,748
	Revetment	Stone	m	0	0	0	0
Pavement	Carriageway	Asphalt	m^2	26,811	23,197	24,675	49,436
	Shoulder	Asphalt	m^2	4,920	0	3,150	7,540
	Service Road	Asphalt	m^2	3,720	25,530	7,440	7,360
	Sidewalk	Concrete Block	m^2	12,853	15,645	9,100	25,292.6
	Overlay	Asphalt	m^2	18,108	1,047	0	42,658
Additional Facility	Kerb	Concrete	m	4,220	5,270	5,740	8,080
	Central Reserved	Concrete	m	1,800	990	1,980	3,390
	Guard Rail	Steel	m	320	860	920	1,340
	Lighting	Steel	m	3,010	2,665	1,785	1,450
	Lane-Marks	Paint	m	1,950	2,600	2,390	4,150
Intersection	At-Grade	Signal	No.	0.5	1	2.5	3
	Interchange	Diamond type	Vol.	0	1	0	0
Bridge	L < 50	Concrete	m^2	0	0	0	0
	L > 50	Concrete	m^2	0	0	0	0
Approach Road			m	0	0	0	0

Table 6.7 CONSTRUCTION QUANTITY OF BRIDGE

No. of lane	Item	Grade	Unit	Prai Roundabout Fly-over Bridge (Route A&B)	Prai River Bridge (Route B) High Level	Prai River Bridge (Route B) Ramp	Prai River Bridge (Route B) Medium Level	Chain Ferry Fly-over Bridge (Route B)	E–W Highway Fly-over Bridge (Route D)	Bagan Jermal Fly-over Bridge (Route E)	Sungai Dua Fly-over Bridge (Route D)	Sungai Dua Fly-over Bridge (Route E)	Prai River Bridge (Route A)	Prai River Bridge (Route C)	Sungai Dua Bridge (Route F&G)
4-lane	Concrete	40	m^3	3,700	17,500	1,900	9,600	3,700	3,700	1,600	3,800	1,900	300	24,000	600
		25	m^3	1,300	10,000	800	5,800	1,300	1,300	600	1,300	700	1,300	13,900	300
	Steel Reinforcement	410	t	440	2,470	210	1,460	430	440	190	450	230	230	3,400	80
	Prestressed Wire	–	t	200	980	90	630	190	200	90	200	100	80	1,350	0
	Structural Steel	BS-4360	t	5	20	0	15	0	5	5	0	0	0	25	0
	Wearing Surface	6 cm	m^2	5,400	24,840	2,810	14,940	5,220	5,400	2,340	5,400	2,700	2,380	34,200	810
	Expansion Joint	–	m	72	252	60	180	72	72	72	72	36	85	347	108
	Guard Rail	–	m	600	2,760	940	1,660	580	600	520	600	600	500	3,800	90
	P.C. Pile	φ 600	m	9,020	45,400	5,100	25,000	8,700	9,000	3,900	9,200	4,600	5,400	62,500	1,600
	Steel Sheet Pile	–	t	0	920	0	920	0	0	0	0	0	0	1,200	0
	Landing Stage	–	m^2	0	870	0	870	0	0	0	0	0	0	1,200	0
6-lane	Concrete	40	m^3	3,700	24,800	1,900	13,600	3,700	3,700	1,600	3,800	1,900	1,840	34,000	600
		25	m^3	1,300	14,000	800	8,200	1,300	1,300	600	1,300	700	1,840	19,700	300
	Steel Reinforcement	410	t	440	3,500	210	2,070	430	440	190	450	230	330	4,800	80
	Prestressed Wire	–	t	200	1,390	90	890	190	200	90	200	100	110	1,910	0
	Structural Steel	BS-4360	t	5	30	0	20	0	5	5	0	0	0	35	0
	Wearing Surface	6 cm	m^2	5,400	35,190	2,810	21,160	5,220	5,400	2,340	5,400	2,700	3,370	48,450	810
	Expansion Joint	–	m	72	357	60	255	72	72	72	72	36	121	491	108
	Guard Rail	–	m	600	2,760	940	1,660	580	600	520	600	600	500	3,800	90
	P.C. Pile	φ 600	m	9,020	64,300	5,100	35,400	8,700	9,000	3,900	9,200	4,600	7,650	88,540	1,600
	Steel Sheet Pile	–	t	0	1,300	0	1,300	0	0	0	0	0	0	1,700	0
	Landing Stage	–	m^2	0	870	0	870	0	0	0	0	0	0	1,200	0

6.4 CONSTRUCTION COST

6.4.1 Road Construction Cost

Based on the construction quantities estimates and the unit cost, the construction cost of the road is estimated.

This cost includes earthwork, pavement, drainage, wall and related facilities.

The construction cost per kilometer is M$1.3 to 1.5 million for the improvement section and M$2.1 to 3.0 million for the new construction section. The cost of segment 4 is comparatively higher than the other segments. This is because Right-of-Way of this segment is wider than that of the other segments.

6.4.2 Bridge Construction Cost

The bridge construction cost is estimated by each type of bridge such as prestressed concrete 30 meter span bridge, 40 meter span bridge and 70 meter span bridge.

The construction cost of each type is estimated at about M$900, M$2,000 and M$2,300 per sq. meter, respectively.

The bridge construction cost estimated is shown in Table 6.15.

6.4.3 Construction Cost Estimate

All of these construction costs are summed up by each segment and tabulated as shown in Table 6.8 to 6.14.

Table 6.8 CONSTRUCTION COST 4-LANE
(In M$ at 1981 Prices)

Segment	Component of Cost	Construction Cost				Total
		Road	Bridge	Land Acquisition	Compen-sation	
Segment 1	Economic Cost	2,403,476	2,326,449	0	0	4,729,925
	Financial Cost	2,533,437	2,448,893	0	0	4,982,330
Segment 2	Economic Cost	5,423,128	31,993,727	1,277,000	3,516,000	42,209,855
	Financial Cost	5,713,585	33,677,606	678,000	3,516,000	43,585,191
Segment 3-1	Economic Cost	2,228,594	4,565,516	9,793,000	1,473,000	18,060,110
	Financial Cost	2,348,362	4,805,806	4,735,000	1,473,000	13,362,168
Segment 3-2	Economic Cost	4,470,118	2,323,884	3,436,000	516,000	10,746,002
	Financial Cost	4,754,883	2,446,193	0	516,000	7,717,076
Segment 4	Economic Cost	13,124,074	2,304,567	8,063,000	1,317,000	24,808,641
	Financial Cost	13,970,529	2,425,860	94,000	1,317,000	17,807,389
Segment 5	Economic Cost	6,457,603	1,967,284	1,673,000	1,304,000	11,401,887
	Financial Cost	6,811,887	2,070,930	1,561,000	1,304,000	11,747,817
Segment 6	Economic Cost	5,028,811	8,037,862	5,358,000	1,819,000	20,243,673
	Financial Cost	5,284,067	8,460,907	5,358,000	1,819,000	20,921,974
Segment 7	Economic Cost	7,105,572	44,654,476	3,364,000	609,000	55,733,048
	Financial Cost	7,476,926	47,004,711	2,765,000	609,000	57,855,637
Segment 8	Economic Cost	4,266,865	3,173,839	8,167,000	4,102,000	19,709,704
	Financial Cost	4,489,025	3,340,883	5,121,000	4,102,000	17,052,908

Table 6.9 CONSTRUCTION COST 6-LANE
(In M$ at 1981 Prices)

Segment	Component of Cost		Construction Cost				Total
			Road	Bridge	Land Acquisition	Compensation	
Segment 1	Economic Cost		2,831,712	2,326,449	1,796,000	0	6,954,161
	Financial Cost		2,983,113	2,448,893	1,796,000	0	7,228,006
Segment 2	Economic Cost	HL	5,746,236	43,421,078	2,916,000	3,516,000	55,599,314
	Financial Cost	HL	6,052,592	45,706,394	2,486,000	3,516,000	57,760,986
	Economic Cost	ML	3,740,109	30,312,101	2,916,000	19,632,000	56,600,210
	Financial Cost	ML	3,937,137	31,907,494	2,486,000	16,632,000	57,962,631
Segment 3-1	Economic Cost		2,940,658	4,565,516	12,449,000	1,473,000	21,428,174
	Financial Cost		3,092,815	4,805,806	7,418,000	1,473,000	16,789,621
Segment 4	Economic Cost		–	–	–	–	–
	Financial Cost		–	–	–	–	–
Segment 5	Economic Cost		–	–	–	–	–
	Financial Cost		–	–	–	–	–
Segment 6	Economic Cost		5,888,685	9,129,323	6,724,000	4,107,000	25,849,008
	Financial Cost		6,186,955	9,609,813	6,724,000	4,107,000	26,627,768
Segment 7	Economic Cost		–	–	–	–	–
	Financial Cost		–	–	–	–	–
Segment 8	Economic Cost		–	–	–	–	–
	Financial Cost		–	–	–	–	–

Note H.L. : High Level Bridge
M.L. : Medium Level Bridge

Table 6.10 CONSTRUCTION COST
(In M$ at 1981 Prices)

Segment	Alternative Plan	No. of Lane	Component of Cost	Construction Cost				Total
				Road	Bridge	Land Acquisition	Compensation	
Segment 2	High Level	4	Economic Cost	5,423,128	31,993,727	1,277,000	3,516,000	42,209,855
			Financial Cost	5,713,585	33,677,606	678,000	3,516,000	43,585,191
	Medium Level	4	Economic Cost	3,267,373	22,858,312	1,277,000	19,632,000	47,034,685
			Financial Cost	3,440,843	23,937,190	678,000	19,632,000	47,688,033
	High Level	6	Economic Cost	5,746,236	43,421,078	2,916,000	3,516,000	55,599,314
			Financial Cost	6,052,592	45,706,394	2,486,000	3,516,000	57,760,986
	Medium Level	6	Economic Cost	3,740,109	30,312,101	2,916,000	19,632,000	56,600,210
			Financial Cost	3,937,137	31,907,494	2,486,000	19,632,000	57,962,611
Segment 5	Full Full Access	4	Economic Cost	6,457,603	1,967,284	1,673,000	1,304,000	11,401,887
			Financial Cost	6,811,887	2,070,930	1,561,000	1,304,000	11,749,817
	Partial Access	4	Economic Cost	5,797,169	1,967,284	1,561,000	1,304,000	10,629,453
			Financial Cost	6,151,453	2,070,930	1,561,000	1,304,000	11,087,383
Segment 8	No. 70 → No. 75	4	Economic Cost	886,171	2,021,555	1,745,000	92,000	4,744,726
			Financial Cost	937,532	2,127,953	1,527,000	92,000	4,684,485

Table 6.11 PROJECT COST BY ALTERNATIVE PLANS (ECONOMIC COST)
(In Thousand M$ at 1981 Prices)

Route	Type of Bridge	Cross-Section	Access Type	Land Acquisition & Compensation	Cost			Engineering Service		Total	Maintenance Cost
					Road	Bridge	Total	Design	Supervision		
Route I	–	4–L	Full	37,641	24,855	22,390	47,250	2,363	2,363	89,617	500
Route II	–	4–L	Full	34,752	33,713	21,526	55,239	2,762	2,762	95,515	502
Route III	High Level	6–L, 4–L Plan 1	Full	37,053	25,678	46,351	72,029	3,601	3,601	116,284	466
			Partial	36,941	25,018	46,351	71,369	3,568	3,568	115,446	329
		6–L, 4–L Plan 2	Full	41,348	26,713	57,778	84,491	4,225	4,225	134,289	492
	Medium Level	6–L, 4–L	Full	53,169	23,522	37,215	60,737	3,037	3,037	119,980	466
Route IV	High Level	6–L, 4–L Plan 1	Full	34,164	34,535	45,481	80,016	4,001	4,001	122,182	468
			Partial	34,052	33,875	45,481	79,356	3,968	3,968	121,344	331
		6–L, 4–L Plan 2	Full	38,459	35,570	56,909	92,479	4,624	4,624	140,186	494
	Medium Level	6–L, 4–L	Full	50,280	32,379	36,346	68,725	3,436	3,436	125,877	468
Route V	High Level	4–L	Full	34,437	24,529	56,685	81,214	4,061	4,061	123,773	472
Route VI	High Level	4–L	Full	31,548	33,386	55,816	89,202	4,460	4,460	129,670	474
Route III (Section 1)	High Level	6–L, 4–L Plan 1	Full	17,855	10,483	38,886	49,369	2,468	2,468	72,160	201
Route III (Section 2)	High Level	6–L, 4–L Plan 1	Full	19,198	15,195	7,465	22,660	1,133	1,133	44,124	265
Route IV (Section 1)	High Level	6–L, 4–L Plan 1	Full	17,855	10,483	38,886	49,369	2,468	2,468	72,160	201
Route IV (Section 2)	High Level	6–L, 4–L Plan 1	Full	16,309	24,052	6,596	30,648	1,532	1,532	50,021	267

Note 4–L : 4–lane
6–L : 6–lane

Table 6.12 PROJECT COST BY ALTERNATIVE PLANS (FINANCIAL COST)
(In Thousand M$ at 1981 Prices)

Route	Type of Bridge	Cross-Section	Access Type	Land Acquisition & Compensation	Cost			Engineering Service		Total	Maintenance Cost
					Road	Bridge	Total	Design	Supervision		
Route I	–	4–L	Full	25,989	26,222	23,574	49,796	2,490	2,490	80,765	500
Route II	–	4–L	Full	18,177	35,703	22,659	58,362	2,918	2,918	82,375	502
Route III	High Level	6–L, 4–L Plan 1	Full	24,802	27,101	48,790	75,891	3,795	3,795	108,283	466
			Partial	24,802	26,440	48,790	75,230	3,762	3,762	107,556	326
		6–L, 4–L Plan 2	Full	29,293	28,184	60,819	89,003	4,450	4,450	127,196	492
	Medium Level	6–L, 4–L	Full	40,918	24,828	39,050	63,878	3,194	3,194	14,184	466
Route IV	High Level	6–L, 4–L Plan 1	Full	16,990	36,582	47,875	84,457	4,223	4,223	109,893	468
			Partial	16,990	35,922	47,875	83,797	4,190	4,190	109,167	331
		6–L, 4–L Plan 2	Full	21,481	37,666	59,904	97,570	4,879	4,879	128,809	494
	Medium Level	6–L, 4–L	Full	33,106	34,310	38,135	72,445	3,622	3,622	112,795	468
Route V	High Level	4–L	Full	22,186	25,881	59,669	85,550	4,278	4,278	116,292	472
Route VI	High Level	4–L	Full	14,374	35,363	58,753	94,116	4,706	4,706	117,902	474
Route III (Section 1)	High Level	6–L, 4–L Plan 1	Full	12,198	11,045	40,932	51,977	2,599	2,599	69,373	201
Route III (Section 2)	High Level	6–L, 4–L Plan 1	Full	12,604	16,056	7,858	23,914	1,196	1,196	38,910	265
Route IV (Section 1)	High Level	6–L, 4–L Plan 1	Full	12,198	11,045	40,932	51,977	2,599	2,599	69,373	201
Route IV (Section 2)	High Level	6–L, 4–L Plan 1	Full	4,792	25,537	6,943	32,480	1,624	1,624	40,520	267

Note 4–L : 4–lane
6–L : 6–lane

Table 6.13 CONSTRUCTION COST BY SEGMENT
(4—lane)

(In M$ of 1981 Prices)

Segment	Station No.	Length (m)	Construction Cost: Road F.C.	Road L.C.	Road Tax	Road Total	Bridge F.C.	Bridge L.C.	Bridge Tax	Bridge Total	Land Acquisition & Compensation	Cost: Total	Total F.C.	Total L.C.	Tax	Total
Segment 1	0—19+50	1,950	1,141,476	1,262,000	129,961	2,533,437	1,260,617	1,065,832	122,444	2,488,893	0	4,729,925	2,402,093	2,327,832	252,405	4,982,330
Segment 2	19+50—46+15	2,665	2,729,952	2,693,176	290,457	5,713,585	17,827,322	14,166,395	1,683,885	33,677,606	4,793,000	42,209,845	20,557,274	21,652,571	1,974,342	44,184,187
Segment 3—1	46+15—60	1,385	1,031,037	1,197,557	119,768	2,348,362	2,472,693	2,092,823	240,286	4,805,802	6,724,000	13,518,110	3,503,730	10,014,380	360,054	13,878,164
Segment 3—2	60—70	1,000	2,110,477	2,359,641	284,765	4,754,883	1,259,133	1,064,751	122,309	2,466,193	0	6,794,002	3,369,610	3,424,392	407,074	7,201,076
Segment 4	70—101+50	3,150	6,264,173	6,859,901	846,455	13,970,529	1,245,542	1,059,025	121,293	2,425,860	1,411,000	16,839,641	7,509,715	9,329,926	967,748	17,807,389
Segment 5	101+50—145+0	4,350	3,281,611	3,175,992	354,284	6,811,887	1,045,771	921,513	103,646	2,070,930	2,865,000	11,289,887	4,327,382	6,962,505	457,930	11,747,817
Segment 6	19+50—61+0	4,150	2,306,960	2,721,851	255,256	5,284,067	3,623,857	4,414,005	423,045	8,460,907	7,177,000	20,243,673	5,930,817	14,312,856	678,301	20,921,974
Segment 7	0—52+0	5,200	3,507,360	3,598,212	371,354	7,476,926	24,873,196	19,781,280	2,350,235	47,004,711	3,374,000	55,134,048	28,380,556	26,753,492	2,721,589	57,855,637
Segment 8	75+0—100+85	3,085	2,035,391	2,231,474	222,160	4,489,025	1,718,566	1,456,273	167,044	3,340,883	9,223,000	16,663,704	3,753,957	12,909,747	389,204	17,052,908

Table 6.14 CONSTRUCTION COST BY SEGMENT
(6—lane)

(In M$ at 1981 Prices)

Segment	Station No.	Length (m)	Construction Cost: Road F.C.	Road L.C.	Road Tax	Road Total	Bridge F.C.	Bridge L.C.	Bridge Tax	Bridge Total	Land Acquisition & Compensation	Cost: Total	Total F.C.	Total L.C.	Tax	Total
Segment 1	0—19+50	1,950	1,386,762	1,444,950	151,401	2,983,113	1,260,617	1,065,832	122,444	2,448,893	1,796,000	6,954,161	2,647,379	4,306,782	273,845	7,228,006
Segment 2	19+50—46+15	2,665	2,916,375	2,829,861	306,356	6,052,592	24,224,480	19,196,599	2,285,315	45,706,394	6,002,000	55,169,315	27,140,855	28,028,460	2,591,671	57,760,986
Segment 3—1	46+15—60	1,385	1,412,871	1,527,787	152,157	3,092,815	2,472,693	2,002,823	240,286	4,805,802	8,891,000	16,397,174	3,885,564	12,511,610	392,443	16,789,617
Segment 6	19+50—61	4,150	2,799,350	3,089,335	298,270	6,186,955	5,030,468	4,098,855	480,489	9,609,812	10,831,000	25,849,008	7,829,818	18,019,190	778,759	26,627,767

Table 6.15 CONSTRUCTION COSTS FOR BRIDGE
(In M$ at 1981 prices)

ITEM		4—Lane				6—Lane			
		L.C	F.C	Tax	Total	L.C	F.C	Tax	Total
Prai Roundabout Fly-over Bridge (Route A & B)		2,131,663	2,521,234	244,889	4,897,786	2,131,663	2,521,234	244,889	4,897,786
Prai River Bridge (Route B)	High Level	12,072,490	15,353,155	1,443,455	28,869,100	17,102,694	21,750,303	2,044,895	40,897,892
	Ramp (Existing Port)	1,068,838	1,234,429	121,225	2,424,492	1,068,838	1,234,429	121,225	2,424,492
	Medium	7,752,373	10,419,877	956,434	19,128,684	10,982,528	14,761,492	1,354,948	27,098,968
Chain Ferry Fly-over Bridge (Route B & C)		2,056,145	2,427,120	235,961	4,719,226	2,056,145	2,427,120	235,961	4,719,226
E—W Highway Fly-over Bridge (Route D)		2,129,501	2,518,266	244,619	4,892,386	2,129,501	2,518,266	244,619	4,892,386
Bagan Jermal Fly-over Bridge (Route E)		925,760	1,095,795	106,398	2,127,953	925,760	1,095,795	106,398	2,127,953
Sungai Dua Fly-Over Bridge	(Route D)	2,118,051	2,491,083	242,586	4,851,720	0	0	0	0
	(Route E)	1,059,026	1,245,541	121,293	2,425,860	1,059,026	1,245,541	121,293	2,425,860
Prai River Bridge (Route A)		1,139,994	1,479,512	137,869	2,757,375	1,614,992	2,095,975	195,314	3,906,281
Prai River Bridge (Route C)		16,621,544	21,138,402	1,987,366	39,747,312	0	0	0	0
Sungai Dua Bridge (Route F & G)		392,000	423,000	43,000	858,000	392,000	423,000	43,000	858,000

6.5 LAND ACQUISITION COST AND COMPENSATION

6.5.1 Land Acquisition Cost

(1) General

The areas that are affected by the Project Road, comprises both private and Government land and properties. For the purpose of compensation, the values of these properties are decided upon after discussion with the authorities from the Land Valuation Office and the MPSP with confirmation from the Technical Committee. It must be noted that the land values differ not only by the type of land uses but also by their location in relation to the road. In this report, the cost is estimated by area where lots of similar values are grouped together.

It must be also noted that the land acquisition cost may differ when expressed in terms of economic cost or financial cost. The economic cost can be expressed as an opportunity cost of the land. For example, the seashore land on the site of the Project Road, after being reclaimed, could be utilized for a residential area instead of for the road. From this viewpoint, it is necessary to determine the adequate opportunity cost of the land. However, the financial cost can be expressed simply as the implementation cost of acquisition of the land for the Project Road.

(2) Unit Cost of Land Acquisition

In order to obtain the value of the land along the route of the Project Road, a survey is made to place a value on the land affected.

On the basis of the survey made, the land values are determined by each of the sub-divided segments.

With regard to the land acquisition in the seashore area, the unit cost is calculated by the following formula:

$$LV^S = LV^A \times 0.8 - (RC + IC)$$

where : LV^S : Land value in the seashore area

LV^A : Land value adjoining the seashore area

RC : Reclamation cost

IC : Infrastructure cost

The land acquisition cost in the seashore area is estimated as follows:

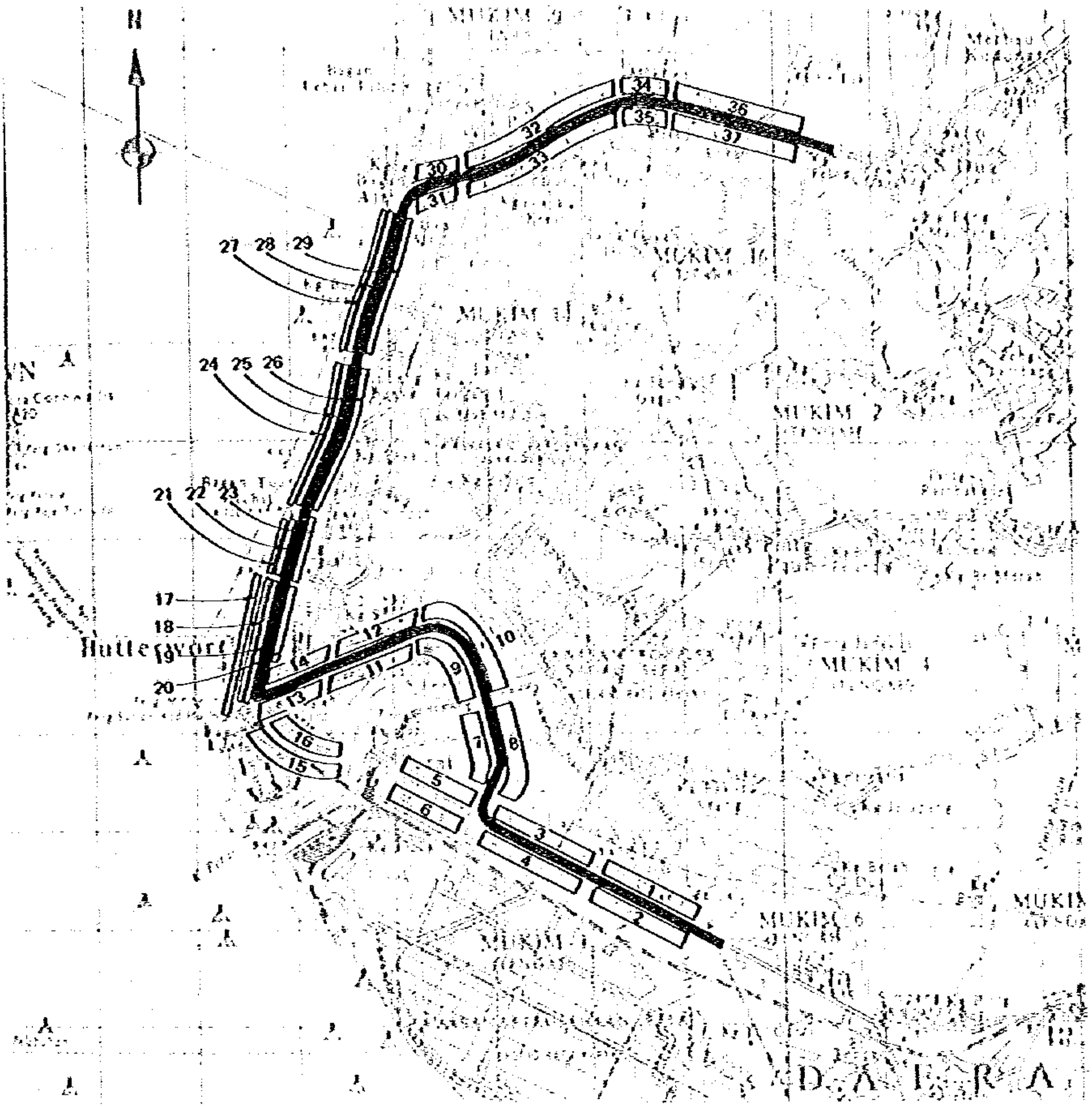
a. Station No. 60 ∿ No. 65 = 669 x 0.8 – 112 = $423 per m²

b. Station No. 65 ∿ No. 85 = 363 x 0.8 – 112 = $176 per m²

c. Station No. 85 ∿ No. 98 = 189 x 0.8 – 112 = $ 39 per m²

The estimation of the land value is shown in Table 6.16.

Table 6.16 UNIT COST OF LAND ACQUISITION



(In M$ at 1981 prices) (Per m²)

Section	Unit Cost	Section	Unit Cost	Section	Unit Cost
1	83	14	281	27	189
2	74	15	66	28	196
3	157	16	63	29	215
4	144	17	511	30	140
5	44	18	585	31	115
6	77	19	614	32	59
7	139	20	658	33	63
8	92	21	669	34	28
9	107	22	673	35	28
10	122	23	814	36	8
11	153	24	363	37	9
12	122	25	418	38	7
13	252	26	418	39	9

(3) Land Acquisition Cost

On the basis of the unit cost and the acreage of the area affected by the Project Road, the land acquisition cost is estimated and is shown in Table 6.17.

Table 6.17 LAND ACQUISITION COST
(In Thousand M$ at 1981 prices)

Segment	Land Acquisition Cost			
	4-lane		6-lane	
	Economic	Financial	Economic	Financial
Segment 1	0	0	1,796	1,796
Segment 2	1,277	678	2,916	2,486
Segment 3-1	9,793	4,735	12,449	7,418
Segment 3-2	3,436	0	n.a.	n.a.
Segment 4	8,063	94	n.a.	n.a.
Segment 5	1,673	1,561	6,724	6,724
Segment 6	5,358	5,358	n.a.	n.a.
Segment 7	3,364	2,765	n.a.	n.a.
Segment 8	8,167	5,121	n.a.	n.a.

6.5.2 Compensation

(1) General

In order to obtain the value of residences affected along the Project Road, a survey is done to count the number of houses and to categorise them according to type. All houses that are located along a distance of two lots from the existing road are denoted as affected buildings. These are identified on a map of scale 1 : 3000 and the data documented according to location, type of building, distance of building to new road, land use, building use, number of storeys and structural condition of building.

In addition, the compensation for the two dockyards situated along the Prai River is also considered in case their relocation is necessary.

(2) Unit Cost

On the basis of the survey mentioned above, the unit cost of compensation is determined by the type of housing and is shown in Table 6.18.

(3) Compensation Cost for Dockyard

It is a highly difficult task to estimate this compensation cost because it involves many complicated related matters. However, compensation is being considered as follows:

Compensation = [Construction cost of new dockyard]
— [Land value of the existing dockyard]
— [Survival value of the existing dockyard]

The compensation for the dockyards is shown in Table 6.19.

Table 6.18 UNIT COST OF COMPENSATION FOR RESIDENTIAL STRUCTURES (In M$ at 1981 prices)

Type of Housing	Material	Unit Cost (M$/m²)
Detached Double – Storey	Concrete	510
– do –	Wooden	300
Detached Single – Storey	Concrete	430
– do –	Wooden	300
Semi–Detached Double–Storey	Concrete	433
– do –	Wooden	300
Semi–Detached Single–Storey	Concrete	433
Terraced Double – Storey	Concrete	344
Terraced Single – Storey	Concrete	344
Terraced Triple – Storey	Concrete	500
Detached Double – Storey	Wooden	300
Terraced 4 – Storey	Concrete	330
Terraced 5 – Storey	Concrete	350
Terraced Single – Storey	Wooden	250
Semi–Detached Single–Storey	Wooden	300
Squatter Single – Storey	Wooden	200

Table 6.19 COMPENSATION FOR DOCKYARDS
(In Thousand M$ at 1981 Prices)

Item		PPC Dockyard	Hong Leong Shipyard
Construction Cost	Reclamation Cost	+2,203	+1,412
	Dockyard	+29,290	+29,530
Sub-Total		+31,493	+30,942
Land Value (existing dockyard)		–8,400	–4,400
Survival Value (existing dockyard)*		–11,000	–11,000
Compensation		12,093	15,542

* The survival value in the above table is the value estimated for the PPC dockyard only and since the survival value of the Hong Leong Shipyard is not obvious, the same value is adopted for the Hong Leong Shipyard.

(4) Compensation

The total compensation cost is estimated by each segment and is shown in Table 6.20.

Table 6.20 COMPENSATION COST BY SEGMENT
(In thousand M$ at 1981 prices)

Segment	Compensation Cost	
	4-lane	6-lane
Segment 1	0	0
Segment 2	3,516	3,516
Segment 3-1	1,473	1,473
Segment 3-2	516	n.a.
Segment 4	1,317	n.a.
Segment 5	1,304	n.a.
Segment 6	1,819	4,107
Segment 7	609	n.a.
Segment 8	4,102	n.a.

Note: 6-lane is not applicable to Segment 3-2, 4, 5, 7 and 8.

6.6 ANNUAL MAINTENANCE COST

Data from "The Malaysia Highway Maintenance Study", "Memorandum for a Case for the Revision for Grant-in-aid for Maintenance to Municipalities in West Malaysia" and other related reference were used in the estimation of the annual maintenance cost of the Project Road in this study. The cross-section of the Project Road is somewhat different from the cross-sections of the roads mentioned in the above references and so a change in the items of maintenance cost must be considered.

The following items must be taken into account in the estimation of the annual maintenance cost.

1) Resurfacing of Roads

The resurfacing of roads including the carriageway and shoulder is to be carried out once every 10 years. The unit cost of resurfacing per square meter of carriageway and shoulder with 3 cm thick premixed asphalt macadam is estimated at M$0.57.

2) Roadside Trees

The maintenance of roadside trees consist of the trimming of branches, ensuring water supply, protection of the trees and others. The unit cost is estimated at M$1,000 per kilometer.

3) Drainage

The lifespan of the drainage system is assumed to be 20 years and 5% of it has to be renewed or repaired every year. The unit cost of drainage maintenance is estimated at M$2.5 per meter.

4) Kerbs

The lifespan of kerbs is assumed to be 20 years and 5% of kerbs have to be renewed or repaired every year. The unit cost of changing kerbs is estimated at M$1.5 per meter.

5) Road Marking and Lighting

The maintenance of the above includes lane-marking painting, kerb repainting, repainting of traffic signs and others. The unit cost is estimated at M$1,000 per kilometer.

6) Traffic Signals

The maintenance of traffic signals includes repairing the signals and renewing them if necessary. The lifespan of signals is 20 years. The unit cost is estimated to be M$1,250.

7) Central Reservation

The maintenance of the central reservation involves the cutting of grass and pruning of trees. The width of the central reservation is 3 meter and one cutting a month is M$0.05 per square meter.

8) Guard Rails

In the maintenance of guard rails, it is necessary to change and repair the guard rails and 5% of guard rails have to be renewed or repaired every year. The cost of changing is estimated to be M$54 per meter.

9) Scupper Pipes and Kerb Outlet Channels

Scupper pipes and kerb outlet have to be cleared regularly. The unit cost is estimated to be M$800 per kilometer.

10) Bridges and Other Structures

The condition of bridges and other structures have to be investigated regularly and repaired if found faulty. The unit cost is estimated at M$1,000 per kilometer.

The maintenance cost is shown in Table 6.21 and 6.22. These are calculations for 4-lane carriageway. These figures are multiplied with a factor of 1.2 to obtain figures for the 6–lane road.

Table 6.21 MAINTENANCE COST (4-LANE)
(In M$ at 1981 prices) (Unit: per km)

Items \ Cost	Unit	Unit Cost	Quantity	Cost		
				Economic	Tax (5%)	Total
Resurfacing of Road	m^2	0.57	20,000	11,400	570	11,970
Roadside Trees	km	1,000	1	1,000	50	1,050
Drainage	m	2.5	2,000	5,000	250	5,250
Kerb	m	1.5	2,000	3,000	150	3,150
Marking and Lighting	km	1,000	1	1,000	50	1,050
Traffic Signals	km	1,250	1	1,250	63	1,313
Central Reservation	m	1.8	1,000	1,800	90	1,890
Guard Rail	m	54	200	1,080	54	1,134
Pipe and Kerb Outlet	km	800	1	800	40	840
Bridge and Other Structures		1,000	1	1,000	50	1,050
Sub-Total				27,330	1,367	28,697
15% Administrative and Technical Staff				4,100	205	4,305
Total				31,430	1,572	33,002

Table 6.22 MAINTENANCE COST OF EACH SEGMENT
(In M$ at 1981 prices)

Segment	Length (Km)	4-lane		
		Economic	Tax	Total
Segment 1	1.950	61,289	3,065	64,354
Segment 2	2.665	83,761	4,189	87,950
Segment 3-1	1.385	43,531	2,177	45,708
Segment 3-2	1.000	31,430	1,572	33,002
Segment 4	3.150	99,005	4,952	103,956
Segment 5	4.350	136,721	6,838	143,559
Segment 6	4.150	130,435	6,524	136,958
Segment 7	5.200	163,436	8,174	171,610
Segment 8	4.350	136,721	6,838	143,559

7. PROJECT EVALUATION

7.1 GENERAL

7.1.1 Procedure

The procedure for the evaluation of the Project Road comprises the following:

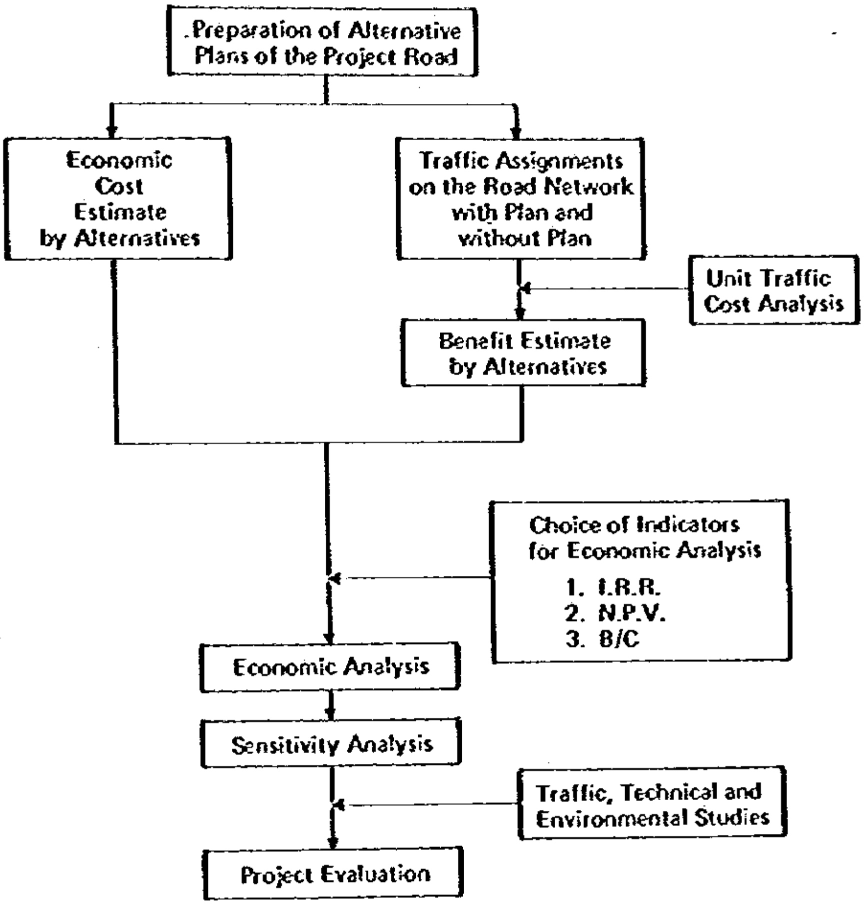


Fig. 7.1 PROCEDURE FOR PROJECT EVALUATION

7.1.2 Choice of Indicators for Economic Evaluation

Three types of economic indicators are used in the economic analysis, for the standard procedure of the Economic Planning Unit and the International Financing Organization.

(1) Internal Rate of Return (IRR)

There are two kinds of internal rate of return, financial and economic. Since the financial rate of return is used only for private investment, the economic rate of return is used for this project. The IRR shows the discount rate which gives the break even point between the present value of benefit and that of cost as given by the following formula.

$$B(R) - C(R) = 0$$

$$B(R) = \sum_{i=1}^{n} \frac{bi}{(1+R)i}$$

$$C(R) = \sum_{i=0}^{n-1} \frac{Ci}{(1+R)i}$$

R : Internal Rate of Return

Ci : Cost in the year (i)

bi : Benefit in the year (i)

n : Project life in years

In order that the project be economically feasible, the IRR should be more than the opportunity cost of capital in Malaysia, generally 12 percent.

(2) Net Present Value (NPV)

The NPV will indicate the difference between the discounted cost and benefits using the rate of opportunity cost of capital. A positive NPV means the project is economically feasible.

(3) Benefit-Cost (B/C Ratio)

The B/C ratio is the ratio obtained by dividing the present value of benefit by that of cost.

$$\text{Benefit-Cost Ratio} = \frac{B}{C}$$

where

$$B = \sum_{i=1}^{n} \frac{bi}{(1+r)i}$$

$$C = \sum_{i=0}^{n-1} \frac{Ci}{(1+r)i}$$

bi : Benefit in the year (i)

Ci : Cost in the year (i)

r : Discount rate

n : Project life in years

Among the three economic indicators, the IRR is mainly used to establish the investment timing and the best combination of the different alternative plans in this study.

7.2 ALTERNATIVES

(1) General

The alternatives discussed in the engineering and traffic studies are evaluated economically with the following items:

a. Route
b. Type of Bridge
c. Cross-Section
d. Access to the Toll Expressway
e. Stage Construction by Road Section

However, the stage acquisition of the Right-of-Way as an alternative is not included in the economic analysis because of the difficulty for acquisition of additional land after the completion of the Project Road.

(2) Route

Six (6) alternative routes of the Project Road are selected from the alternative routes which were discussed in the engineering study, as shown in Figs. 5.2 and 7.2.

a. Route I : The route passes through routes A, D and E combination and route G.

b. Route II : The route passes through routes A, D and G.

c. Route III : The route passes through routes B, D and E combination and route G.

d. Route IV : The route passes through routes B, D and G.

e. Route V : The route passes through routes C, D and E combination and route G.

f. Route VI : The route passes through routes C, D and G.

(3) Type of Bridge

The alternative types of bridge that have been selected from the engineering study are:

a. The High Level Bridge with a clearance height of 25 meters.

b. The Medium Level Bridge with a clearance height of 16 meters.

(4) Cross-Section

The following cross-sections, selected as alternatives for Route III and IV, are considered in the economic evaluation:

a. Plan 1 : A six (6)–lane road from the Toll Expressway to the Prai Roundabout and a four (4)–lane road for the other part of the Project Road.

b. Plan 2 : A six (6)–lane road from the Toll Expressway to the North Butterworth Container Wharf and a four (4)–lane road for the other part of the Project Road.

For other alternatives, however, a four (4)–lane plan is only considered in the economic evaluation.

(5) Access to Toll Expressway

The types of interchange with the Project Road to the Toll Expressway at Jalan Sungai Dua, selected as the alternatives, are as follows:

a. Full Access Interchange

b. Partial Access Interchange

(6) Stage Construction by Section

The following alternative stage construction plans are considered in the economic evaluation for alternative Route III and IV.

a. Section 1 (Southern Section of the Project Road)

b. Section 2 (Northern Section of the Project Road)

(7) Combination of Alternatives

The following combinations of the above-mentioned alternatives are evaluated economically as shown in Table 7.1.

(8) Evaluation Process of the Alternatives

In the economic evaluation, the alternatives are evaluated through the following process: (See Fig. 7.2)

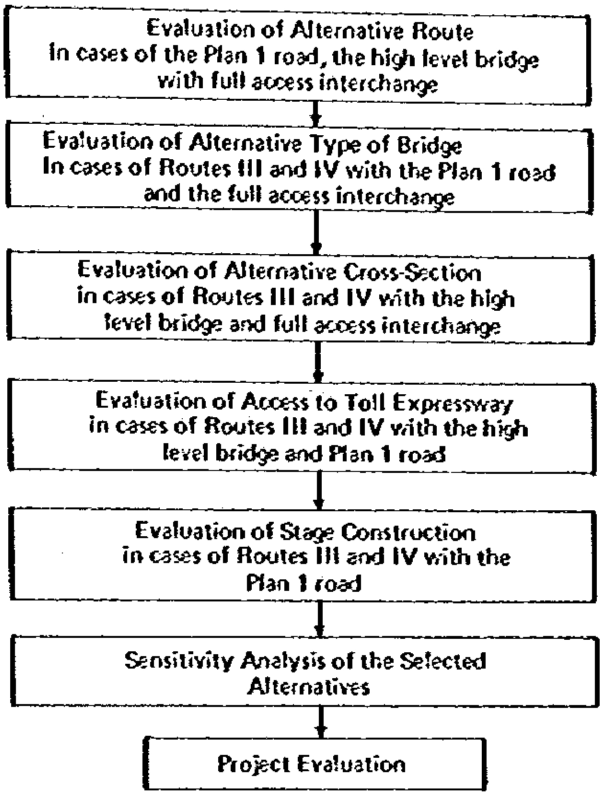


Fig. 7.2 PROCEDURE FOR ECONOMIC EVALUATION

Table 7.1 ALTERNATIVE PLANS FOR ECONOMIC EVALUATION

Alternative Route	Type of Bridge	Cross-Section Plan	Access Type	Abbreviation of Alternative Plan
Route I	–	4-lane	Full	Route I-F, 4-L
Route II	–	4-lane	Full	Route II-F, 4-L
Route III	High Level	Plan 1	Full	Route III-F, Plan 1
			Partial	Route III-P, Plan 1
		Plan 2	Full	Route III-F, Plan 2
	Medium Level	Plan 1	Full	Route III-F, Plan 1 with Medium Level
Route IV	High Level	Plan 1	Full	Route IV-F, Plan 1
			Partial	Route IV-P, Plan 1
		Plan 2	Full	Route IV-F, Plan 2
	Medium Level	Plan 1	Full	Route IV-F, Plan 1 with Medium Level
Route V	High Level	4-lane	Full	Route V-F, 4-L
Route VI	High Level	4-lane	Full	Route VI-F, 4-L

Note: Plan 1: 6-lane road from the Toll Expressway to the Prai Roundabout and 4-lane road for the other part of the Project Road.

Plan 2: 6-lane road from the Toll Expressway to North Butterworth Container Wharf and a 4-lane road for the other part of the Project Road.

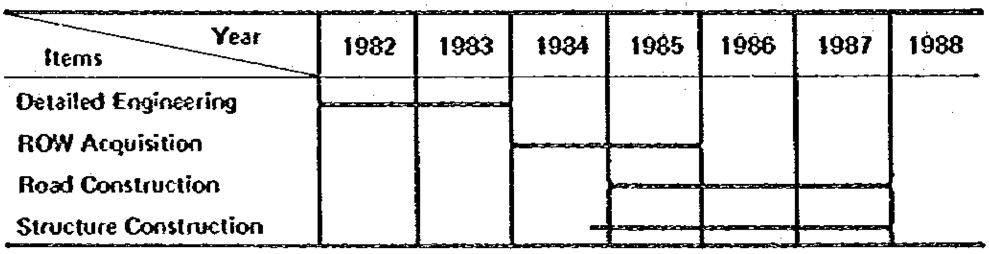
7.3 ECONOMIC COST ESTIMATES

7.3.1 Construction Schedule for Economic Cost Estimates

For the purpose of establishing the best investment timing of the Project Road, a construction schedule including detailed engineering and actual construction work is assumed where the Project Road is to be constructed within the shortest possible period.

July 1982 – Dec. 1983	Detailed Engineering
Jan. 1984 – Dec. 1985	ROW Acquisition
Jan. 1985 – Dec. 1987	Road Construction
Oct. 1984 – Dec. 1987	Structure Construction

Table 7.2 PRELIMINARY CONSTRUCTION SCHEDULE



Accordingly, the Project Road is expected to be opened to traffic in the year 1988.

7.3.2 Economic Costs

The construction cost estimates were already described in detail in Chapter 6. The construction costs consist of land acquisition and compensation and the construction of road and structure.

For the evaluation of the Project, the costs and benefits should be expressed in economic values. Therefore, the following considerations are made to estimate the economic cost:

a. The economic cost is basically estimated from the financial costs less taxes.

b. This cost includes the land value of government land.

c. This cost also includes the land value along the coastal area.

The results of the economic cost estimates of each alternative are shown in Table 7.3 and 7.4.

Table 7.3 ECONOMIC COSTS BY ALTERNATIVE PLANS

Alternative Route	Type of Bridge	Cross-Section	Access Type	Economic Cost (M$'000)
Route I	–	4–lane	Full	89,617
Route II	–	4–lane	Full	95,515
Route III	High Level	Plan 1	Full	116,284
			Partial	115,446
		Plan 2	Full	134,289
	Medium Level	Plan 1	Full	119,980
Route IV	High Level	Plan 1	Full	122,182
			Partial	121,344
		Plan 2	Full	140,186
	Medium Level	Plan 1	Full	125,877
Route V	High Level	4–lane	Full	123,773
Route VI	High Level	4–lane	Full	129,670

Table 7.4 ECONOMIC COSTS BY ALTERNATIVE PLANS

Alternative Route	Type of Bridge	Cross-Section	Access Type	Section	Economic Cost (M$'000)
Route III	High Level	Plan 1	Full	Section 1	72,160
				Section 2	44,124
Route IV	High Level	Plan 2	Full	Section 1	72,160
				Section 2	50,021

7.3.3 Stream of Economic Costs

Considering the construction activities, the implementation period of the Project Road will take about 6 years. The stream of the economic costs by type of construction work is assumed and shown in Table 7.5.

Table 7.5 STREAM OF ECONOMIC COSTS

Items / Year	Detailed Study	R.O.W. Acquisition	Road Construction	Structure Construction
1982	50%	–	–	–
1983	50%	–	–	–
1984	–	50%	–	10%
1985	–	50%	25%	30%
1986	–	–	30%	30%
1987	–	–	45%	30%

7.3.4 Maintenance Cost

The maintenance cost which is described in Chapter 6 is used for the economic evaluation.

7.4 TRAFFIC COST ESTIMATES

7.4.1 General

The traffic cost can be divided into two (2) components; vehicle operating cost and time cost. The vehicle operating cost can be further sub-divided into two (2) components; distance related running cost (running cost) and time related running cost (fixed cost). The method of estimation in this study is similar to that used in the "Year Book of Transport Statistics 1979".

The vehicle operating costs are originally estimated based on the following vehicle type:

a. M/Cycle
b. Car
c. Taxi
d. Bus
e. Light-Van
f. Medium Lorry
g. Heavy Lorry

7.4.2 Vehicle Operating Cost

(1) Running Cost

1) Fuel Cost (Petrol and Diesel)

The fuel cost is calculated based on the fuel consumption per kilometer, the running speed and the current fuel price per litre.

2) Oil Cost

The oil cost is calculated based on the oil consumption per kilometer and the current oil price.

3) Tyre Cost

The tyre cost is calculated based on the tyre life span, the annual running kilometer and the set prices of tyres.

4) Maintenance and Repair Cost

The maintenance and repair cost are divided into those of labour and spare parts cost. The labour cost is calculated by using the total labour hour for each type of vehicle while the cost of spare parts is estimated on the basis of vehicle cost in percentage.

5) Depreciation Cost

The distance determined depreciation cost is estimated by setting up the percentage of depreciation to the total depreciation cost as shown in Table 7.6 which also indicates the salvage value.

Table 7.6 DEPRECIATION AND SALVAGE VALUE

Item / Type of Vehicle	Percentage of Depreciation (%)	Salvage Value (% of Vehicle Cost)
M/Cycle	30	15
Private Car	30	20
Taxi	85	15
Bus	70	15
Light-Van	60	15
Medium Truck	70	15
Heavy Lorry	70	15

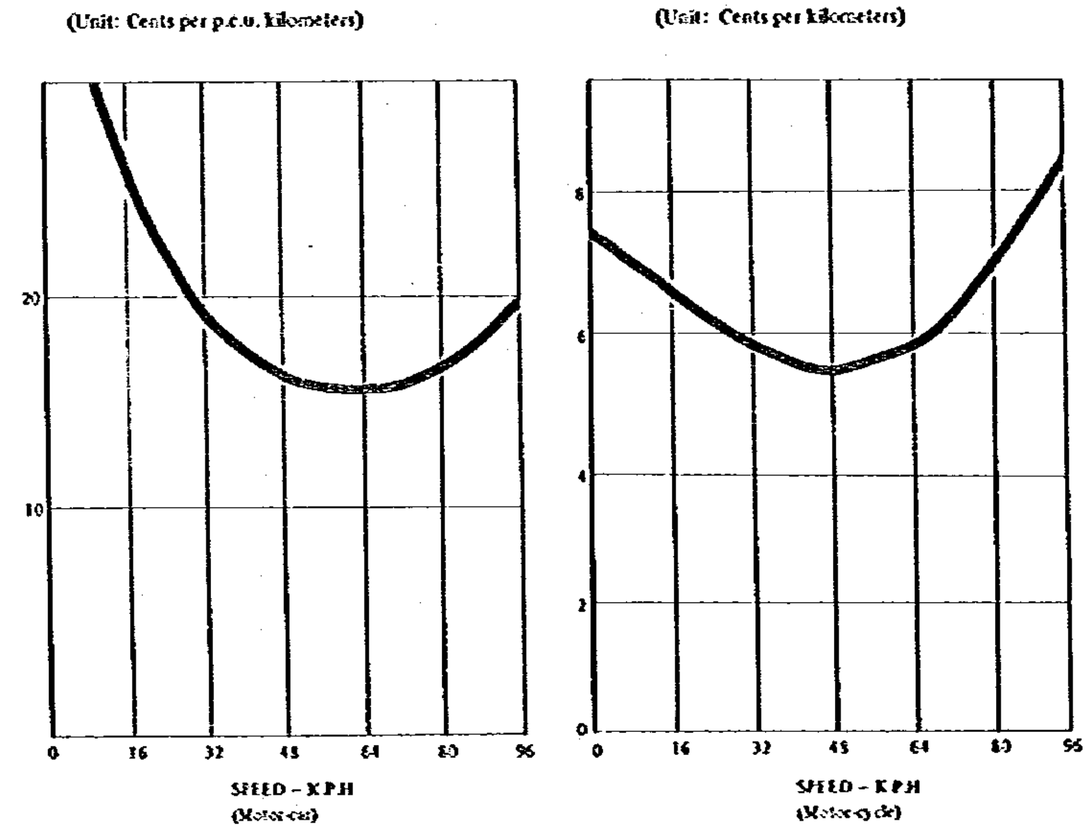
Source: Year Book of Transport Statistics 1975

The basic running cost per kilometer is calculated by summing up all the elements mentioned above as shown in Table 7.7.

Table 7.7 DISTANCE-DETERMINED RUNNING COSTS
(In cents per km at 1981 Prices)

Type of vehicle / Cost	M/Cycle	Car	Taxi	Bus	Light Van	Medium Lorry	Heavy Lorry
Running Cost	5.59	14.93	11.13	24.84	17.54	38.59	46.30
Fuel	2.95	7.70	3.24	6.29	7.18	11.91	11.01
Oil	0.22	0.76	1.13	1.51	1.13	1.51	2.32
Tyres	0.24	0.90	1.20	6.42	1.91	7.24	10.70
Maintenance	1.45	3.40	2.66	5.49	4.38	12.05	15.02
Depreciation	0.73	2.17	2.90	5.13	2.94	5.88	7.25

Factors affecting running cost are vehicle speed and surface characteristics of the roads. However, as the surface condition of roads in Penang State is good, only vehicle speed is taken into account. Running cost by vehicle speed is shown in Fig. 7.3.



Note: The figure for motor car is obtained by using the p.c.u. by vehicle type and the composition rate of vehicles.

Fig. 7.3 RELATIONSHIP BETWEEN RUNNING COSTS AND SPEED

(2) Fixed Cost

1) Crew Cost

The crew cost is calculated separately for taxi drivers, bus and lorry drivers, bus conductors and cargo loading and unloading labourers for heavy lorries.

2) Time-related Depreciation

The time-related depreciation is given by subtracting the distance determined depreciation from total depreciation. Then the depreciation cost per hour is calculated by estimating vehicle life and annual running hours.

3) Interest

Since the opportunity cost of capital was assumed to be twelve percent (12%) annually, the interest for commercial vehicles are, therefore, calculated by using the same interest rate.

4) Overhead Cost

As a substitute for accident cost, insurance cost and overhead cost are included as a part of the fixed cost.

After the determination of the various cost items above, the fixed cost per operational hour is estimated for each type of vehicle and is shown in Table 7.8.

Table 7.8 TIME-DETERMINED RUNNING COSTS
(In M$ per hr. at 1981 Prices)

Type of vehicle / Item	M/Cycle	Car	Taxi	Bus	Light Van	Medium Lorry	Heavy Lorry
Fixed Cost	0.35	1.51	2.97	6.41	1.56	3.93	6.38
Crew	–	0.25	1.74	4.36	2.09	2.70	3.11
Depreciation	0.19	0.56	0.16	0.66	0.19	0.35	0.43
Interest	0.15	0.70	0.45	1.76	0.38	0.93	1.15
Overhead	–	–	0.62	2.38	0.46	1.71	1.69
Sub-Total	0.35	0.51	2.97	9.16	3.13	5.69	6.38
Fleet substitutability factor	1.0	1.0	1.0	0.7	0.5	0.7	1.0

7.4.3 Time Cost

Time cost is calculated using the family income approach method with the following assumptions:

a. Travellers will be willing to pay in order to save travel time.

b. The traveller's value of travel time is a function of his personal income.

c. The traveller's value of travel time is a function of his travel purpose.

Time cost of each type of vehicle is calculated by the following formula.

$$Cj = Nj \cdot Ij \times \sum_{i} Ti \cdot Pi$$

where:

Cj	:	Time Cost of vehicle "j"
Nj	:	Average occupancy of vehicle "j"
Ij	:	Hourly income of passenger of vehicle "j"
Ti	:	Composition Ratio of Trip Purpose "i"
Pi	:	Time value factor of Trip Purpose "i"

Then each item of the formula is determined as follows:

(1) Average Occupancy (Nj)

a. Passenger Car	:	3.0 Passengers/car
b. Motor-cycle	:	1.4 passengers/car
c. Bus	:	24 Passengers/car
d. Taxi	:	3.6 Passengers/car

Source: Yearbook of Transport Statistics Malaysia 1979

(2) Hourly Income (Ij)

The hourly income is calculated by the annual income of families and annual working hours by non-vehicle owners, motor-cycle owners and motor-car owners.

a. Non-Vehicle Owner	M$1.44/hour
b. Motor-Cycle Owner	M$2.41/hour
c. Motor-Car Owner	M$5.41/hour

(3) Time Value of Vehicles

The time value factor by each trip purpose is determined based on the aforementioned assumption and tabulated with the composition ratio of each trip purpose to the total trip as shown in Table 7.9.

Table 7.9 TIME VALUE FACTOR AND COMPOSITION RATIO BY TRIP PURPOSE

Trip Purpose (i)	Time Value Factor (Pi)	Composition Ratio (Ti)	
		for owner	for non-owner
Business	100% of hourly income	18%	14%
To and from work	50% of hourly income	60%	46%
Private	No value	22%	40%
Total		100%	100%

Therefore: $\sum_i Pi \cdot Ti$ = 48% (for Vehicle Owner)
= 38% (for Non-Vehicle Owner)

Accordingly the time cost of each vehicle type is given as follows:

Table 7.10 TIME VALUE OF VEHICLES
(In M$ per hr. at 1981 Price)

Passenger Car	M$7.79/hr.
Motor-Cycle	M$1.62/hr.
Bus	M$13.14/hr.
Taxi	M$6.75/hr.

7.5 BENEFIT ESTIMATES

7.5.1 Benefits Accounted

The direct benefits obtained from the construction of the Project Road to traffic can be defined as the difference in the traffic cost between the case where the project is implemented and the case where it is not. The traffic is classified into three categories:

a. Vehicles which currently use the unimproved project roads (normal traffic).

b. Vehicles which will be diverted to the project roads (diverted traffic)

c. Vehicles not diverted to the project roads (non-diverted traffic).

Normal traffic is that which will always use the Project Road with or without improvement and will experience benefits in terms of savings in running cost and travel time.

The diverted traffic relates to that which will be diverted to the Project Road upon its completion. This diverted traffic will experience savings in running cost and travel time compared to its previous longer and congested route.

Incidentally, most of the Project Road consists of newly constructed roads where only diverted traffic will run.

Non-diverted traffic will benefit in traffic cost terms due to decongestion of existing roads.

Besides these three kinds of benefits, there is also the generated benefits from generated traffic. This type was not taken into account in this study because its benefits are assumed to negligible.

The benefit from the Project Road is therefore derived from normal, diverted and non-diverted traffic in the following way.

a. Reduction in travel time (Time Benefit)

b. Savings in vehicle operating cost (Running Benefit)
   – savings in running cost (distance-determined)
   – savings in fixed cost (time-determined)

7.5.2 Benefit Calculation Method

Each type of benefit is calculated using the following formulae.

1) Time Benefits

$$TB = \sum_{ij} [P_{ij} \ (t_{ij}^{WO} - t_{ij}^{W}) \ V]$$

where

- TB : time benefit
- P_{ij} : passenger using the project road between zone i and j
- t_{ij}^{WO}: travel time between zones i and j in the case where the project is not implemented
- t_{ij}^{W} : travel time between zones i and j in the case where the project is implemented
- V : time value

2) Savings in Vehicle Operating Cost

$$RB = \sum_{ij} T_{ij} \ [(L_{ij}^{WO} \cdot RC_{ij}^{WO} - L_{ij}^{W} \cdot RC_{ij}^{W}) + (t_{ij}^{WO} - t_{ij}^{W}) \times FC_{ij}]$$

where

- RB : savings in running cost
- T_{ij} : traffic volumes between zones i and j using the project road
- L_{ij} : travel distance between zones i and j
- RC_{ij} : running cost between zones i and j (distance-determined)
- FC_{ij} : fixed cost between zones i and j (time-determined)

7.5.3 Benefits Calculations

Using the network assignment model, the benefits from each alternative plan are calculated and Table 7.11 shows benefits by type, and Tables 7.12 and 7.13 shows the benefits by alternative plans.

Table 7.11 BENEFITS BY TYPE

Alternative Route		Vehicle Operating Cost			Time Cost	Total
		Running Cost	Fixed Cost	Total		
1990	Route III	7,117 (32.2%)	3,103 (16.2%)	10,220 (53.4%)	8,906 (46.6%)	19,126 (100.0%)
	Route IV	6,643 (34.3%)	3,285 (17.0%)	9,928 (51.3%)	9,407 (48.7%)	19,335 (100.0%)
2000	Route III	17,849 (35.0%)	8,687 (17.0%)	26,536 (52.0%)	24,415 (48.0%)	50,951 (100.0%)
	Route IV	18,505 (34.5%)	9,198 (17.2%)	27,703 (51.7%)	25,873 (48.3%)	53,576 (100.0%)

Note: Upper figure : Benefit (M$'000)
Lower figure : Composition (%)

Table 7.12 BENEFIT BY ALTERNATIVE PLANS

Alternative Route	Type of Bridge	Cross-Section	Access Type	Benefit in 1990 (M$'000)	Benefit in 2000 (M$'000)	Year for Exceeding Capacity
Route I	–	4-lane	Full	13,455	34,431	1999
Route II	–	4-lane	Full	13,664	36,626	1999
Route III	High Level	Plan 1	Full	19,126	50,951	2001
			Partial	17,558	42,816	2001
		Plan 2	Full	19,126	52,596	2005
	Medium Level	Plan 1	Full	19,126	50,951	2001
Route IV	High Level	Plan 1	Full	19,335	53,576	2001
			Partial	17,757	45,047	2001
		Plan 2	Full	19,335	55,317	2005
	Medium Level	Plan 1	Full	19,335	53,576	2001
Route V	High Level	4-lane	Full	19,226	50,615	2001
Route VI	High Level	4-lane	Full	19,135	53,184	2001

Notes: Plan 1 in cross-section: 6-lane from the Toll Expressway to the Prai Roundabout and 4-lane for the other part of the Project Road.

Plan 2 in cross-section: 6-lane from the Toll Expressway to the North Butterworth Container Wharf and 4-lane for the other part of the Project Road.

Table 7.13 BENEFIT BY SECTION

Alternative Route	Type of Bridge	Cross-Section	Access Type	Section	Benefit in 1990 (M$'000)	Benefit in 2000 (M$'000)	Year for Exceeding Capacity
Route III	High Level	Plan 1	Full	Section 1	11,749	37,814	2000
	High Level	Plan 1	Full	Section 2	7,378	13,137	2005
Route IV	High Level	Plan 1	Full	Section 1	11,749	37,814	2000
	High Level	Plan 1	Full	Section 2	7,585	15,762	2005

7.6 ECONOMIC ANALYSIS

(1) Evaluation of Alternative Routes

The economic analysis of the alternative routes is shown in Table 7.14. The economic indicators show that all the alternative routes are economically feasible. Among them, the two most feasible routes are Routes III and IV.

Table 7.14 ECONOMIC INDICATOR BY ROUTE PLANS

Alternative Route	Discounted Benefits ($'000)	Discounted Costs ($'000)	B/C Ratio	Net Present Value ($'000)	Internal Rate of Return (%)
Route I-F, 4-L	80,712	57,615	1.401	23,097	15.5
Route II-F, 4-L	80,952	60,662	1.384	23,290	15.4
Route III-F, Plan 1	124,880	73,302	1.704	51,578	17.5
Route IV-F, Plan 1	129,343	76,351	1.694	52,992	17.4
Route V-F, 4-L	124,628	77,621	1.606	47,007	16.8
Route VI-F, 4-L	124,130	80,665	1.539	43,465	16.4

Notes: a. Discount Rate : 12%
b. Project Life : 25 years
c. In case of the High Level Bridge

(2) Evaluation of Alternative Types of Bridge

The result of economic analysis of the alternative types of bridge is summarized in Table 7.15. All of the alternatives are economically feasible. However, the High Level Bridge with a clearance height of 25 meters in found to be more feasible than the Medium Level Bridge with a clearance height of 16 meters.

Table 7.15 ECONOMIC INDICATORS BY TYPE OF BRIDGE

Alternative Route	Type of Bridge	Discounted Benefit ($'000)	Discounted Cost ($'000)	B/C Ratio	Net Present Value ($'000)	Internal Rate of Return (%)
Route III-F Plan 1	High Level Bridge	124,880	73,302	1.704	51,578	17.5
	Medium Level Bridge	124,880	76,820	1.626	48,060	16.9
Route IV-F Plan 1	High Level Bridge	129,343	76,351	1.694	52,992	17.4
	Medium Level Bridge	129,343	79,869	1.619	49,474	16.8

Notes: a. Discount Rate : 12%
b. Project Life : 25 years

(3) Evaluation of Alternative Cross-Sections

The economic analysis of the alternative cross-section plans is shown in Table 7.16. Both plans are economically feasible. However, Plan 1 (6–lane road from the Toll Expressway to the Prai Roundabout and 4–lane road for other part of the Project Road) is more feasible than Plan 2.

Table 7.16 ECONOMIC INDICATORS BY CROSS-SECTION PLAN

Alternative Route	Type of Plan	Discounted Benefit ($'000)	Discounted Cost ($'000)	B/C Ratio	Net Present Value ($'000)	Internal Rate of Return (%)
Route III-F	Plan 1	124,880	73,302	1.704	51,578	17.5
	Plan 2	141,116	84,438	1.672	56,722	16.8
Route IV-F	Plan 1	129,343	76,351	1.694	52,992	17.4
	Plan 2	147,220	87,485	1.683	59,735	16.9

Notes : a. Discount Rate : 12%
b. Project Life : 25 years

(4) Evaluation of Access to Toll Expressway

Table 7.17 shows the result of economic analysis of access plans. From this table, it is found that the Full Access Type has a higher feasibility than the partial one, in both Route III and IV.

Table 7.17 ECONOMIC INDICATORS BY ACCESS PLANS

Alternative Route	Type of Access	Discounted Benefit ($'000)	Discounted Cost ($'000)	B/C Ratio	Net Present Value ($'000)	Internal Rate of Return (%)
Route III Plan 1	Full Access	124,880	73,302	1.704	51,578	17.5
	Partial Access	108,690	72,266	1.504	36,424	16.2
Route IV Plan 1	Full Access	129,343	76,351	1.694	52,992	17.4
	Partial Access	112,547	75,312	1.494	37,235	16.1

Notes: a. Discount Rate : 12%
b. Project Life : 25 years

(5) Evaluation by Section

The purpose of this analysis is to clarify the priority of the road section in the Project Road. The results of the analysis indicate that the Section 1 has a higher priority for construction than the Section 2.

Table 7.18 ECONOMIC INDICATORS BY SECTION

Alternative Route	Type of Section	Discounted Benefit ($'000)	Discounted Cost ($'000)	B/C Ratio	Net Present Value ($'000)	Internal Rate of Return (%)
Route III Plan 1	Section 1	84,443	44,894	1.925	41,549	18.6
	Section 2	40,437	28,411	1.423	12,026	15.5
Route IV Plan 1	Section 1	84,443	44,894	1.925	41,549	18.6
	Section 2	44,677	31,463	1.420	13,214	15.3

7.7 SENSITIVITY ANALYSIS

The sensitivity analysis is made to find the range of variation in the economic indicators of the Project Road by changing the following indicators.

a. Project Cost
b. Project Benefit
c. Change in Cost Stream
d. Project Life
e. Change in P.C.U. of Motor-Cycle
f. Additional Alignment of the East-West Highway Supporting Road
g. Whether Routes III and IV are feasible or not, when route A is expanded to a 4–lane road

The results of the sensitivity analysis are summarized in Table 7.19. The detailed explanation is presented below:

(1) Construction Cost

The factors which influence the construction cost are as follows:

a. Quantity
b. Unit cost of material
c. Unit cost of equipment
d. Efficiency of equipment
e. Efficiency of labour

Even when an increase of 20% in the project cost changes in the above factors and accrues no change in the project benefits, Routes III-F and IV-F are still feasible.

(2) Project Benefit

As mentioned in the traffic cost study, the factors which influence the benefits are as follows:

a. Vehicle-mileage
b. Vehicle-time
c. Time value
d. Unit running cost
e. Unit fixed cost

Even if the project benefits are reduced by 20% while the project cost remains the same, both plans are still feasible.

(3) Combination of Construction Cost and Project Benefit

Even when the Project Cost is increased by 20% and at the same time the benefit decreased by 20%, both plans are still feasible.

(4) Construction Cost Stream

A study is made to change the yearly cost stream where a larger initial cost is required compared to the original case while the construction period is kept constant.

Even when the yearly stream is changed, all plans are still feasible.

(5) Project Life

A study is made of the case where the project life is cut by 5 years from 25 years to 20 years. Even with this change, all plans are still feasible.

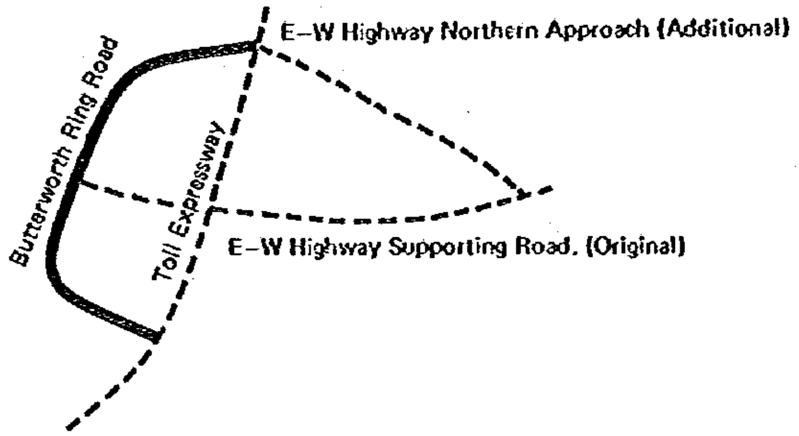
(6) Change in P.C.U. Conversion Factor of Motor-Cycles

A study is made of the case where the P.C.U. conversion factor of motor-cycles is adopted to be 0.75 instead of 0.5 which is used in the original plan.

It is found that when the P.C.U. conversion factor is changed, the project is more feasible than the original plan.

(7) Additional Alignment of the East-West Highway Supporting Road

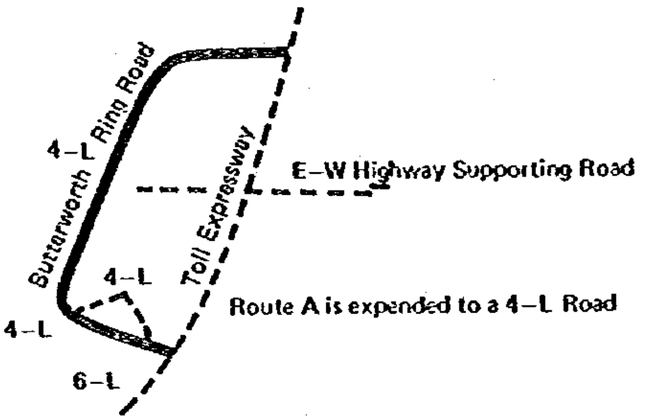
A study is made of the case where another East-West Highway Supporting Road will be added to the northern alignment as below.



Even when the addition alignment is made, the project is still feasible.

(8) Whether Routes III and IV are feasible or not, when Route A is expanded to a 4–lane road

A study is also made of the case where Route A (Jalan Chain Ferry) is expended to a 4–lane road as follows:



Even in this case, the project is still bound to be feasible.

Table 7.19 RESULTS OF SENSITIVITY ANALYSIS

Items \ Alternative Route	Route III – F, Plan 1			Route IV – F, Plan 1		
	B/C Ratio	NPV (M$'000)	IRR (%)	B/C Ratio	NPV (M$'000)	IRR (%)
1. Original Results	1.704	51,578	17.5	1.694	52,992	17.4
2. 20% Cost Increase	1.420	36,918	15.5	1.412	37,723	15.4
3. 20% Benefit Decrease	1.363	26,603	15.0	1.355	27,125	15.0
4. 20% Cost Increase and 20% Benefit Decrease	1.136	11,943	13.2	1.129	11,856	13.2
5. Change in Cost Stream	1.619	47,727	16.7	1.614	49,222	16.6
6. Project Life 20 Years	1.560	41,027	16.9	1.549	41,849	16.8
7. Change in PCU of M/Cycle	2.163	85,257	20.8	2.153	87,938	20.7
8. Alignment of the supporting road of the East-West Highway	1.550	40,346	16.4	1.551	42,082	16.4
9. When Route A is expanded to 4–lane road	1.591	52,808	16.3	1.605	55,867	16.4

7.8 PROJECT EVALUATION

1) Judging from the result of the economic evaluation, Route III and Route IV, with a six (6)–lane road from the Toll Expressway to the Prai Roundabout and a four (4)–lane road for the other part of the Project Road, are economically more feasible than the other alternative routes.

By the following reasons, it is finally concluded that Route IV is a more preferable route than Route III.

a. It is expected that most of the intra-urban traffic will be generated along Jalan Bagan Ajam where it forms part of the Project Road in the case of Route III.

In the case where the Project Road is aligned on Route III, Route III will function as both a primary distributor and a local distributor where mixed traffic such as lorries, passenger car traffic, inter-urban and intra-urban traffic will run. However, in the case where the Project Road is aligned on Route IV, these functions can be segregated. Route IV will be able to function as the primary distributor where mainly lorries and inter-urban traffic will run and Jalan Bagan Ajam will be able to function as the local distributor where mainly intra-urban traffic and passenger car traffic will run.

From the viewponts of traffic safety, environmental protection and effective usage of road, it is concluded that Route IV is a better route than Route III.

b. It is important to provide an alternate road in road planning which can be utilised by emergency or security vehicles, etc. if the need arises. From this viewpoint, Route IV is a more desirable plan than Route III.

c. Judging from the result of traffic assignment mentioned in Section 6.3, Route IV is superior to Route III in reducing congestion rate on the roads.

d. The Project Road is comparatively easier to construct on Route IV than on Route III. This is because in Route III disturbances to the existing heavy traffic flow can be expected on Jalan Bagan Ajam during the construction period.

2) On the basis of the economic evaluation and the traffic study, it is concluded that the carriageway of the Project Road should be 6–lane from the Toll Expressway to the Prai Roundabout and 4–lane for the other part of the Project Road.

3) On the basis of the economic evaluation and technical study, it is concluded that the High Level Bridge with a clearance height of 25 meters is a more feasible plan than the Medium Level one. This recommended plan will allow for the expansion program of the two shipyards along the Prai River.

4) From the results of the economic evaluation and the traffic study, It is recommended that the Full Access Type be constructed at the intersection with the Project Road and the Tolly Expressway.

5) If limitations of finance and/or capacity of contractors requiring stage construction, Section 1 (Southern part of the Project Road) should be launched first, then followed by Section 2 (Northern part).