MALAYSIA

URBAN TRANSPORT STUDY IN GREATER METROPOLITAN AREAS

OF

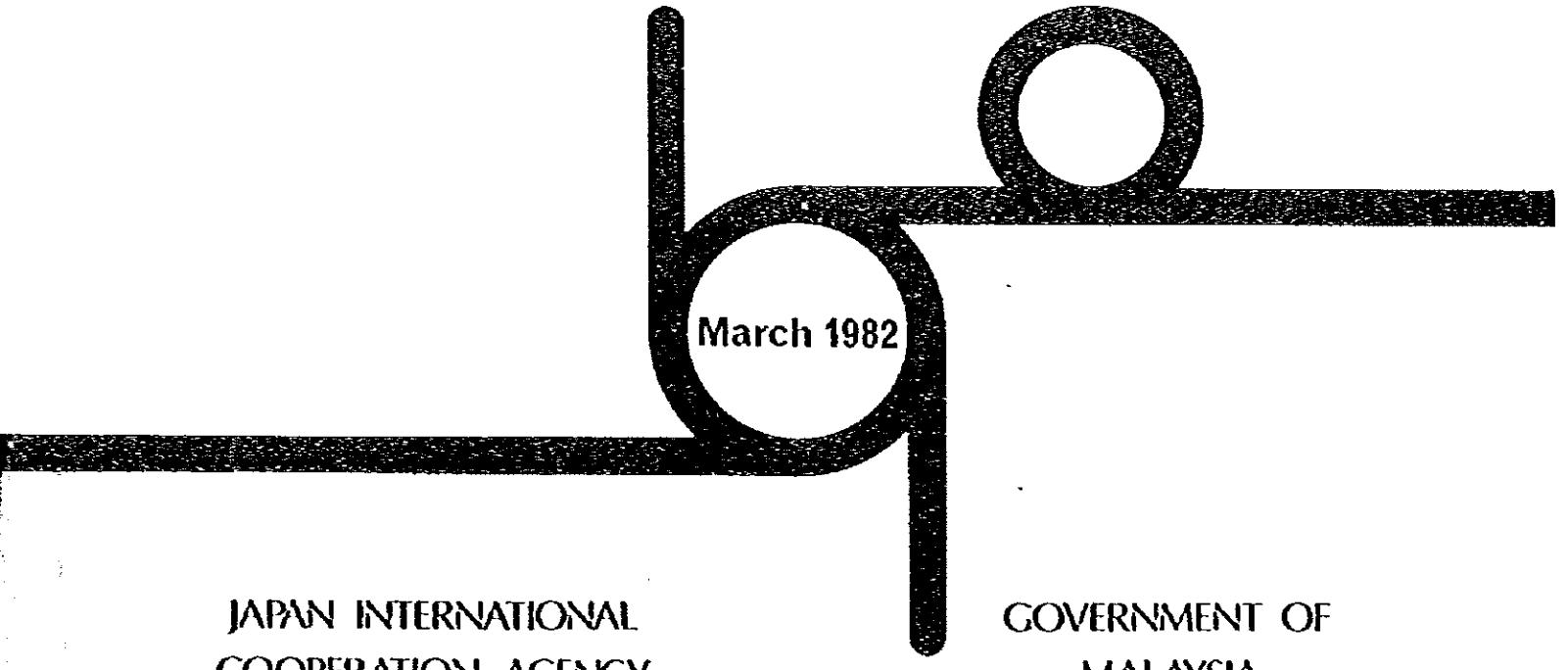
GEORGE TOWN, BUTTERWORTH AND BUKIT MERTAJAM

FINAL REPORT

PHASE II - STAGE II

BUTTERWORTH RING ROAD PROJECT

Main Volume



March 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF MALAYSIA

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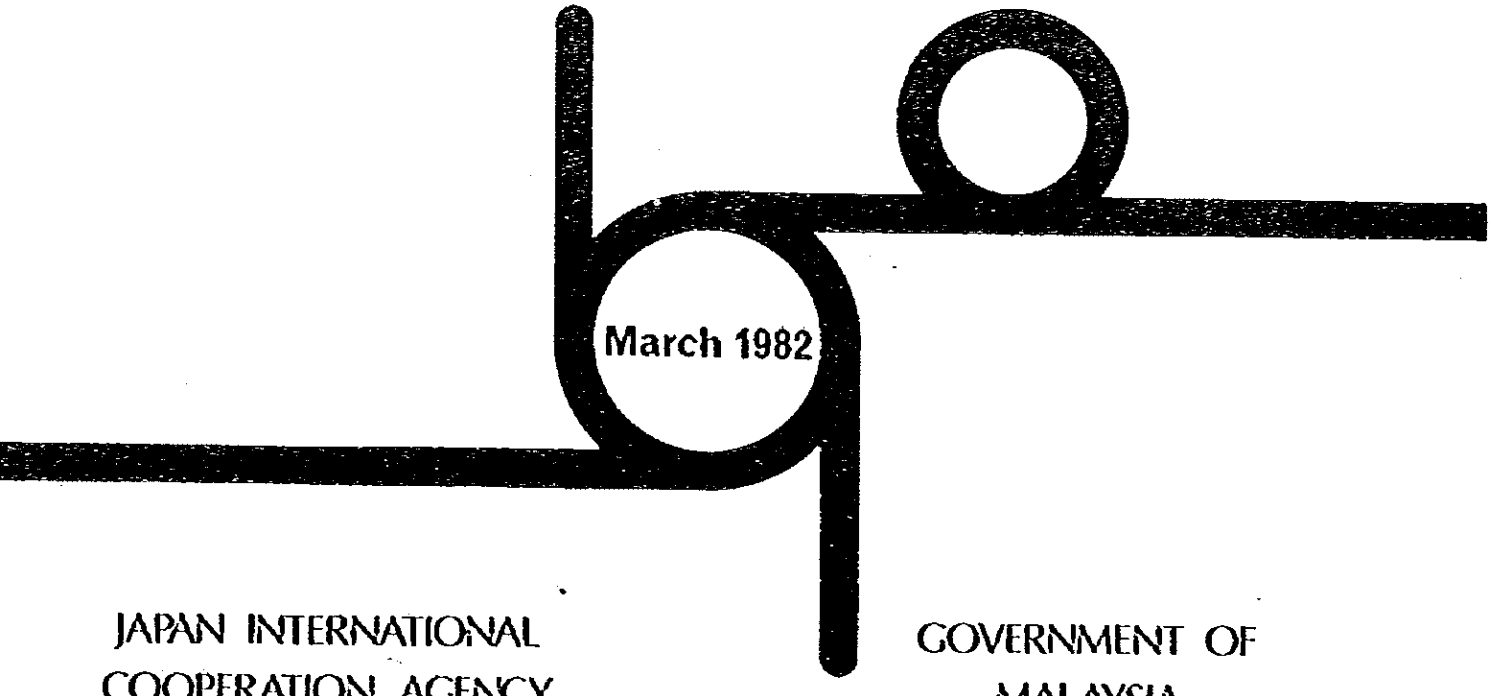

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of Malaysia, the Government of Japan decided to conduct a feasibility study on the Butterworth Ring Road Project in the Greater Metropolitan Areas of George Town, Butterworth and Bukit Mertajam, and entrusted it to the Japan International Cooperation Agency (JICA).

The JICA sent to Malaysia a study team headed by Prof. Takashi Inouye from April 1981 to December 1981.

The team exchanged views with the officials concerned of the Government of Malaysia over the Project and conducted a full scale field survey.

After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

March, 1982

Keisuke Arita

Keisuke Arita
President
Japan International Cooperation Agency

CONTENTS

MAIN VOLUME

APPENDICES

LIST OF TABLES

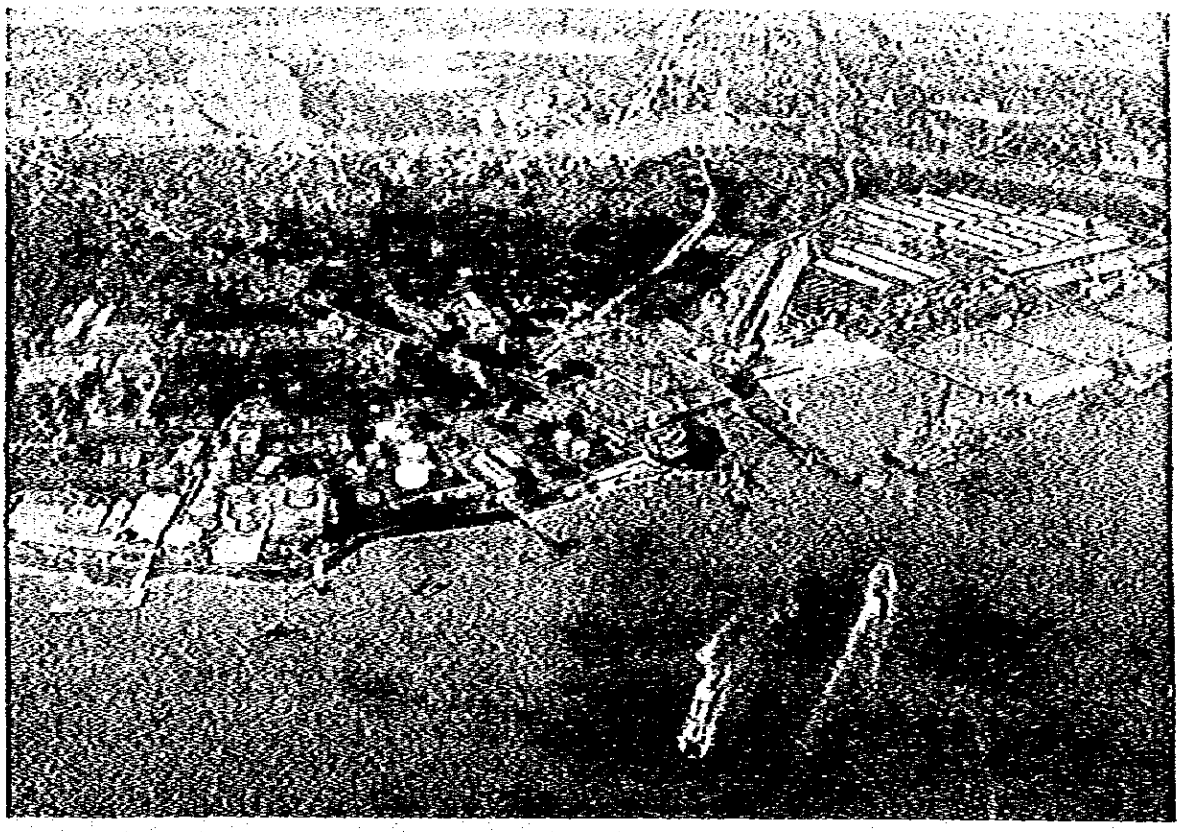
RECOMMENDATION AND SUMMARY

MAIN VOLUME

LIST OF FIGURES

RECOMMENDATION AND SUMMARY

MAIN VOLUME



RECOMMENDATION AND SUMMARY

A. RECOMMENDATION

A.1 GENERAL

Due to the intensive economic development as well as transport developments in Province Wellesley, it's Metropolitan Area is facing serious urban transport problems and is expected to have more intensive problems in the near future.

The Butterworth Ring Road Project (hereinafter referred to as the "Project Road") is proposed in the Phase I Study to solve these problems. The Project Road is proposed as an Intra-Urban Primary Distributor to serve traffic generating from and to urban transport development projects in the Metropolitan Area and to conform to the road network with the Toll Expressway and the East-West Highway Spporting Road which are presently in the design stage for construction.

As a result of the feasibility study for the Project Road in the Stage II of the Phase II Study, the following recommendations are arrived at.

A.2 ROUTE AND DESIGN

1. Judging from the results of the economic evaluation, technical and environmental studies, the Project Road is feasible.

2. No significant difference has been found in the result of the economic evaluation between route III (passing along the combined route D and E) and route IV which are the most feasible routes among the alternatives. However, taking into account the separate road functions of a primary distributor and a local distributor, the provision of an alternative route to the existing Federal Route 1, the reduction of traffic congestion on Jalan Bagan Ajam and the easier implementation, it is concluded that Route IV is the best route among others (See Fig. A.1, A.3)

3. On the basis of the economic evaluation and traffic study, it is recommended that the carriageway of the Project Road for Jalan Prai (Toll Expressway -- Prai Roundabout) is six (6)–lane and that for the other part of this Road is four (4)–lane.

4. In order to disperse traffic effectively as a primary distributor, a design speed of 80 kms/hour is recommended.

5. From the results of economic and technical evaluation, it is concluded that the high level bridge with a clearance height of 25 meters is preferable to the medium level bridge for the Prai River. This is mainly

because the medium level bridge incurs a compensation of over M$15.5 million for the shifting of the Hong Leong–Lürssen Shipyard. The selected plan is clearly compatible with the expansion program of the existing dockyards along the Prai River.

6. On the basis of the economic evaluation and traffic study, it is concluded that a full service interchange should be provided at the intersection of the Project Road at Jalan Sungai Dua with the Toll Expressway.

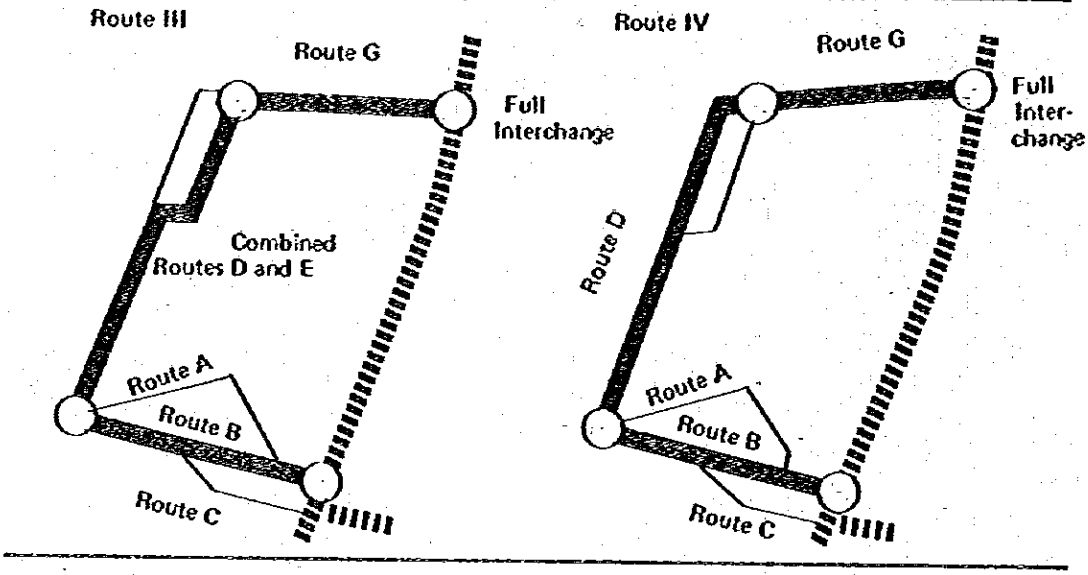


Fig. A.1 ILLUSTRATION OF ALTERNATIVE ROUTE III AND IV

A.3 PROJECT COST

The project cost for the recommended plan is estimated to be M$109.9 million at 1981 prices as tabulated in Table A.1, of which the foreign currency component amounts to M$46.1 million and the local currency amounts to M$63.8 million.

The project cost is shown in Table A.1.

Table A.1 THE PROJECT COST
(In thousand M$ at 1981 prices)

Land Acquisition & Compensation	16,990
Road Construction	36,582
Structure Construction	47,875
Sub-Total	101,447
Engineering Service	8,446
Total	109,893
In Foreign Currency	46,107
In Local Currency	63,786

A.4 IMPLEMENTATION SCHEDULE

Judging from the result of economic and financial analysis and the traffic study, it is recommended that the Project Road should be implemented in stages. The stage construction should preferably be implemented in the following schedule:

Phase 1: Southern Section (Section 1) of the Project Road (1983 – 1987)
(from Jalan Prai – Toll Expressway interchange to the intersection at the approach road of the North Butterworth Container Wharf)

Phase 2: Northern Section (Section 2) of the Project Road (1986 – 1990)
(from the intersection at the approach road of the North Butterworth Container Wharf to Jalan Sungai Dua – Toll Expressway interchange)

In order that the construction of the Phase 1 of the Project Road can be completed by the end of 1987, the detailed engineering for the Project Road should be implemented at the earliest possible time.

The investment requirements corresponding to the aforementioned schedule is M$64.2 million for Phase 1 and M$37.3 million for Phase 2 as shown in Table A.2.

Table A.2 SUMMARY OF FINANCIAL COST
(In thousand M$ at 1981 Prices)

Item \ Components	Foreign	Local	Total
Detailed Engineering and Construction Supervision	4,192	4,254	8,446
Phase 1			
Land Acquisition	0	12,198	12,198
Road Construction	5,148	5,897	11,045
Structure Construction	21,561	19,371	40,932
Total	26,709	37,466	64,175
Phase 2			
Land Acquisition	0	4,792	4,792
Road Construction	11,656	13,881	25,537
Structure Construction	3,550	3,393	6,943
Sub-Total	15,206	22,066	37,272
Total			
Land Acquisition	0	16,990	16,990
Road Construction	16,804	19,778	36,582
Structure Construction	25,111	22,764	47,875
Total	41,915	59,532	101,447
Grand Total	46,107	63,786	109,893

Note: Tax is included in Local Currency.

Implementation Schedule is shown in Fig. A.2.

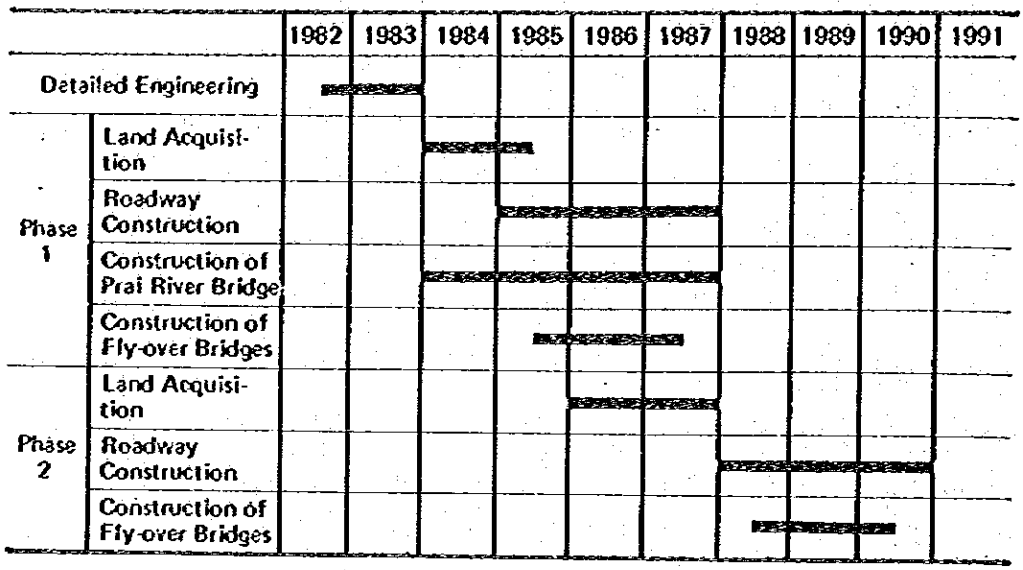


Fig. A.2 RECOMMENDED IMPLEMENTATION SCHEDULE

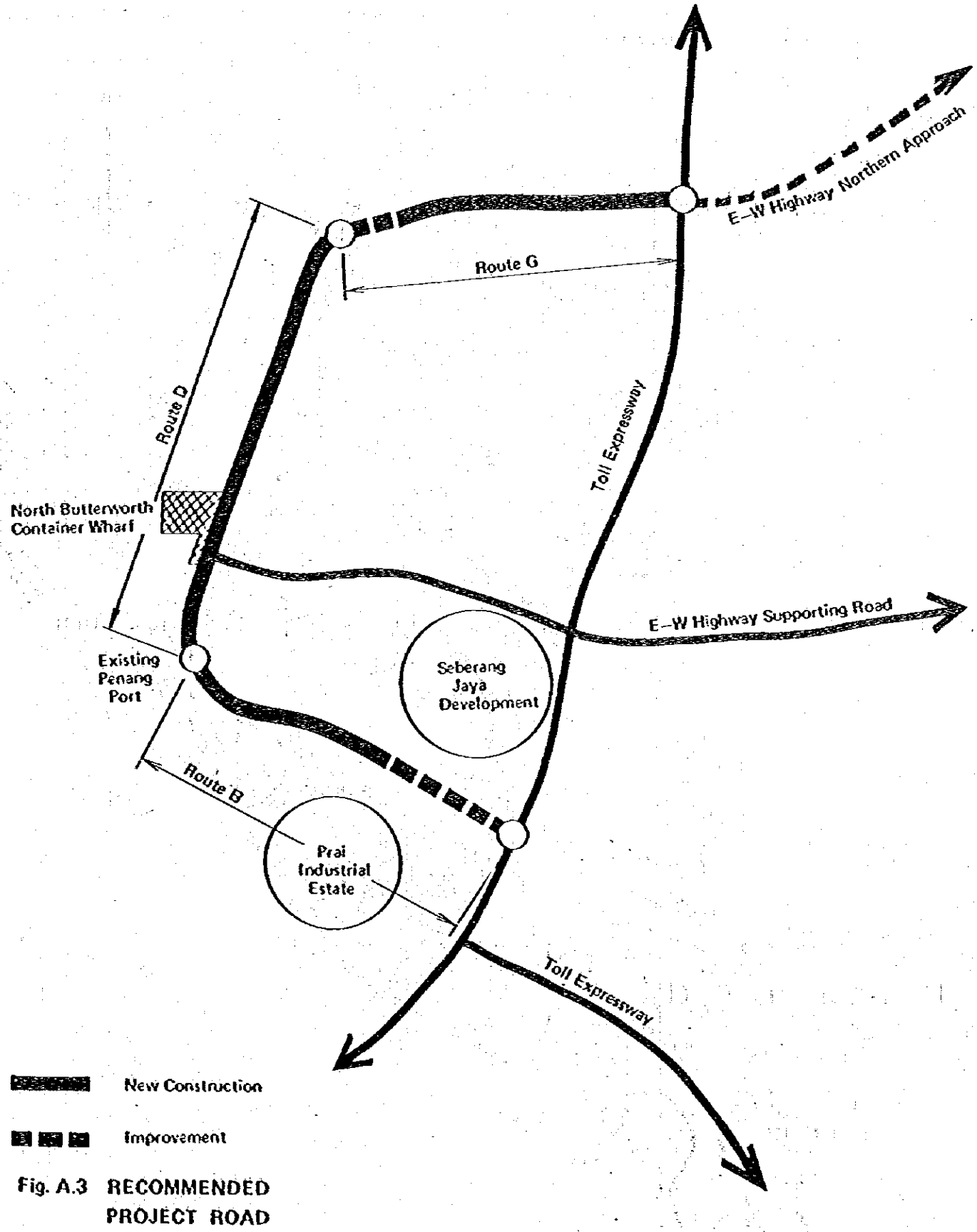


Fig. A.3 RECOMMENDED PROJECT ROAD

B . SUMMARY

B.1 INTRODUCTION

B.1.1 Project Background

The Greater Metropolitan Areas of George Town, Butterworth and Bukit Mertajam (Penang Metropolitan Area) has serious urban transport problems due to the intensive industrial and other urban development undertakings in the area as well as the rapidly increasing number of private vehicles in recent years. Moreover, the intensive transport development projects such as the Penang Bridge Project, the Toll Expressway Project (Alor Star – Changkat Jering Highway), the East-West Highway Supporting Road Project and the Penang Port Development Project will bring about the necessity to renew and develop the existing transport system in the region.

In order to solve the urban transport problems, the Government of Malayia requested the Government of Japan to conduct an Urban Transport Study in the Greater Metropolitan Areas of George Town, Butterworth and Bukit Mertajam (hereinafter called the "Study"). In compliance with the request of the Government of Malaysia, the Government of Japan had decided to undertake the study through the Japan International Cooperation Agency (JICA).

The Study is divided into two phases. Phase I of the study (hereinafter called the "Phase I Study") is aimed at formulating a master plan for the Penang Metropolitan Area and Phase II of the Study (hereinafer called the "Phase II Study") is aimed at determining the feasibility of specific projects selected on the basis of the recommendations made from the Phase I Study.

The Phase I Study, conducted over a period of one year from March, 1979, has established the following set of recommendations for the implementation of its transport system.

1) Long Term Transport Plans
   a. Construction and Improvement of Roads
   b. Improvement of Public Transport
   c. Private Vehicle Restraints
   d. Construction of Transport Terminal Complex

2) Short Term Actions
   a. Implementation of Traffic Engineering and Management Measures

b. Construction and Improvement of Roads
c. Improvement of Bus Transport

Among both the short and long term plans and actions, the Outer Ring Road Project in Penang Island and the Butterworth Ring Road Project in Province Wellesley are both identified as high priority projects.

The Phase II Study is sub-divided into two stages, namely Stage I and Stage II. Stage I of the Phase II study, the feasibility study of the Outer Ring Road Project in Penang Island was carried out from April 1980 to May 1981.

Following this, the Stage II study, the feasibility study of the Butterworth Ring Road Project is taken up and conducted.

B.1.2 Objectives of Stage II of the Phase II Study

The objective of Stage II of the Phase II Study is to determine the technical, economical and environmental feasibility of the construction of the Project Road in accordance with a standard acceptable to the International Financing Institution.

Furthermore, the Japanese team seek to transfer its technology to their Malaysian counterpart during the study period.

B.1.3 Study Approach

The following are the principal activities and processes in the Stage II of the Phase II study.

a. Route Location
b. Traffic Projection
c. Preliminary Engineering and Environmental Study
d. Cost Estimates
e. Economic Evaluation
f. Implementation Program

In this Study, alternatives for the following items of the Project Road are prepared and evaluated from the technical, environmental and economical stand points in order to select the best alternative.

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

The alternatives of the Project Road are proposed and evaluated through the results of studies and discussions made at the technical and steering committee meetings.

The first selection of the alternatives is made from the transport and town planning, environmental study and engineering viewpoints and the second selection is made from the economical viewpoint.

B.2 PRESENT TRANSPORT CONDITIONS

B.2.1 Road Network

The road network configuration in the Study Area consists mainly of grid or ladder pattern. Most of the roads in the network comprise only of a single carriageway. Even though the Federal Route 1 is functioning as a primary distributor in the area, it has only a single carriageway with its width ranging from 7.00 meters to 12.50 meters. The other roads are mostly narrow single carriageways with widths ranging from 5.00 meters to 8.00 meters.

B.2.2 Characteristics of Existing Traffic

(1) Traffic Volume

Based on the traffic volume counting survey and the JKR traffic census data in April, 1981, the traffic volume on the major roads for a period of 12 hours (7 a.m. – 7 p.m.) in Butterworth is obtained. From these figure, it can be recognized that the traffic volume on the Federal Route 1 is comparatively larger than that on the other roads.

(2) Vehicle Composition

On the main roads, such as the Federal Route 1, the composition rate of motor cars is bigger than that of motor-cycles. On the contrary, the minor roads such as Jalan Sungai Dua, the composition rate of motor cars is lower than that of the motor-cycles. It is noted that composition rate of lorries is comparatively bigger on both classes of roads.

(3) Hourly Variation

The hourly fluctuation of the traffic volume at the major roads clearly indicate that there are two peaks, in the morning and in the evening.

B.3 PROJECTION OF TRAFFIC DEMAND

B.3.1 Procedure

The travel data collected and the same traffic projection models developed in the Phase I Study are employed in Stage II of the Phase II Study. The procedure of traffic projection is shown in Fig. B.3.1:

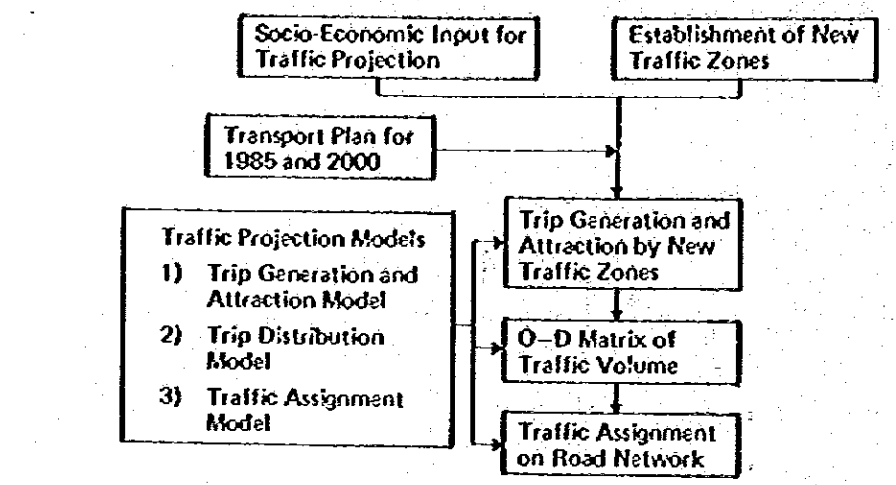


Fig. B.3.1 PROCEDURE FOR TRAFFIC PROJECTION

In order to obtain more detailed traffic volume data on the Project Road, the traffic zones in the Study Area as specified in Phase I study are further sub-divided into 59 zones, 52 internal zones and 7 external zones.

B.3.2 Socio Economic Input for Traffic Projection

As the premises of traffic projection, the socio economic indicators predicted for the year 1985 and the year 2000 in the Phase I Study are adjusted on the basis of the recent 1980 housing and population census, the vehicle registration data in 1980 and the latest land development schemes.

The planned population in the Study Area is 322.0 thousand in 1985 and 482.1 thousand in 2000. The employed population is expected to reach 135.9 thousand in 1985 and 224.7 thousand in 2000.

Based on the socio-economic trends, the number of vehicles in the same area is expected to increase to 87.2 thousand in 1985 and 163.5 thousand in 2000. The socio economic indicators in the Study Area is shown in Table B.3.1.

Table B.3.1 SOCIO ECONOMIC INDICATORS IN THE STUDY AREA

Items		Year			Annual Growth Rate (%)	
		1980	1985	2000	1980–1985	1980–2000
Population		282,300	322,000	482,100	2.7	2.7
Employed Population		112,500	135,900	224,700	3.8	3.5
Number of Vehicles	Motor car	21,500	33,600	78,900	9.3	6.7
	Motor-cycle	40,400	53,600	84,600	5.8	3.8
	Total	61,900	87,200	163,500	7.1	5.0

B.3.3 Results of Traffic Projection

(1) Trip Generation

Number of trips generated in the Study Area is expected to increase from 202.3 thousand P.C.U. in 1979 to 321.9 thousand P.C.U. in 1985 and 579.1 thousand P.C.U. in 2000 in the case where the P.C.U. conversion factor of motor-cycle is assumed to be 0.5. The annual growth rate between 1979 to 1985 is 8.1% and that between 1979 to 2000 is 5.1% in the same case.

The number of trips generated in the Study Area is shown in Table B.3.2.

Table B.3.2 NUMBER OF TRIPS GENERATED IN THE STUDY AREA
(In thousand P.C.U.)

Items		Year			Annual Growth Rate (%)	
		1979	1985	2000	1979–1985	1979–2000
Motor Car		125.0	211.7	420.7	9.2	5.9
Motor-Cycle	Case A	77.3	110.2	158.4	6.1	3.5
	Case B	115.9	165.3	237.6	6.1	3.5
Total	Case A	202.3	321.9	579.1	8.1	5.1
	Case B	240.9	377.0	658.3	7.8	4.9

Notes: Case A assumes that P.C.U. of M-Cycle is 0.5
Case B assumes that P.C.U. of M-Cycle is 0.75

Though case A is mainly used in this study, case B is applied as an alternative case in the sensitivity analysis of economic evaluation.

(2) Traffic Volume on Traffic Lines

Fig. B.3.2 shows the traffic volume on the traffic lines which is computed by a minimum path traffic assignment method.

From this figure, the following observations can be made:

a. The highest growth rate from 1979 to 2000 is in the link between Prai and Seberang Jaya. This is mainly due to intensive transport development such as the Toll Expressway and the Penang Bridge.

b. The growth rate between Butterworth and Prai from 1979 to 2000 is higher than the average growth rate. This is because the urban development in these areas is expected to increase rapidly and the need for access of the traffic from/to the Toll Expressway, Penang Bridge and the North Butterworth Container Wharf is great.

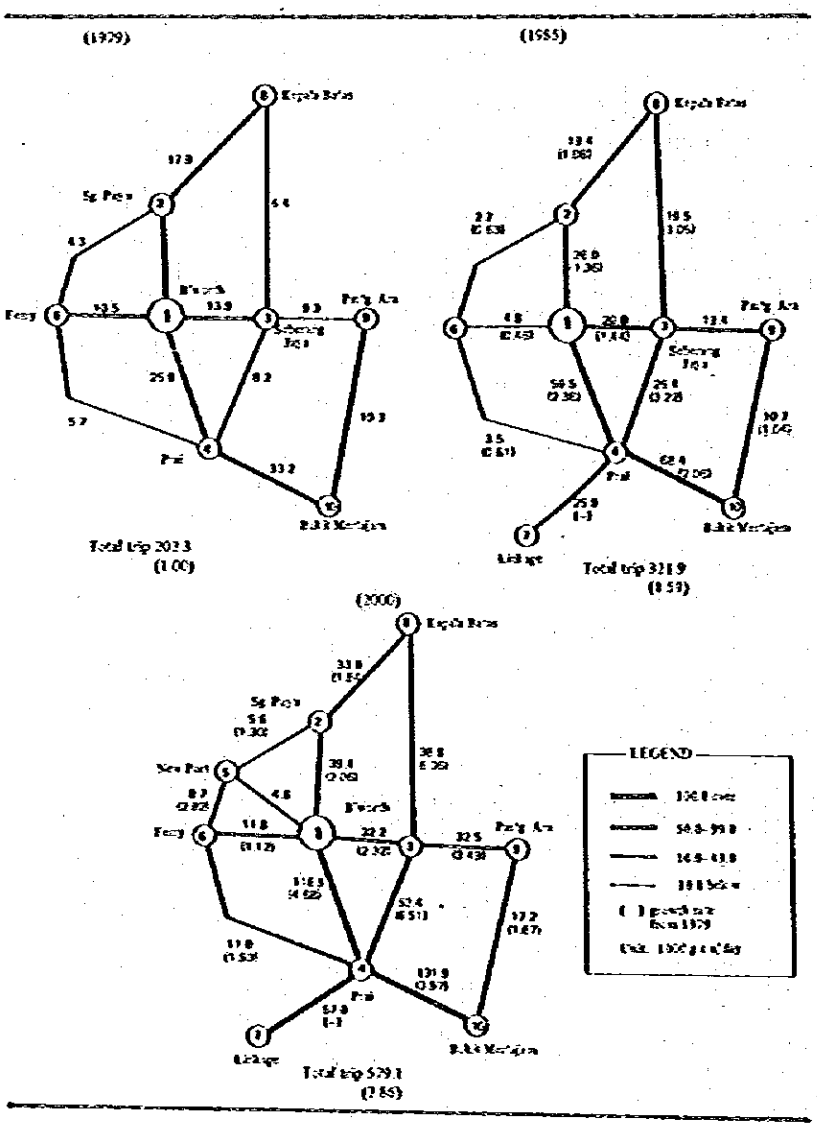


Fig. B.3.2 TRAFFIC VOLUME ON MAJOR SECTIONS

B.4 PRELIMINARY ENGINEERING

B.4.1 Characteristics of the Project Road

The Project Road is planned as an Intra-Urban Primary Distributor in the Phase I Study. The Project Road is expected to serve traffic coming in and out of the planned North Butterworth Container Wharf and the existing Butterworth Port as well as the Prai Industrial Estate. This Project Road is also expected to conform to the effective road networks with the Inter-Urban Primary Distributors such as the Toll Expressway and the East-West Highway Supporting Road. In addition, the Project Road will disperse traffic passing through the urbanized area.

In order that the Project Road can function more effectively, it is necessary to control partially the access traffic to/from minor roads and to have grade separations at major intersections. Moreover, U-turns will be allowed only at limited median openings.

B.4.2 Surveys for Preliminary Engineering

The following surveys are conducted in order to make a preliminary engineering study.

a. Topographic Survey
b. Road Inventory Survey
c. Geotechnical Investigation
d. Material Survey
e. Socio Economic/Environmental Survey

B.4.3 Design Standard

(1) Road Design Standard

The Malaysian Design Standard is basically adopted for the Project Road after a careful comparative review of the other design standards is made.

The design standard adopted is presented below:

a.	Design Speed	80 kms/hr
b.	Carriageway (per lane)	3.75 m
c.	Median Width	3.50 m
d.	Shoulder Width	
	Right Shoulder	0.5 m
	Left Shoulder	2.0 m
e.	Central Reservation	4.50 m
f.	Maximum Gradient	5%
g.	Minimum Radius	210 m

(2) Bridge Design Standard

The Standard Specifications for Highway Bridges and other structures, adopted by the British Standard Institution and the Public Works Department (JKR) in Malaysia, are used as principal guidelines for the structural design of the bridge.

The design live load to be adopted for the design of bridges is used for either the Design HA loading or Design HA loading combined with the design HB loading of 45 units.

B.4.4 Alternative Route Study

Based on the field investigations, the environmental and the land use surveys along the proposed routes and the traffic study, the alternative routes shown in Fig. B.4.1 are established in this study.

The alternative routes are evaluated by a comparative analysis of the following points:

a. Land Use
b. Social and Environmental Factors
   - Disruption of Community
   - Impacts on existing urban facility
   - Impacts on urban environment
c. Design Factors
d. Construction Cost
e. Traffic Flow
f. Road Network Pattern

The results of the comparative analysis of each route are shown in Tables B.4.1, B.4.2 and B.4.3.

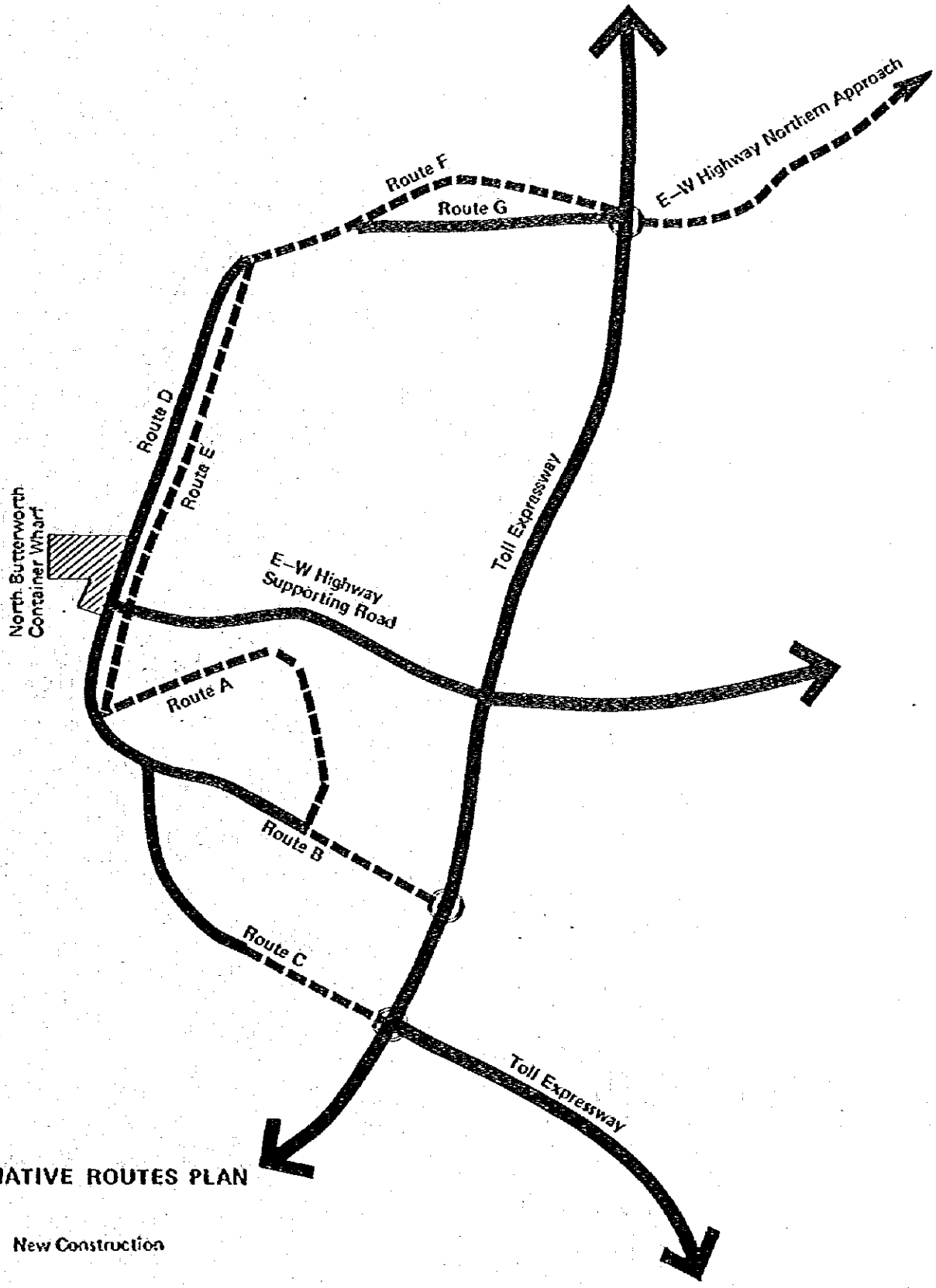


Fig. B.4.1
ALTERNATIVE ROUTES PLAN

New Construction

Improvement

(1) Route A, B and C

Table 8.4.1 COMPARISON OF ALTERNATIVE ROUTES

Items \ Route	Route A	Route B	Route C
1. Land Use	Developed Area for Residence and Commerce	Developed Area for Residence and Transportation	Developed Area for Industry and Transportation
2. Social & Environmental Factors			
a. Disruption of Community	Anticipated	Small	Anticipated
b. Impacts on existing urban facilities	Market would be affected	Insignificant	Malayawata and Malayan Railway yard would be affected
c. Impacts on urban environment	Anticipated	Small	Small
3. Design of the Project Road	Prai River Bridge would be required	Prai River Bridge would be required	Major structure over Malayan Railway yard as well as Prai River Bridge would be required
4. Construction Cost	M$26 million	M$49 million	M$59 million
5. Traffic Flow	Smooth traffic flow can not be expected since passing through urbanized area	Smooth traffic flow can be expected	Smooth traffic flow can be expected
6. Network Pattern	Not suitable network pattern	Suitable network pattern	Suitable network pattern

The comparative analysis mentioned above shows that 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 described in Chapter 8.7.

(2) Route D, E and combined route D and E

Table 8.4.2 COMPARISON OF ALTERNATIVE ROUTES

Items \ Route	Route D	Route E	Combined Route D and E
1. Land Use	Seashore Area for Recreation	Developed Area for Residence and Commerce	Seashore and Developing Area for Residence
2. Social & Environmental Factors			
a. Disruption of Community	Small	Anticipated	Small
b. Impacts on existing urban facilities	Insignificant	Many shops and houses would be affected	Some residential houses would be affected
c. Impacts on urban environment	Park along seashore area would be affected	Anticipated	Small
3. Design of the Project Road	No problem	Service road would be required	Service road would be required
4. Construction Cost	M$39 million	M$64 million	M$38 million
5. Traffic Flow	Smooth traffic flow can be expected	Smooth traffic flow can not be expected because of passing urbanized area	Smooth traffic flow can be expected
6. Network Pattern	Alternative of Federal route 1 could be prepared	Alternative of Federal route 1 couldn't be prepared	Alternative of Federal Route 1 could partially be prepared

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$1 million (the latter route is cheaper than the former one), however, the former route may cause less social and environmental problems and a possibility of preparing an alternative to the Federal Route 1.

However, the choice of these two alternatives will only be made after the economic evaluation.

(3) Route F & G

Table B.4.3 COMPARISON OF ALTERNATIVE ROUTES

Items \ Route	Route F	Route G
1. Land Use	Kampong Area	Agricultural Area for Padi
2. Social & Environmental Factors		
a. Disruption of Community	Anticipated	Small
b. Impacts on existing urban facilities	Small houses would be affected	Insignificant
c. Impacts on urban environments	Anticipated	Small
3. Design of the Project Road	2 water pipes (24 inches and 54 inches in diameter) will be affected.	No problem
4. Construction Cost	M$16 million	M$12 million
5. Traffic Flow	Smooth traffic flow	Smooth traffic flow
6. Network Pattern	Alternative of Jalan Sungai Dua could not be provided	Alternative of Jalan Sungai Dua could be provided

Considering the above-mentioned aspects, it is recommended that Route G be selected from the view of less construction cost and smaller environmental problems.

Following the comparative analysis mentioned above the alternative routes shown in Fig. B.4.2 are further subjected to an economic evaluation as in Chapter B.7.

B.4.5 Preliminary Design of Project Road

(1) Alignment Study

Based on the alternative routes selected in section B.4.4, a preliminary alignment study is made and presented below:

1) Horizontal and Vertical Alignments

The horizontal and vertical alignments adopted for each alternative routes are presented on the plan and profile sheets with horizontal scale 1 : 3,000 and in drawings.

The elements of horizontal and vertical alignments, the stations, radii of horizontal curves, finished grade line and existing ground line are presented in drawings.

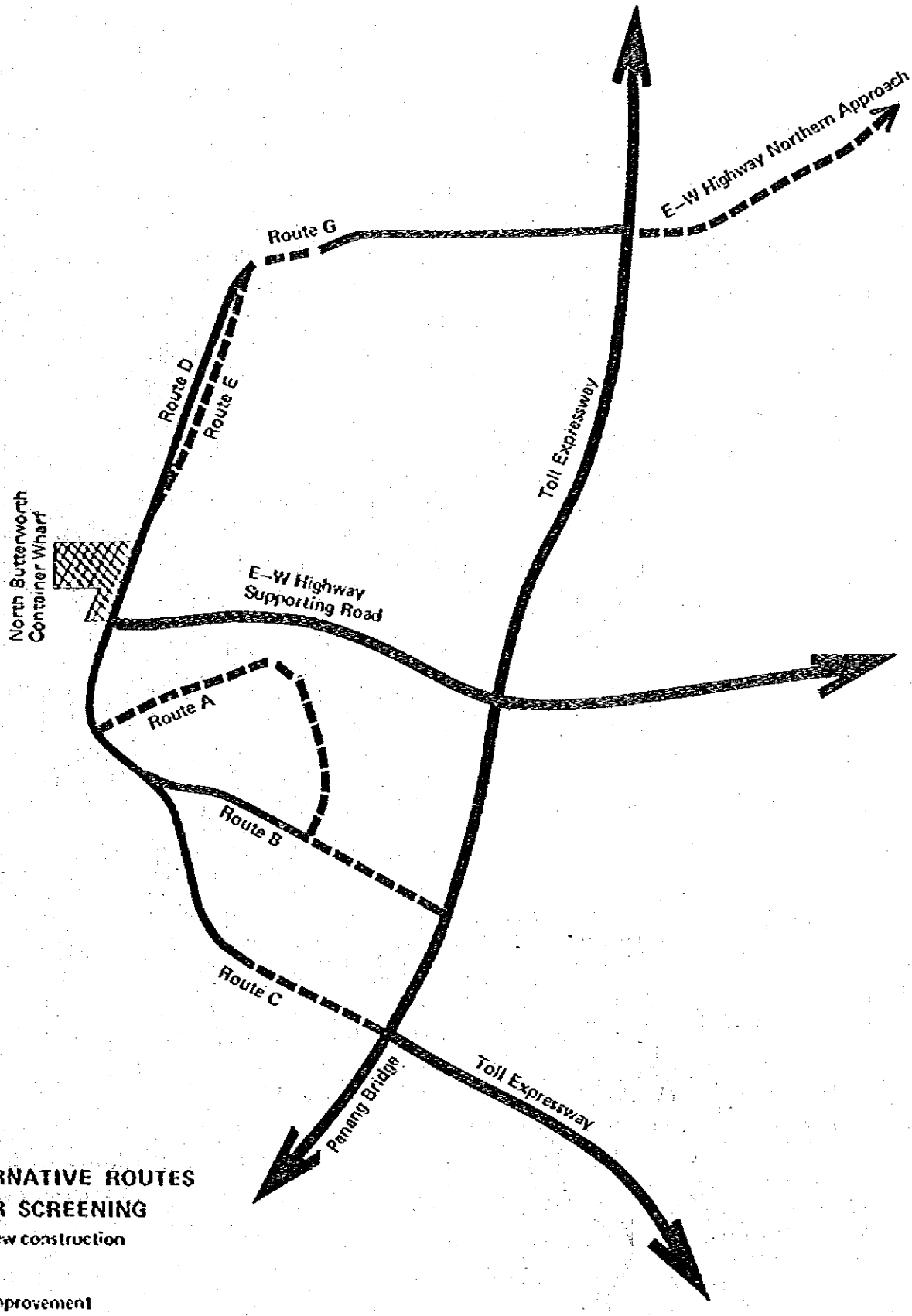


Fig. B.4.2
ALTERNATIVE ROUTES AFTER SCREENING

New construction

Improvement

In the alignment study, the following factors controlling the engineering aspects are considered:

a. In sections subject to improvement of the existing road, the existing alignment of that road is basically adopted with some modification of radii section.
b. Maximum gradient of 4.0% is adopted for the Prai River Bridge.
c. Minimum gradient of 0.3% is adopted for roadway surface drainage.
d. Minimum vertical clearance for grade separated structure is 4.75 meters.
e. Maximum embankment height is adopted as 4.0 meters.
f. A combination of horizontal and vertical alignments is also considered.

(2) Cross-Section

Based on the elements of cross-section components applicable to the Project Road mentioned in Section B.4.3, the typical cross-section is presented in Fig. B.4.3 and B.4.4.

It is proposed that two alternative cross-sectional plans 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 part of the Project Road.

2) 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.

Fig. B.4.4 shows Plan 1 being applied to the Project Road.

(3) Interchange and Intersection Designs

Regarding the main intersections, five (5) grade-separated intersections and five (5) at-grade intersections are proposed in this study and are shown in Fig. B.4.5. Regarding the interchange to the Toll Expressway, a partial and a full service interchange are prepared as the alternatives which are later subjected to a final selection in the economic evaluation.

(4) Pavement Design

A comparative analysis show that asphalt pavement is superior not only from the technical, but also from the economical considerations, and hence is recommended as the pavement type for the Project Road. It is also compatible to the recent pavement work in Penang.

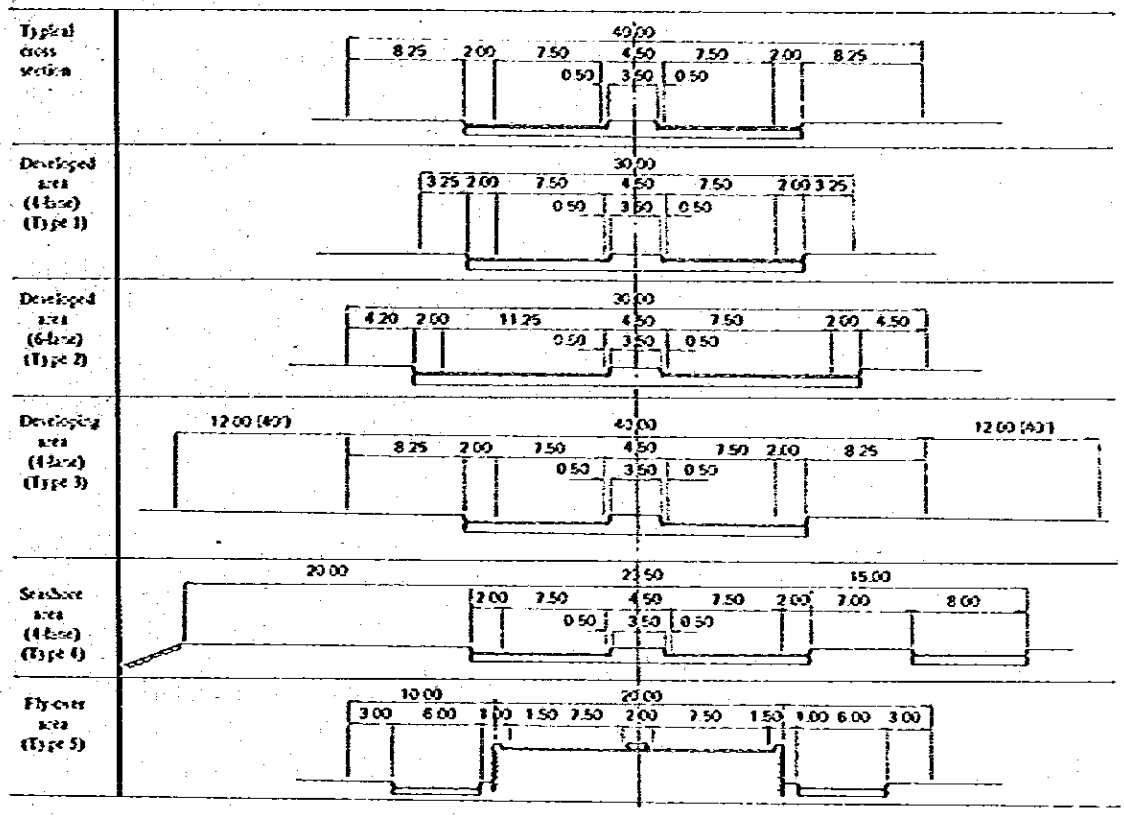


Fig. B.4.3 TYPE OF CROSS-SECTION

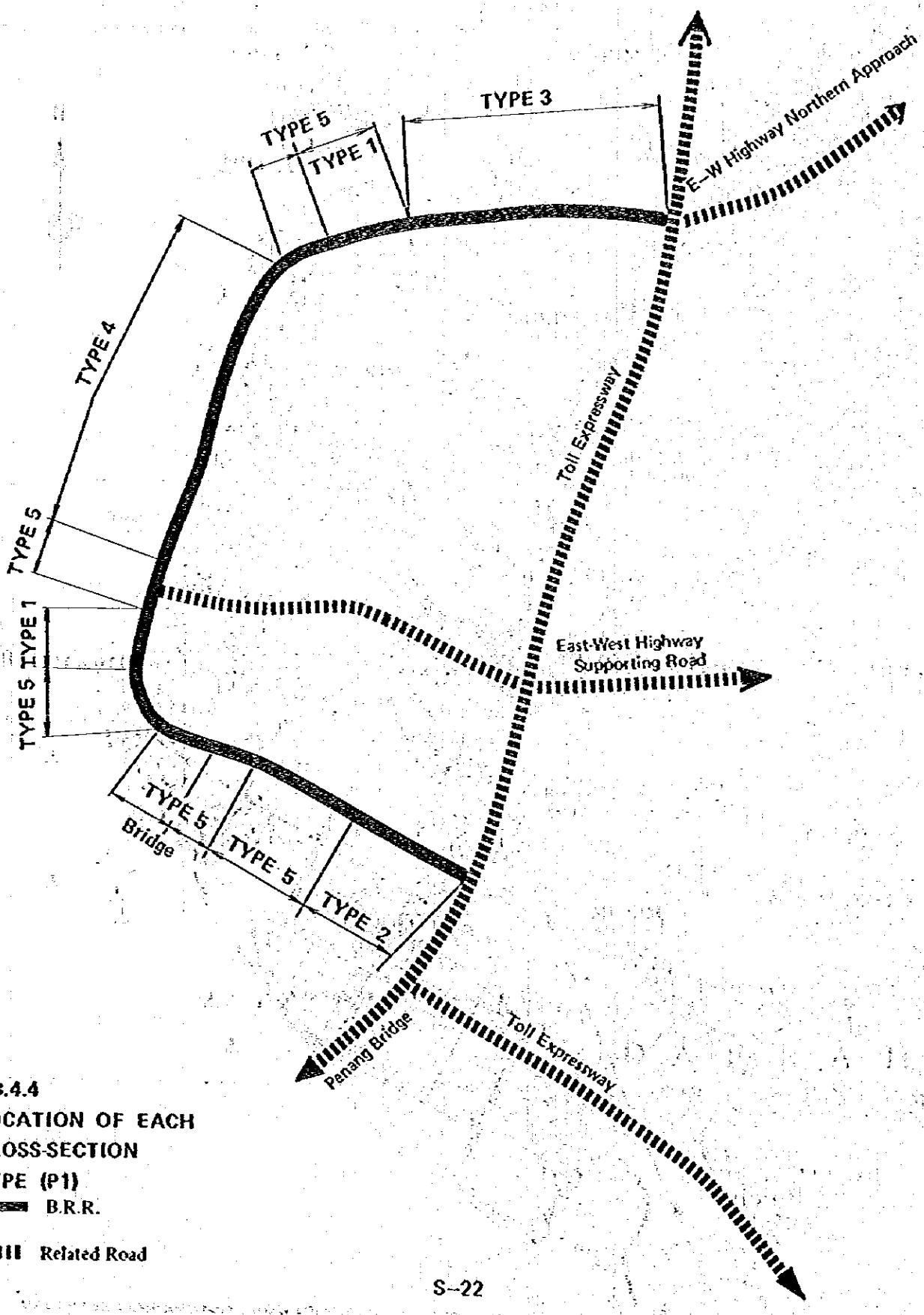


Fig. B.4.4
LOCATION OF EACH
CROSS-SECTION
TYPE (P1)

B.R.R.

Related Road

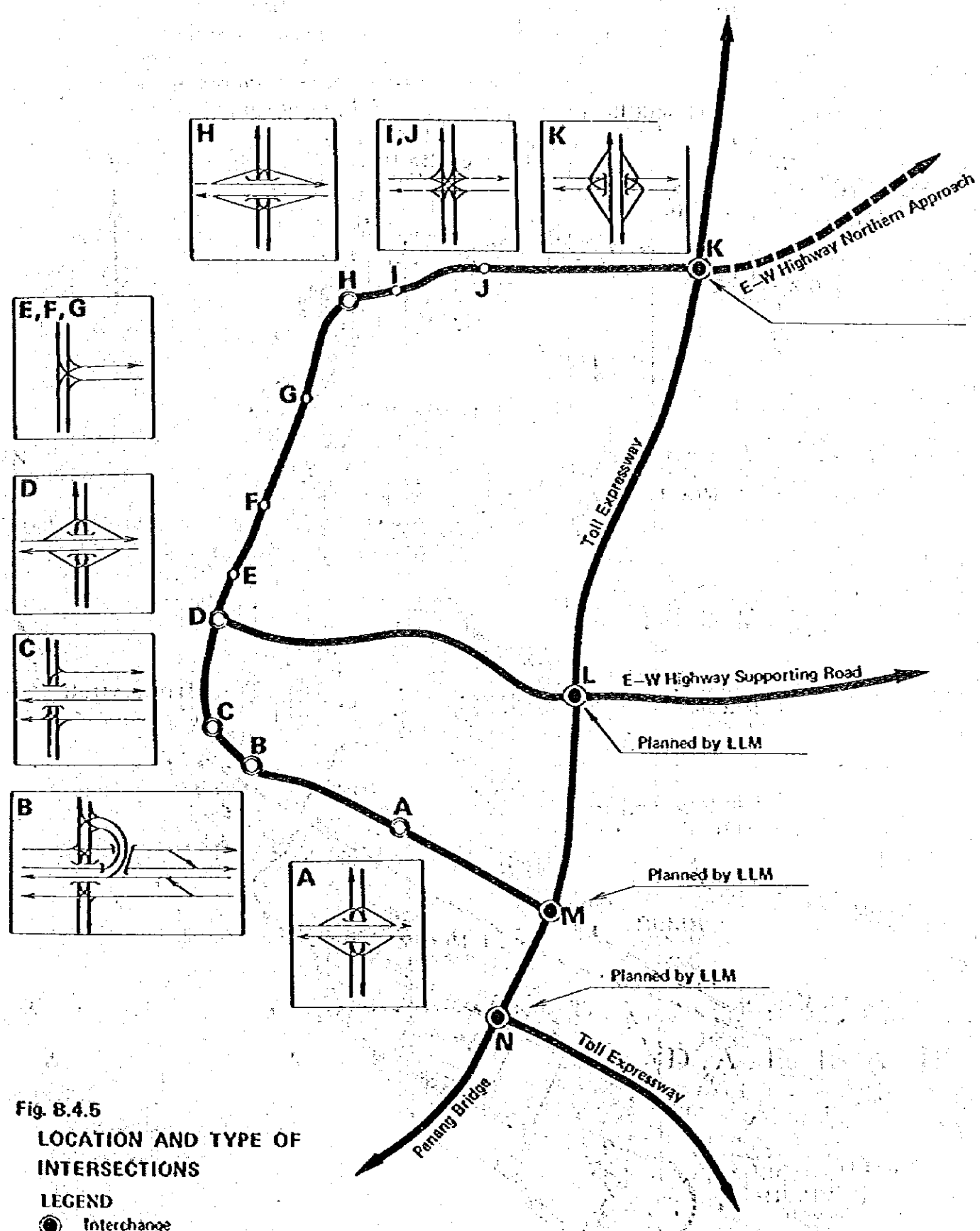


Fig. 8.4.5

LOCATION AND TYPE OF INTERSECTIONS

LEGEND

- Interchange
- Grade Separation Intersection
- At-Grade Intersection

B.4.6 Study on Alternative Structures for the Prai River

(1) General

Prior to the commencement of the alternative structure study, the following investigations are made in order to help determine the type, span length, dimensions, etc, of the structure.

a. Soil investigation at locations of proposed sub-structure.

b. Topographic survey and sounding survey at the project site.

c. Other relevant investigations, including availability of materials, navigation opening etc.

Based on these investigations, the navigation opening is found to be a critical condition for the design of structure with the following three alternatives being considered.

a. A clearance height of 25.0 meters

b. A clearance height of 16.0 meters

c. A clearance height of 3.5 meters

(2) Alternative Structures for the Prai River

Based on the field investigations, the navigation opening, the construction materials and method, etc., the alternative structures for the Prai River (established in this study) are shown in Table B.4.4.

Table B.4.4 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 P.P.C. Dockyard	Medium Level Bridge Low Level Bridge	

Based on the alternative structure plans mentioned above, the initial Structure plans for the Prai River are made and are shown in Fig. B.4.6.

(3) Comparative Analysis of Structure Plans for the Prai River

The alternative structure plans for the Prai River are analyzed comparatively from the viewpoints of technical possibility, cost and function of the Project Road. The comparison of the alternative plans are shown in Table B.4.5.

Table B.4.5 COMPARISON OF ALTERNATIVE STRUCTURE PLANS

Alternative Plans	Construction Cost (M$'000)	Shifting of Shipyard	Other Viewpoints
1. High Level Bridge (1)	51,681	Not necessary to shift shipyards	–
2. High Level Bridge (2)	40,839	– do –	–
3. Underwater Tunnel	128,036	– do –	Technically possible, but rather hard to construct. Maintenance and operating costs of tunnel are required.
4. Medium Level Bridge	45,660	Shifting of Hong Leong Shipyard is necessary	–
5. Low Level Bridge	52,656	Shifting of both H.L. and P.P.C. Dockyard is necessary	–
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.
7. Low Level Bridge (Movable)	33,078	No Need	Same problems as mentioned in No. 6.

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.

The following conclusions can be derived from Table B.4.5.

a. From the functional point of view at the Project Road (mentioned in Section B.4.1), 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.

Alternative Structure Plan		Navigation Opening	Compensation	Longitudinal Profile of Structure	Construction Cost (M$'000)
B-1	High Level Bridge (1)	30 30	No Need	L=300 PRAI ROUNDABOUT L=2120 JALAN CHAIN FERRY 6% 6% 4% 4% H=28 6%	51,681
B-2	High Level Bridge (2)	30 30	No Need	L=300 L=1380 L=280 6% 6% 4% 4% H=26.0 6% 6%	40,839
B-3	Under water Tunnel		No Need	L=300 L=1100 L=280 6% 6% 4% 4%	128,036
B-4	Medium Level Bridge	30 30	Need for Hong Leong-Lurssen Shipyard	L=300 L=830 L=280 6% 6% 4% 4% H=16.0 6% 6%	45,660
B-5	Low Level Bridge	30 30	Need for Hong Leong-Lurssen Shipyard and Bagan Dalam Dockyard	L=300 L=670 L=280 6% 6% 4% 4% 6% 6%	52,656
B-6	Medium Level Bridge (Movable)	30 30	No Need	L=300 L=830 L=280 6% 6% 4% 4% H=16.0 6% 6%	38,917
B-7	Low Level Bridge (Movable)	30 30	No Need	L=300 L=670 L=280 6% 6% 4% 4% 6% 6%	33,078

Fig. B.4.6 ALTERNATIVE STRUCTURE PROFILES

B.4.7 Preliminary Bridge Design

(1) Super-Structure

1) Prai River Bridge – Route A

The total bridge length, span length and proposed height are the same as in the existing bridge.

The recommended structure type is the Prestressed Concrete T-Shaped girder bridge.

2) Prai River Bridge – Route B

For the main span bridge, the Prestressed Concrete box girder bridge with a central span of 70 m is recommended, paying considerations to the cost, construction condition, maintenance and aesthetics.

For the approach span bridge, the Prestressed Concrete hollow slab bridge with a span length of 30 to 35 m is recommended from the same viewpoints as in the main span bridge.

3) Prai River Bridge – Route C

The same structure type as that of Route B is adopted.

4) Fly-over Bridge

Same as the approach span bridge of the Prai River Bridge.

(2) Sub-Structure

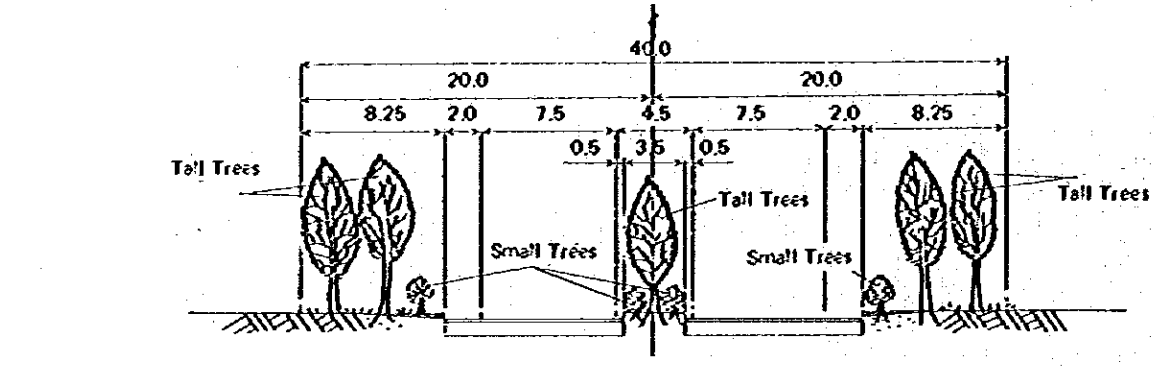
As a result of the geotechnical investigation, it is found that the geotechnical condition at the bridge sites is very poor. Therefore, pile foundation should be employed for the sub-structures of all bridges, as follows:

a. Type of pile : Prestressed Concrete Pile
b. Diameter of pile : 60 centimeters
c. Length of pile : 55 meters

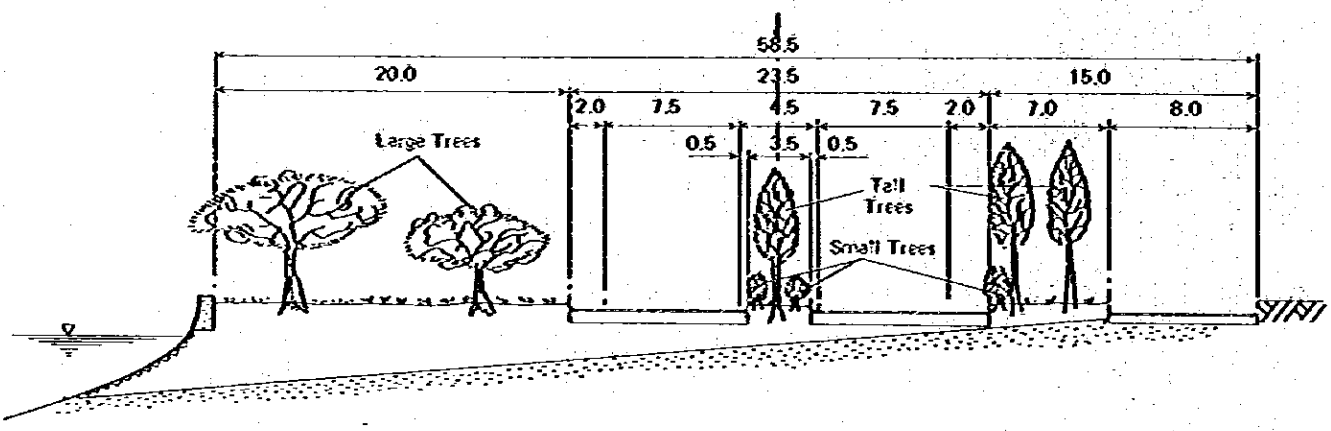
B.4.8 Environmental Considerations

The environmental study is aimed to assess the roadside environment in terms of protection, setting up planning measures in order to mitigate environmental disturbances if and when they are foreseeable, and to define the conceptual role of road development.

In order to reduce any foreseeable disturbances, mitigation measures such as providing a buffer zone and planting of roadside tree are proposed. An example of such a design is shown in Fig. B.4.7.



RESIDENTIAL AREA



SEASHORE AREA

Fig. 8.4.7 TYPICAL CROSS-SECTION FOR ENVIRONMENTAL PROTECTION

B.5 TRAFFIC ASSIGNMENT TO ALTERNATIVES

B.5.1 Procedure

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

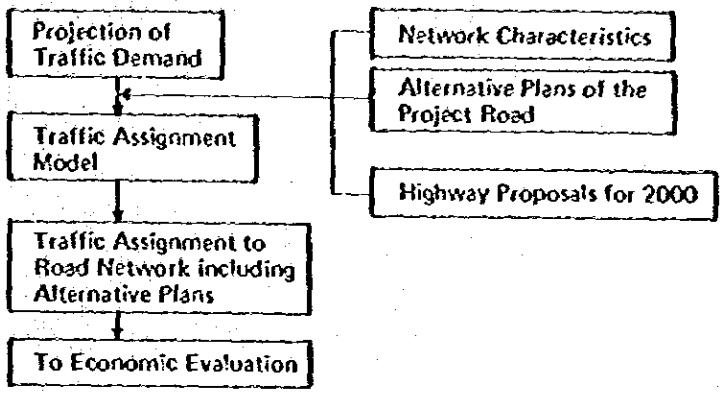


Fig. B.5.1 PROCEDURE FOR TRAFFIC ASSIGNMENT

B.5.2 Road Network

The road network in the year 2000 proposed in Phase I Study is adopted in this study.

It is also assumed that the ferry services in transporting passengers, motor-cycles and motor-cars will continue its services even after the completion of the Penang Bridge and the East-West Highway Supporting Road will pass through the central area in Butterworth and will terminate at the North Butterworth Container Wharf.

Regarding the Project Road, after many alternative routes were examined from viewpoint of engineering and environmental aspects as well as the road network configuration aspects, six (6) alternative routes, shown in Fig. B.5.2, are selected.

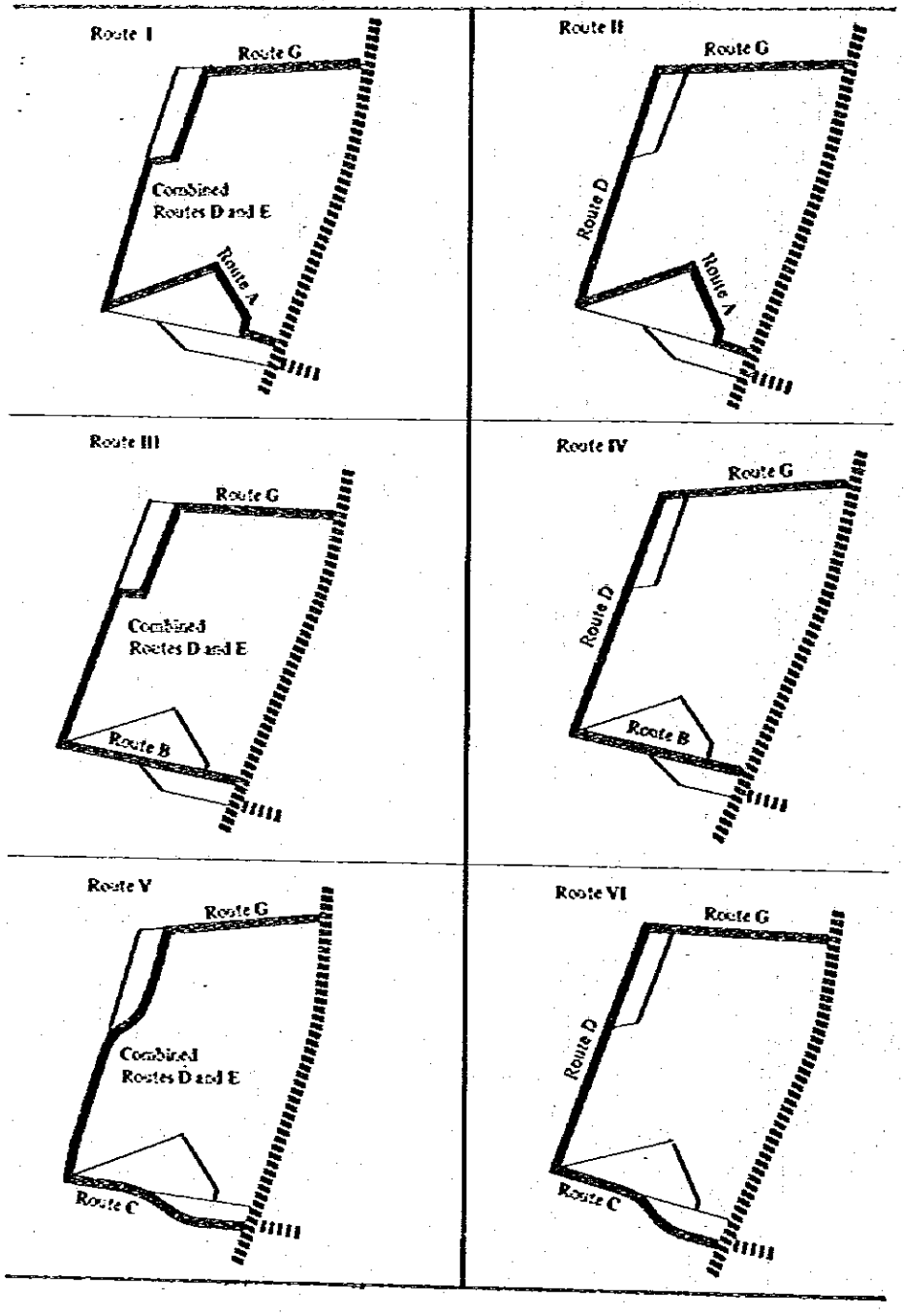


Fig. B.5.2 ALTERNATIVE ROUTES FOR THE PROJECT ROAD

B.5.3 Results of Traffic Assignment

(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 1990 and 2000 is expected to be 92 thousand P.C.U. and 136 thousand P.C.U., respectively.

The average annual growth rate during 1990 – 2000 will be about 4.0 per cent per annum.

Table B.5.1 DAILY TRAFFIC VOLUME ON THE PROJECT ROAD

Items	Year	Traffic Volume ('000 P.C.U.)	Vehicle Kilometer ('000 P.C.U.-Kms)
Route III (Plan 1) and full access interchange	1990	95.9	381.2
	2000	146.9	539.5
Route IV (Plan 1) and full access interchange	1990	91.7	403.5
	2000	135.7	538.4

Fig. B.5.5, B.5.6 illustrates the flow of the daily traffic volume on road network. From this figure, the following observations can be made:

a. The assigned traffic volume on the Project Road is comparatively large. Especially, that on the Prai River Bridge in the year 2000 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).

(2) Congestion Rate of Alternative Routes

Table B.5.2 shows the congestion rate of alternative routes. Judging from the congestion rate, Route IV is clearly superior to the other alternative routes, especially to reduce the congestion rate in C.B.D. in Butterworth.

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

Table 8.5.2 CONGESTION RATE BY ALTERNATIVE ROUTES

Area	Item \ Alternative Route	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	639.6	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:

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

(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, Route III or IV are verified in being effective in decreasing the traffic congestion as well as increasing the travel speed which is shown in Fig. B.5.3.

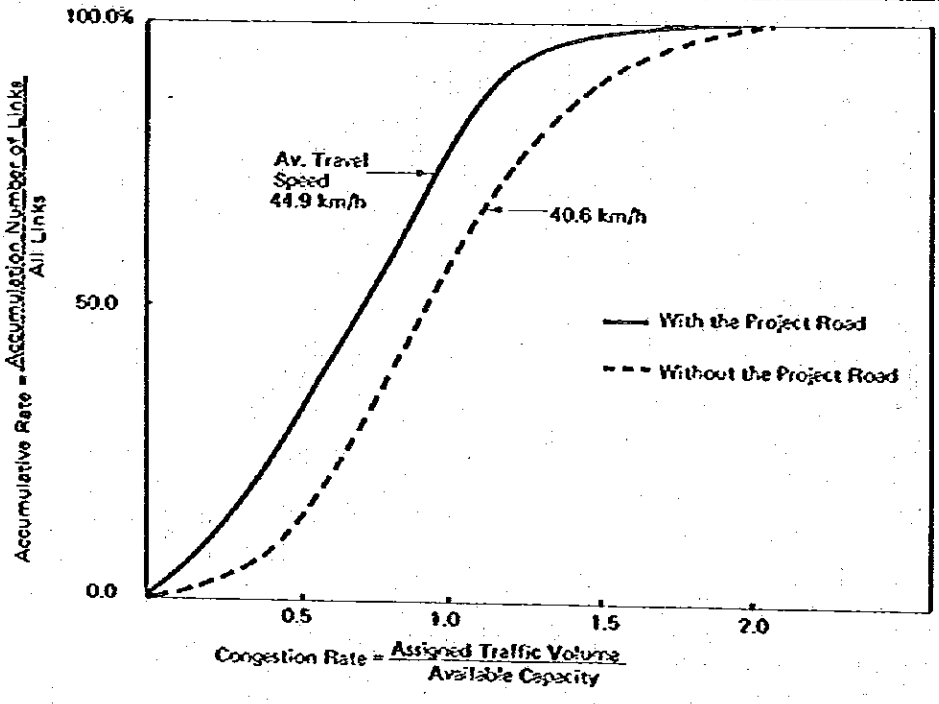


Fig. B.5.3 DISTRIBUTION OF CONGESTION RATE ON ALL LINKS (YEAR 2000)

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. B.5.4.

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

where Ai : Accessibility of zone i
Pj : Population of zone j
tij : Travel time between zone i and zone j

This figure clearly indicated that the Project Road will contribute to improve its accessibility to each traffic zone.

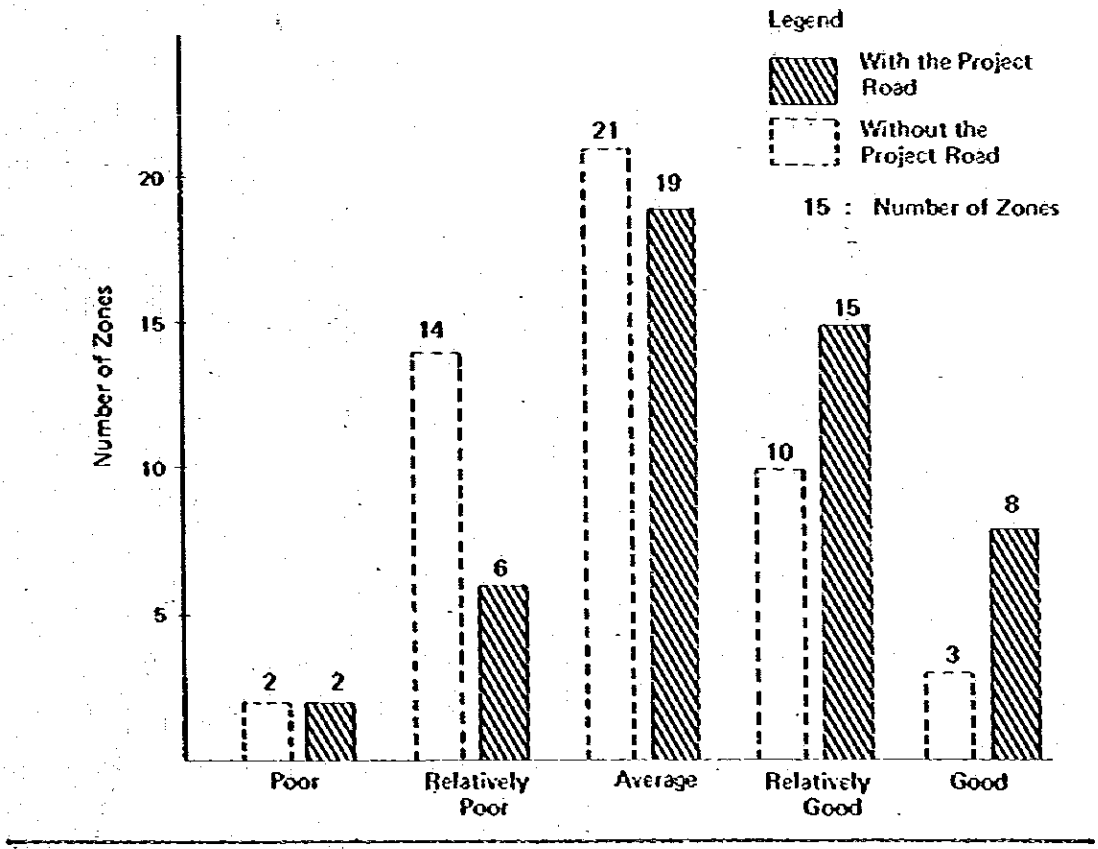


Fig. B.5.4 DISTRIBUTION OF ACCESSIBILITY BY ROAD NETWORK

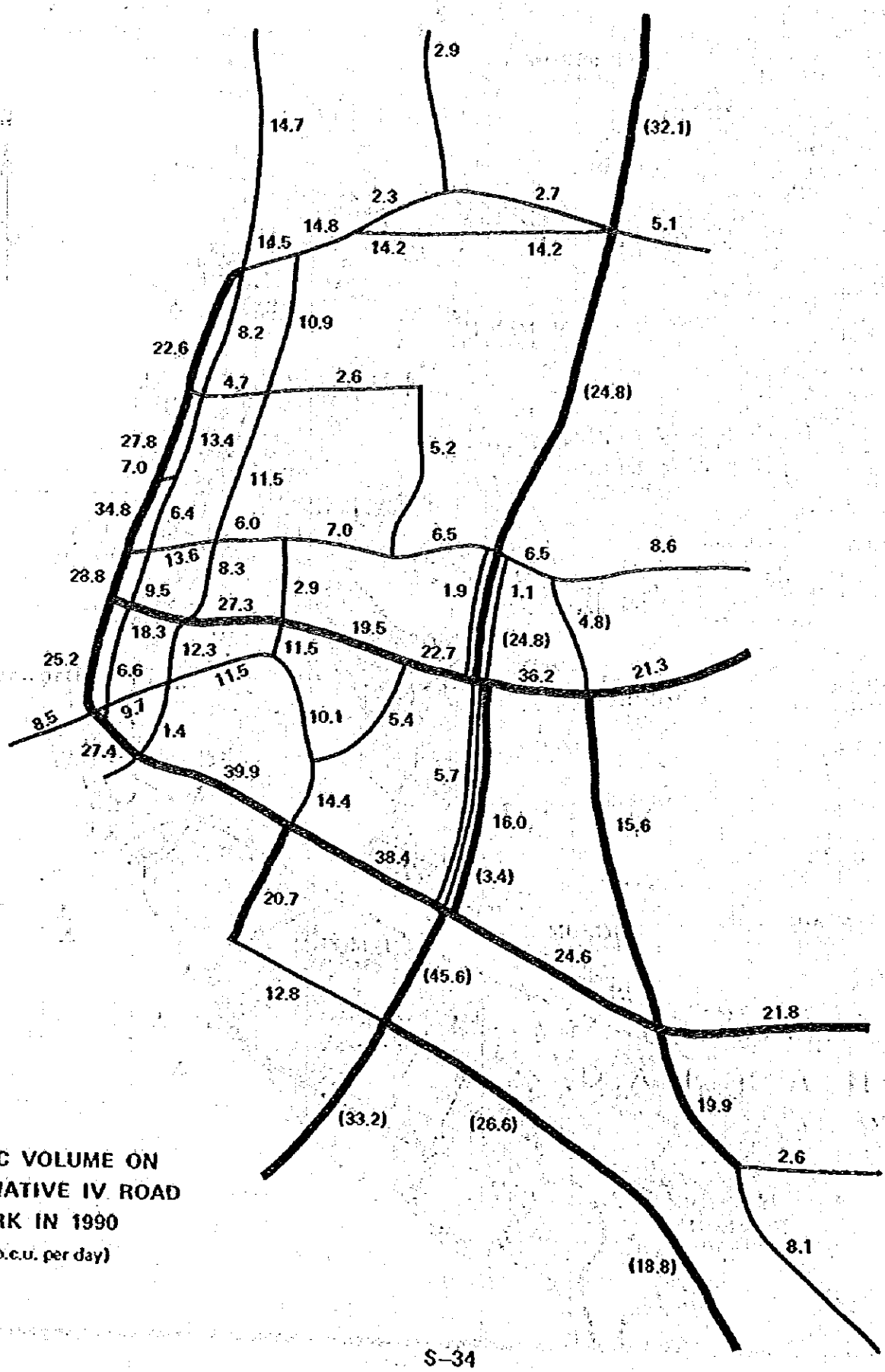


Fig. B.5.5
TRAFFIC VOLUME ON ALTERNATIVE IV ROAD NETWORK IN 1990
(Unit: 1000 p.c.u. per day)

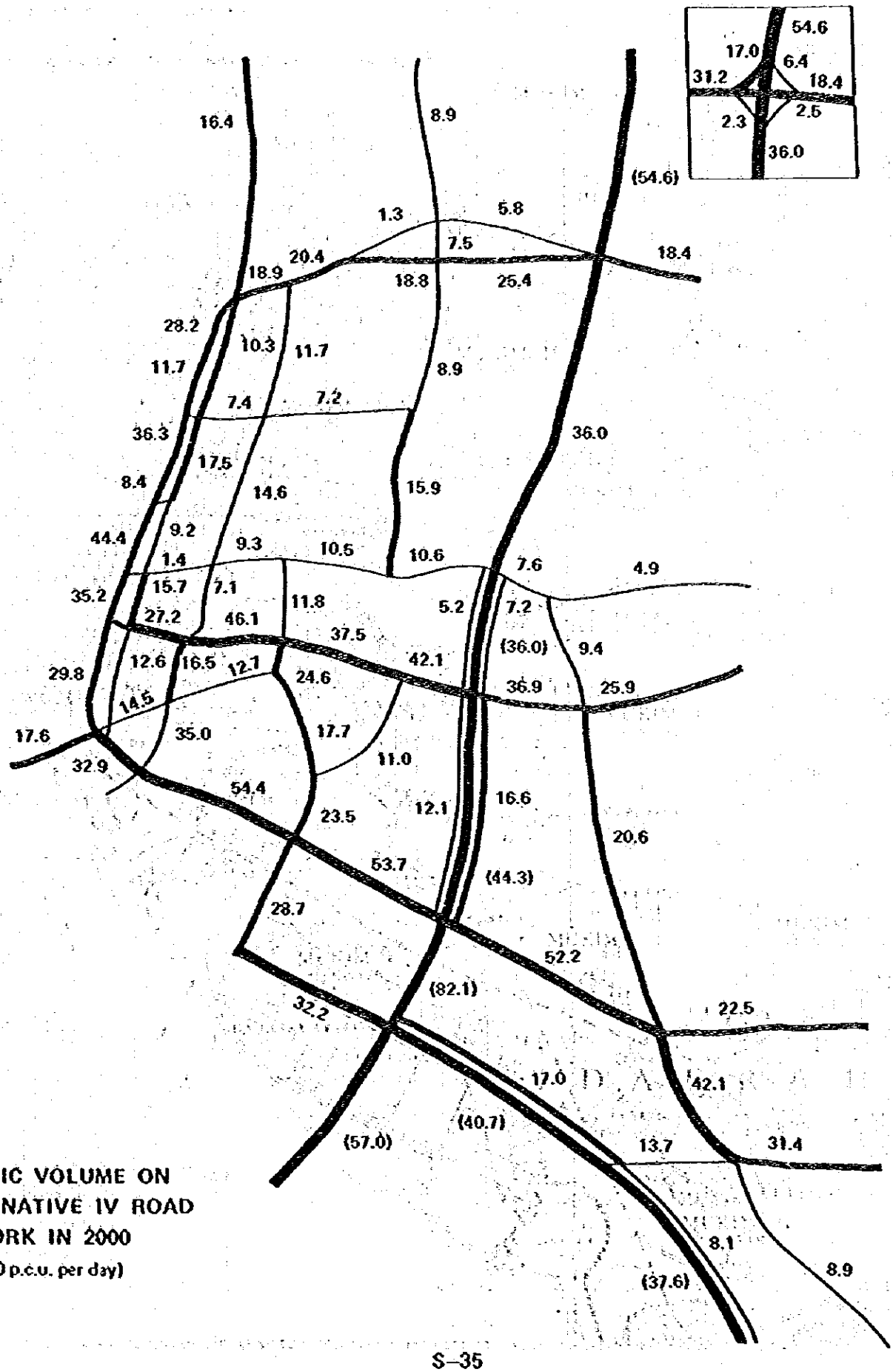


Fig. B.5.6
TRAFFIC VOLUME ON ALTERNATIVE IV ROAD NETWORK IN 2000
(Unit: 1000 p.c.u. per day)

B.6 ESTIMATION OF THE PROJECT COSTS

B.6.1 Construction Cost

a. Based on the preliminary engineering study, the quantities for main work items by alternatives are calculated. Subsequently, the unit cost by main work items are analysed from the aspects of material cost, labour cost, equipment, etc., taking into consideration the local condition in the Penang State.

b. Based on the quantities for main work items estimated and the unit cost analysed, the construction costs are estimated and are split into three components, i.e. foreign currency, local currency and tax.

c. The construction cost is calculated in 1981 prices in terms of economic cost and financial cost.

d. Economic cost consists of foreign and local currency and financial costs consists of foreign and local currency and tax.

e. The construction cost estimate by alternative routes is shown in Table B.6.1 and Table B.6.2.

B.6.2 Land Acquisition and Compensation Cost

(1) Land Acquisition Cost

The land acquisition cost is estimated based on unit cost and the land area acquired. The unit cost is obtained from data of the Land Valuation Office and some other surveys. The land acquisition cost is estimated for both the economic and financial costs. For the economic cost estimates, the land costs of the affected seashore area, the affected government land and the affected private land are all included. For the financial cost estimates, however, it only includes the land cost of the affected private land.

The land acquisition cost is shown in Table B.6.1 and Table B.6.2.

(2) Compensation Cost

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 types. All houses that are located on both side of 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 from road, land use, building use, number of storeys and structural condition of building.

In the case where the proposed medium-level bridge would affect the Hong Leong – Lurssen Shipyard and masts of the PPC ferries, the compensation cost is estimated as M$15.5 million.

B.6.3 Maintenance Costs

In estimating the maintenance cost, data from "The Malaysia Highway Maintennace Study" (1974, Public Works Department) and other related references are used. The maintenance cost include cost for resurfacing, roadside trees, drainage facilities, kerbs, road markings, traffic lights, etc.

The basic maintenance cost per year for a four–lane and six–lane roads are about M$31.4 thousand per km and M$37.7 thousand per km, respectively.

Table B.6.1 PROJECT COST BY ALTERNATIVE PLANS (ECONOMIC COST)

(In Thousand M$ at 1981 Prices)

Alternative 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	25,013	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	6L, 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

Table B.6.2 PROJECT COST BY ALTERNATIVE PLANS (FINANCIAL COST)

(In Thousand M$ at 1981 Prices)

Alternative 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	Full	24,802	27,101	48,790	75,891	3,795	3,795	108,283	466
		Plan 1	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	Full	16,990	36,582	47,875	84,457	4,223	4,223	109,893	468
		Plan 1	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

B.7 PROJECT EVALUATION

B.7.1 Evaluation Procedure

The procedure for the project evaluation is as follows:

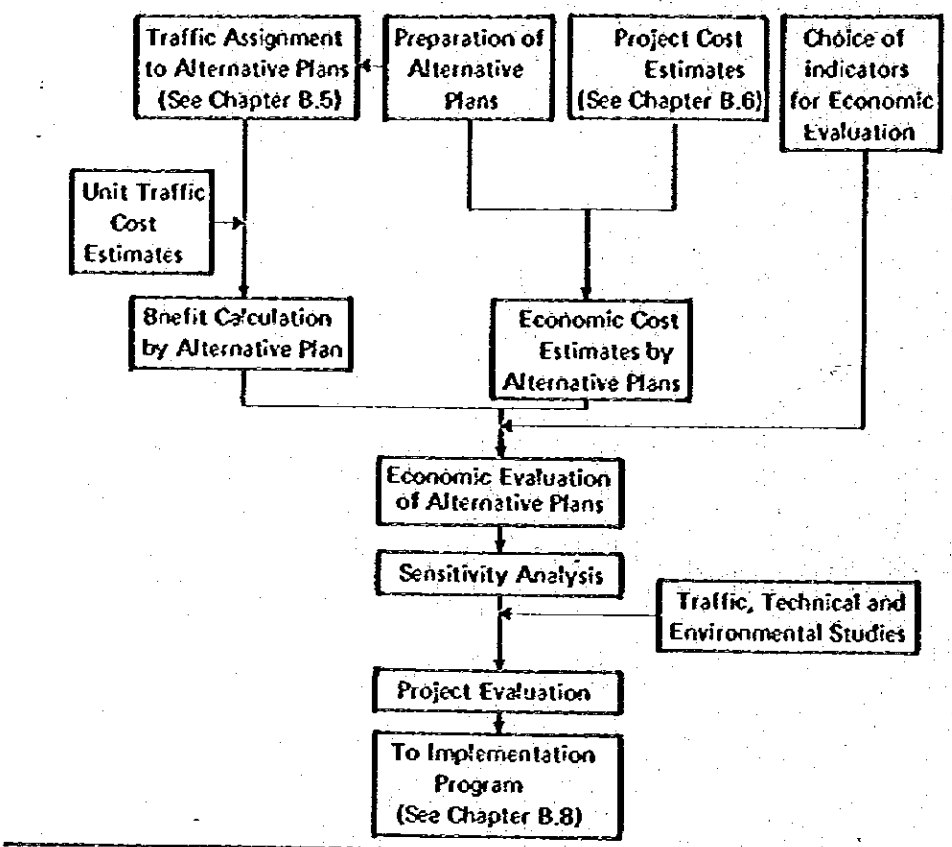


Fig. B.7.1 PROCEDURE FOR PROJECT EVALUATION

The evaluation procedure consists of two aspects : one is an economic evaluation based on the quantitative benefits and costs and the other is a social evaluation which is not quantified in monetary terms. On the basis of these two aspects, the best plan among the alternative plans would be selected.

B.7.2 Indicators of Economic Evaluation

The Project Road is evaluated economically by the following three indicators commonly used by the Economic Planning Unit (EPU) and the International Financing Organization.

a. Internal Rate of Return (IRR)
b. Net Present Value (NPV)
c. Benefit – Cost Ratio (B/C Ratio)

In order to obtain the economic indicators, the following conditions are assumed:

a. Project Life : 25 years
b. Opening Year for Traffic : 1988
c. Opportunity Cost of Capital : 12%

B.7.3 Alternatives for Economic Evaluation

The following alternatives are subject to the economic evaluation. (See Figs B.5.1 and B.7.2)

(1) Route

The following alternative routes that have been selected from the engineering and environmental studies are evaluated.

a. Route I : Passing through Route A, combined Routes D and E, and Route G
b. Route II : Passing through Routes A, E and G
c. Route III : Passing through Route B, combined Routes D and E, and Route G
d. Route IV : Passing through Routes B, E and G
e. Route V : Passing through Route C, combined Routes D and E, and Route G
f. Route VI : Passing through Routes C, E and G

(2) Type of Bridge

The types of bridge which have been selected as alternatives for Routes III and IV 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.

(3) Cross-Section

The following cross-sections, selected as alternatives for Routes 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.

(4) Type of Access to the Toll Expressway

The types of access from the Project Road to the Toll Expressway at Jalan Sungai Dua, selected as alternatives for Routes III and IV are as follows:

a. Full Access Interchange

b. Partial Access Interchange

(5) Stage Construction by Section

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

a. Section 1

b. Section 2

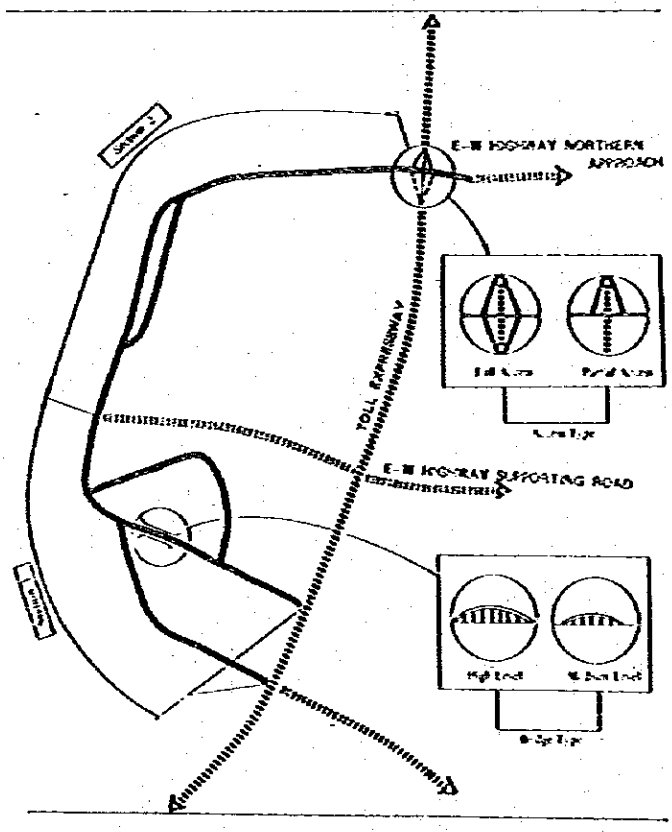


Fig. B.7.2 ALTERNATIVES OF BRIDGE TYPE AND ACCESS TYPE

B.7.4 Economic Cost

For the economic evaluation of the Project Road, the costs and benefits are expressed in economic values with the economic cost of each alternative obtained by deducting tax from the financial cost and adding values for seashore land and government land. The economic cost by alternative plans is shown in Tables 8.7.1 and 8.7.2.

Table 8.7.1 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 8.7.2 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 1	Full	Section 1	72,160
				Section 2	50,021

B.7.5 Benefit Calculation

(1) Type of Benefits

Among various benefits, the following are the benefits derived directly from the construction of the Project Road which can be calculated in monetary terms.

1) Reduction in travel time (Time Benefit)
2) Saving in vehicle operating cost (Running Benefit)

a. Saving in running cost
b. Saving in fixed cost.

(2) Unit Traffic Cost

In order to measure benefits, it is necessary to set up the unit traffic cost. The unit traffic cost is divided into two components : one is time cost the other is vehicle operating cost.

The unit time cost of each trip is calculated by using the monthly household income and the monthly working hours by motor car owner, motor-cycle owner and non-vehicle owner.

The unit time cost of each vehicle type which is estimated from a composition by trip purpose and average occupancy rate of each vehicle is shown in Table 8.7.3.

Table 8.7.3 UNIT TIME COST OF EACH VEHICLE TYPE (1981 Price)

Type of Vehicle	M$/hr
Motor car	7.79
Motor-cycle	1.62
Bus	13.14

The vehicle operating cost consists of the following types:

a. Distance related Running Cost : Fuel, Oil, Tyre, Maintenance, Repair and Distance related Depreciation Costs

b. Fixed Cost (Time related Running Cost) : Crew, Interest, Overhead and Time related Depreciation Costs

The unit vehicle operating cost by vehicle types is calculated and shown in Table 8.7.4.

Table 8.7.4 UNIT VEHICLE OPERATING COST (1981 Price)

Item \ Type of vehicle	M/C	Car	Taxi	Bus	Van	Lorry	Heavy Lorry
Running Cost (cents per kilometer)	5.59	14.93	11.13	24.84	17.54	38.59	46.30
Fixed Cost (cents per hour)	34.6	151.1	297.3	641.5	156.3	398.1	638.4

(3) Benefit Calculation

Using the network assignment model, the benefits of each alternative plan are calculated and shown in Table 8.7.5 and Table 8.7.6.

Table 8.7.5 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 8.7.6 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

8.7.6 Economic Analysis

(1) Evaluation of Alternative Routes

The economic analysis of the alternative routes is shown in Table 8.7.7.

The economic indicators shown that all the alternative routes are economically feasible. Among them, more feasible routes are Routes III and IV.

Table B.7.7 ECONOMIC INDICATOR BY ALTERNATIVE ROUTES

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
	II-F, 4-L	80,952	60,662	1.384	23,290	15.4
	III-F, Plan 1	124,880	73,302	1.704	51,578	17.5
	IV-F, Plan 1	129,343	76,351	1.694	52,992	17.4
	V-F, 4-L	124,628	77,621	1.606	47,007	16.8
	VI-F, 4-L	124,130	80,665	1.539	43,465	16.4

Notes: a. Discounted 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 B.7.8. All the alternatives are economically feasible. However, the high level bridge with a clearance height of 25 meters is more feasible than the medium bridge with a clearance height of 16 meters.

Table B.7.8 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 B.7.9. 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 B.7.9 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 B.7.10 shows the result of economic analysis of access plans. From this table, it is found that the full service interchange has higher feasibility than the partial one.

Table B.7.10 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 Service	124,880	73,302	1.704	51,578	17.5
	Partial Service	108,690	72,266	1.504	36,424	16.2
Route IV Plan 1	Full Service	129,343	76,351	1.694	52,992	17.4
	Partial Service	112,547	75,312	1.494	37,235	16.1

Notes: a. Discounted 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 that the Section 2.

Table B.7.11 ECONOMIC INDICATORS BY SECTION

Alternative Route	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

B.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 B.7.12

From this table, the following observations can be made:

a. Even when the project cost is increased by 20% or the project benefit decreased by 20%, Route III (Plan 1) and Route IV (Plan 2) are still feasible.

b. Even if the risky construction cost stream with a constant construction period is assumed, the economic indicators change little.

c. Even when the project life is cut by 5 years from 25 years to 20 years, the project still remains feasible.

d. When the P.C.U. conversion factor of motor-cycles is changed from 0.5 to 0.75, both plans are more feasible than the original one.

e. Even when the East-West Highway Supporting Road is added to northern part, the project is more feasible than the original one.

f. Even when the existing Federal Route 1 is expanded to a 4-lane road, the Project Road (Route III and Route IV) are still feasible.

Table B.7.12 RESULTS OF SENSITIVITY ANALYSIS

Economic Indicator / Items	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 P.C.U. of M/Cycle	2.163	85,257	20.8	2.153	87,998	20.7
8. Additional 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

B.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 to generate most of the intra-urban traffic along Jalan Bagan Ajam where it is a part of the Project Road in case of Route III.

      In 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 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 viewpoints 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 8.5.3, Route IV is superior to Route III from the viewpoint of 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 the disturbance to heavy traffic flow is predicted 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 conforms with 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 service interchange be constructed at the intersection with the Project Road and the Toll Expressway.

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

B.8 IMPLEMENTATION PROGRAM

Based on the results of the economic analysis and the financial cost estimates, the implementation program of the Project Road is established below:

B.8.1 Recommended Implementation Schedule

Taking into account the results of the economic evaluation, construction cost and the predicted traffic volume on the Project Road, the following stage construction is recommended:

Phase 1 : Southern Section (Section 1) of the Project Road.
(Jalan Prai – Toll Expressway interchange to the intersection at the approach road of the North Butterworth Container Wharf)

Phase 2 : Northern Section (Section 2) of the Project Road.
(From the intersection at the approach road of the North Butterworth Container Wharf to Jalan Sungai Dua – Toll Expressway interchange)

Based on the stage construction plan, the implementation schedule for the two phases as shown in Fig. B.8.1 is recommended.

In order to complete the Phase 1 of the Project Road by the end of 1987, the detailed engineering for the Project Road should be implemented immediately.

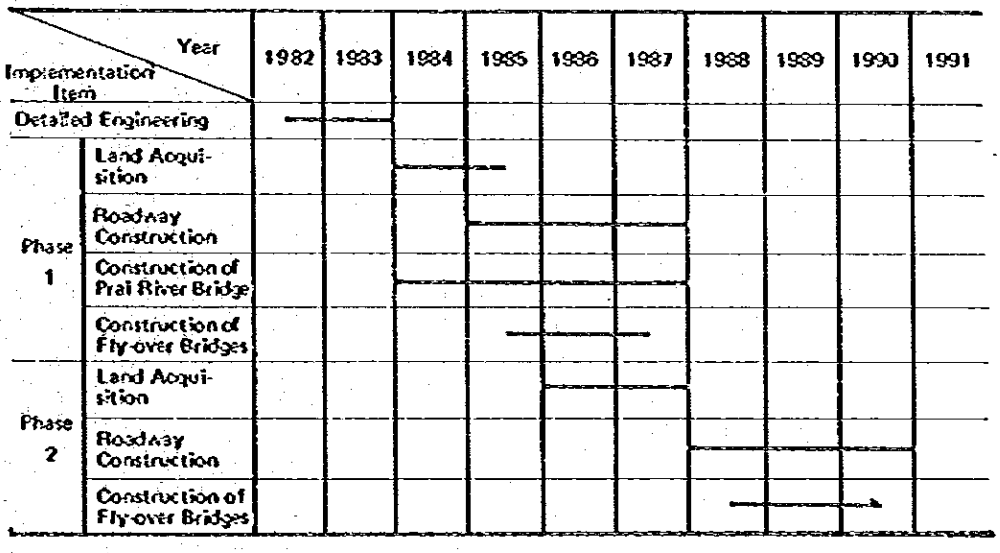


Fig. B.8.1 RECOMMENDED IMPLEMENTATION SCHEDULE

B.8.2 Investment Requirements

Based on the implementation schedule, the investment requirements for the Project are estimated for land acquisition, compensation and construction of roadway and structures. They are divided into foreign and local currency and presented in 1981 prices. The investment requirements of the Project Road by Phase and annually are shown in Table B.8.1 and Table B.8.2 respectively.

Table B.8.1 PROJECT COST
(In thousand M$ at 1981 Prices)

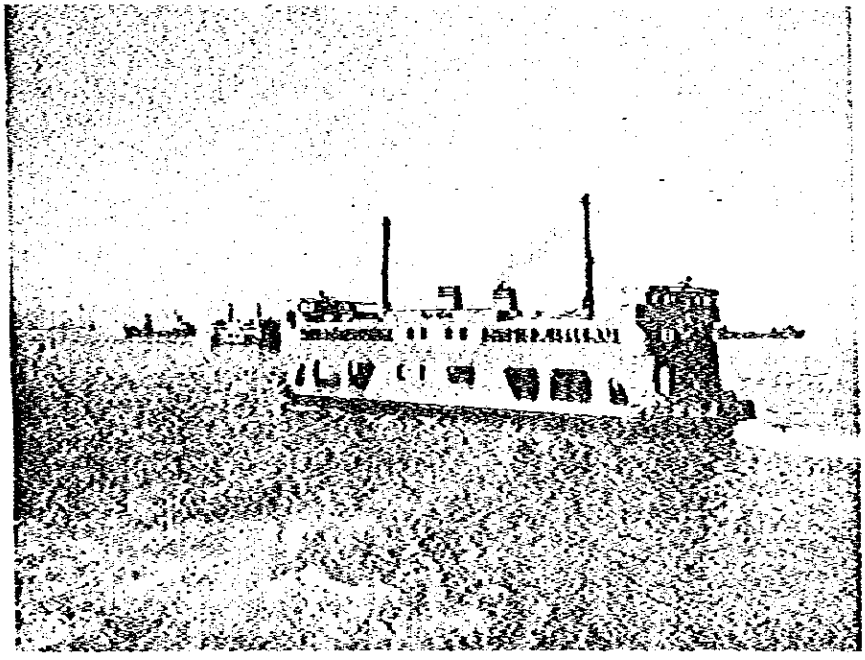
Item \ Component	Foreign	Local	Total
Detailed Engineering and Construction Supervision	4,192	4,254	8,446
Phase 1			
Land Acquisition	0	12,198	12,198
Road Construction	5,148	5,897	11,045
Structure Construction	21,561	19,371	40,932
Total	26,709	37,466	64,175
Phase 2			
Land Acquisition	0	4,792	4,792
Road Construction	11,656	13,881	25,537
Structure Construction	3,550	3,393	6,943
Total	15,206	22,066	37,272
Total			
Land Acquisition	0	16,990	16,990
Road Construction	16,804	19,778	36,582
Structure Construction	25,111	22,764	47,875
Total	41,915	59,532	101,447
Grand Total	46,107	63,786	109,893

Note: Tax is included in Local Currency.

Table 8.8.2 ANNUAL INVESTMENT REQUIREMENTS FOR PHASE 1 AND 2
(In thousand M$ at 1981 Price)

Year	Land Acquisition	Road Construction			Structure Construction			Total		
	Local	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
1982	0	528	528	1,056	0	0	0	528	528	1,056
1983	0	1,584	1,584	3,168	0	0	0	1,584	1,584	3,168
1984	9,148	0	0	0	3,224	2,838	6,062	3,224	11,986	15,210
1985	3,050	1,082	1,238	2,320	4,522	4,063	8,585	5,604	8,351	13,955
1986	2,396	1,621	1,857	3,478	7,434	6,710	14,144	9,055	10,963	20,018
1987	2,396	2,703	3,096	5,799	6,135	5,484	11,619	8,838	10,976	19,814
1988	0	4,895	5,830	10,725	1,263	1,202	2,465	6,174	7,016	13,190
1989	0	3,672	4,373	8,045	2,525	2,404	4,929	6,197	6,777	12,974
1990	0	3,672	4,372	8,044	1,262	1,202	2,464	4,934	5,574	10,508

Notes: a. The Construction includes the detailed engineering and construction supervision
b. Tax is included in the Local Currency.



MAIN VOLUME

1 . INTRODUCTION

1.1 BACKGROUND

The Government of Japan, in compliance with the request of the Government of Malaysia, has agreed to extend technical cooperation on the Urban Transport Study in the Greater Metropolitan Areas of George Town, Butterworth and Bukit Mertajam (hereinafter called the "Study").

Based on this decision, the Japan International Cooperation Agency ("JICA"), an official agency responsible for the execution of the technical coopeation program of the Japanese Government, carried out the Study jointly with the Government of Malaysia.

In November 1978, JICA dispatched a preliminary survey mission with a scope of work for the Study and was duly agreed upon by both Governments.

The study is broadly divided into two phases. Phase I of the Study (hereinafter called the "Phase I Study") is aimed at formulating a master plan of urban transport systems for the Metropolitan Area while Phase II of the Study (hereinafter called the "Phase II Study") is aimed at studying the feasibility of specific projects selected from the Phase I Study's recommendations.

The Phase I Study, conducted over a period of one year, from March, 1979, has established the following set of recommendations for the implementation of its transport infrastructure.

1) Long-Term Transport Plans
   a. Construction of New Roads and Improvement of Existing Roads
   b. Improvement of Public Transport System
   c. Private Vehicle Restraints
   d. Construction of Transport Terminal Complex

2) Short-Term Actions
   a. Implementation of Traffic Engineering and Management Measures
   b. Construction and Improvement of Roads
   c. Improvement of Bus Transport

Among both the short and long-term plans and projects, the Outer Ring Road Project in Penang Island and the Buttenvorth Ring Road Project were identified as high priority projects.

The Phase II Study is further divided into two stages, namely Stage I and Stage II. Stage I of the Phase II Study is the feasibility study of the project recommended in Phase I as the Outer Ring Road Project of George Town in Penang Island. This study was commenced on the 1st of April, 1980 and the Final Report was submitted to the Government of Malaysia in May, 1981.

Stage II of the Phase II Study is the feasibility study of the Butterworth Ring Road Project which was identified as one of the high priority projects in the Phase I Study.

1.2 DESCRIPTION OF THE BUTTERWORTH RING ROAD PROJECT

Due to the current intensive industrial and other urban development projects, as well as transport development projects, such as the Penang Port Development Project, the Toll Expressway Project (Alor Star – Changkat Jering Highway), the East-West Highway Supporting Road Project and the Penang Bridge Project, the Butterworth Metropolitan Area must renew and up-grade its existing transport system.

Therefore, the Butterworth Ring Road Project (hereinafter referred to as "The Project Road") was proposed in the Phase I Study to serve traffic coming in and out of the new port as well as the existing port. It will form the backbone for an effective network for the area and a larger region when the inter-urban primary distributors such as the Toll Expressway and the East-West Highway Supporting Road are completed.

Fig. 1.1 illustrates the general alignment of the Project Road. Starting at the intersection of Jalan Prai and the Toll Expressway, it passes along Jalan Prai and crosses over the Prai River. After which it passes along Jalan Bagan Dalam and turns towards the north at the intersection of Jalan Bagan Luar and Jalan Chain Ferry. It is planned to pass beside the new port which is expected to be completed by 1986 and follows the seashore line. At Kg. Bagan Ajam, the Project Road turns towards the east and proceeds along Jalan Sungai Dua to intersect the Toll Expressway.

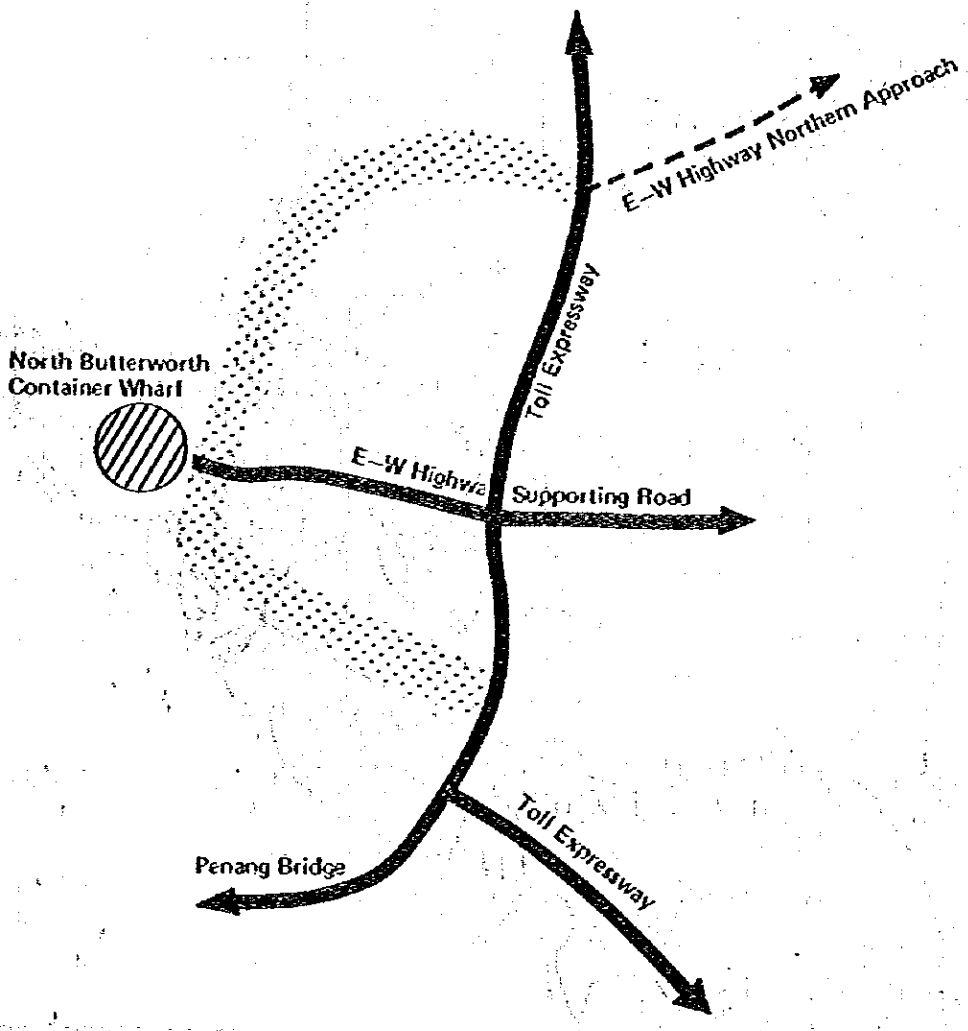


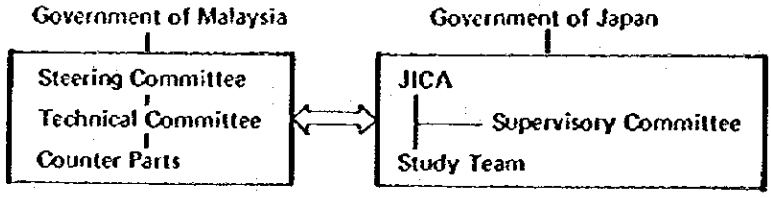
Fig. 1.1 GENERAL ALIGNMENT OF PROJECT ROAD

Legend

Project Area

1.3 STUDY ORGANIZATION

The project is being carried out jointly by JICA and the Government of Malaysia in co-ordination with other related agencies. The organization for the project is as follows:



The members of each organization are presented in the Appendix.

1.4 STUDY APPROACH

1.4.1 Study Items

The general approach adopted for the Study is illustrated in Fig. 1.2 and consists of the following principal activities.

a. Route Location
b. Traffic Projection
c. Preliminary Engineering and Cost Estimates
d. Environmental Study
e. Economic Evaluation
f. Implementation Program

A brief description of each activity is presented below.

(1) Route Location

In order to derive the most feasible route for the Project Road, alternatives are prepared and selected through the various reconnaissance surveys such as topographic, soil and material investigation, land use and environmental surveys.

(2) Traffic Projection

The traffic demand for the Project Road is forecasted by modifying the traffic projection data from the Phase I Study. Hence a more precise projection data used for preliminary engineering and benefit calculation.

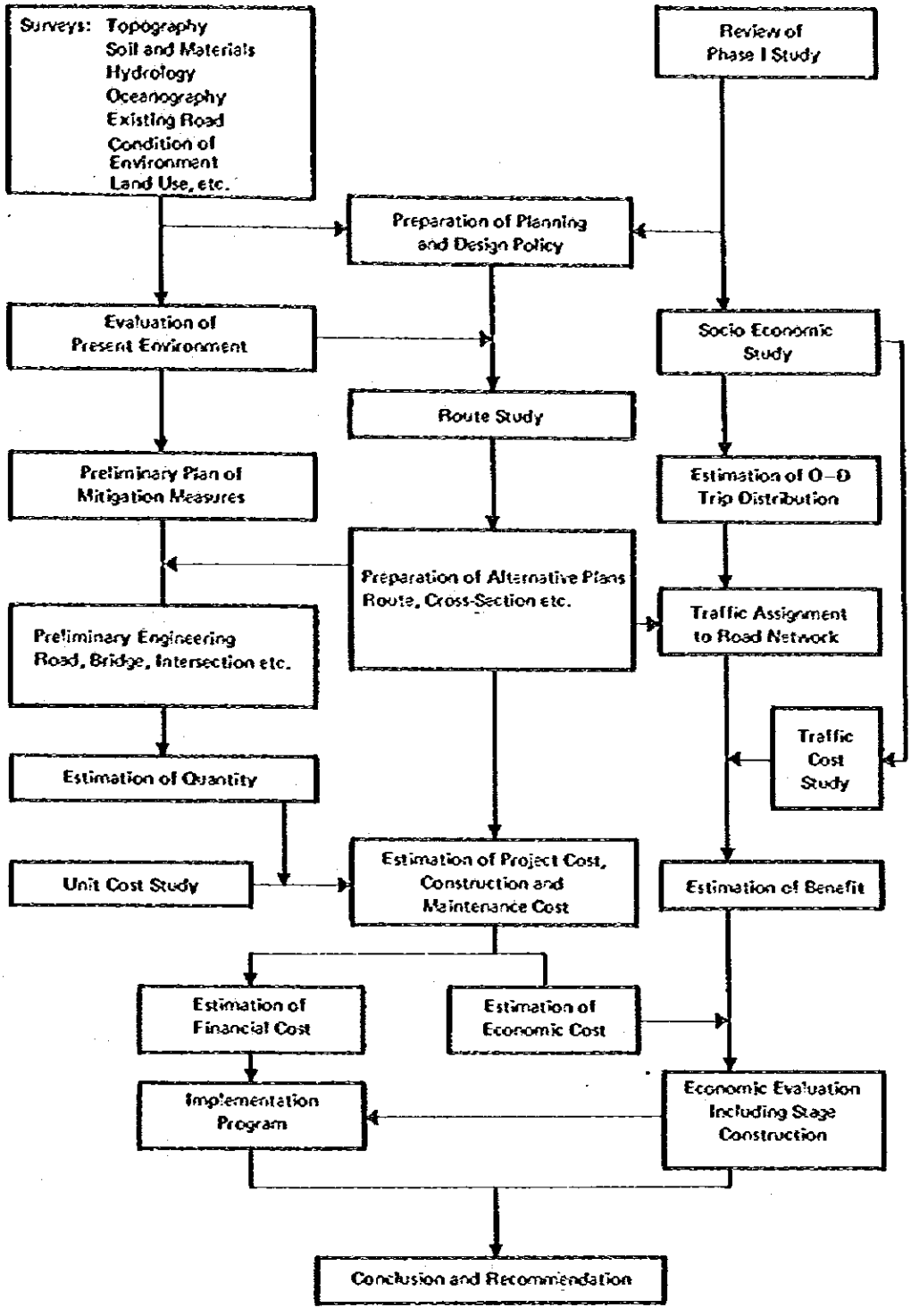


Fig. 1.2 GENERAL FLOW CHART

(3) Preliminary Design and Cost Estimate

The preliminary road and bridge design is elaborated using a basic scale of 1 to 3000, taking into account the result of the route location study and the traffic projection. Using this design plan, the construction and maintenance costs of the Project Road are calculated by estimating the unit costs for each of the work item and multiplying them with their respective length or units.

(4) Environmental Study

The environmental study is conducted not only in consideration of evaluating the qualitative impacts on land use, the community segregation resulted from the Project Road and the provision of an adequate mitigation measures, but also to suggest a proper road design by evaluating the present environmental conditions.

(5) Economic Evaluation

The economic analysis is made using the results from the benefit and economic cost estimates, where the alternative plans are evaluated and the investment timing determined.

(6) Implementation Program

Based on the above-mentioned studies, the implementation program of the Project Road is proposed taking the prevailing conditions into account.

1.4.2 Alternatives

In this study, alternatives for the following items of the Project Road are prepared and evaluated from the technical, environmental and economical standpoints.

a. Route
b. Bridge Type
c. Cross-Section (4-lane or 6-lane)
d. Access to the Toll Expressway
e. Stage Construction by Road Section

The alternatives of the Project Road are proposed and evaluated through the results of studies and discussions made at the technical and steering committee meetings.

The major viewpoints to be evaluated on the alternative items are as follows:

Alternatives / Evaluation Viewpoints	Route	Bridge Type	Cross-Section	Access to the Toll Expressway	Interchange & Intersection	Stage Construction
Transport and Town Planning, Environmental Study	O					
Engineering (Design, Cost)	O	O	O	O	O	
Traffic Study	O		O	O	O	
Economic Evaluation	O	O	O	O	O	O

The first selection of the alternatives is made from the transport and town planning, environmental study and engineering viewpoints and the second selection is made from the economical viewpoint.

1.5 TRAFFIC ZONING

Since it is necessary to project precise traffic demand on the Project Road, the traffic zones used in the Phase I Study are further divided when used in the Phase II Study (See Fig. 1.3).

According to the new traffic zoning, the internal study area in Province Wellesley is sub-divided into 52 zones including the existing Penang Port and the North Butterworth Container Wharf while the external study area is sbu-divided into 7 zones, a total of 59 zones.

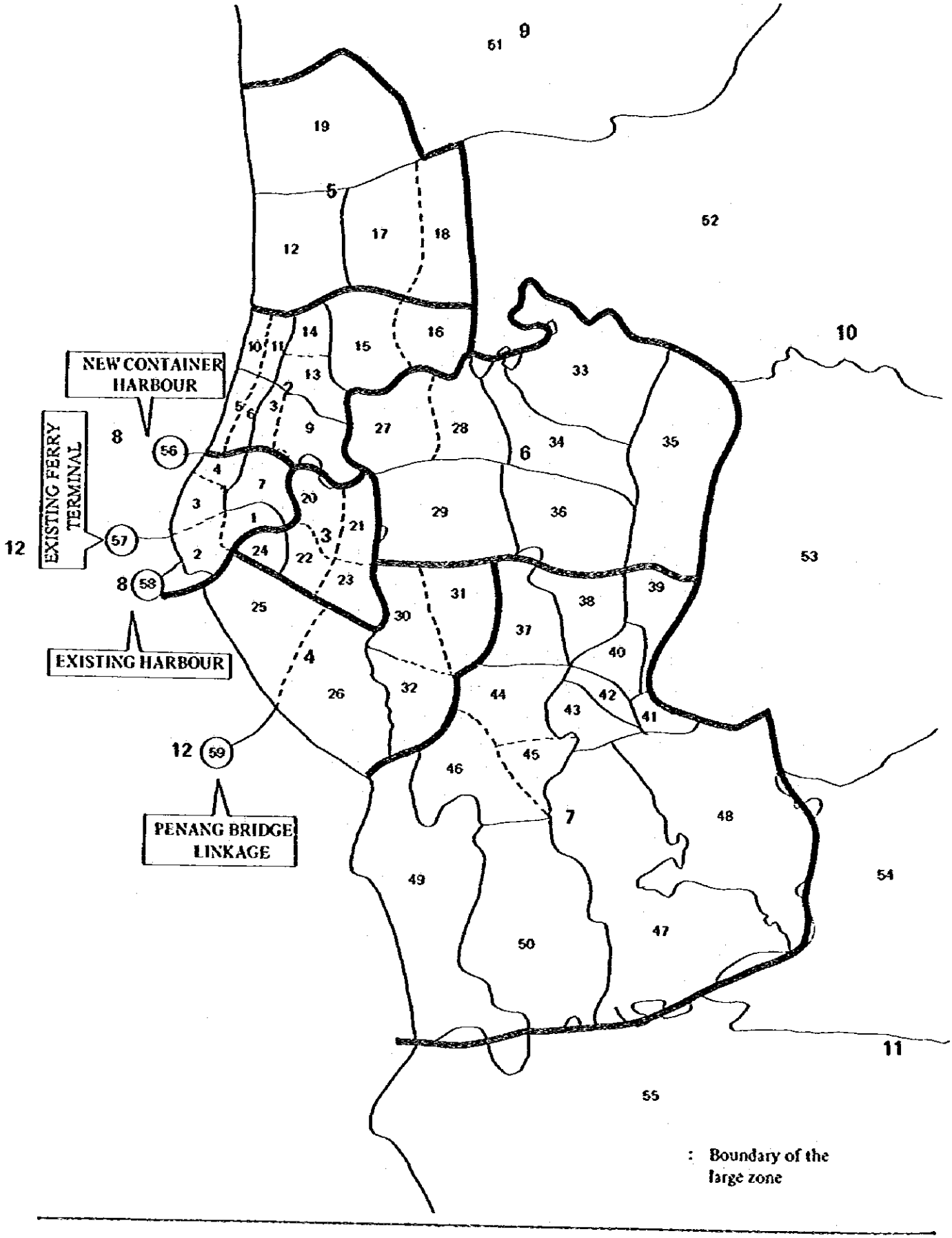


Fig. 1.3 TRAFFIC ZONING

1.6 STUDY SCHEDULE

Stage II of the Phase II Study began on April, 1981 when a Steering Committee Meeting was held between the Government of Malaysia, the Supervisory Committee of JICA and the Study Team to discuss the Inception Report.

Since then, the following Committee Meetings have been held before the submission of the Final Report.

1) Steering Committee Meetings

Date	
8th April, 1981	Submission of Inception Report
24th August, 1981	Submission of Progress Report II
23rd October, 1981	Submission of Interim Report
8th December, 1981	Submission of Draft Final Report

2) Technical Committee Meetings

Date	
3rd April, 1981	Discussion of Inception Report
29th June, 1981	Discussion of Progress Report I
17th August, 1981	Discussion of Alternative Bridge Plans
28th September, 1981	Discussion of Alternative Routes
19th October, 1981	Discussion of Interim Report
4th December, 1981	Discussion of Draft Final Report

2. PRESENT TRANSPORT CONDITIONS

2.1 ROAD CONDITIONS

The existing road network in the study area is a partially developed grid or ladder pattern in which the Federal Route 1 passing through the urbanized area from the north to the south-west is functioning as the primary distributor. Even then, some parts of its carriageway are narrow with only two (2)-lanes and its width is only 7 meters. Most of the other roads are also narrow single carriageways with their width ranging between 6 meters and 10 meters.

The pavement of these roads are mostly asphalt-concrete and their conditions are generally poor.

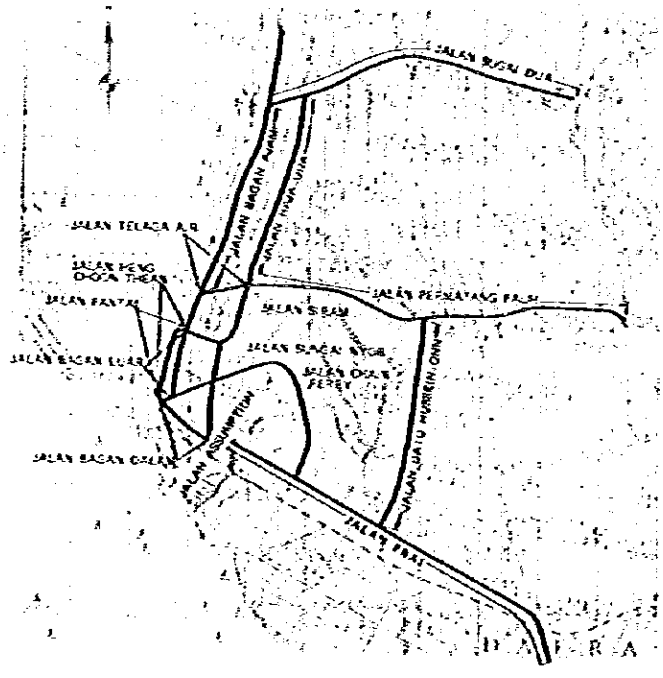


Fig. 2.1 EXISTING MAJOR ROADS

2.2 CHARACTERISTICS OF EXISTING TRAFFIC

2.2.1 Number of Trips

On the basis of the 1979 O-D survey, the total number of trips related to the Study Area is 202,300 P.C.U. trips per day while that in the internal area is 139,200 P.C.U. per day. The number of trips across the Straits is 19,400 P.C.U. trips per day of which a sixty-five (65) per cent is related to the Study Area and the rest are through trips. (See Table 2.1).

Table 2.1 TRIPS BY TYPES AND PURPOSE

(Unit: P.C.U. per day)

Type of Vehicle		Internal Trip	Trip Across the Straits	External and Through Trip	Total
Private Car	To work	12,870	1,800	2,910	17,580
	Business	9,400	2,210	3,340	14,950
	Private	11,150	2,250	4,360	17,760
	To Home	17,950	2,690	5,370	26,010
	Sub-Total	51,370	8,950	15,980	76,300 (37.7)
Lorry		16,440	3,380	16,380	36,200 (17.9)
Taxi		250	180	1,670	2,100 (1.0)
Bus		9,220	340	840	10,400 (5.1)
Motor Car		77,280	12,850	34,870	125,000 (61.8)
Motor-Cycle		61,920	6,550	8,830	77,300 (38.2)
Total		139,200	19,400	43,700	202,300

Source: 1979 OD Survey

2.2.2 Traffic Volume

Based on the traffic volume counting survey data and the JKR traffic census data in April, the traffic volume on the major roads for a period of 12 hours (7 a.m. – 7 p.m.) in Butterworth is shown in Fig. 2.2, where the traffic volume is indicated by Passenger Car Unit (P.C.U.).

From these figures, it can be recognized that most of the traffic pass on Jalan Prai, Jalan Chain Ferry, Jalan Bagan Luar and Jalan Bagan Ajam which form part of the Federal Route 1 with traffic volume ranging from 20,000 P.C.U. to 33,000 P.C.U. per 12 hours. (See Fig. 2.2)

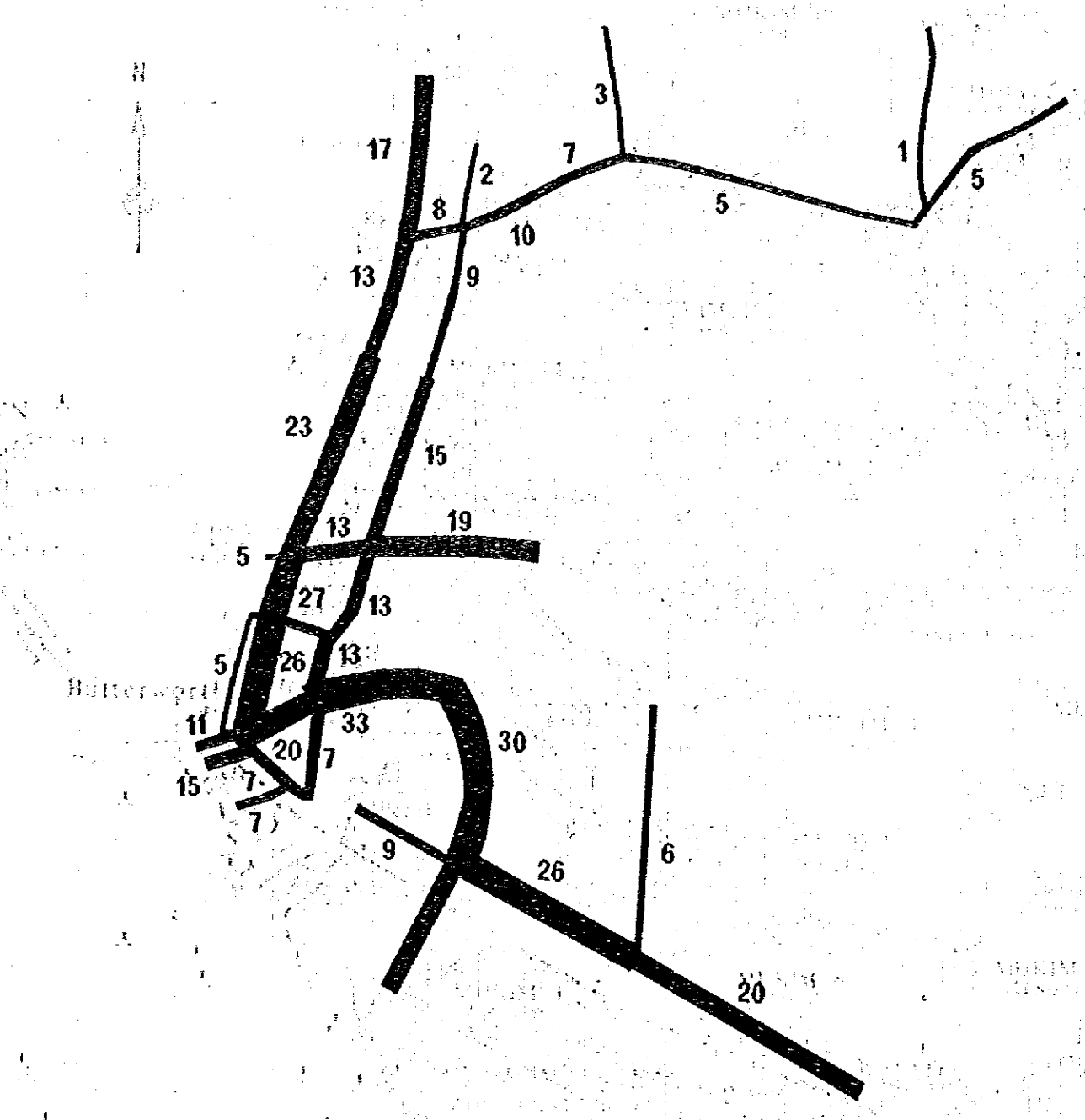


Fig. 2.2 TRAFFIC VOLUME IN 1981

LEGEND

20 — Passenger Car Unit (P.C.U.) Per 12 hours (Thousand)

2.2.3 Vehicle Composition

The vehicle composition on the major roads is shown in Fig. 2.4. On the main roads, such as the Federal Route I, the composition rate of motor cars is bigger than that of the motor-cycles. On the contrary, in minor roads such as Jalan Sungai Dua, the composition rate of motor cars is lower than that of the motor-cycles. It is noted that the composition rate of lorries is comparatively bigger on both classes of roads.

2.2.4 Fluctuation of Traffic Volume

(1) Daily variation

There are two JKR traffic census stations in Butterworth where traffic volume counting survey is conducted manually for a continuous 16 hours (6 a.m. – 10 p.m.) daily in a week. These two stations are located on the main entry point of the Project Road. The daily variation in the traffic flow pattern in one week is illustrated in Fig. 2.3 and Fig. 2.5.

At Jalan Prai, which is the south entry point, the traffic volume heading towards the south is extremely high on Friday and Saturday. Traffic volume for incoming traffic is also high on Friday. At Jalan Bagan Ajam, which is the north entry point, the traffic volume is slightly higher on Thursday, Friday and Saturday than on the other days for both directions.

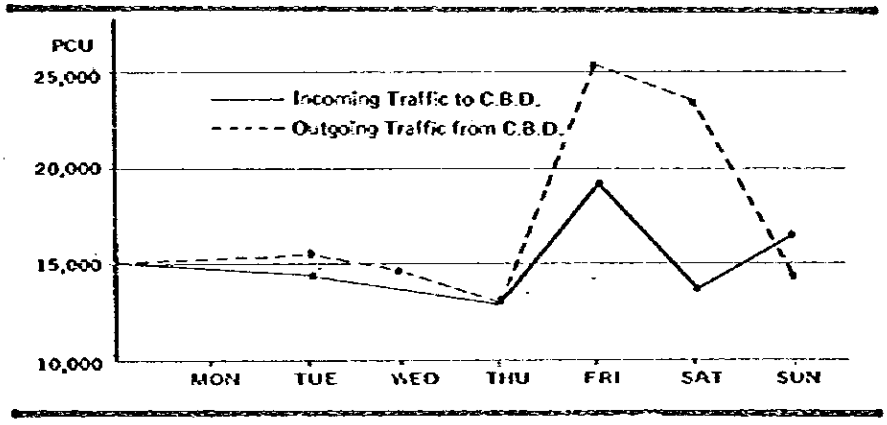


Fig. 2.3 DAILY VARIATION OF TRAFFIC FLOW AT JALAN PRAI

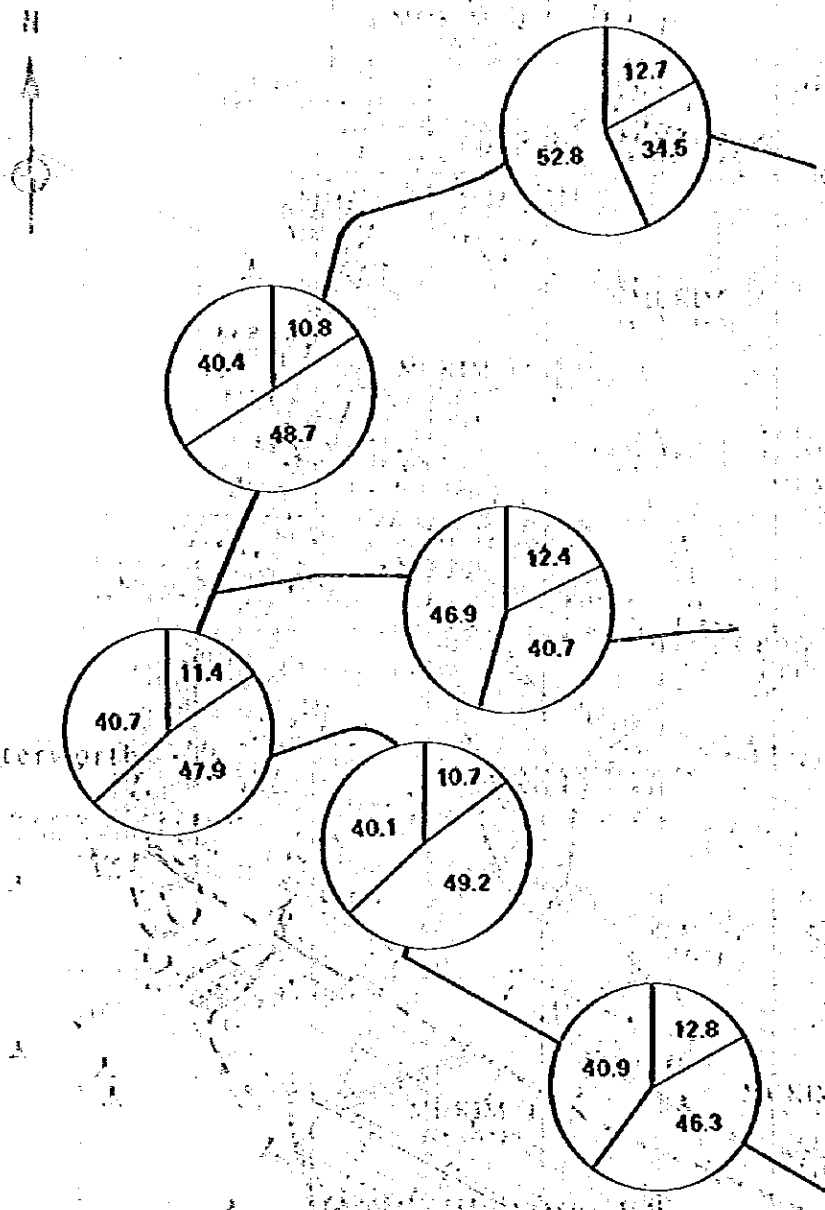


Fig. 2.4
VEHICLE COMPOSITION ON THE MAJOR ROAD
(Unit: percentage)

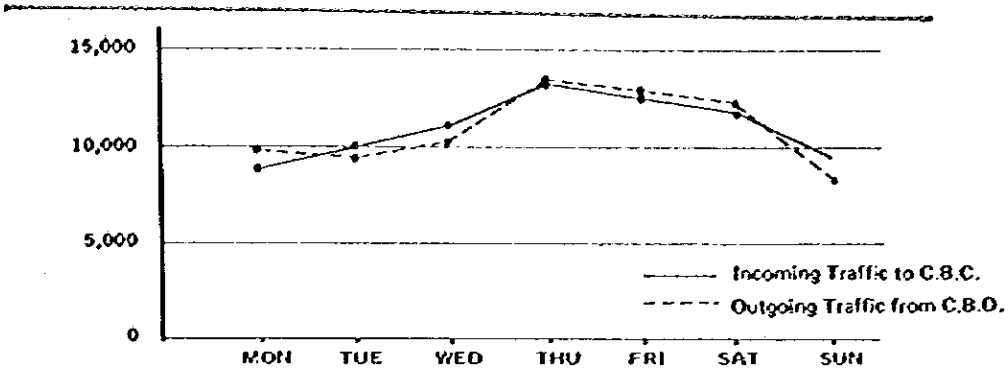


Fig. 2.5 DAILY VARIATION OF TRAFFIC FLOW AT JALAN BAGAN AJAM

(2) Hourly fluctuation

Based on the traffic volume counting survey conducted by the study team, the hourly fluctuations of traffic volume at Jalan Chain Ferry are illustrated in Fig. 2.6.

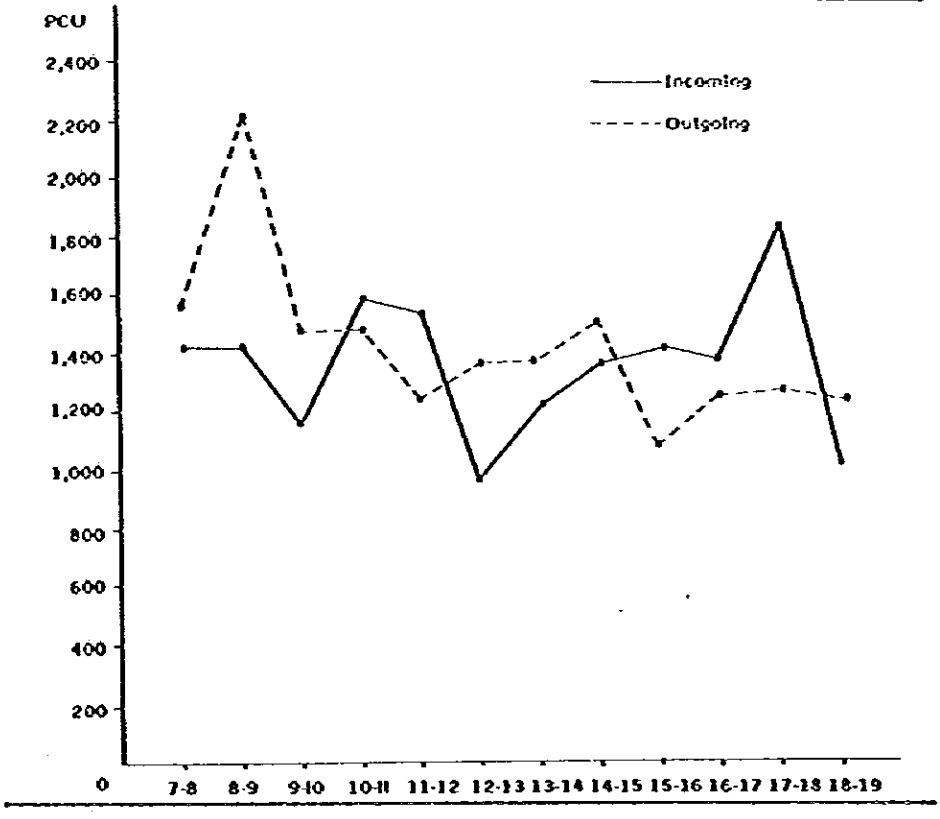
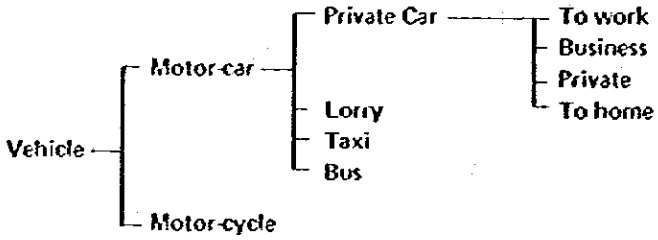


Fig. 2.6 HOURLY FLUCTUATION OF TRAFFIC VOLUME AT JALAN CHAIN FERRY

3. PROJECTION OF TRAFFIC DEMAND

3.1 PROCEDURE

This Study employs the same basic data and traffic projection models as those developed in the Phase I Study. The future traffic demand is categoried by vehicle type and trip purpose which are also similar to the Phase I Study.



The procedure of the traffic demand projection is shown in Fig. 3.1 with the major steps being described as follows:

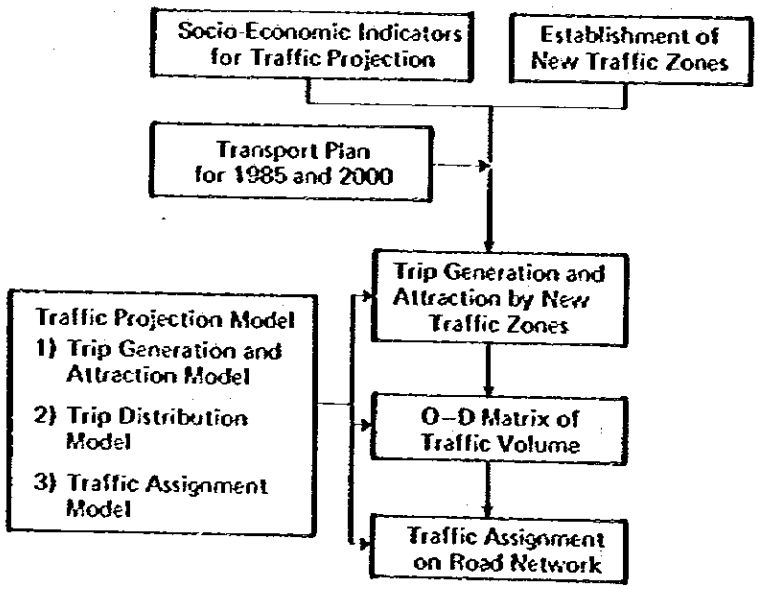


Fig. 3.1 PROCEDURE FOR TRAFFIC PROJECTION

3.2 SOCIO-ECONOMIC INDICATORS FOR TRAFFIC PROJECTION

The population in the years 1985 and 2000 were already projected in the Phase I Study on the basis of the population census in the year 1970. In this study, however, the projected population is reviewed and re-projected by using the latest population census data (1980

housing and population census) and other relevant data. The results of this re-projection of the socio-economic indicators are presented below.

3.2.1 Population

The population in the Study Area as shown in Table 3.1 is expected to increase from 282,300 in 1980 and 322,000 in 1985 and 482,100 in the year 2000 with the annual growth rate between 1980 and 2000 being 2.7%.

Table 3.1 POPULATION PLAN

Area	Population				Annual Growth Rate (%)	
	1970 [a]	1980 [a]	1985 [b]	2000 [b]	1980–1985	1980–2000
Study Area	–	282,300	322,000	482,100	2.7	2.7
Province Wellesley	343,000	435,600	496,000	725,000	2.6	2.6

Note: a) 1980 housing and population census
b) Modified with Phase I Study figures

3.2.2 Employed Population

The employed population in the Study Area shown in Table 3.2 is expected to increase from 112,500 in 1980 and 135,900 in 1985 and 224,700 in the year 2000 with the annual growth rate of 3.5% between 1980 and 2000.

Table 3.2 EMPLOYED POPULATION

Area	Population			Annual Growth Rate (%)	
	1980 [a]	1985 [b]	2000 [b]	1980–1985	1980–2000
Study Area	112,500	135,900	224,700	3.8	3.5
Province Wellesley	147,200	168,400	260,100	2.7	2.9

Note: a) 1980 Housing and Population Census
b) Modified with Phase I Study figures.

3.2.3 Future Land Use

The future land use plan in this study is prepared with an amendment to the future land use plan in the Phase I Study. This amendment is done with reference to the latest land use plan in the Seberang Jaya and Northern Prai area, prepared by the State Planning Authority.

Table 3.3 FUTURE LAND USE IN THE STUDY AREA

(Unit: hectares)

Type of Land Use	Area		Change between 1979 and 2000
	1979	2000	
Residential	3,100	5,491	2,391
Commercial	160	518	358
Industrial	1,020	1,635	615
Transport	--	499	499
Institution	--	48	48
Open Space	1,620	340	-1,280
Agriculture	16,200	13,883	-2,317
Others	--	137	137
Total	22,100	22,550	450

The residential area is expected to expand from 3,100 hectares to 5,490 hectares with the annual growth rate between 1979 and 2000 being 2.8%. Compared with the population growth, this rate of growth is reasonable for the residential area. (See Table 3.3)

3.2.4 Number of Vehicles

The number of vehicles in the Study Area is projected based on the hypothesis that the increase in per capital income will enable people to purchase a car rather than a motor-cycle.

The number of motor-cars in the Study Area is expected to increase from 21,500 in 1980 to 33,600 in 1985 and 78,900 in 2000. While, the number of motor-cycles is expected to increase from 40,400 in 1980 to 53,600 in 1985 and 84,600 in 2000. (See Table 3.4)

Table 3.4 NUMBER OF VEHICLES BY TYPE

	Type of Vehicles	Vehicles				Annual Growth Rate	
		1979[a]	1980[b]	1985[b]	2000[b]	1980-1985	1980-2000
Study Area	Car	16,290	18,240	28,410	67,930	9.3	6.8
	Taxi	100	120	200	470	10.8	7.1
	Lorry	2,580	2,880	4,610	9,540	9.9	6.2
	Bus	230	260	380	960	7.9	6.7
	Motor Car	19,200	21,500	33,600	78,900	9.3	6.7
	M/C	37,400	40,400	53,600	84,600	5.8	3.8
	Total	56,600	61,900	87,200	163,500	7.1	5.0
Province Wellesley	Motor Car	26,000	29,100	46,500	118,500	9.8	7.3
	M/C	54,500	58,900	78,300	127,200	5.9	3.9
	Total	80,500	88,000	124,800	245,700	7.2	5.2

Notes: a) 1979 O-D Survey
b) Estimated by the Study Team

3.3 TRIP GENERATION AND ATTRACTION

The number of trips generated in the Study Area is projected by using the present number of trips by vehicle type and the projected number of vehicles. The total trips in this Area is expected to increase from 202.3 thousand P.C.U. in 1979 to 321.9 thousand P.C.U. in 1985 and 579.1 thousand P.C.U. in 2000 in the case when the P.C.U. conversion factor of motor-cycle is assumed to be 0.5. The average annual growth rate between 1979 and 2000 is 5.1% in the same case. (See Table 3.5)

Table 3.5 TOTAL TRIP RELATED TO STUDY AREA

(Unit: In thousand P.C.U.)

Type of Vehicle		Number of Trip			Average Annual Growth Rate (%)	
		1979	1985	2000	1979–1985	1979 – 2000
Motor Car		125.0	211.7	420.7	9.2	5.9
	Car	76.3	128.0	249.1	9.0	5.8
	Lorry	36.2	63.9	127.6	9.9	6.2
	Taxi	2.1	3.7	7.7	9.9	6.4
	Bus	10.4	16.1	36.3	7.6	6.1
Motor cycle	Case A	77.3	110.2	158.6	6.1	3.5
	Case B	115.9	165.3	237.6	6.1	3.5
Total	Case A	202.3	321.9	579.1	8.1	5.1
	Case B	240.9	377.0	658.0	7.8	4.9

Note: The following P.C.U. conversion factor is used:

Type of Vehicle	Car	Lorry	Bus	Taxi	Motor-Cycle	
					Case A	Case B
P.C.U.	1.0	2.0	3.0	1.0	0.5	0.75

The Trip generation and attraction by traffic zones is projected using trip generation and attraction model which was developed in the Phase I Study.

3.4 O–D TRAFFIC VOLUME

The future O–D matrix is obtained by using the projected trip generation and trip attraction and the time-distance between each zone pair in the form of the gravity model which was developed in the Phase I Study and is shown in Figs. 3.2 and 3.3.

Fig. 3.4 shows the traffic volume on the traffic lines which is computed by a minimum path traffic assignment method.

Based on the assigned traffic volume, the traffic volume and its growth rate by each screenline is shown in Table 3.6.

Table 3.6 TRAFFIC VOLUME AND GROWTH RATE BY SCREENLINE

Year	Prai River Screenline		BW–BM Screenline		Straight Screenline	
	Traffic Volume	Growth Rate	Traffic Volume	Growth Rate	Traffic Volume	Growth Rate
1979	39,300	1.00	46,700	1.00	19,500	1.00
1985	90,500	2.30	92,100	1.97	31,400	1.61
2000	167,700	4.27	171,400	3.67	74,600	3.82

According to this, the traffic volume and its growth rate on the Prai River Screenline is higher than the others. This is mainly due to the intensive urban and transport developments such as the Prai Industrial Estate Project, the Toll Expressway Project, the Penang Bridge Project, etc. that are scheduled in this area.

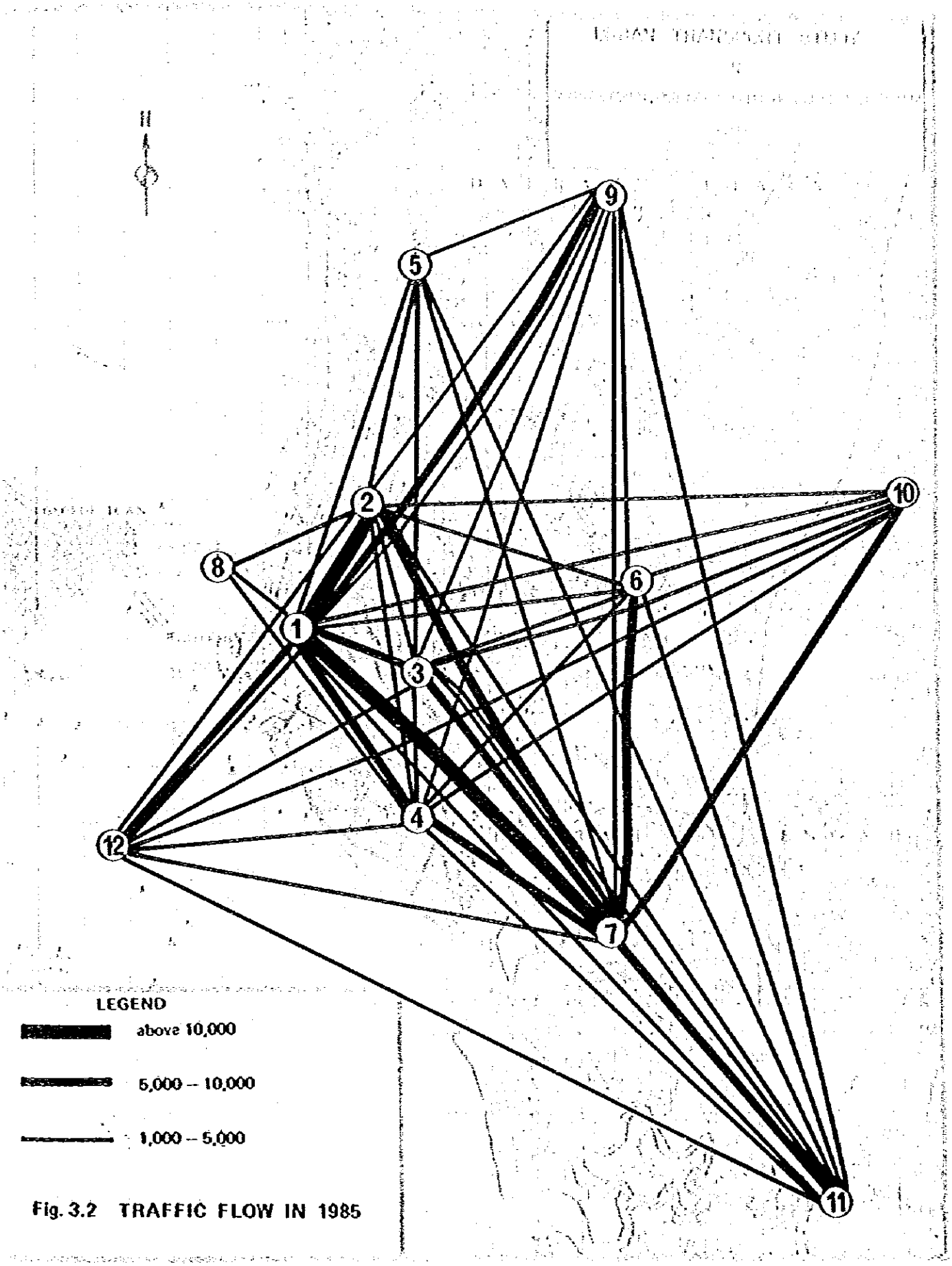


Fig. 3.2 TRAFFIC FLOW IN 1985

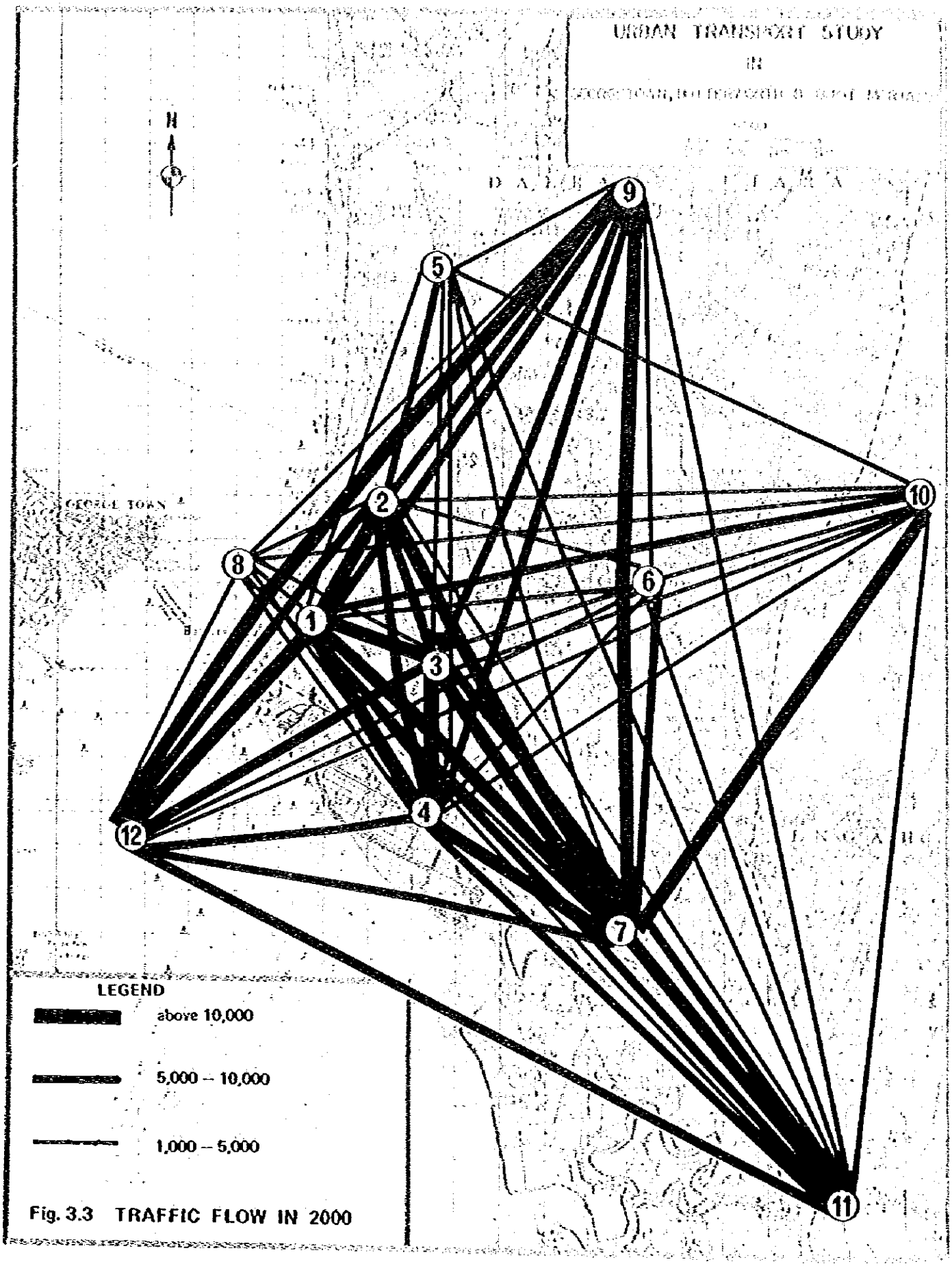


Fig. 3.3 TRAFFIC FLOW IN 2000

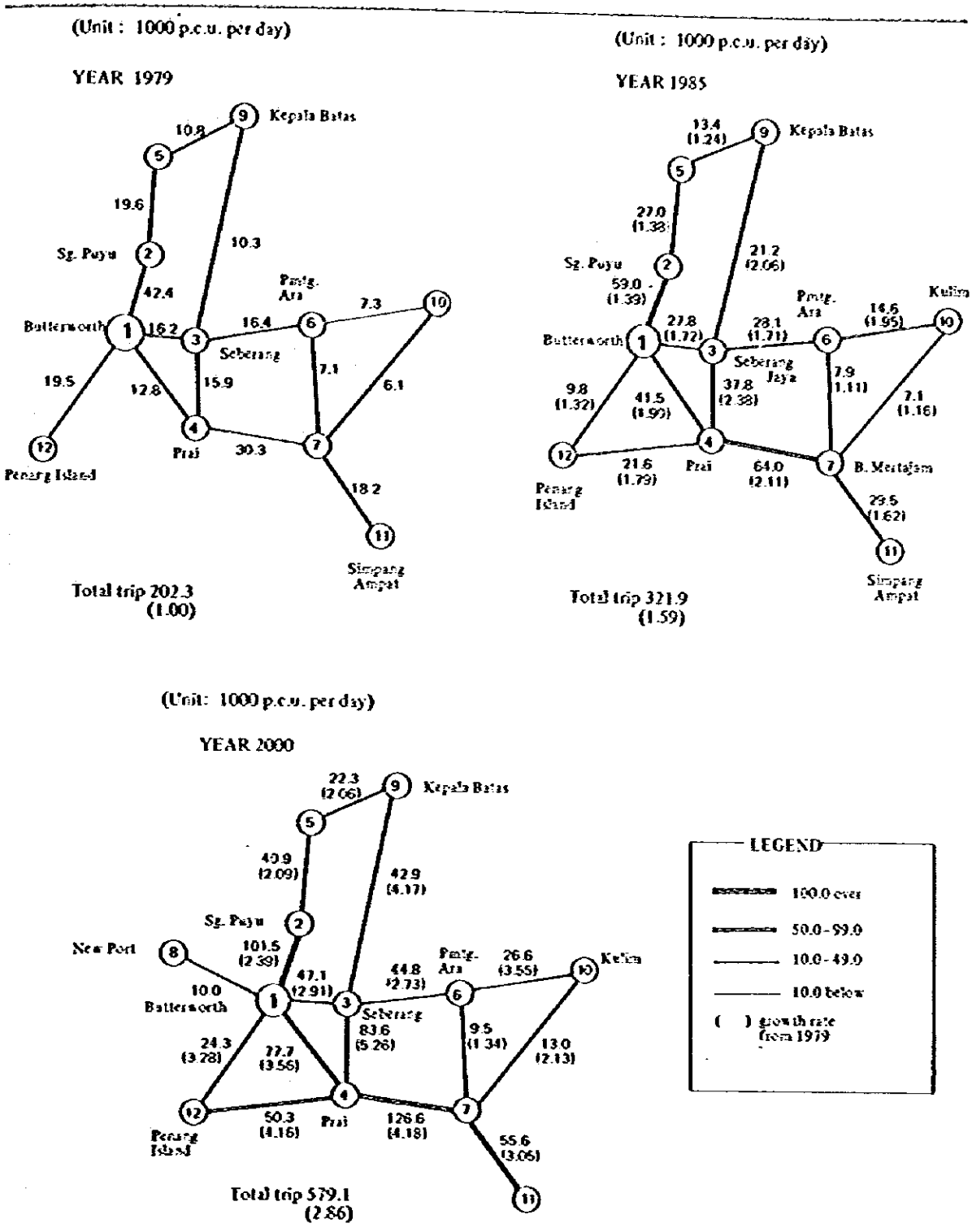


Fig. 3.4 TRAFFIC VOLUME ON MAJOR SECTIONS

4. PRELIMINARY ENGINEERING

4.1 THE NATURAL CONDITIONS

4.1.1 Topography

Butterworth is located in the mid-west of the Province Wellesley and it faces the North Channel which separates Penang Island from the mainland.

The terrain in Butterworth is predominantly flat disrupted only by the Prai River in the south which divides the metropolitan area. The height of the terrain is about 2.0 meters to 3.0 meters from the sea level and the width of the Prai River is about 300 meters.

4.1.2 Climate

The climate is hot and wet with a high humidity level of about 70% to 90%. The average highest temperature is 32.2°C and the average lowest temperature is 23.3°C.

The annual rainfall is about 2,670 mm throughout the year. The heaviest rainfall occurs between September and November during which the humidity is also the highest.

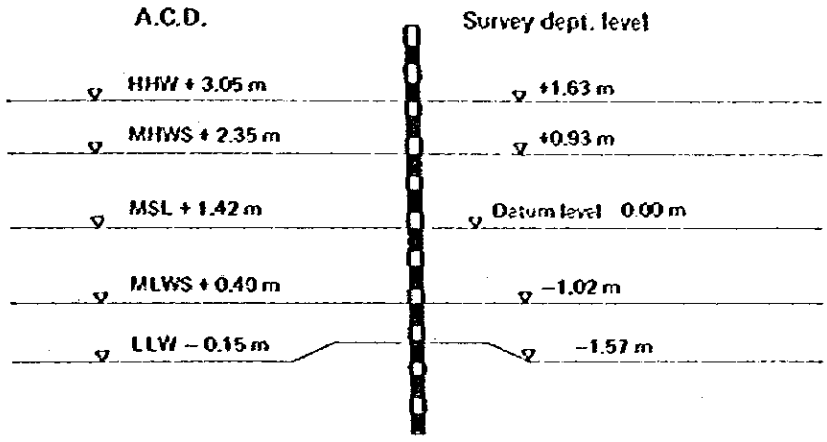
4.1.3 Wind Conditions

The coast of Butterworth is affected only by winds from the north-west and south-west directions. Judging from the wind speed, the winds are not violent, but as a phenomenon of the tropics, sudden gusts due to thunderstorms that occur at a frequency of 170 – 190 times a year. The wind duration is about 1 – 2 hours in the afternoon.

4.1.4 Water Level

The water level at Butterworth is as follows:

		A.C.D.	Survey dept. level
Highest high water	HHW	+3.05 m	+1.63 m
Mean high water springs	MHWS	+2.35 m	+0.93 m
Mean sea level	MSL	+1.42 m	Datum level (0.00 m)
Mean Low water springs	MLWS	+0.40 m	–1.02 m
Lowest low water	LLW	–0.15 m	–1.57 m



4.1.5 Tidal Current

According to the flow velocity pattern given in the Final Report Vol. 4 of the Penang Island Dispersal Study, August 1977, prepared by the Malaysia International Consultants Sdn. Bhd., relatively swift currents of a maximum of approximately 1 m/sec. occur in both the up and down streams between the North Channel and the South Channel. However, the drawings reveal that the current velocity is extremely slow in the shallow area along the West Beach Coast line.

4.2 FIELD SURVEYS

4.2.1 Geotechnical Investigation

(1) Investigation Conducted

This geotechnical investigation consisted of:

a. Exploratory drilling with Standard Penetration Test and undisturbed sampling.

b. Construction material investigation.

c. Laboratory tests on soil and material samples obtained from the site.

(2) Geological Outline

The proposed road alignment is laid out on the predominantly flat terrain from north to south of Butterworth where geologically the area consists of sedimentary rocks, a mass of granite and alluvium. A swampy area of alluvium is found around the mouth of Prai River. (See Fig. 4.1 and Fig. 4.2)

1) Sedimentary Rocks

Heavily weathered shale, mudstone and sandstone are found at the area adjacent to the project area. The rocks found here probably belong to the Mahang Formation and the Sungai Petani Formation. These formations are probably of "Lower Palaeozoic rocks", and they are generally composed of shale, chart, mudstone and sandstone.

The Sungei Petani Formation underlies the area North of the Western Part of the Kulim granite area and is believed to extend under the whole area of the coastal plain to the north and west beneath the alluvium.

2) Granite

Granite bodies are extensively distributed throughout the country and commonly form topographic heights. The granite at the area adjacent to the project area is the Kulim granite mass. The granite seems to be intruded during the Jurrassic period, radiometrically between 165 million to 208 million years ago. The granite mass has been highly weathered by the tropical climate in this region, the surface portion of which changed into residual soil. The granite is essentially medium to coarse-grained granite and commonly porphyritic. The fresh granite around Bt. Mertajam has been used for construction works of road and structure.

3) Alluvium

About 20,000 years ago, sea water level was more than 100 m below the present level. Then as the level gradually started to rise, erosion worked severely and cut valleys through the area and simultaneously, the eroded materials were deposited under the water. About 6,000 years ago, the invasion of sea ceased at about 5 m above the present sea level and the present Butterworth town area became calm shallow sea where sedimentation continued. About 2,000 years ago, by a regression to the present sea level, the area became coastal plain and the Sungai Prai started to flow around the present route with a much wider flood area and the present swampy area was also formed on both sides of the Sungai Prai.

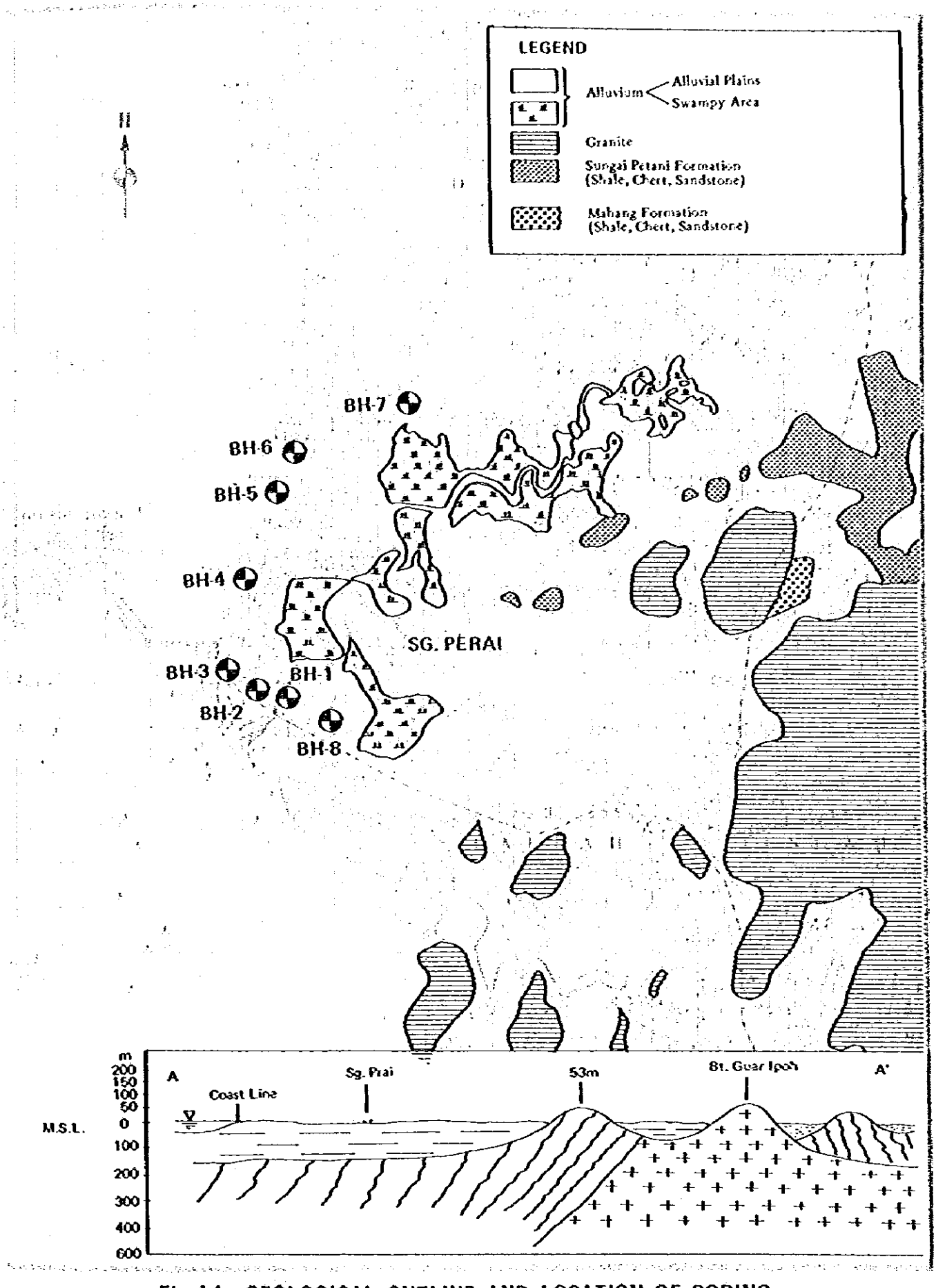


Fig. 4.1 GEOLOGICAL OUTLINE AND LOCATION OF BORING

(3) Subsurface Ground Conditions Along the Road Alignment

Ground conditions along the road alignment based on the results of geotechnical survey, exploratory drillings and laboratory soil tests are summarized below. (See Fig. 4.2).

1) Upper Sand Layer

This layer is the top layer and covers all areas of the road alignment with thickness of 1 to 8 m. This layer is generally composed of coastal sand with a lot of shell fragments and the colour is brown to brownish grey. N-Value is in the range of 1 to 20. There is ground water in this layer and is encountered at the depth of 0.75 to 2.1 m below ground surface.

2) Middle Sandy Layer

This layer is mainly found at BH–2 and BH–3 and underlies the marine clay layer. This layer consists of silty or clayey sand and sand with gravel and has a lot of shell fragments. The colour is light to dark grey. The thickness of this layer is 11 to 16 meters and the N–Value is 3 to 12.

3) Lower Sandy Layer

This layer is thick and is the predominant layer along the proposed alignment. This layer consists of sand, gravelly sand, sand with gravel, silty sand with gravel and has occasional organic matter. The colour is brownish grey to brown. The thickness is about 40 meters or more and the N–Value is 3 to 30 or more.

4) Marine Clay Layer

This layer is soft marine clay with shell fragments. The thickness is in the range of 8 to 13 m from Sta. 10 to Sta. 90, and is about 3 m at around Sta. 126 and it is cut by Clayer Layer with organic matter, Co at around Sta. 90 to Sta. 114. The colour is grey to dark grey. The N–Value is 0 to 2.

5) Clayey Layer with Organic Matter

The thickness is 2 to 6 m at Sta. 16 to Sta. 90 and it is 4 to 10 m from Sta. 90 to Sta. 140. This layer is composed of silty clay with gravel, sandy clay and clay. Organic matter is found in all portions of the layer. The colour of the layer is light shade of brownish grey (occasionally black). The N–Value is 1 to 5.

6) Medium to Stiff Clayey Layer

This layer is encountered in the Lower Sandy Layer, S1, and the thickness is 1 to 5 m. This layer is generally composed of clay and silty clay and has organic matter occasionally. N-Value of the layer is 5 to 20 or more. The colour of the layer is grey to dark grey.

4.2.2 Investigation for Construction Materials

Construction of the road requires concrete materials and earth. Details of such materials and their sources are given below.

1) Fine Aggregate

Fine aggregate is available from several sand quarry pits in Province Wellesley. Almost all the sand pits are located along the present Sungai Muda in which the sand is the river sand of Sungai Muda. The present capacity of each site ranges from 30 lorries to 250 lorries per day.

2) Coarse Aggregate

Crushed aggregates of granite are used as coarse aggregate for construction works in Province Wellesley.

The production capacity of each quarry site ranges from 2000 tons per day to 3000 tons per day.

3) Embankment Materials

Earth materials are available in abundance from the foothills. The soils are residual sandy and clayey materials or talus deposits derived from heavily weathered granite, and are composed mainly of clayey sand with gravel and silty sand with gravel.

4) Reclamation Material

The Penang Port Commission has performed an offshore soil investigation. A soil profile is made from the result of the investigation to obtain an easier understanding on the usability of the subsurface soil as road construction material.

The profile indicates that:

a. Clayey materials are deposited in the northern portion of the North Channel.

b. Sandy materials are deposited at the southern portion of the North Channel.

Soil with a sand content of 80 to 98% is encountered and it is highly probable that the soil will be usable for road construction by means of reclamation by dredging ship. However, the volume of the usable material must be confirmed.

4.2.3 Topographical Survey

The following topographic surveys are conducted in this study in order to supplement the topographic map.

1) Plane – Table Survey

The plane-table survey covering an area of 12,500 m^2 was conducted along Jalan Prai and Jalan Bagan Dalam. This survey included the sounding survey for the Prai River.

2) Cross-Section Survey

The cross-section survey was conducted along Jalan Bagan Dalam and 10 cross-section survey points were surveyed.

3) Levelling Survey

The levelling survey was conducted along Jalan Prai, Jalan Chain Ferry, Jalan Bagan Dalam, Jalan Bagan Luar, Jalan Bagan Jermal and Jalan Sungai Dua. The total length of the area surveyed was 20 km.

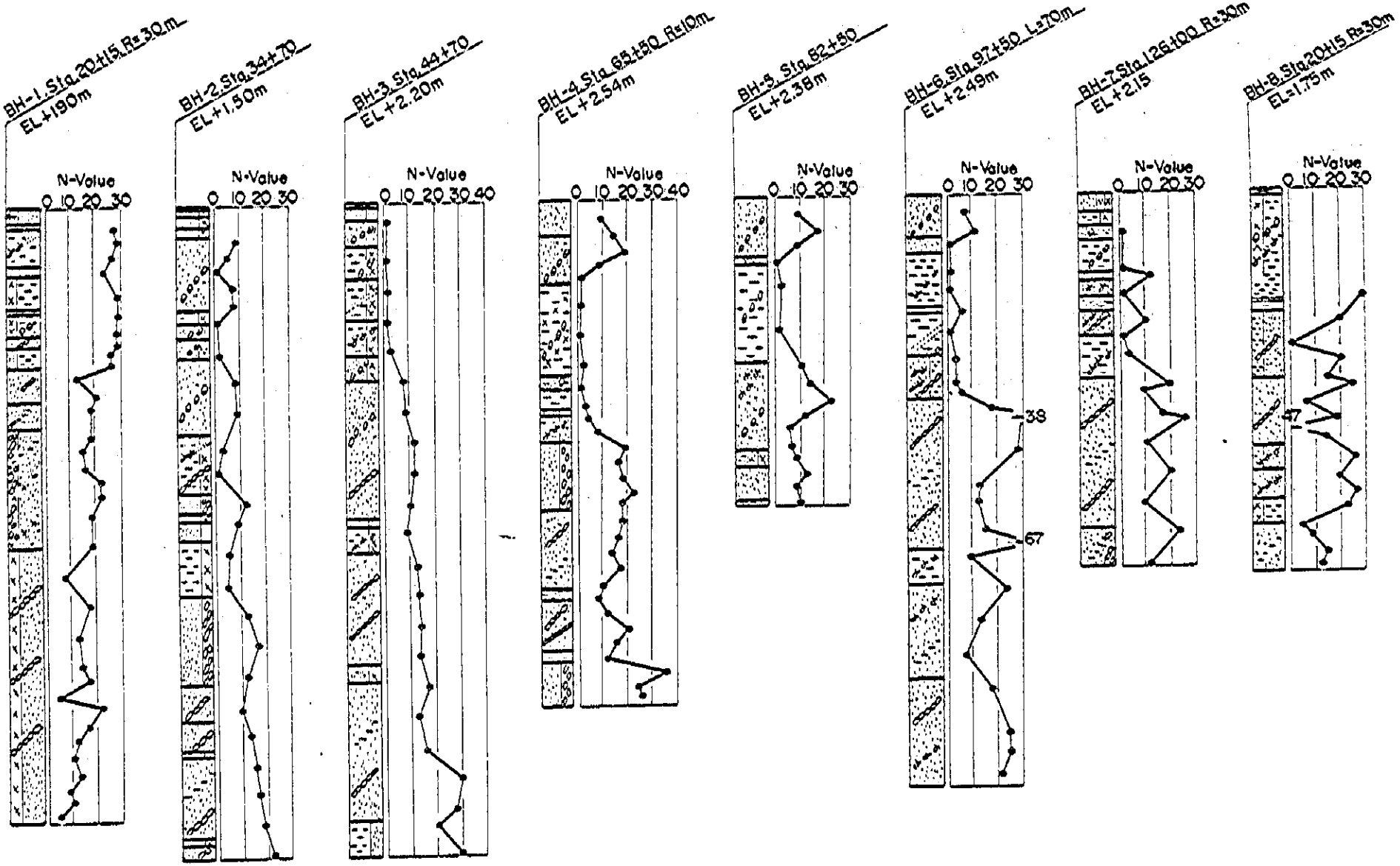


Fig. 4.2 PROFILE OF THE SOIL CONDITION

4.3 CHARACTERISTICS OF THE PROJECT ROAD

4.3.1 General

(1) Project Road

The Project Road, proposed as a Primary Distributor by the Phase I Study, is generally aligned as follows: (See Fig. 4.3).

a. The Project Road, starting at the intersection of Jalan Prai and the Toll Expressway, passes along Jalan Prai and crosses over the Prai River and arrives at the roundabout in front of the ferry terminal.

b. Then, it passes beside the North Butterworth Container Wharf and arrives at Kampong Bagan Ajam.

c. After turning right to the east, it runs along Jalan Sungai Dua and reaches the interchange of Jalan Sungai Dua and the Toll Expressway.

(2) Present and Future Traffic Demands

The average daily traffic volume A.D.T. on two screen lines is as follows:

1) Prai River Screen Line

	A.D.T. ('000 P.C.U.)		
	1979	1985	2000
Jalan Chain Ferry Jalan Permatang Pauh	39.3 (1.00)	90.5 (2.30)	167.7 (4.27)

2) Jalan Permatang Pauh Screen Line

Jalan Bagan Ajam Jalan Raja Uda	29.9 (1.00)	48.2 (1.62)	83.3 (2.79)

Note: The figures in parentheses indicate the growth rates

According to the traffic demands projected, the traffic volume is expected to increase by 2.3 times in 1985 and by 4.3 times in 2000 on the Prai River Screen Line as compared with the present volume.

(3) General Land Use

The land use in the Prai area is predominantly industrial and residential. In contrast with the Prai Area, the land use in the south Butterworth area is diverse, mainly transportation, institutional, commercial and residential. However, the north Butterworth area is mainly residential.

Presently, the area along Jalan Sungai Dua is largely agricultural being devoted to padi fields and coconut plantations. It is expected to be utilized as a residential area in future. (See Fig. 4.4).

(4) Urban Developments

In Butterworth, many intensive industrial and urban development projects are on-going and/or under-planning. They are:

1) Urban Development Projects

a. Prai Industrial Estate
b. Seberang Jaya Development Project
c. Mak Mandin Industrial Estate
d. Housing Projects along the Federal Route 1

2) Transport Projects

a. North Butterworth Container Wharf Project
b. Improvement Project of Butterworth Port including the Port Approach Road Project
c. Toll Expressway Project
d. East-West Highway Supporting Road Project
e. Penang Bridge Project

The Project Road is greatly expected to serve the traffic coming in and out of these projects.

4.3.2 Characteristics of the Project Road

In the context, the Project Road is planned as an Intra-Urban Primary Distributor in the Phase I Study.

The Project Road is expected to serve traffic coming in and out of the planned North Butterworth Container Wharf and the existing Butterworth Port as well as the Prai Industrial Estate and other urban development projects. This Project Road is also expected to form part of an effective road networks with the Inter-Urban Primary Distributors such as the Toll Expressway and the East-West Highway Supporting Road. In addition, the Project Road will disperse traffic passing through the urbanized area.

In order that the Project Road can function more effectively to serve this traffic, it is recommended that there be partial control of the access traffic to/from the minor roads and to have grade separations at the major intersections. It is also recommended that service roads be provided to the Project Road and U-turns be allowed only at limited medium openings.

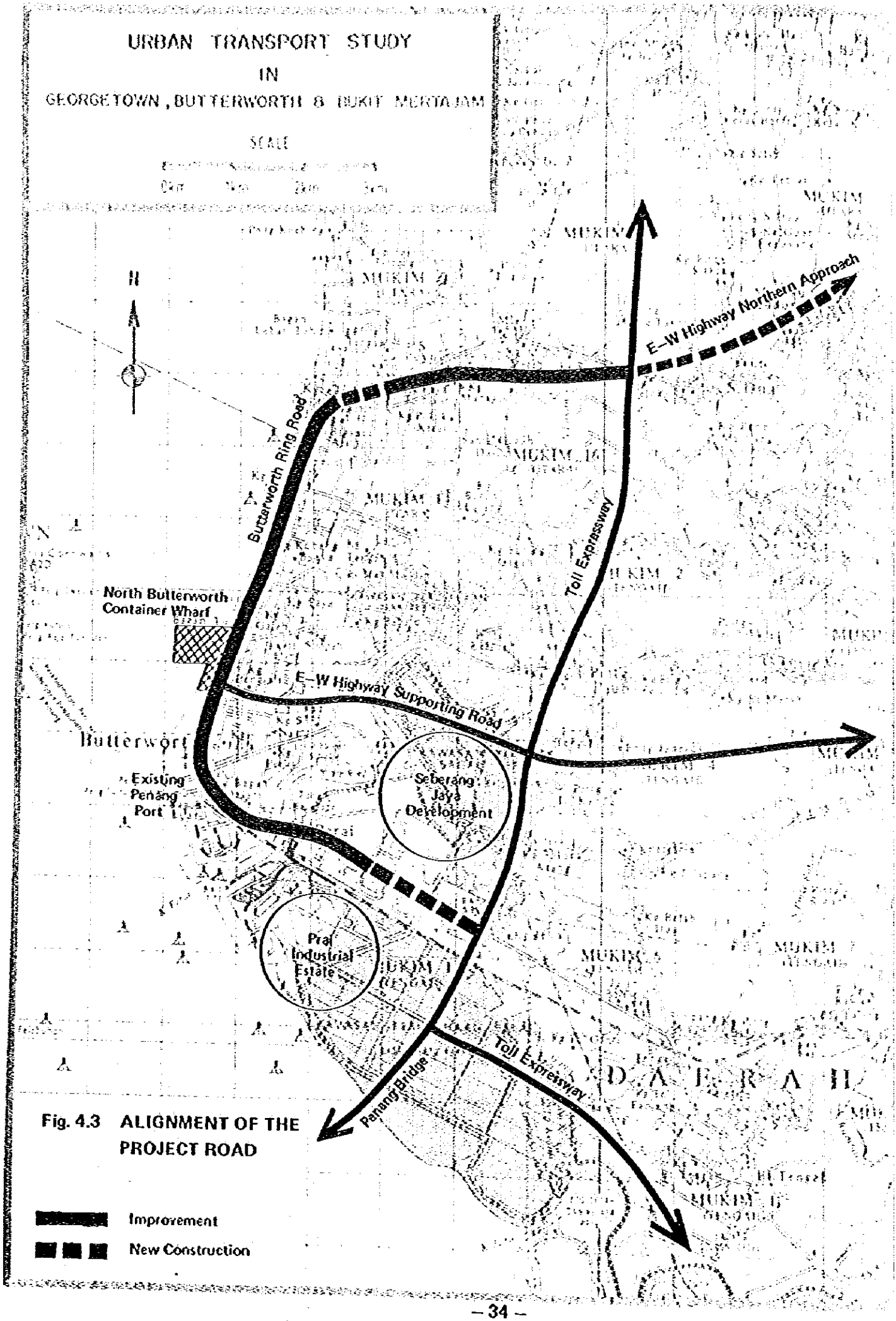


Fig. 4.3 ALIGNMENT OF THE PROJECT ROAD

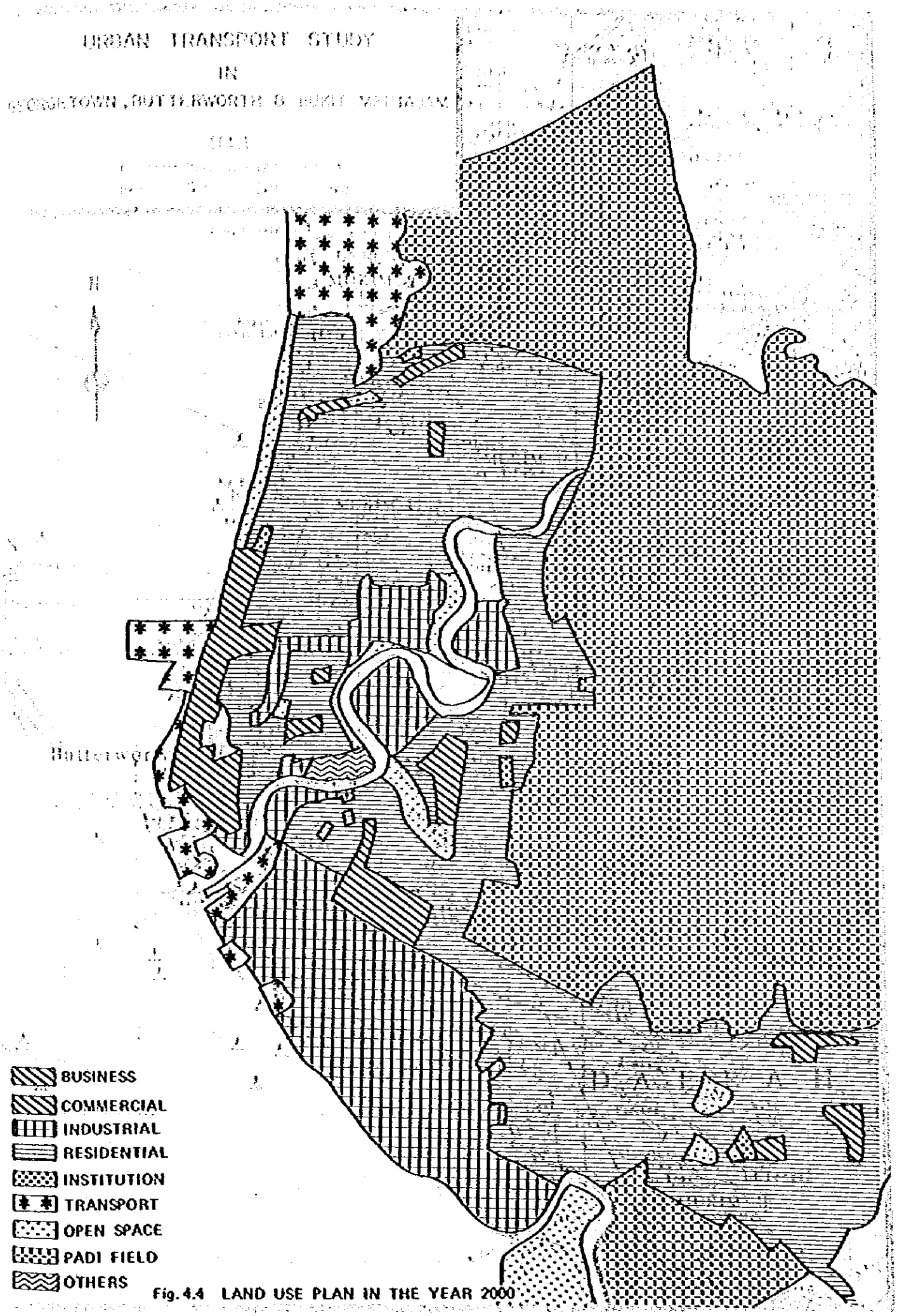


Fig. 4.4 LAND USE PLAN IN THE YEAR 2000