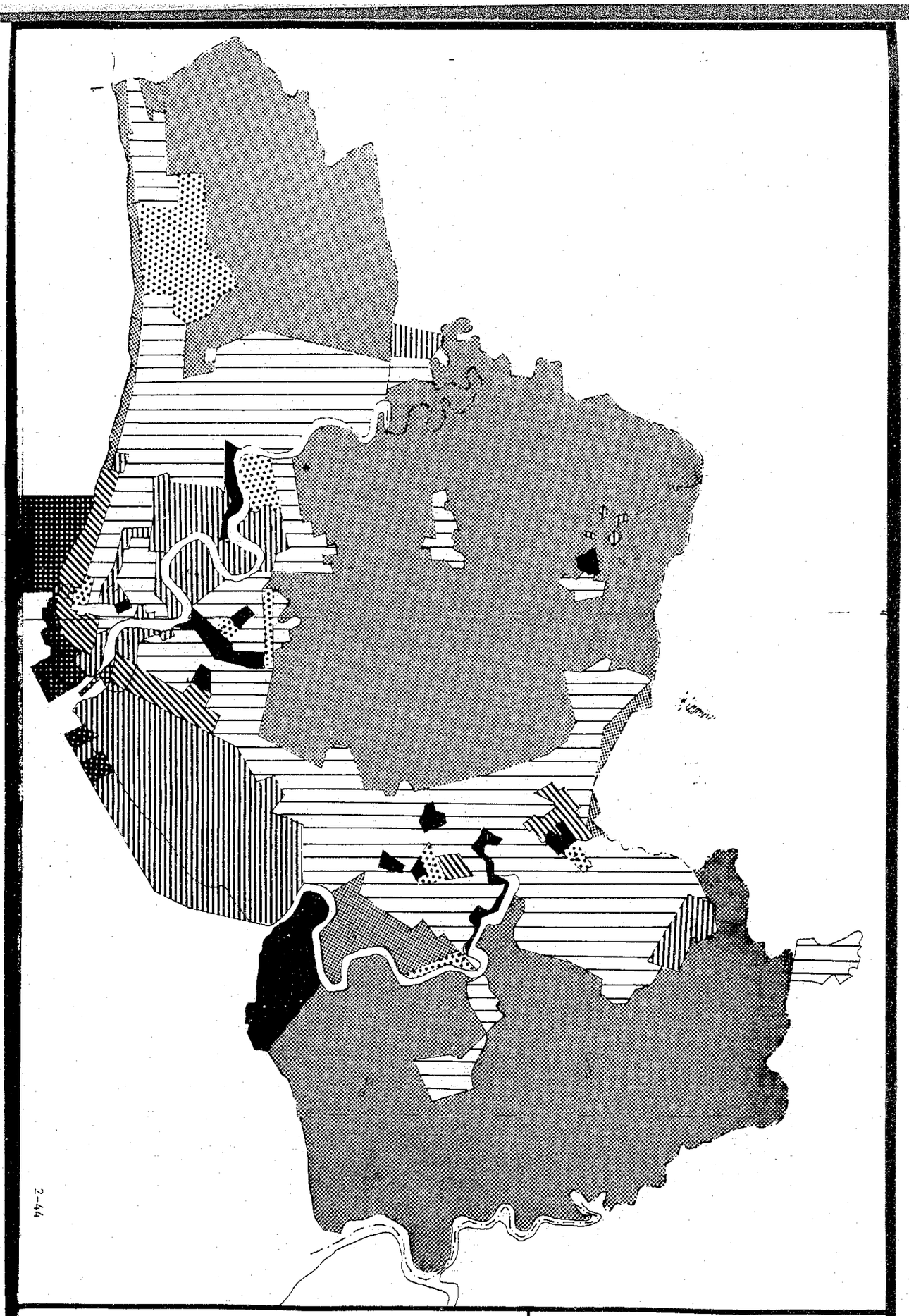

Fig. 2.13 **FUTURE LANDUSE**
SEBERANG PRAI 2000

scale: 1 inch to 1 mile

N

Legend

residential
industrial
open space
transportation
commercial
institution
forest
agriculture

2.3.4.3 Future Land Use.

Based on the policies mentioned earlier, future land use was planned as illustrated in Figs. 2.12 and 2.13 while the following table shows the change of area size by land use.

Table 2.26 AREA SIZE BY LAND USE

(ha)

Area	Penang Island		Province Wellesley		Total		Change of '79-90'
	1979	2000	1979	2000	1979	2000	
Residential	2,700	5,100	3,100	5,100	5,800	10,200	+4,400
Commercial	210	600	160	420	370	1,020	+ 650
Industrial	360	320	1,020	1,930	1,380	2,250	+ 870
Institutional	730	1,140	-	700	730	1,840	+1,110
Open Space	390	740	1,620	1,280	2,010	2,020	+ 10
Others	10,300	7,300	16,200	13,100	26,500	20,400	-6,100
Total	14,690	15,200	22,100	22,530	36,990	37,730	+ 940*

* Supplied through reclamation of land.

Provided that the populace live in residential and commercial areas, the population density will undergo change. In Penang Island, gross density will lessen due to the decrease in density of built-up areas

Penang Island		Province Wellesley	
1979	2000	1979	2000
162 per/ha	119 per/ha	80 per/ha	96 per/ha

where population density is often more than 300 persons per hectare. On the other hand, in Province Wellesley the built-up areas will be more than the present whereby there will be an increase in the population density.

2.4 Populations Distribution Plan

2.4.1 The Present Population Spread.

2.4.1.1 Population Spread in 1970

The Population Census of 1970 describes the population of each

mukim, town and village. The traffic zones used in this study were based mainly on the mukims except in several instances where the mukims were divided into several traffic zones. These instances were in the urbanized areas like George Town, Bayan Baru, Butterworth and Bukit Mretajam.

The method of breaking down the mukims into the traffic zones was done by using the population of the enumeration blocks which show the population of smaller units of zones.

2.4.1.2 Population Spread in 1979.

The population growth from 1957 to 1970 was used as a base to show population trend from 1970 to 1979. Thus the population of each traffic zone was expanded by the rate which was obtained from the population change between 1957 and 1970.

1. Penang Island

The comparison of the 1957 and 1970 population census gives us the population growth of each mukim. In the case of the mukims which were divided into traffic zones, the growth rate of the mukim was adopted for all the traffic zones.

2. Province Wellesley

Population growth rate used here is based on the growth rate of Butterworth, Bukit Mertajam and the rest of the districts from 1957 to 1970.

After the above calculations, total population was adjusted to the population of the State of Penang as projected by the department of statistics.

(1) The population growth rate of Penang Island from 1970 to 1979 is 1.9 percent, therefore, the control total is about 533,000 persons.

(2) As the population of the State in 1979 is 946,580, the population of Province Wellesley is obtained through the following calculations.

Population of Province Wellesley = 946,580 - 533,000
= 413,580

(3) The population of the traffic zones in Province Wellesley was adjusted to make its total equal that of the population obtained through (2).

2.4.2 Population Distribution Plan

2.4.2.1 Population Distribution Plan in the year 2000.

Projected future population in the State of Penang is distributed to each zone by the method of multiplying future residential areas by population density. Sizes of residential areas by zones were obtained from the land use plan. Therefore only population density has to be determined.

According to the guidelines of the interim zoning plan, five (5) types of net population density were planned:

- Low density
- Low medium density
- Medium density
- High medium density, and
- High density.

However, gross population density instead of net population density is used in this study, because the aim of this study is to prepare the population data for traffic projection.

In the population plan, it is assumed that the gross density is equal to 60 percent of the net density. On the basis of this assumption, the following typical population density can be made.

Typical Population Density

	Net Density	Gross Density
Low Density	15 - 89 persons/ha	10 - 50 persons/ha
Low Medium	90 - 220 persons/ha	51 - 130 persons/ha
Medium Density	221 - 440 persons/ha	131 - 260 persons/ha
High Medium Density	441 - 880 persons/ha	261 - 530 persons/ha
High Density	881 and more persons/ha	531 and more persons/ha

On the basis of the above-mentioned density, the following population density is adopted for each zone.

*	Low	40	persons/ha
*	Low - Medium -1	60	persons/ha
	-2	80	persons/ha
	-3	100	persons/ha
	-4	120	persons/ha
*	Medium	150	persons/ha
	High - Medium	200	persons/ha
*	High	300	persons/ha

Note: Planning Guide line of Population Density in Residential Areas, based on the Interim Zoning Plan.

a. Low Density: Net Density range of 1-6 residential units/36 persons per acre (88.8 p/ha)

b. Low Medium Density: 7-16 units/90 persons per acre (222.2 p/ha)

c. Medium Density: 16-30 units/180 persons per acre (444.4 p/ha)

d. High Medium Density: 31-60 units/360 persons per acre (888.8 p/ha)

e. High Density: Exceeding a net density of 60 units/360 person persons per acre. Regarding each of the above, any other suitabale uses are subject to the approval of the Council.

2.4.2.2 Population Distribution Plan in 1985.

Population of the zones for 1985 was estimated on the assumption that the population of each zone would change constantly from 1979 to the year 2000. The population of each zone was adjusted to the eatimated population in the framework plan.

Population Density in the Year 2000

George Town

Zone	Residential Area (has.)	Population Density (Persons/ha.)	Pop lation
111	106*	300	31,800
121	93*	300	27,900
122	223	150	33,450
123	146	150	21,900
124	141	150	21,180
125	146	120	13,920
131	282*	300	84,500
132	166	200	33,200
133	165	200	33,000
141	103	150	15,400
142	128	200	25,500
143	180	200	36,000

* including commercial area

Tg. Bungah Corridor

211	207	90	18,640
212	140	90	12,570
221	206	40	8,230

Ayer Itam and its periphery

143	180	200	36,000
311	738*	-	3,780
321	134	200	36,720
322	492*	-	2,080
323	539*	-	750

* including open space

Paya Terubong and its periphery

331	418	100	41,840
332	78	100	7,800
333	368	100	36,820
334	259	60	15,550
335	382*	-	2,740

* including open space

Bayan Lepas Corridor

411	306	100	30,620
412	668	100	66,850
413	219	60	13,120

Butterworth and its periphery

Zone	Residential Area (has.)	Population Density (Persons/ha.)	Population
511	182	200	36,480
512	152*	120	18,240
513	200	100	20,000
514	142	120	17,040
521	127	80	10,160
522	260	80	20,800
523	548	80	43,880
524	122**	40	4,880
525	187	80	14,960

* including commercial area
** including kampung area

Seberang Jaya and its periphery

611	424	200	84,880
612	165	120	19,800
621	82	80	6,560
622	137*	40	5,480
623	434	80	34,720

* including kampung areas

Bukit Mertajam and its periphery

711	70	40	2,790
712	56	40	2,250
713	219	40	8,740
721	125	40	5,000
722	70	40	2,800
723	62	80	4,960
731	140	60	8,400
732	165	120	20,040
733	66	100	6,600
734	100	80	8,000
741	158	80	12,660
742	602	80	48,150

Simpang Ampat and its periphery

811	190	80	15,200
812	469	80	37,560
821	109	40	4,350
822	116	40	4,620

Table 2.27 SUMMARY TABLE OF POPULATION DISTRIBUTION

State of Penang 1979, 1985 and 2000.

	1979		1985		2000		Average Annual Growth Rate (%)		
	Number	Per Cent	Number	Per Cent	Number	Per Cent	1979 - 85	1985-2000	1979-2000
100	341,220	66.5	349,900	60.6	378,900	50.5	0.4	0.5	0.5
200	26,980	5.3	29,940	5.3	39,440	5.3	1.8	1.9	1.8
300	73,630	14.3	91,590	16.4	148,080	19.7	3.7	3.0	3.4
400	27,870	5.4	47,890	8.9	110,590	14.8	9.4	5.4	6.8
Inter Total	469,700	91.5	519,320	91.2	677,000	90.3	1.7	1.8	1.8
External	43,550	8.5	49,780	8.8	73,000	9.7	2.3	2.4	2.4
Penang Is. Total	513,250	100.0	569,100	100.0	750,000	100.0	1.7	1.8	1.8
500	111,310	25.7	126,630	24.1	186,440	23.3	2.2	2.5	2.5
600	49,330	11.4	81,770	16.4	151,440	18.9	8.8	3.9	5.5
700	67,210	15.5	79,710	15.3	130,390	16.3	2.8	3.2	3.2
800	26,310	6.1	29,510	5.6	61,730	7.7	1.9	4.7	4.1
Internal Total	254,160	58.7	317,620	61.9	530,000	66.3	3.8	3.3	3.6
External	178,500	41.3	293,820	38.1	270,000	33.7	2.2	1.8	2.0
Pro. Wellesley Total	433,330	100.0	520,900	100.0	800,000	100.0	3.1	2.9	3.0

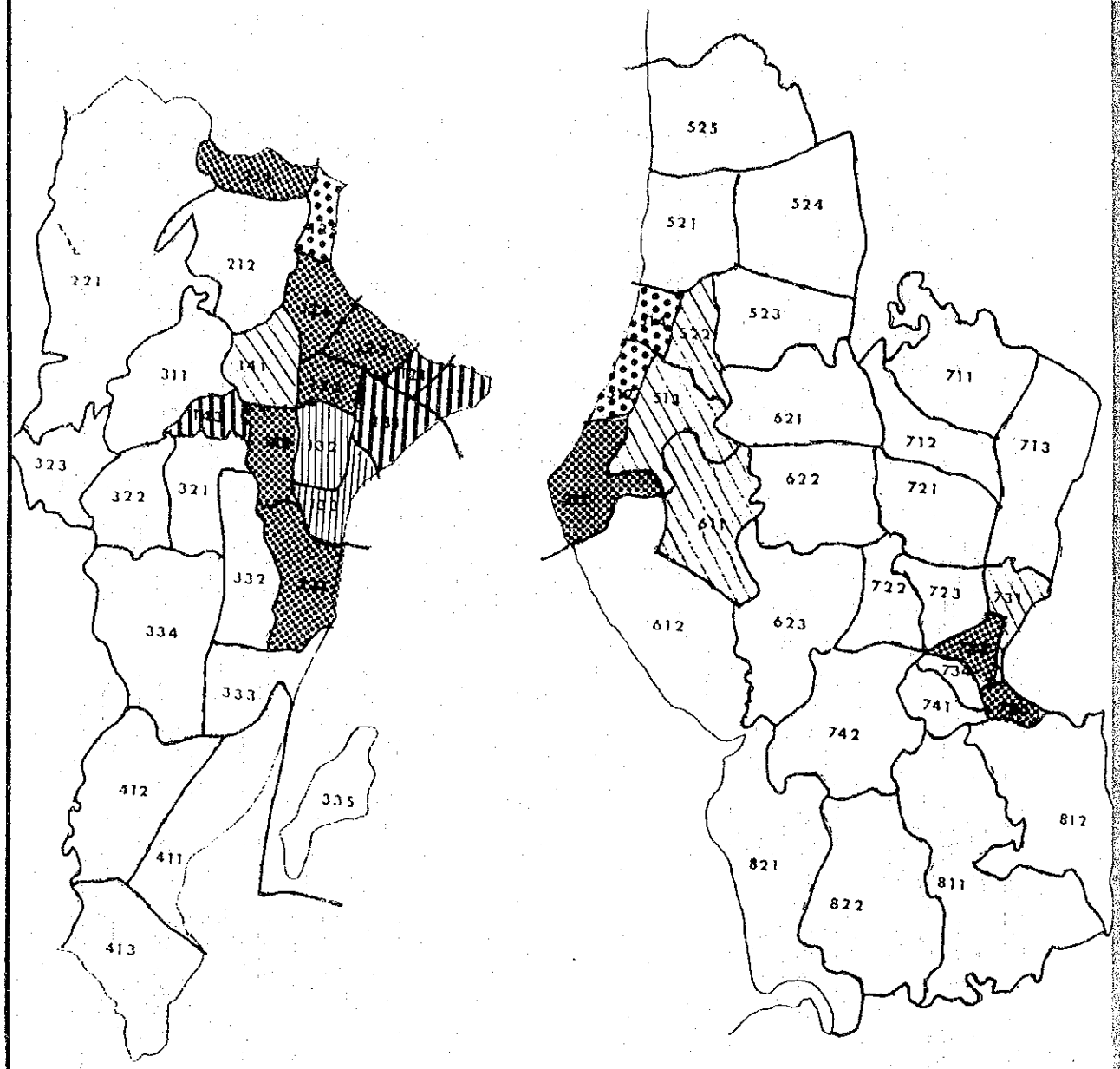

FIG. 2.14: POPULATION DENSITY (1979)

0 - 20 Persons/ha
20 - 40
40 - 80
80 - 120
120 - 180
above 180

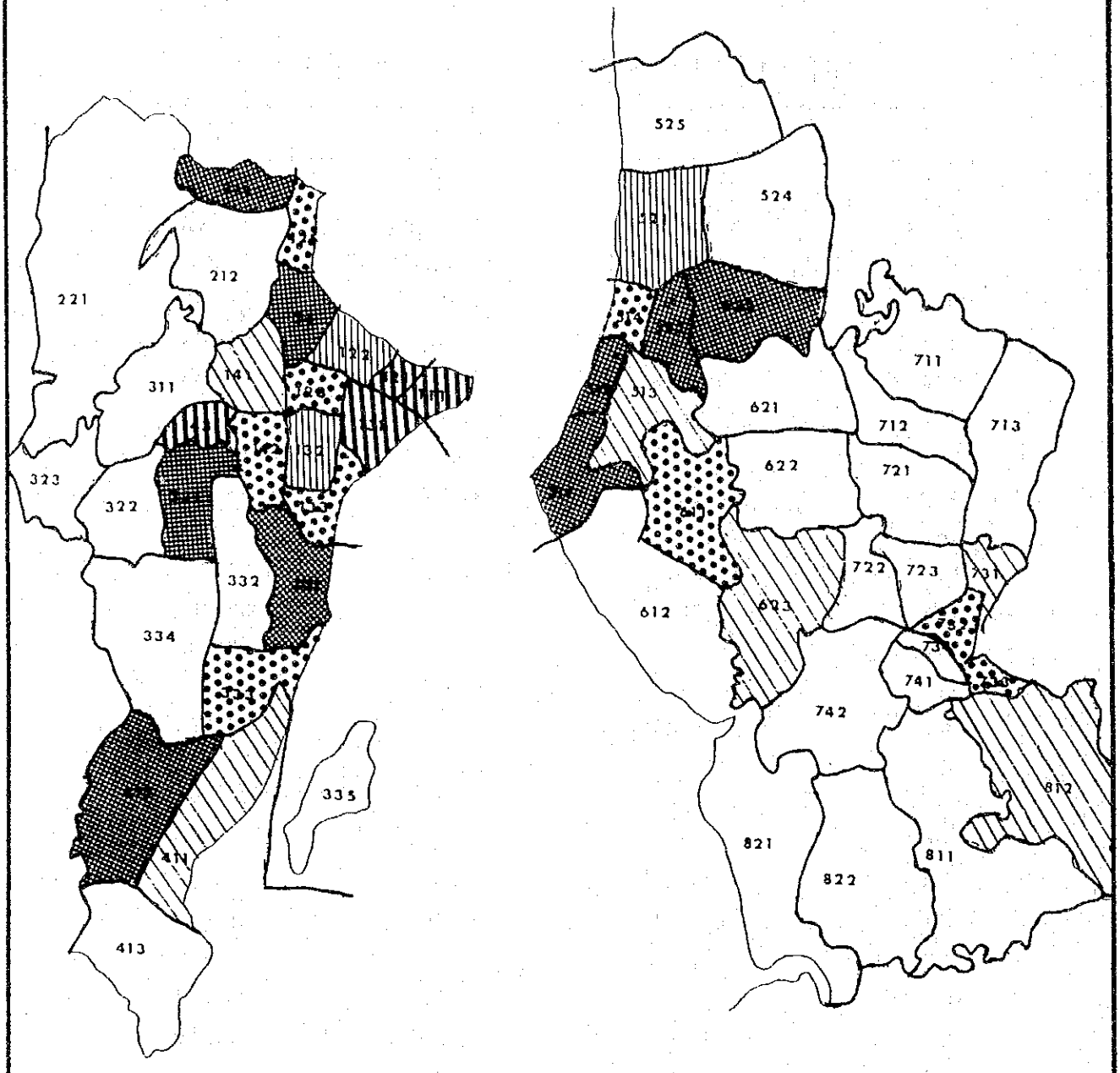

FIG. 2.15: POPULATION DENSITY (2000)

	0 - 20 Persons/ha
	20 - 40
	40 - 80
	80 - 120
	120 - 180
	above 180

Table 2.28 (1) POPULATION DISTRIBUTION PLAN

	1979	1985	2000
111	55,540	49,790	31,800
121	27,980	27,960	27,900
122	17,060	20,980	33,450
123	13,080	15,190	21,900
124	13,350	15,430	11,180
125	13,630	13,700	13,920
131	75,080	77,100	84,500
132	32,300	32,540	33,300
133	32,630	32,670	33,000
141	11,550	12,450	15,450
142	13,820	16,610	25,500
143	35,290	35,460	36,000
211	14,890	15,790	18,640
212	8,380	9,340	12,570
221	3,710	4,810	8,230
311	1,620	2,150	3,780
321	33,050	33,940	36,720
322	1,150	1,400	2,080
323	320	420	750
331	22,950	27,510	41,840
332	2,460	3,750	7,800
333	8,300	15,180	36,820
334	2,360	5,560	15,550
335	1,420	1,740	2,740
411	8,050	13,520	30,620
412	13,760	26,600	66,850
413	6,060	7,770	13,120
Total	469,700	569,100	677,000

Table 2.28 (2) POPULATION DISTRIBUTION PLAN

	1979	1985	2000
511	29,740	32,560	36,480
512	15,570	16,680	18,240
513	15,020	16,680	20,000
514	14,100	15,330	17,040
521	8,510	8,690	10,160
522	10,780	14,130	20,800
523	4,260	8,520	43,880
524	3,300	3,470	4,880
525	10,030	10,560	14,960
611	21,700	48,130	84,880
612	11,770	14,460	19,800
621	4,150	4,410	6,560
622	5,760	5,800	5,480
623	5,950	8,980	34,720
711	2,500	2,530	2,790
712	2,070	2,090	2,250
713	7,970	8,050	8,740
721	4,100	4,180	5,000
722	2,420	2,460	2,800
723	4,020	4,120	4,960
731	6,170	6,410	8,400
732	14,060	18,310	20,040
733	4,200	5,200	6,600
734	5,850	5,010	8,000
741	6,430	7,110	12,660
811	9,650	10,240	15,200
812	10,710	12,960	37,560
821	2,870	3,050	4,350
822	3,080	3,260	4,620
Total	254,160	317,620	530,000

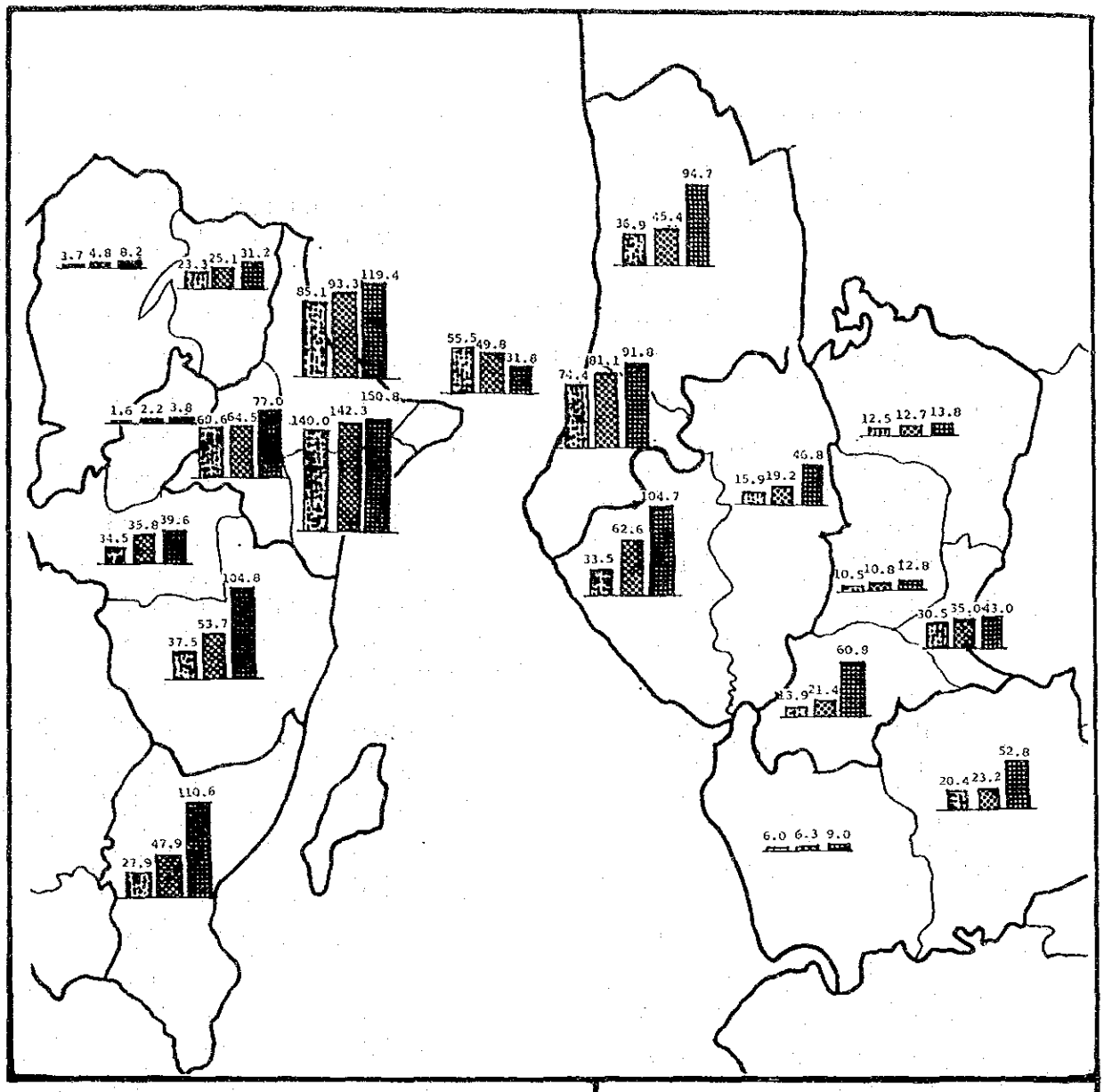

Fig. 2.16 POPULATION DISTRIBUTION PLAN
(In thousand)

2.4.3 Employed Population by Work Place

The distribution plan of employed population by work place is made on the basis of employment projected in the State of Penang.

Classification of employment is as follows:

Primary Industry		Agriculture, Fishing and Forestry
Non-Primary Industry	Secondary Industry	Manufacturing, Construction and Mining.
	Tertiary Industry	Commerce, Financing Transport and Communication and Services.

There is no available data for employment by industry and zone and so the two (2) classifications of industry are used for our study.

1. Primary Industry

Size of employment in the primary industry will decrease steadily in the future. This is because lower productivity is expected in this industry than in the other industries, while moreover, urbanization will be promoted in the future. Employment in this sector will decrease form 54,000 in 1979 to 22,000 by the year 2000. Primary employment for each zone is projected by using an average reduced rate of agricultural lands between the years 1979, 1985 and the year 2000.

2. Non-Primary Industry

The projection for this industry is made by adding the increase in secondary and tertiary employment between the design years 1985 the year 2000 and the base year 1979 to the employment of non-primary industry in the base year 1979. Increase in the employment in the non-primary industries was already estimated in the previous section.

The pattern of increase in employment in the secondary and tertiary industries is quite different. Employment in the secondary industry is mostly located in the industrial development sites.

On the other hand, some of the employment in the tertiary industry is distrubuted to each zone in proportion to the population increase while the others are distributed only to major urban cores.

The former pattern of employment belongs to the neighbourhood commerce and services while the latter belongs to regional and district commerce, services and financing. Considering these concepts, the increase of employment in the non-primary industry is distributed to each zone and the results are shown in Table 2.30. The results show that major growth areas within Metropolitan Penang Area are Bayan Lepas and Seberang Jaya, which will record a growth rate of over 12 percent per annum between 1979 and 1985. The other growth district is Batu Ferringhi where there is a growing tourist industry.

Table 2.29 EMPLOYED POPULATION DISTRIBUTION PLAN
Penang State, 1979, 1985 and 2000

	1979			1985			2000			Average Annual Growth Rate %	
	Primary	Non-Primary	Total	Primary	Non-Primary	Total	Primary	Non-Primary	Total	1979-85	1985-2000
100	1,310	87,260	88,570	1,120	95,830	96,950	0	125,400	125,400	1.6	1.7
200	690	2,990	3,680	590	4,060	4,650	400	6,930	7,330	4.0	3.1
300	1,710	30,430	32,140	1,490	32,240	33,730	480	44,020	44,500	0.1	1.8
400	2,220	9,350	11,570	1,910	25,290	23,380	380	63,330	63,710	12.4	6.9
500	2,110	45,110	47,220	1,830	51,720	53,550	850	72,050	72,900	2.1	2.0
600	1,260	21,900	23,160	1,090	45,210	46,300	510	126,570	127,080	12.2	6.9
700	3,510	21,640	25,150	3,030	25,140	28,170	1,510	35,250	36,760	1.9	1.8
800	3,590	2,210	5,800	3,100	2,870	5,970	1,570	8,750	10,320	0.5	3.7
Internal Total	16,400	222,600	239,000	14,150	282,360	296,510	5,700	482,300	488,000	3.7	3.4
External Total	37,250	17,750	55,000	32,150	22,040	54,190	16,000	37,700	53,700	0.0	0.0
Grand Total	53,650	240,350	294,000	46,300	304,400	350,700	21,700	520,000	541,700	3.0	2.9

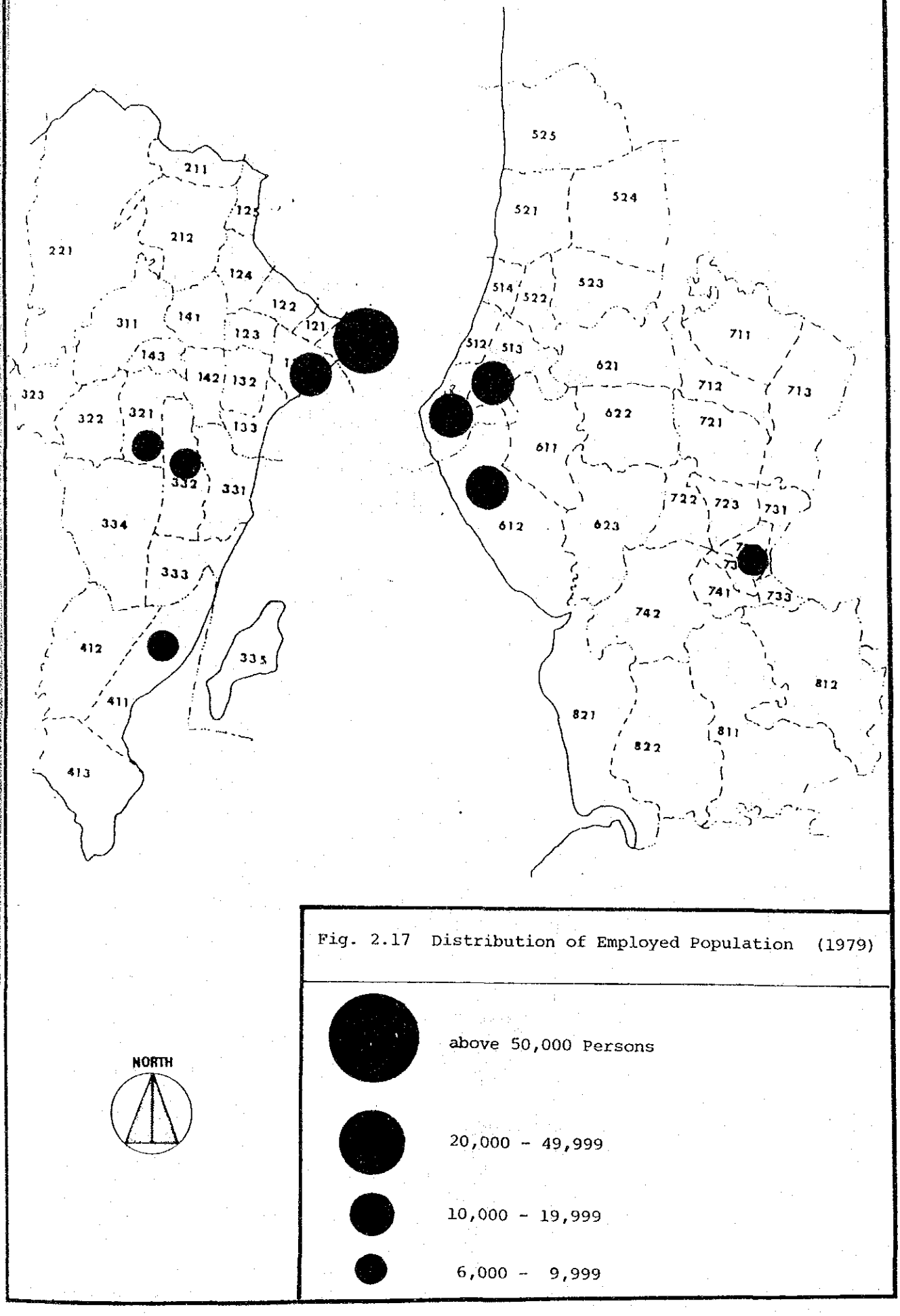

Fig. 2.17 Distribution of Employed Population (1979)

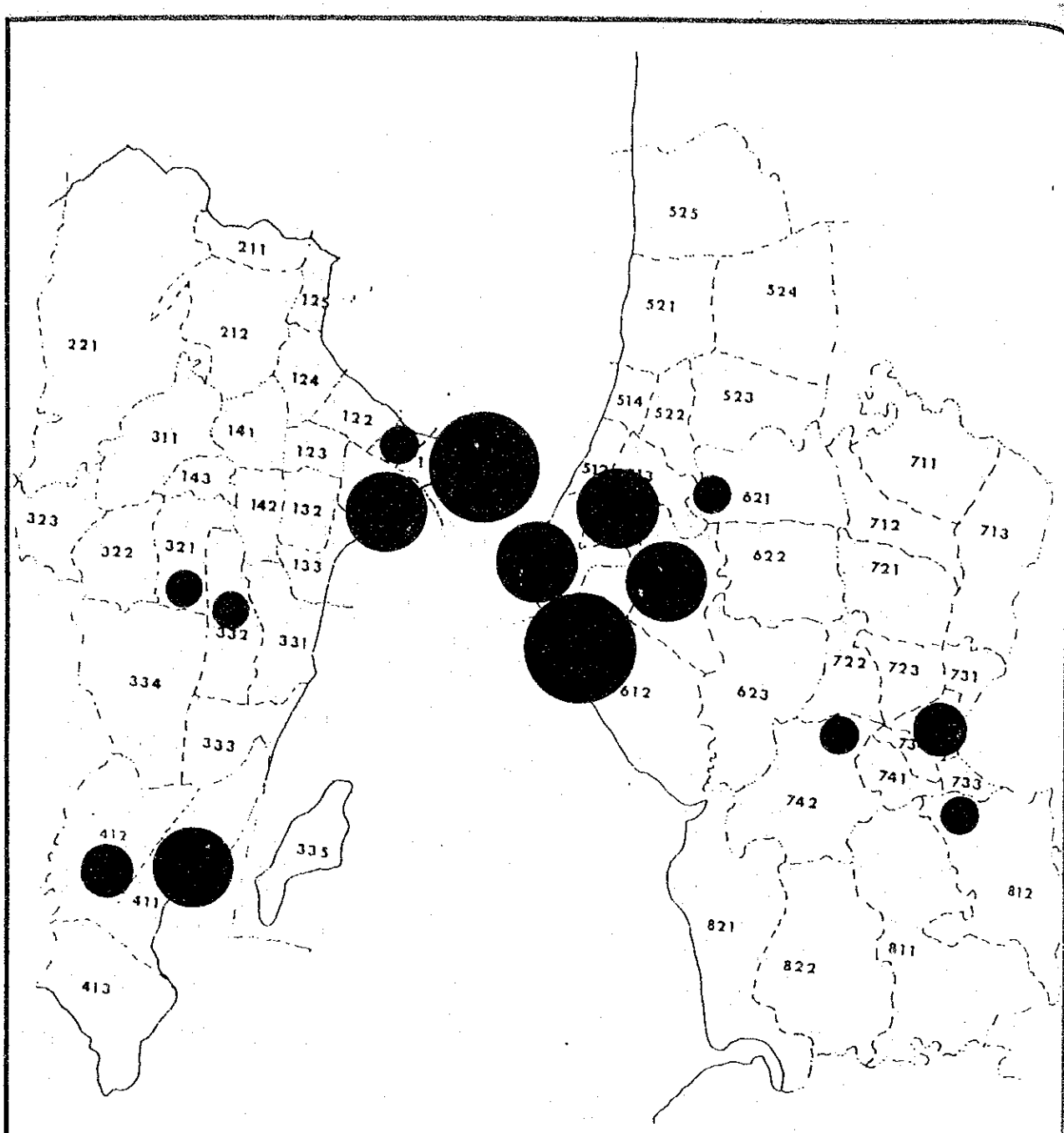

Fig. 2.18 Distribution of Employed Population (2000)

above 50,000 Persons

20,000 - 49,999

10,000 - 19,999

6,000 - 9,999

Table 2.30 (1) EMPLOYED POPULATION BY ZONE
Penang Island, 1979, 1985 and 2000

	1979			1985			2000		
	Primary	Non-Primary	Total	Primary	Non-Primary	Total	Primary	Non-Primary	Total
111	980	41,750	42,730	840	47,210	48,050	0	65,720	65,720
121	0	4,680	4,680		5,140	5,140	0	6,710	6,710
122	0	1,430	1,430		1,730	1,730	0	2,740	2,740
123	0	4,160	4,160		4,320	4,320	0	4,870	4,870
124	0	5,070	5,070		5,230	5,230	0	5,770	5,770
125	0	900	900		950	950	0	1,100	1,100
131	330	13,910	14,240	280	15,670	15,950	0	22,260	22,260
132	0	4,160	4,160		4,180	4,180	0	4,240	4,240
133	0	4,420	4,420		4,400	4,400	0	4,290	4,290
141	0	780	780		850	850	0	1,080	1,080
142	0	3,050	3,050		3,270	3,270	0	4,000	4,000
143	0	2,950	2,950		2,880	2,880	0	2,620	2,620
211	370	1,340	1,710	320	1,430	1,750	210	1,740	1,950
212	50	350	400	40	450	490	30	800	830
221	270	1,300	1,570	230	2,180	2,410	160	4,390	4,550
311	100	500	600	90	550	640	50	730	780
321	110	8,200	8,310	100	8,290	8,390	60	8,590	8,650
322	110	4,260	4,370	100	4,280	4,380	60	4,360	4,420
323	100	4,290	4,390	90	4,300	4,390	60	4,340	4,400
331	0	3,510	3,510	0	3,970	3,970	0	5,540	5,540
332	450	7,540	7,990	390	7,670	8,060	0	8,110	8,110
333	400	1,430	1,830	340	2,130	2,470	0	4,490	4,490
334	440	530	970	380	850	1,230	250	1,950	2,200
335	0	170	170	0	200	200	0	5,910	5,910
411	790	6,630	7,420	680	18,770	19,450	0	44,600	44,600
412	780	1,940	2,720	670	5,570	6,240	0	17,190	17,190
413	650	780	1,430	560	950	1,510	380	1,540	1,920
Internal Total	5,930	130,030	135,960	5,110	157,420	162,530	1,260	239,680	240,940
External	7,260	4,380	11,640	6,270	4,960	11,230	3,120	8,490	11,610
Total	13,190	134,410	147,600	11,380	162,380	173,760	4,380	248,170	243,790

Table 2.30 (2) EMPLOYED POPULATION BY ZONE
Province Wellesley, 1979, 1985 and 2000

	1979			1985			2000		
	Primary	Non-Primary	Total	Primary	Non-Primary	Total	Primary	Non-Primary	Total
511	140	18,080	18,220	120	20,290	20,410	0	27,790	27,790
512	0	3,270	3,270	0	3,700	3,700	0	5,140	5,140
513	0	12,050	12,050	0	15,680	15,680	0	25,130	25,130
514	330	3,370	3,700	280	3,420	3,700	140	3,610	3,750
521	180	6,160	6,340	160	6,190	6,350	80	6,290	6,370
522	0	630	630	0	810	810	0	1,430	1,430
523	460	640	1,100	400	1,370	1,770	200	3,820	4,020
524	460	450	910	400	480	880	200	580	4,800
525	540	460	1,000	470	550	1,020	230	860	1,090
611	100	3,150	3,250	90	8,210	8,300	0	21,960	21,960
612	0	14,740	14,740	0	31,840	31,840	0	87,190	87,190
621	440	90	530	380	130	510	190	8,480	8,670
622	450	3,370	3,820	390	3,380	3,770	200	3,400	3,600
623	270	550	820	230	1,650	1,880	120	5,540	5,660
711	660	250	910	570	250	820	290	270	560
712	330	460	790	280	460	740	140	470	610
713	910	1,180	2,090	790	1,190	1,980	390	1,240	1,630
721	330	820	1,150	280	840	1,120	140	890	1,030
722	230	90	320	200	100	300	100	120	220
723	230	550	780	200	570	770	100	630	730
731	230	2,000	2,230	200	2,040	2,240	100	2,180	2,280
732	0	9,540	9,540	0	10,200	10,200	0	12,630	12,630
733	0	2,550	2,550	0	2,590	2,590	0	2,740	2,740
734	0	2,720	2,720	0	3,120	3,120	0	4,550	4,550
741	50	490	540	40	600	640	20	990	1,010
742	540	990	1,530	470	3,180	3,650	230	8,540	8,770
811	790	990	1,780	680	1,090	1,770	340	1,440	1,780
812	1,180	490	1,670	1,020	990	2,010	520	6,290	6,810
821	750	330	1,050	650	360	1,010	330	450	780
822	870	400	1,270	750	430	1,180	380	520	900
Internal Total	10,470	90,860	101,330	9,040	124,940	133,980	4,440	242,620	247,060
External	*29,990*	*15,080*	*45,070*	*25,880*	*17,080*	*42,960*	*12,880*	*29,210*	*42,090*
Total	40,460	105,940	146,400	34,920	142,020	176,940	17,320	271,830	289,150
Grand Total	53,650	240,350	294,000	46,300	304,400	350,700	21,700	520,000	541,700

3. 交　通　量　予　測

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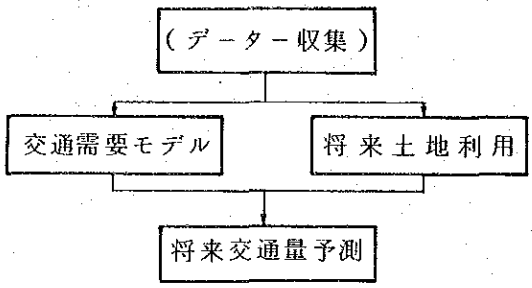
3.1 はじめに

本章では、将来の交通需要量を交通規制などの条件がない基本的場合について予測した結果について述べる。

本章の作業フローは次のとおりである。



3.2 交通量予測手法

交通量予測はＯＤ調査結果に基づいて、６６ゾーン間のＯＤ表を作成した。分布交通量はグラビィティモデルにより推計した。

3.3 交通量予測

車種別、目的別に、人口及び就業人口を説明変数とする交通発生モデル式を作成し、ゾーン別に新規開発地、空港、港などの発生量を考慮して発生・集中量を予測した。スタディ地域の域内ゾーンでは総発生量はおおむね２０００年には現在の３倍となる。またグラビティモデルによって分布交通量を推計した。バヤン・レパス、プライ等の開発によって、将来はペナン島南部、バタワースでの交通の伸びが著しいものと想定される。また架橋の開通により、ペナン島と半島をつなぐ交通量は著しく増加し、２０００年には現在の約3.9倍の交通が往来するものと予想される。

3.4 バス旅客需要

人口当りバス乗車人数は0.５６で、これを基に将来需要量を推計すると、２０００年には約３５万人の乗客数となる。同じようにグラビィティモデルによって、将来のバス旅客ＯＤ表を作成した。

3.5 総交通量の検討

各車種別に推計した将来交通量をパーソン・トリップ量に換算してみると、１９７９年の1.６４トリップ／人が２０００年に1.８３トリップ／人となる。全体としてほぼ妥当な交通需要量と考えることができる。

3. TRAFFIC PROJECTION OF BASE SITUATION

3.1 Introduction

Fig. 3.1 shows the main steps in the long-term transport planning of this urban transport study. The procedure starts with the collection of data which will constitute the basis for the analysis of statistical relationships. Then a traffic demand forecast model is formulated on the basis of the present analysis and the future land use.

Future traffic demand of base situation is estimated according to the land use pattern and the methodology of traffic estimation. This estimation is conducted in order to obtain guidelines in the preparation of the proposals for the future transport plan.

After this work is done, the transport plans are selected. The traffic estimation and cost estimation are conducted by alternative transport plans. When the distribution of traffic in the network is obtained, the total trip length and travel time are also computed. These figures, together with construction costs, constitute the basis for the economic evaluation of the alternative transport plans.

In this chapter, the formulation of a traffic demand forecast model and the estimation of the future traffic demand of base situation are only dealt with. The detailed contents of other items will be shown in the following chapter.

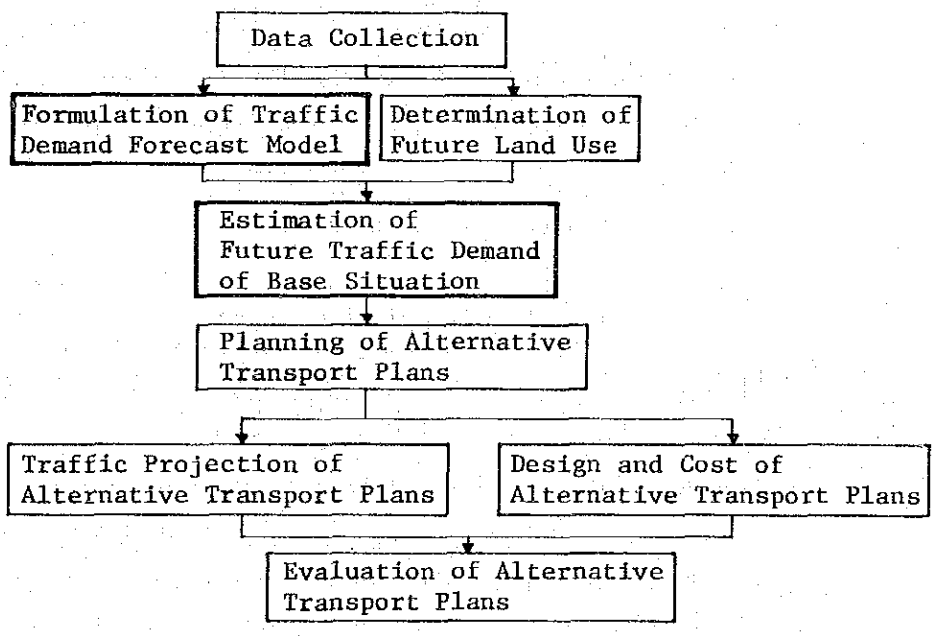


Fig. 3.1 FLOW CHART OF TRAFFIC PROJECTION

3.2 Procedure of Traffic Estimation

The traffic estimation of base situation regarding the traffic demand of vehicles and the bus passengers demand are conducted separately.

The flow chart is as follows:

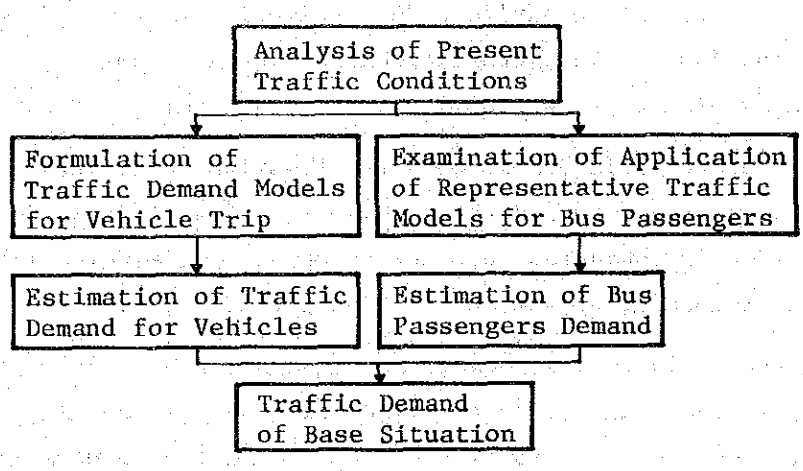


Fig. 3.2 FLOW CHART OF ESTIMATION OF BASE SITUATION

3.2.1 Procedure of Traffic Estimation for Vehicles

Car Owner Interview Surveys were executed in order to obtain the present vehicle movements on ordinary days in June 1979. By using these results, the traffic models are developed and verified with the present figures.

Based on the land use pattern and the socio-economic framework, the future traffic demand of vehicles is estimated through three (3) steps, viz. trip production, trip generation and attraction, and trip distribution.

Here follow some brief explanations about these steps.

1. Trip Production

This is the first step in the estimating of O-D tables. The purpose of this is to estimate the total number of trips related to the Study Area. As is usually done, trip product is estimated by multiplying the total number of vehicles by the unit trip production of each vehicle. The unit trip production used is obtained from the actual survey, i.e., the car O-D survey. Another method which is used occasionally is the correlation

formula which is calculated from the population figure, the number of vehicles, etc.

2. Trip Generation and Attraction

This is the estimation of the number of trips that start from and arrive at each traffic zone. It is easy to understand this concept if we consider the purpose of each trip. For example, when the purpose of the trip is to get to the working place, a single commuter usually produces one (1) trip. Therefore, the trip generation for this purpose is related to the number of residents, number of employees, landuse area by utilization etc.

3. Trip Distribution

This is the most complicated step in the estimation of future traffic demand because, if there are 66 traffic zones, we must estimate for 4,356 (66 x 66) pairs of trip distribution. Many empirical formulae were formulated by many of our predecessors for the purpose of estimating the trip distributions. Among them, the gravity model is the most general method.

Although these estimations are conducted by type of car, the final figures are expressed by using the following car passengers unit.

Table 3.1 CAR PASSENGERS UNIT

(Unit: p.c.u.)

	Car	Lorry	Bus	Taxi	M/C
P.C.U	1.0	2.0	3.0	1.0	0.5

Source: "Roads in Urban Areas" Scottish Development

3.2.2 Procedure of Traffic Estimation for Bus Passengers

The projection is made according to the following keynotes.

1. Up to the present moment, the demand for bus trips which is measured by per capita riding is inclined to follow past trends.
2. Even if ownership ratio increases to a great extent, the demand for bus trips still remains as the bus should provide its services to the 'transport poor' such as elders and children.

3. The projection of bus passenger demand is conducted by using the tendency of the per capita riding factor.

3.3 Estimation of Vehicle Traffic Demands

3.3.1 Formulation of Traffic Demand Forecast Model

The traffic models are drawn up while paying attention to the following matters:

1. The data which is used for the models has been obtained from the various traffic surveys conducted in Penang.
2. The traffic models make use of the methodology which has been developed, e.g., the basic unit method, the growth rate method, the regression method and the stimulation method.
3. The compatibility of the model is verified by using the present data.
4. Some of the existing data is from the last few years or from the previous year only. Therefore, various appropriate hypotheses are made for formulating the traffic models.

This analysis is conducted according to the trip purpose and type of vehicle used because in this way it is easier to decide on the variables used for the estimation, viz., the trip generation with the trip purpose of 'going to work' is proportional to the resident population, and the trip attraction is proportional to the number of workers at the work place.

Therefore, in this analysis, vehicles are divided into the following types;

Table 3.2 CLASSIFICATION OF TYPE OF VEHICLES

1 Car: trip to work	5 Lorry
2 Car: business trip	6 Taxi
3 Car: private trip	7 Bus
4 Car: trip home	8 Motor-cycle

Note: 'Bus' in Table 3.2 means only company bus and school bus, not scheduled bus.

1. Analysis of Trip Production

From the owner-interview survey, the average number of trips per day can be obtained. Using the technical term in traffic studies, these figures are called "unit trip production". There are two (2) types of unit trip production. One is the gross unit trip production while the other is the net unit trip production.

Some vehicles did not make any trips on the day of the interview. Therefore the former (the gross unit trip production) is the average trip per day of one (1) vehicle which also includes zero (0) and the latter is the actual average number of trips per day of one vehicle.

Table 3.3 THE UNIT TRIP PRODUCTION

(Unit: trip per vehicle per day)

	The unit trip production (gross)	The unit trip production (net)	The % of zero number of trips
Car	3.98	4.25	6.3%
Lorry	3.01	3.60	16.4%
Taxi	8.07	8.07	0%
Bus	20.6	20.8	0.9%
(Vehicles)	4.09	4.43	7.7%
Motor-cycle	3.78	4.01	5.7%
All vehicles	3.90	4.17	6.5%

The relationship between the traffic volume and vehicle ownership shows that the size of the traffic volume is close to vehicle ownership.

It can be said that the traffic volume up to this time increases in proportion to the size of vehicle ownership. Therefore it is estimated that the unit trip production is constant every year.

On the basis of these considerations, the unit trip production will be used in principle for the future. However, in developed urban areas a situation where the unit trip production of private cars and motor-cycles is decreasing in proportion to the rapid growth of ownerships must be reckoned with.

2. Analysis of Trip Generation and Attraction

The analysis was conducted using two (2) methods, viz, the basic unit method and the regression method. The results of both methods were examined and the regression method was selected to be used in the traffic model of trip generation and attraction.

In the regression method, the least square method is used to obtain the regression equation. The regression equation consists of the explained variable and the explanatory variables. In this case, it is natural that the explained variable is the trip generation by zone while the explanatory variables make use of the following factors, viz, the area by land-use, the floor size by purpose of building, the population and the employed population by industry, etc.

For the purpose of drawing up the traffic model of trip generation only some factors need be chosen. However, the following criteria must be observed:-

1) The explanatory variables for the present and also for the estimated target year must be obtained.

2) The explanatory variables must not be chosen only from the degree of the co-efficient of correlation, in order to avoid a causal relationship.

Taking into consideration the above matter, some indices of population are chosen as the explanatory variables in this study as shown in the following figures:-

Table 3.4 TRIP MODEL OF TRIP GENERATION AND TRIP ATTRACTION

		Trip generation	Trip attraction
Car	Trip to work	$y = 0.0916xp + 0.844$ (R=0.774)	$y = 0.405x_E - 404$ (R=0.884)
	Business trip	$y = 0.172x_E - 80.7$ (R=0.894)	$y = 0.172x_E - 80.7$ (R=0.894)
	Private trip	$y = 0.0560xp + 0.0829x_E - 101$ (R=0.828)	$y = 0.250x_E - 38.2$ (R=0.811)
	Trip home	$y = 0.440x_E - 247$ (R=0.864)	$y = 0.101xp + 177$ (R=0.711)
Lorry		$y = 0.116x_E + 92.4$ (R=0.851)	
Taxi		$y = 0.000941xp + 0.0186x_E - 12.2$ (R = 0.770)	
Bus		$y = 0.0242xp + 0.00728x_E - 44.5$ (R = 0.736)	
Motor-cycle		$y = 0.340xp + 1.01x_E - 1,514.5$ (R = 0.945)	

y = trip generation or trip attraction by zone

xp = population by zone

x_E = employed population by zone

R = co-efficient of correlation

This model is to be used for the calculation of increasing trip generation and attraction from the year 1979 to 1985 or the year 2000.

3. Analysis of Trip Distribution

For the purposes of estimating the trip distribution, the following two (2) methods are representative. One is the present pattern method and the other is the model method. Usually, the former is used for short term estimation or when it is anticipated that the land-use pattern will not be subject to too much change.

On the other hand, the model method which is designed for adjusting to the change in land-use pattern is suitable for long term estimation.

In our land-use plan, it is perceived that the future land-use pattern would be different from the present pattern. In addition to this, the main flow of traffic would be diverted because the Penang Bridge plan and the East-West Highway plan would have reached fruition and consequently there would be a change in the major road network. As a result of the above, the most popular method was chosen for our estimation and this is the gravity model method.

The gravity model is as follows:-

$Tij = \alpha gi \cdot aj \cdot tij - r$

Tij : number of trips between zone i and j

gi : total number of trip generation in zone i.

ai : total number of trip attraction in zone i

α : constant of proportion

γ : exponent of gravity model

tij : time distance between zone i and j

The exponent of the gravity model is estimated by the trip purpose or vehicle type through the least square method applied to the relationship between the present O-D tables and the present travel time of each zone pairs.

The results from using the model for all the zone pairs in the Study Area are as follows:-

Table 3.5 FORMULA OF TRIP DISTRIBUTION

		The formula for Trip Distribution
Car	trip to work	$Tij = 1.147 \frac{Ai^{0.340} gj^{0.424}}{tij^{0.624}}$
	business trip	$Tij = 0.461 \frac{Ai^{0.402} gj^{0.398}}{tij^{0.396}}$
	private trip	$Tij = 0.749 \frac{Ai^{0.398} gj^{0.404}}{tij^{0.576}}$
	trip home	$Tij = 1.269 \frac{Ai^{0.415} gj^{0.367}}{tij^{0.709}}$

Continued

(Cont'd)

	The formula for Trip Distribution
Lorry	$Tij = 1.737 \frac{Ai^{0.355} gj^{0.381}}{tij^{0.635}}$
Taxi	$Tij = 0.0998 \frac{Ai^{0.425} gj^{0.413}}{tij^{0.115}}$
Bus	$Tij = 0.523 \frac{Ai^{0.417} gj^{0.407}}{tij^{0.419}}$
Motor-cycle	$Tij = 0.237 \frac{Ai^{0.514} gj^{0.510}}{tij^{1.100}}$

However, the use of one formula alone is not enough to explain the present traffic distribution because the traffic patterns in Penang Island, Province Wellesley and across the straits each have their unique characteristics. Therefore these formula are amended according to each area pair. The Study Area is divided into four (4) areas that is, two (2) areas in Penang Island and two (2) areas in Province Wellesley. Therefore one trip distribution formula is made up of 16 formula (4x4) from each pair.

3.3.2 Estimation for Traffic Demand of Base Situation

The estimations for the future traffic demand are carried out on the basis of the traffic model and the above mentioned premises.

1. Estimation of Trip Production

The future traffic volume related to the Study Area is divided into the following types, viz, internal trip, external trip, through trip and trip production from specific facilities. 'Particular facilities' in this section means the new port, other port facilities and the airport.

These facilities will produce more traffic than that produced as a result of population increase. This is because there will be a rapid increase in the volume of cargo handled by the port and also in the volume of air passengers. Therefore, trip production from these facilities must be considered separately from the usual trip production.

(a) Internal trip

The internal trip production is estimated by multiplying the number of vehicles with the unit trip production already determined in this analysis. With regards to Penang Island, the growth rate of external trips is estimated by using the growth rate of population and vehicle ownerships in the external area of Penang Island.

With regard to Province Wellesley on the other hand, the feasibility study of Federal Route 1 and the East-West Highway are used in addition to the growth rate of population and vehicle ownership in the external area.

Some explanation is needed regarding the trip production of private cars and motor-cycles. As the ratio of ownership increases, the unit trip production made by private cars and motor-cycles will decrease. Therefore, in the estimation of the volume of trip production of those vehicles, the unit trip production is to decrease with the increase of the ownership ratio of these vehicles.

(b) External trip and through trip

The growth rate of external trips and through trips in the future depends on the economic and social growth rate of external area.

(c) Trip production from specific facilities

Trip production from wharfs is estimated on the basis of their carrying volume by each commodity type, and trip production from the airport is based on the number of passengers arriving and departing.

Regarding the specific facilities, only increased volume is added to the future trip production because the present volume of these facilities is obtained through traffic surveys and is already included in the internal trips, external trips and through trips of the present trip production data.

Table 3.6 TRIP PRODUCTION FROM SPECIFIC FACILITIES

(unit: 1,000 trips per day)

year	1979	1985	2000
New development area	-	4.0	15.9
Other area	15.5	17.6	25.1
Port	15.5	21.6	41.0
Penang Airport	2.2	3.5	13.0

(d) Total number of trips related to the Study Area

The estimation for the number of trips is conducted separately according to the type of trips. The summary of this estimation is as follows:

Table 3.7 TOTAL NUMBER OF TRIPS

(unit: 1,000 trips per day)

year	1979	1985	2000
Internal Trip	286.1	381.5	864.2
External and Through Trip	35.3	51.5	144.4
Increased Trip from Port	-	6.1	25.5
Increased Trip from Airport	-	1.3	10.8
Vehicles ex. m/c	321.5	440.0	1,044.9
Internal Trip	397.3	437.7	499.3
External and Through Trip	25.1	27.7	28.6
Motor-cycle	422.4	465.3	477.9
P.C.U (1,000 p.c.u.)	609.8	776.6	1,538.1

2. Estimation of Trip Generation and Attraction

The future volume of trip generation and attraction is calculated by the population data and the trip generation and attraction models which are derived from the present traffic situation.

Fig. 3.3 shows that the growth rate of trip generation is almost proportional to the growth rate of the resident population. Therefore the growth rate of trip generation in Province Wellesley is more rapid than that in Penang Island.

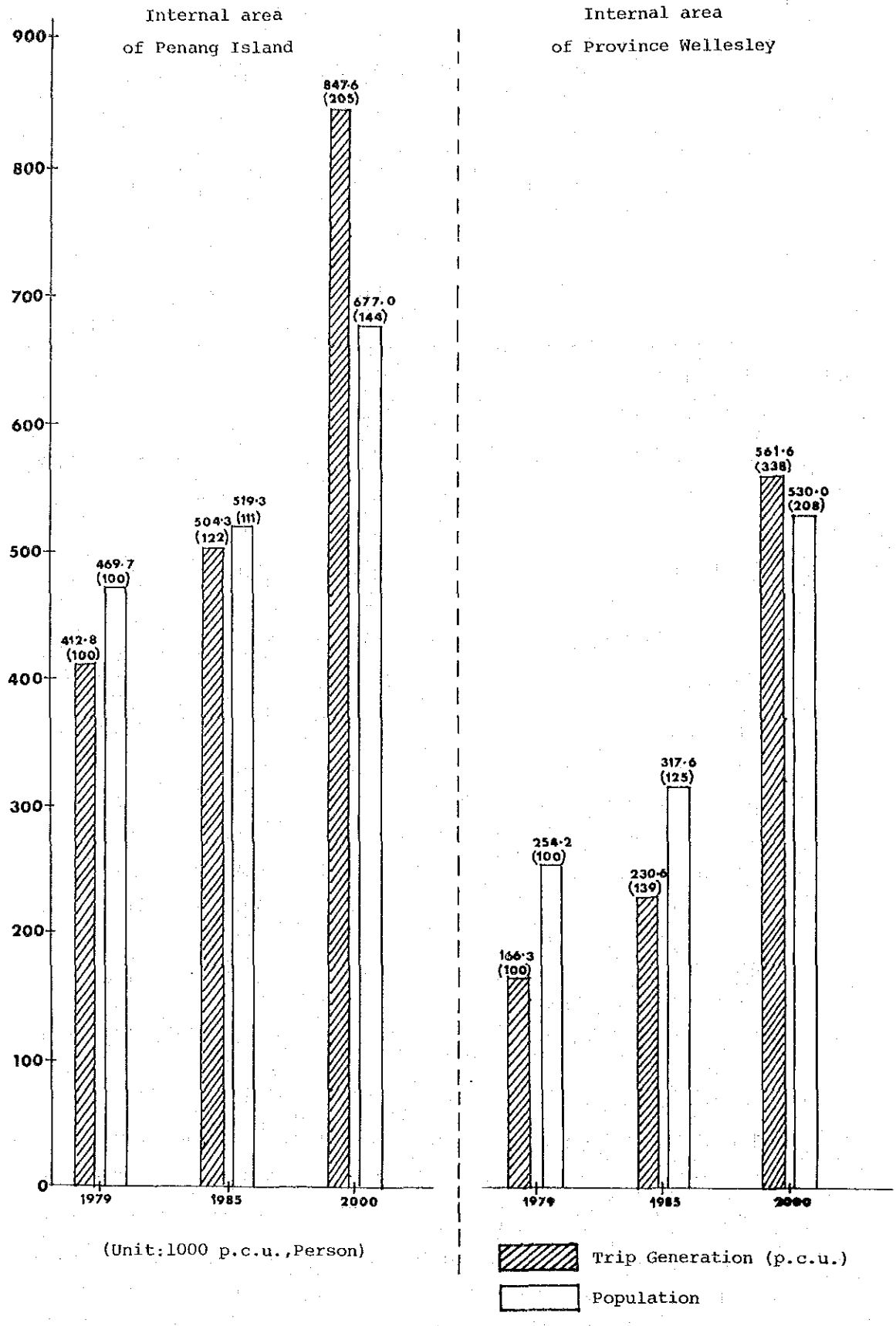


Fig. 3.3 The Relationship with Trip Generation and Population

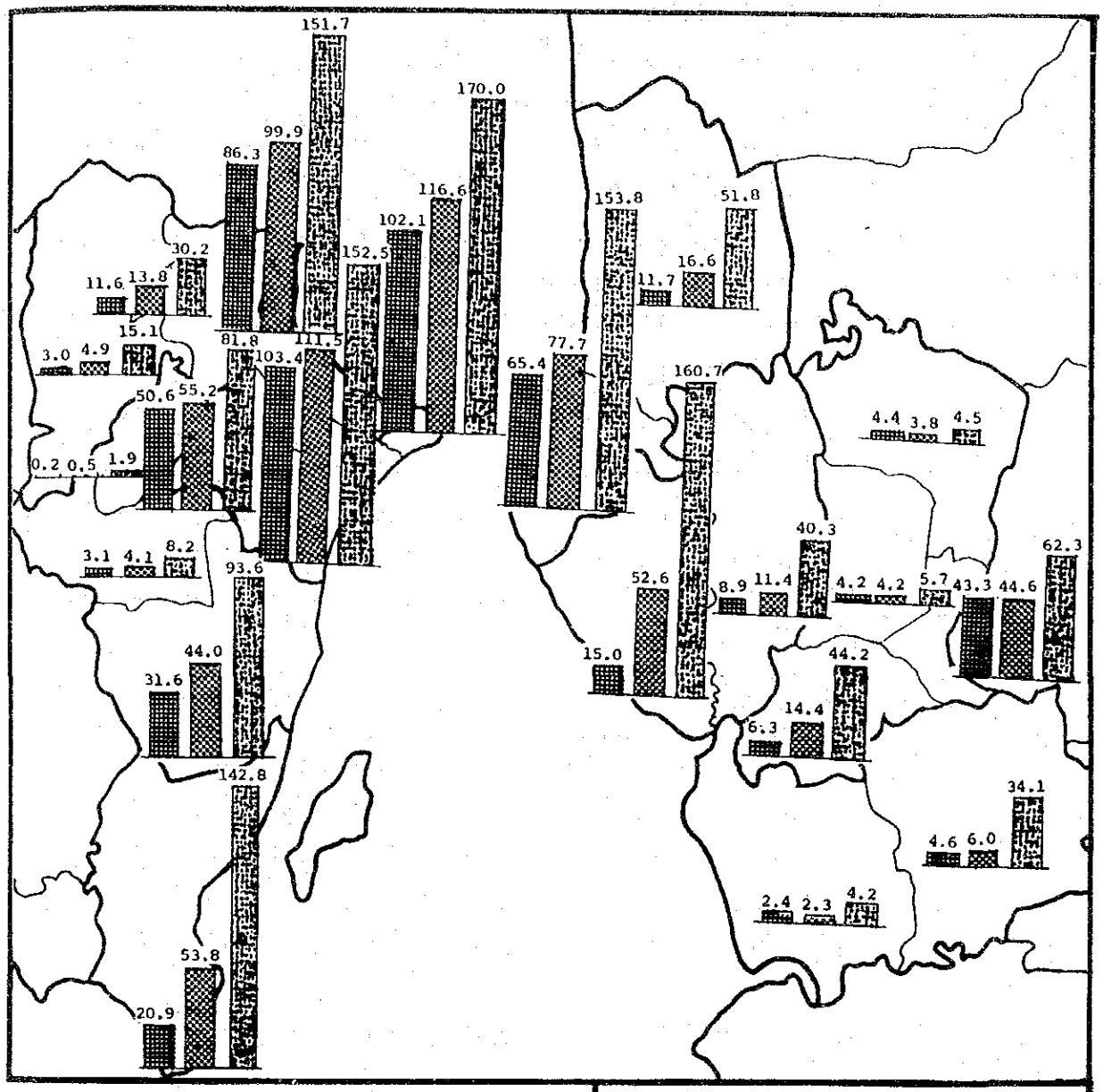


Fig. 3.4 Projected Trip Generation by Zones

3. Estimation of Future O-D Table of Base Situation

O-D tables for the future are estimated by using the future trip generation, trip attraction and time distance between each zone pair together with the gravity model which is derived from the present traffic data.

The desired lines show that the movement of vehicles is becoming more active due to the reduction in time distance. This is brought about by the improvement of the road network, especially by the construction of the Penang Bridge.

(a) Number of trips in each type of traffic flow

According to the rapid growth of car ownership, the number of trips are increasing year by year and in future the total number of trips will become 776,600 and 1,538,100 in 1985 and the year 2000 respectively from a total of 609,800 trips in 1979.

From the volume of each type of traffic flow, it can be observed that the annual growth rate of internal trips is 5.2 percent from 1979 to 1985 and 5.6 percent from 1985 to the year 2000; on the other hand, those of external trip are 7.0 percent and 7.9 percent respectively.

The growth rate of external trip is more rapid than of internal trip due to the reduction in time distance.

Table 3.8 NUMBER OF TRIP IN EACH TRAFFIC TYPE

(Unit: 1,000 trips)

		Vehicle									
		Car									
	Year	Going to Work	On Business	Private	Going Home	Sub-Total	Lorry	Taxi	Bus	Sub-Total	M/C
internal trip	1979	66.4	33.4	53.1	83.2	236.0	28.4	2.7	19.0	286.1	397.3
	1985	88.1	44.0	70.8	110 1	312.9	43.2	6.1	24.7	386.9	437.7
	2000	200.1	100.0	160.7	249.9	710.7	92.2	24.5	51.5	878.9	449.3
external and through trip	1979	4.3	4.8	6.4	7.5	23.2	9.8	2.1	0.4	35.3	25.1
	1985	6.0	7.2	9.8	10.3	33.3	15.8	3.4	0.6	53.1	27.7
	2000	14.4	21.6	27.3	25.5	89.0	66.4	9.2	1.4	166.0	28.6
Total	1979	70.7	38.2	59.5	90.7	259.2	38.2	4.8	19.4	321.5	422.4
	1985	94.1	51.2	80.6	120.4	346.2	59.0	9.5	25.3	440.0	465.3
	2000	214.5	121.6	188.0	275.4	799.7	158.6	33.6	52.9	1,044.9	477.9

Table 3.9 NUMBER OF TRIP PRODUCTION IN EACH TRAFFIC TYPE (P.C.U.)

(Unit: 1,000 P.C.U.)

year	1979	1985	2000
internal trip	551.2 (100)	692.2 (126)	1,287.5 (234)
external and through trip	58.6 (100)	84.4 (144)	250.6 (428)
total	609.8 (100)	776.6 (127)	1,538.1 (252)

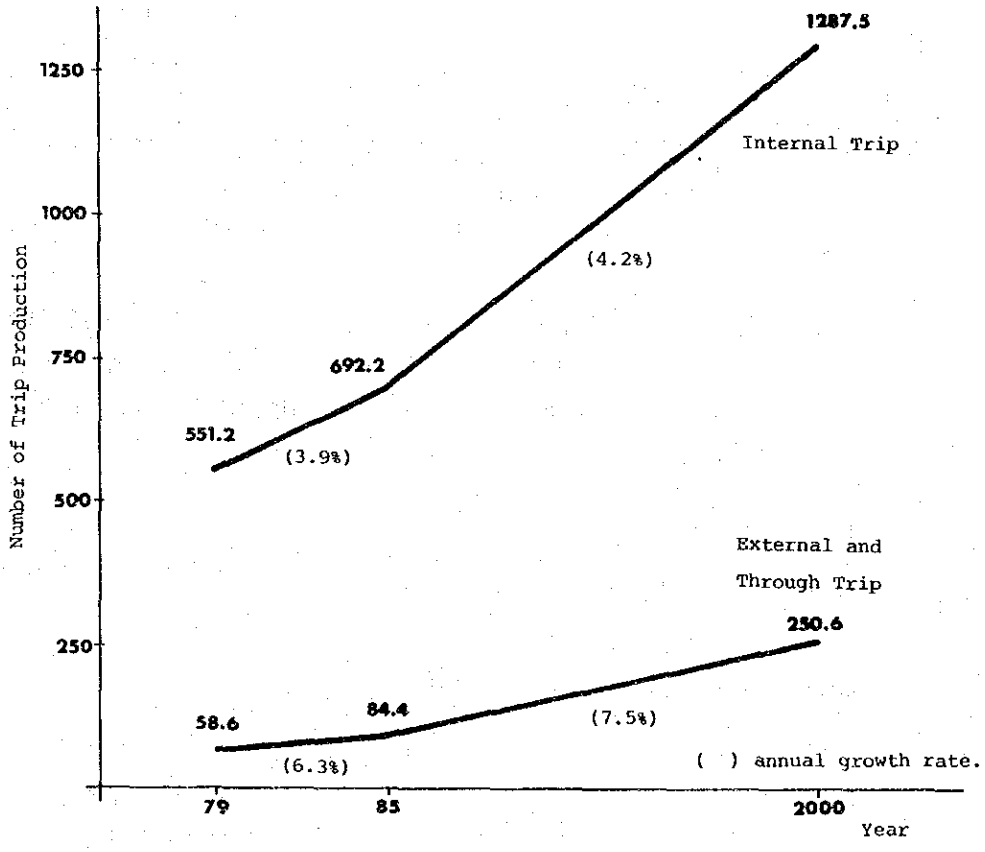


Fig. 3.5 TREND OF EACH TRAFFIC TYPE

(b) O-D Pattern

The estimated O-D table is as follows:

Table 3.10 VEHICLE O-D TABLE

(Unit: 1,000 p.c.u. per day)

	Internal Area		External Area		
	Penang Island	Province Wellesley	Penang Island	Province Wellesley	Total
	399.9	6.2	3.8	3.1	413.0
P.I	480.6	10.5	8.1	4.5	503.7
	786.2	23.7	26.3	11.5	847.7
	6.1	138.9	0.2	20.9	166.1
P.W	10.2	190.9	0.4	28.0	229.5
	23.3	454.3	1.9	82.0	561.5
	3.8	0.2	0.0	0.1	5.9
P.I	8.1	0.5	0.0	0.3	8.9
	26.3	2.0	0.1	1.3	29.7
	3.2	20.8	0.1	1.8	25.9
P.W	4.8	27.7	0.1	1.9	34.4
	11.7	81.5	1.3	4.7	99.2
			upper	in year 1979	609.8
			middle	in year 1985	776.6
			lower	in year 2000	1,538.1

From this table, internal trip in Province Wellesley shows a more rapid growth rate than in Penang Island, due to the more rapid increase of resident population and employment in Province Wellesley.

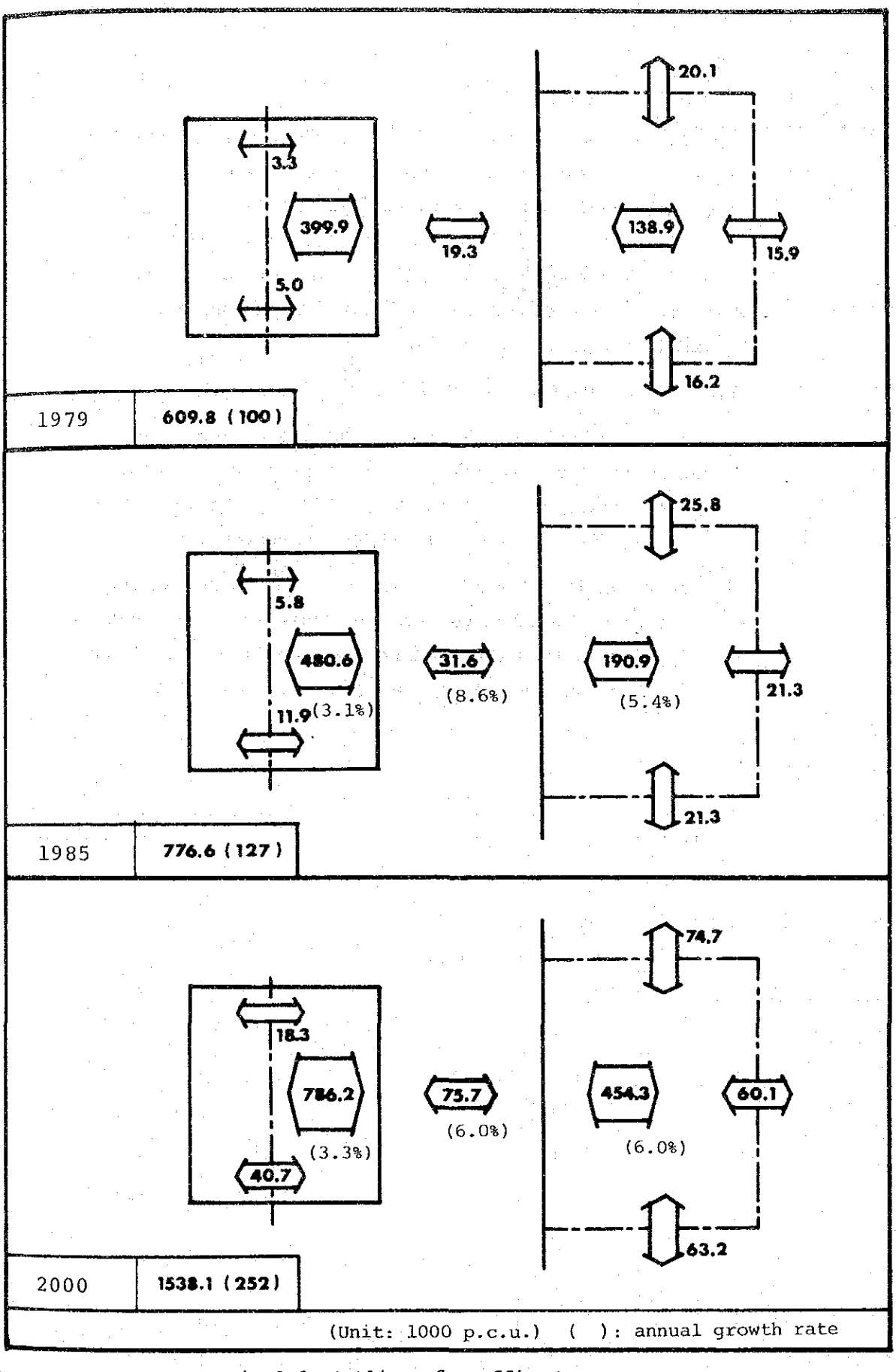


Fig.3.6 Outline of Traffic Movement

(c) Desired Assignment

For the purpose of grasping the traffic movement approximately, the desired assignment is conducted using the method of simple assignment. Here, the traffic demand of each O-D pair (in this case middle zone pair) is assigned to the shortest desired route according to the distance. The growth rate of traffic demand on major section estimated by the desired assignment are as follows:

From these figures, the following can be observed:

1. In Penang Island, the traffic movement between George Town and Bayan Lepas will become greater. (Section C). The traffic movement in 1979, 1985 and the year 2000 are 63,000, 106,000 and 239,000 respectively.

2. In Province Wellesley, the traffic movement between Butterworth, Seberang Prai and Bukit Mertajam (Section F) will be increased remarkably from 41,000 to 73,000 in 1985, and further to 20,400 in the year 2000.

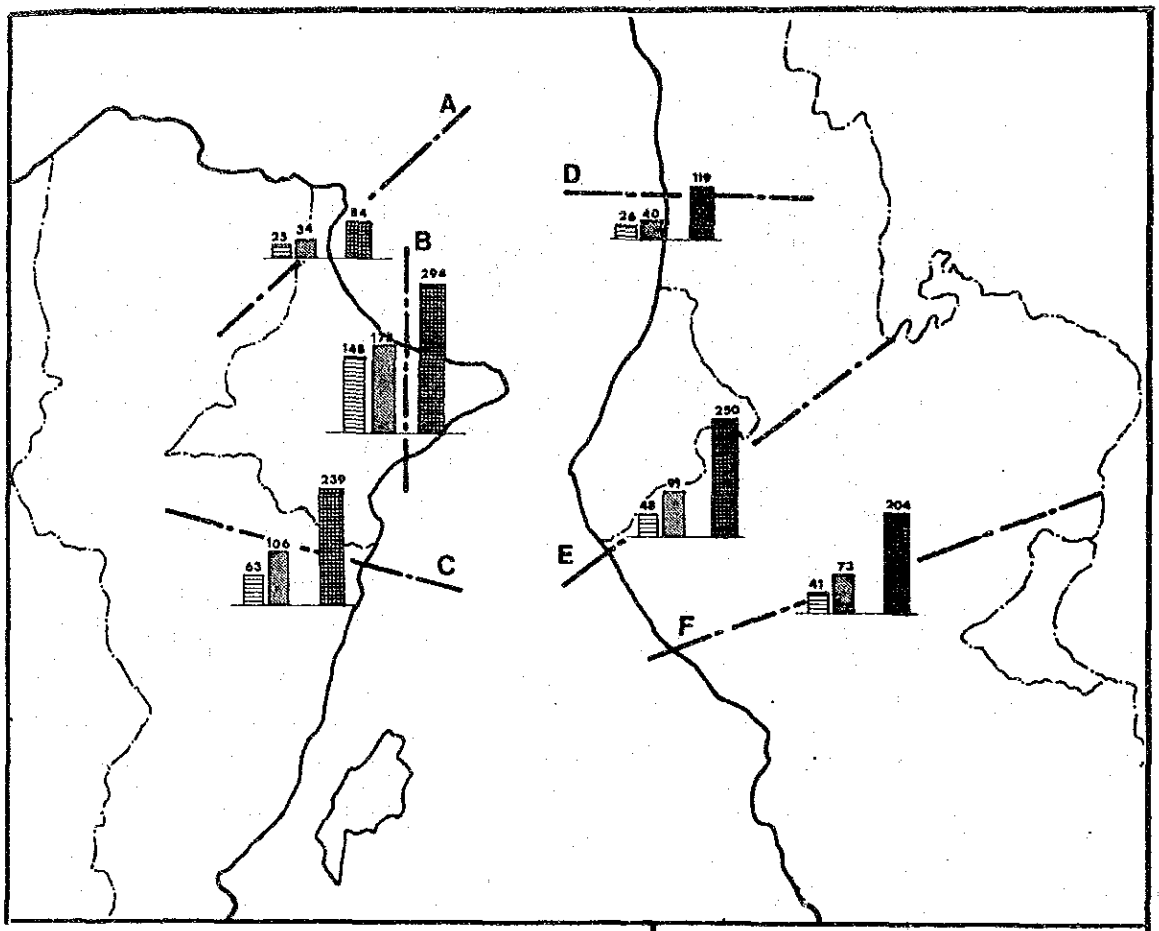


Fig.3.7 Traffic Demand on Major Section

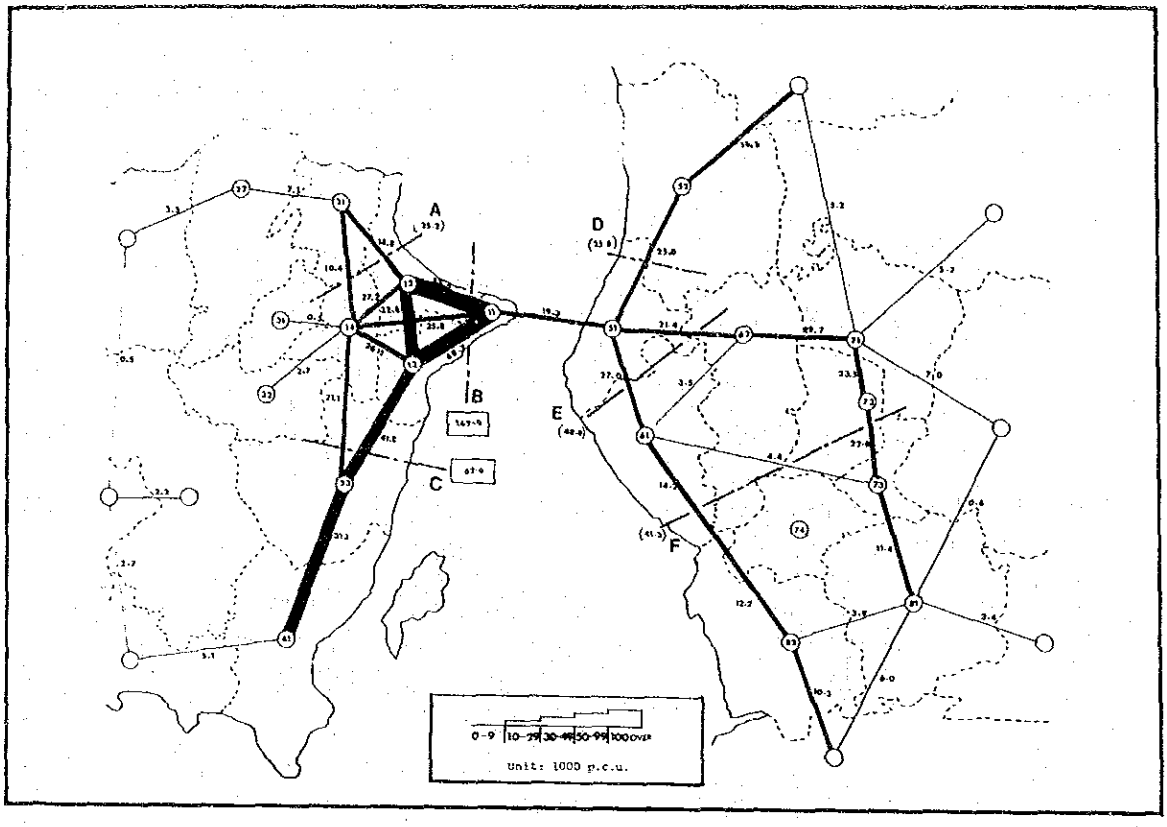


Fig. 3.8 Desired Assignment in 1979

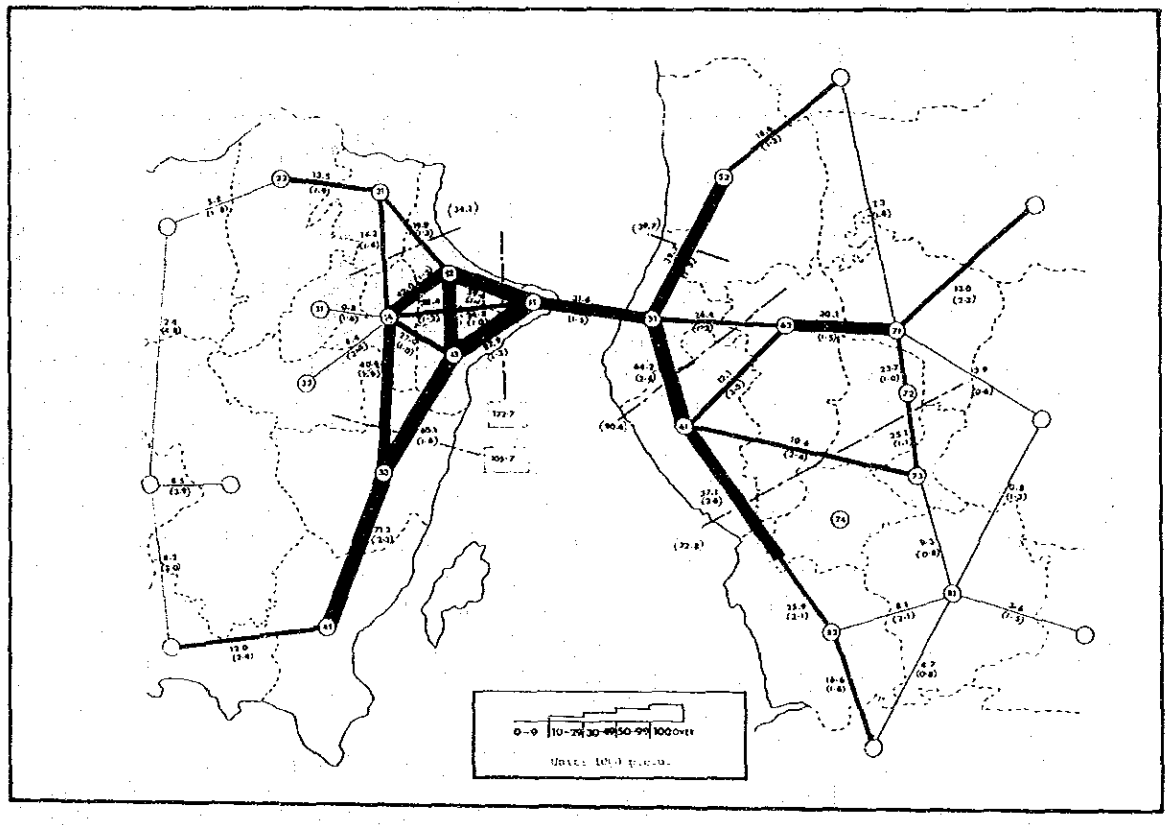


Fig. 3.9 Desired Assignment in 1985

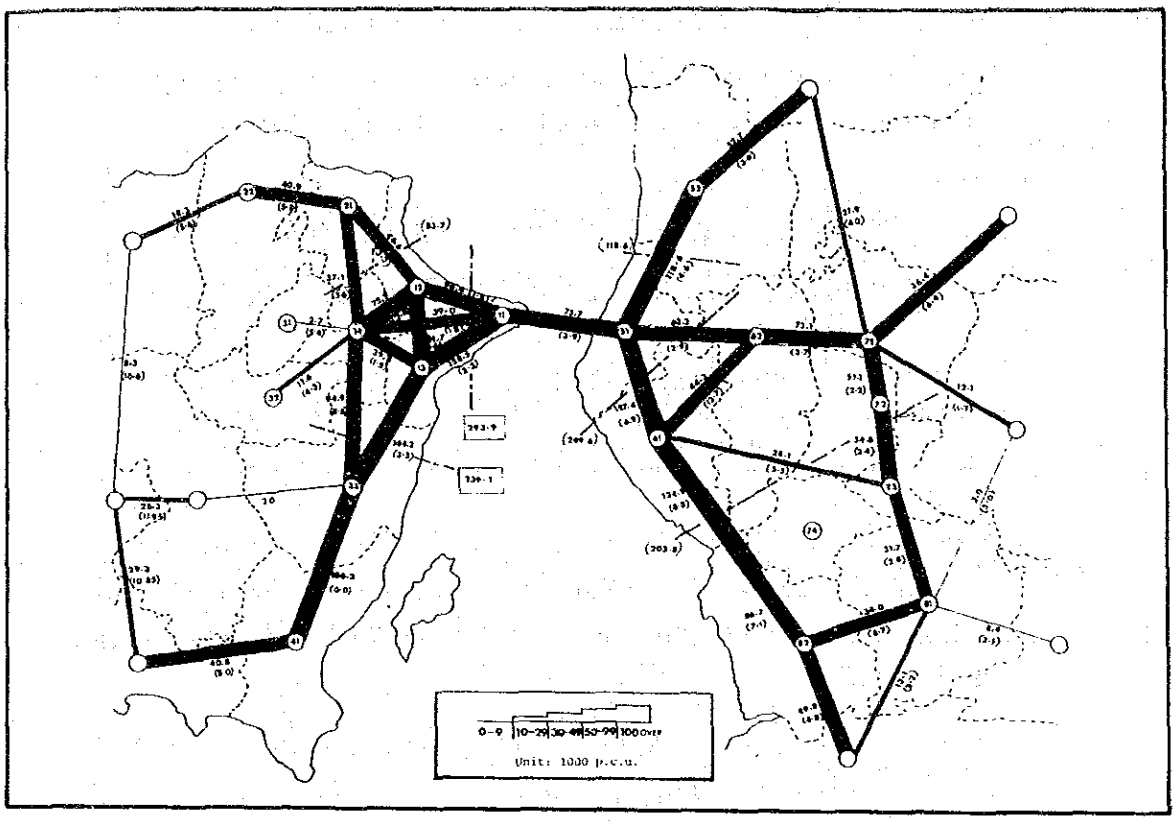


Fig. 3.10 Desired Assignment in 2000

4. Traffic Volume Across the Straits

The traffic volume over the unique section, viz. across the straits is estimated by future O-D tables as follows:

Table 3.11 TRAFFIC VOLUME ACROSS THE STRAITS

(Unit: 1,000 trips, 1,000 p.c.u.)

year	1979	1985	2000
Vehicles (trips)	10.8	19.2	52.9
Motor-cycles (trips)	13.0	14.7	15.8
P.C.U. (p.c.u.)	19.3	31.6	75.7

From the results, the induced trips brought about at the completion of the Penang Bridge can be obtained. In 1985, these trips will total 6,000 p.c.u but by the year 2000 will total 28,000 p.c.u.

From this, we can infer that the effects of the Penang Bridge will be quite considerable.

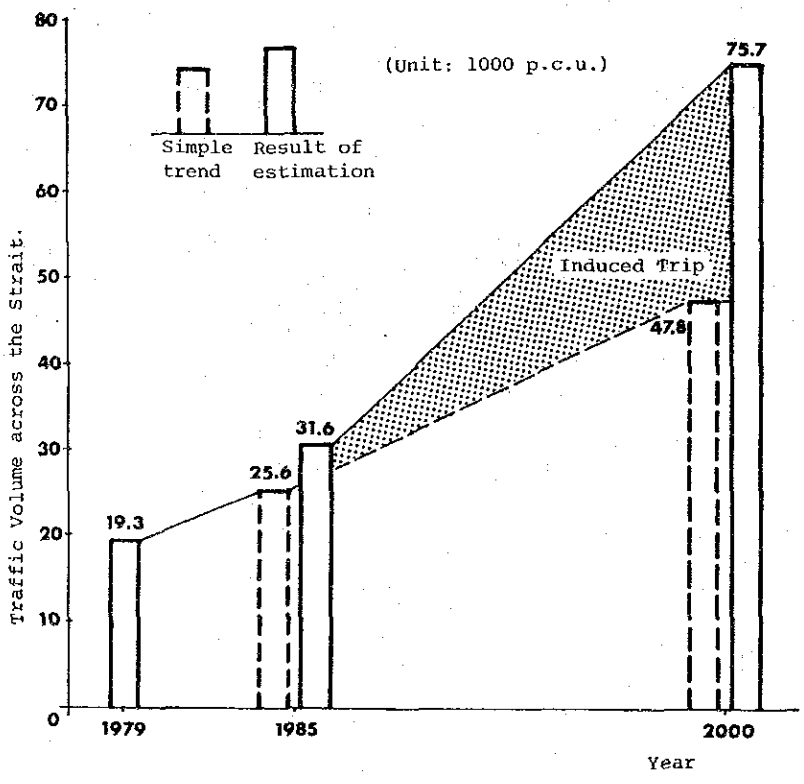


Fig. 3.11 Induced Trip by Linkage

3.4 Estimation of Bus Passenger Demand

3.4.1 Total Demand of Bus Passengers

Firstly the inclination of bus passenger demand is examined from various data obtained. The inclination is indicated as the rate of bus passengers to population (per capita riding). In 1979 there are 256,000 passengers by scheduled buses related to the Study Area, while the population (above 15 years old) is 458,000. Accordingly the per capita riding factor is 0.56, which has been decreasing at an annual rate of 1.3 percent since 1970 in accordance with the increase in car ownership.

This tendency will continue in the future, therefore the per capita riding factor in future and total number of bus passengers are forecasted as follows.

Table 3.12 TOTAL NUMBER OF BUS PASSENGERS

(Unit: 1,000 person)

	per capita riding	No. of bus passengers	annual growth rate
1979	0.56	256.0	-
1985	0.52	279.4	1.3%
2000	0.43	348.8	1.4%

Although the per capita riding decreases year by year, the number of passengers increases at a growth rate of 1.3 to 1.4 percent because of higher population increases.

3.4.2 O-D Pattern of Bus Passengers

In this stage, the total number of bus passengers is first reduced in consideration of transfers. Those linked trips are as follows:

Table 3.13 TOTAL LINKED TRIPS MADE BY BUS PASSENGERS

(Unit: 1,000 trips)

year	Total number of passengers	Total trips made by passengers	Average no. of transfer
1979	256.0	235.8	1.09
1985	279.4	249.1	1.12
2000	348.4	296.4	1.18

The O-D table is forecasted as follows.

Table 3.14 BUS PASSENGER O-D TABLE

(Unit: 1,000 trips)

	O \ D	Internal Area: Penang Island	Internal Area: Province Wellesley	External Area: Penang Island	External Area: Province Wellesley	Total
Study Area	Penang Island	149.2 151.6 157.9	8.3 10.1 13.1	3.4 3.8 4.5	-	160.9 165.5 175.5
Study Area	Province Wellesley	9.4 10.2 13.3	50.1 57.1 86.9	-	5.0 5.5 7.2	64.5 72.8 107.4
Outside Study Area	Penang Island	3.6 3.7 4.5		-	-	3.6 3.7 4.5
Outside Study Area	Province Wellesley	-	5.2 5.5 7.2	-	1.6 1.6 1.8	6.8 7.1 9.0
						235.8 249.1 296.4

Note: The first figure corresponds to 1975, the second to 1985 and the third to the year 2000.

The O-D distribution of these bus trips is forecasted by means of the gravity method which was already examined by using present data.

3.5 Verification of the Total Traffic Volume

The projection of traffic demand was done by type of transport mode, that is car, lorry, motor-cycle and bus. In this section, simple verification about the total number of trips is conducted by using the person trip method.

The unit of trip production per person is determined to be about 1.0 - 2.0 from person trip surveys. This figure usually does not include trips made on foot.

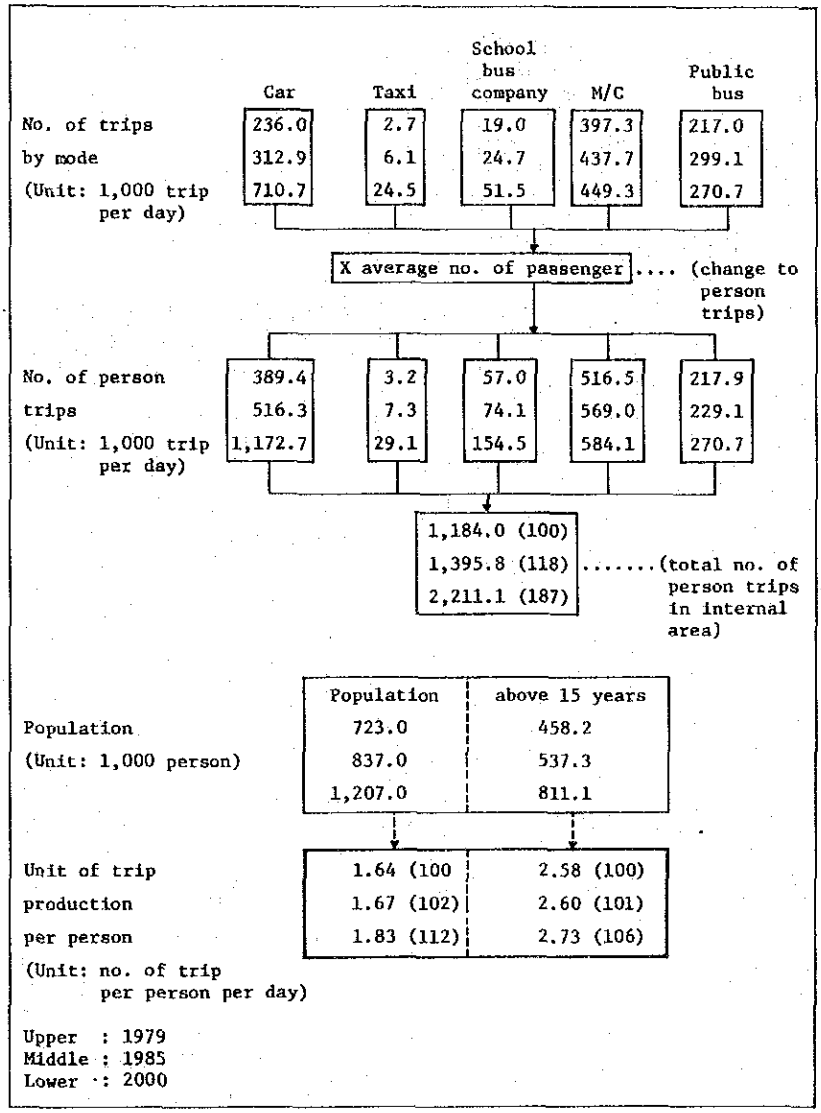
Therefore, by the standard of this result, the unit of trip production in this study is calculated. Firstly, the number of vehicle trips in this study area is converted to number of person trips by multiplying the average number of passengers, and then dividing by the population.

The unit of trip production per person is calculated in this way and the resulting figures are 1.64, 1.68 and 1.83 in 1979, 1985 and the year 2000 respectively with these figures having a range between 1.0 and 2.0 and experiencing increases year by year.

Considering the growth of the economic level, it is accepted that this tendency to increase yearly will continue.

Therefore, it can be said that the projection of traffic demand is neither overestimated or underestimated.

Table 3.15 UNIT OF TRIP PRODUCTION PER PERSON



Note: Above figures use the total number of internal trips in the study area.

4. 交　通　体　系　計　画

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4.1 計画目的

4.1.1 背　景

将来の人口増、都市開発に対応した交通施策が必要となっている。

4.1.2 方　針

計画にあたっては、経済的・社会的背景及び地域の環境特性に合ったプランとする必要がある。計画すべき事項は、将来道路網の計画、公共交通の計画、交通の管理・運営である。

4.2 道路網

4.2.1 前　提

フェデラル・ルートⅠ、ペナン架橋、トラフィック・ディスパーサル道路は上位計画とする。

4.2.2 交通需要の確認

将来は、バヤン・レパス、バタワースでの開発が進行し、交通パターンについてもこれらの地域と既開発地との有機的結合が重要である。

4.2.3 計画方針

ペナン島東部は基本的にラダーパターン道路網としてとらえ、このうちジョージ・タウンについては放射環状道路網を採用するものとした。またバタワース、ブキット・メルタジャムは格子状の道路網を考えるものとする。

4.2.4 道路網計画

本調査では、主として主要幹線、幹線道路網について提案を行った。

4.3 交通施策

4.3.1 基本方針

将来交通需要に対応するには交通施設の拡充だけでは不充分で、需要のコントロールが必要となる。このための施策について提案するものとする。

4.3.2 需要コントロール

検討する施策はバス専用レーンの導入、新交通システムの導入、駐車規制、カープーリングである。

4.3.3　比 較 案

道路網の案と需要コントロール案の組み合せによって都市交通システムの比較案を作成する。

道路網は現状のままの網も含め６ケース、需要コントロールは各施策の組み合せで４ケース作成し、両者をさらに組み合わせて、１９８５年、２０００年の交通システム案を作成した。またフェリーの存続の有無を条件としてさらにつけ加えた。

4. ALTERNATIVE TRANSPORT PLANS

4.1 Planning Goals

4.1.1 Background

By the year 2000 the population of the State of Penang will have increased to about 1.6 million and about 6,000 hectares of land will have been developed for urban activities in the Study Area. This economic growth in the Study Area will result in a large increase in demand for transport whereby there will be twice the present trip trip production. In addition the basic transport structure of the State will be changed after completion of the Penang Bridge Project and the New Federal Route I. Thus, improvements of the transport system are urgently needed to meet future demand.

4.1.2 Policy fot the Improvement of the Transport System

The team identified the following goals for the future transport system:-

To maintain a high quality of urban environment.
To maximize the benefits of the urban and urban transport economy.
To minimize resource consumption.
To provide a safe means of transport.

In order to achieve these goals, the following should be planned:-

The establishement of the future road network.
The improvement of the Public Transport System.
The improvement of Traffic Management and Operations.

The following items should also be taken into account in order to obtain better results.

The preservation of historical places and their environs in George Town itself is seen as part of the maintenance of the good quality of life and urban environment, and the continued preservation of these sites are taken into account.

Future transport systems should correspond to the changes in land use, such as the development of Bayan Lepas and Prai,

as well as to the changes in road network, as in the construction of the Penang Bridge, the traffic dispersal roads and the New Federal Route I.

4.2 Road Network Plan

4.2.1 The Premise

Prior to the formulation of the transport plan, the committed projects within the Study Area are as follows:-

Federal Route No. 1 and two (2) of its related intersections.
Penang Bridge which connects Province Wellesley and Penang Island.
Dispersal Road connecting with the Penang Bridge.

These schemes are totally committed.

4.2.2 Examination of Transport Demand

In order to get the guidelines for road network planning, the results of the land use plan and the traffic demand estimation were reviewed.

The expected changes estimated in the Study Area from 1977 to the year 2000 are summarized as follows:-

A. Change of Urban Structure

The population increase of about 483,000 in the Study Area will be absorbed mainly in Bayan Lepas and the area along the Federal Route I between Butterworth and Bukit Mertajam. Accordingly, in the year 2000, there will be two (2) conurbations i.e. the conurbation of George Town and Bayan Lepas and the conurbation of Butterworth and Bukit Mertajam.

Increase in employed population will be absorbed mainly in Bayan Lepas and Prai. Thus, there will be four (4) major employment areas, while in the C.B.D. of George Town, the population is expected to decline and this will further characterize it as a C.B.D.

B. Change in Transport Demand

Total number of trips will increase to about twice the present number. Especially in Bayan Lepas and Prai, a very large

number of trips will be produced.

Main desired traffic flow will be as follows.

- Between Penang Island and Province Wellesley.
- Between George Town and Bayan Lepas.
- Between the Prai-Butterworth conurbation and the conurbation of Bukit Mertajam.

Corresponding to the expansion of residential areas and urban functions, trips will be longer and the pattern of commuting trips will change to that which is shown in the following figures.

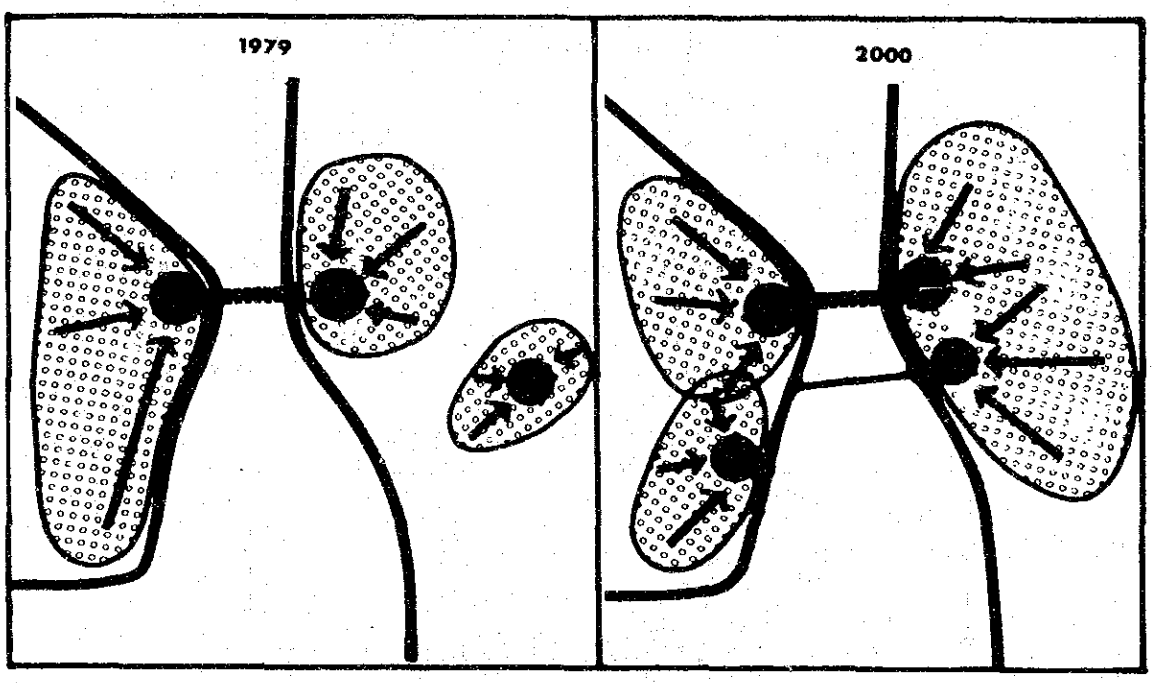
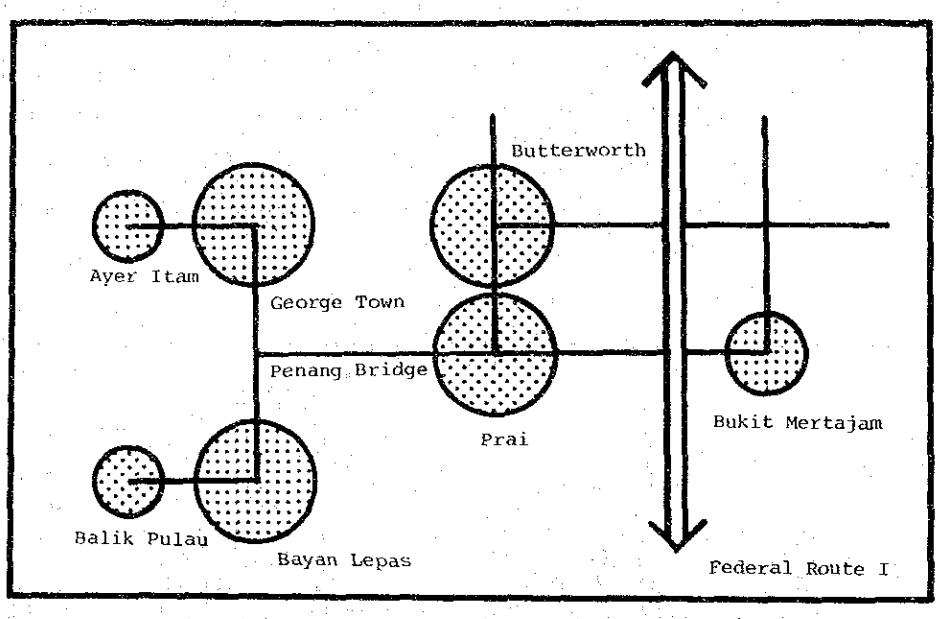


Fig. 4.1 TERRITORY OF COMMUTING TRIPS

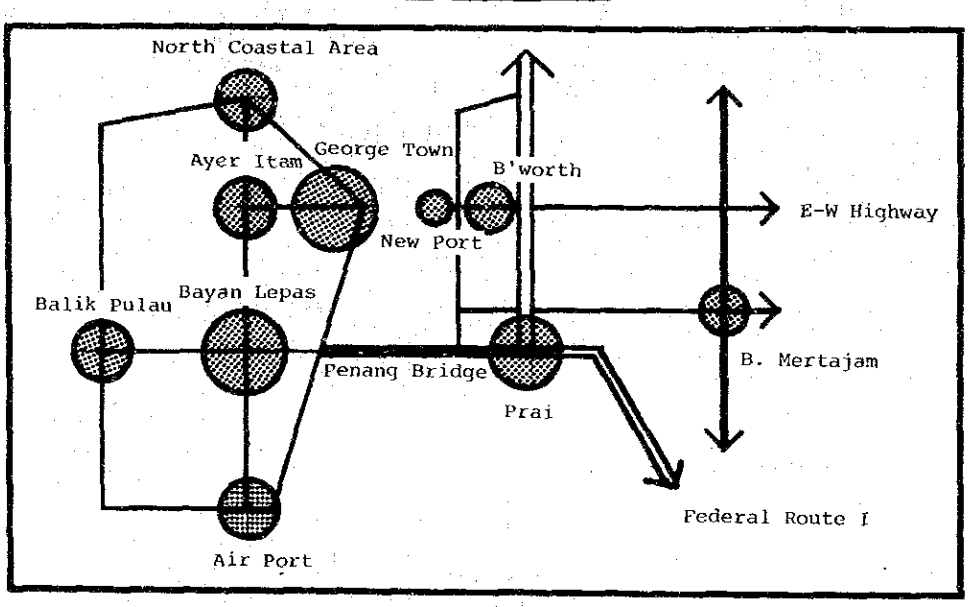
4.2.3 Conceptual Planning

Bearing in mind the policies and the traffic demand characteristics, the conceptual plans for road network were prepared using the following procedures.



Objective of the Plan:-
To connect the major regional cores
To establish the functional Network

Fig. 4.2 CONCEPT PLAN I



Objective of the Plan:-
To identify the basic road network

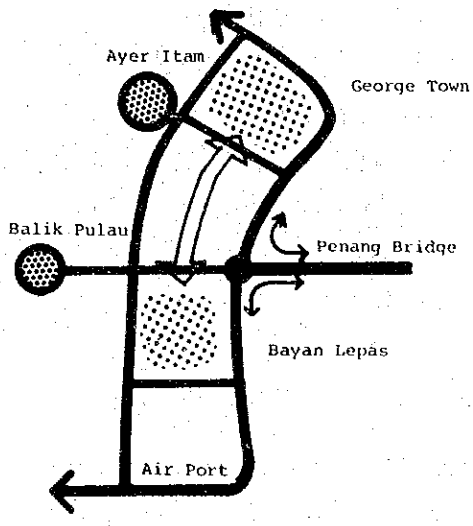
Fig. 4.3 CONCEPT PLAN II

Penang Island

Objectives of the plan: To identify traffic circulation in the Urban Areas.

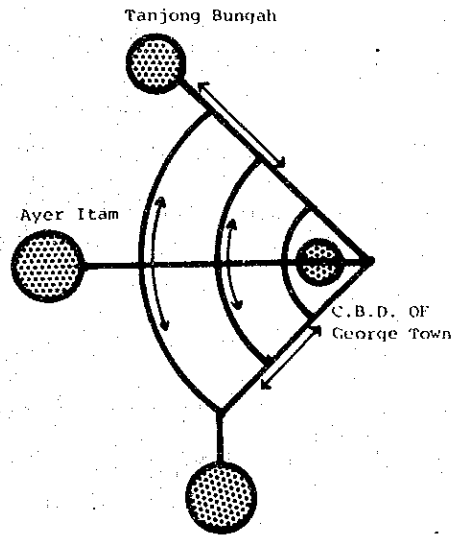
Ladder Pattern

for the East Coastal Corridor



Ring and Radial Pattern

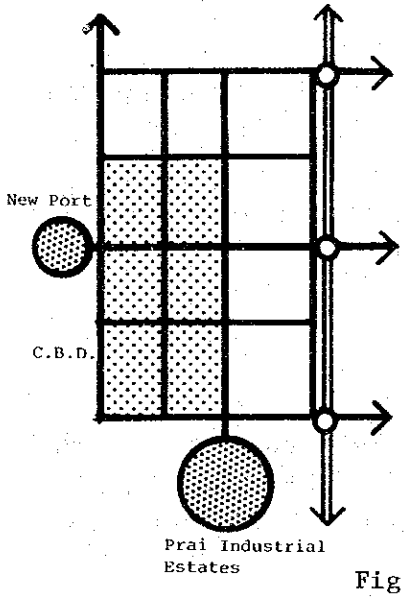
for George Town



CONCEPT PLAN IV

Grid Pattern

for Butterworth



Province Wellesley

Ladder Pattern

Conurbation between Prai and Bukit Mertajam.

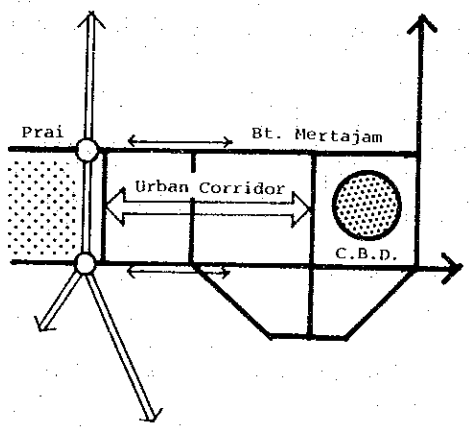


Fig. 4.4 CONCEPT PLAN III
Panang Island

4.2.4 Road Network Plan

Considering the various local conditions, the team prepared the future road network the content of which is described in Chapter 6. With the team proposing mainly primary distributors defined in the following categories of roads.

a) Primary distributors (Concept Plan I and II)

These roads form the primary network for the town as a whole. All long-distance traffic movements to, from and within the town should be channelled to the primary distributions. The primary distributors may be divided into two (2) types; one type between urban area (inter-urban) while the other is in the urban areas (intra-urban).

b) District distributors (Concept Plan III and IV)

These roads distribute traffic within the residential and industrial areas and principal business districts of the town while forming the link between the primary network and the roads within the surrounding areas.

c) Local distributors (Concept Plan III and IV)

These roads distribute traffic within the surrounding areas while forming the link between district distributors and access roads.

d) Access roads

These roads give direct access to buildings and land within the surrounding areas.

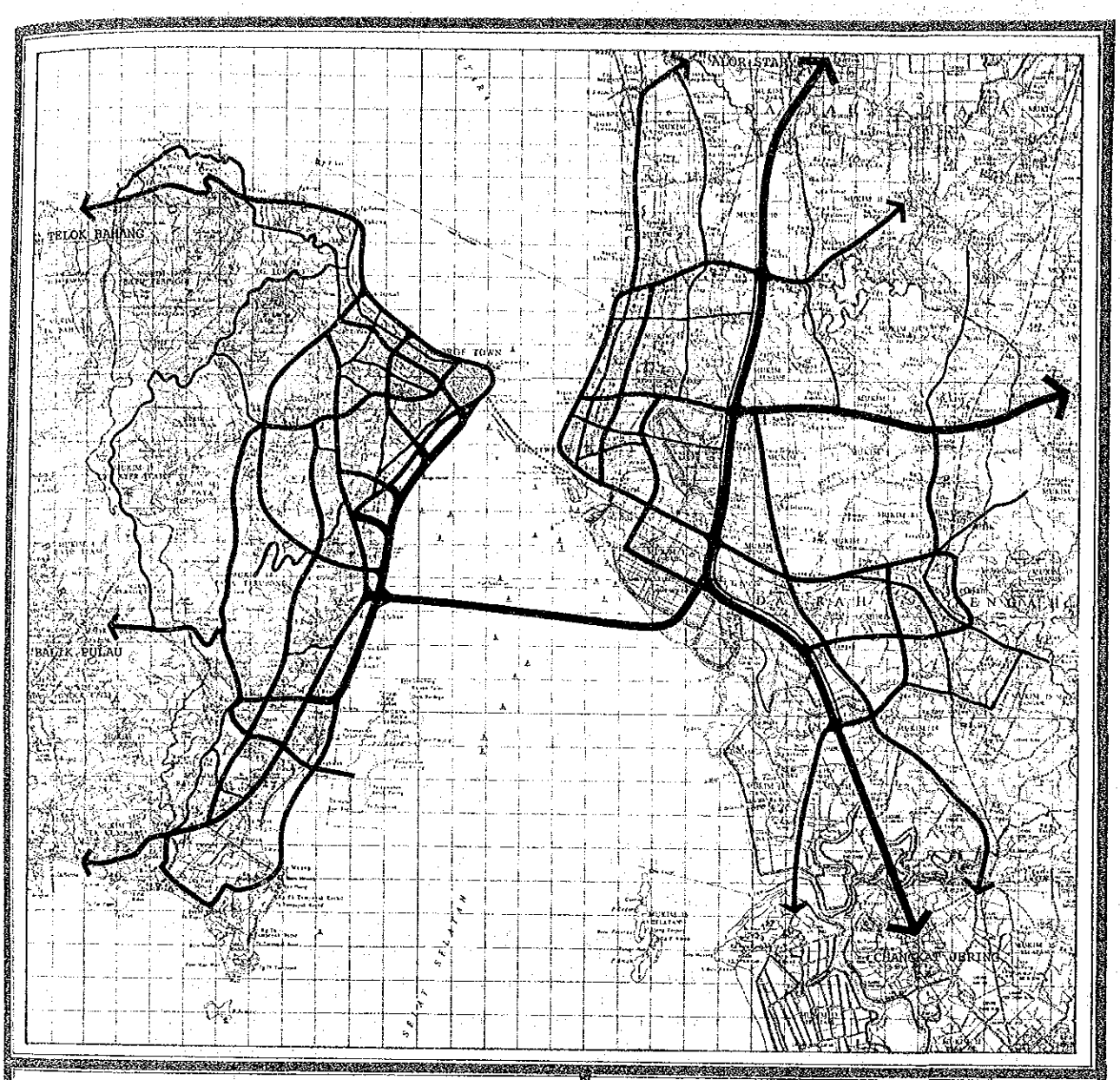


Fig. 4.5 Proposed Road Network

Primary Distributor (Inter-Urban)

Primary Distributor (Intra-Urban)

District Distributor

PENANG URBAN TRANSPORT STUDY

URBAN TRANSPORT STUDY IN GREATER METROPOLITAN AREAS OF GEORGETOWN, BUTTERWORTH AND BUKIT MERTAJAM

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4.3 Alternatives of Transport Strategies

4.3.1 General Considerations

Transport strategies proposed in this chapter are on how to deal with an increase in transport demand in the future. In most large cities it is almost impossible to deal effectively with the increase in traffic volume. Generally speaking, there are two (2) strategies, i.e., to improve the capacity of the transport systems and to reduce the transport demand.

In the Study Area, the projection of future transport demand revealed that not only is it necessary to improve the capacity of the transport system but a reduction of the transport demand will also be necessary.

Major Strategies	To improve Capacity	To reduce demand	Implementation Cost **
Improvement of road network	*		H
Improvement of intersections	*		M
Improvement of system of traffic flow	*		M
Improvement of the present public transport system	*	*	M
Introduction of the new transport system	*	*	H
Intensify parking control		*	L
Introduction of car pooling or road pricing system		*	M
Increasing the cost of owning cars		*	L

** H : assume high cost
M : assume medium cost
L : assume low cost

4.3.2 Transport Strategies

Besides the imporvement of road network which was planned in the previous section, the team prepared the following transport strategies as a major means of coping with the increase of transport demand, with due consideration given to the actual transport conditions of the Study Area and the effects of the strategies. All of these strategies are expected to reduce the traffic volume of vehicles.

1. Public Transport Strategies

Strategies A. Introduction of Exclusive Bus Lane

To assure that the bus service can absorb more commuters, operations should be effective. For this purpose, exclusive bus lanes, where the average speed of the buses is 25 km/hr., are introduced along the following roads.

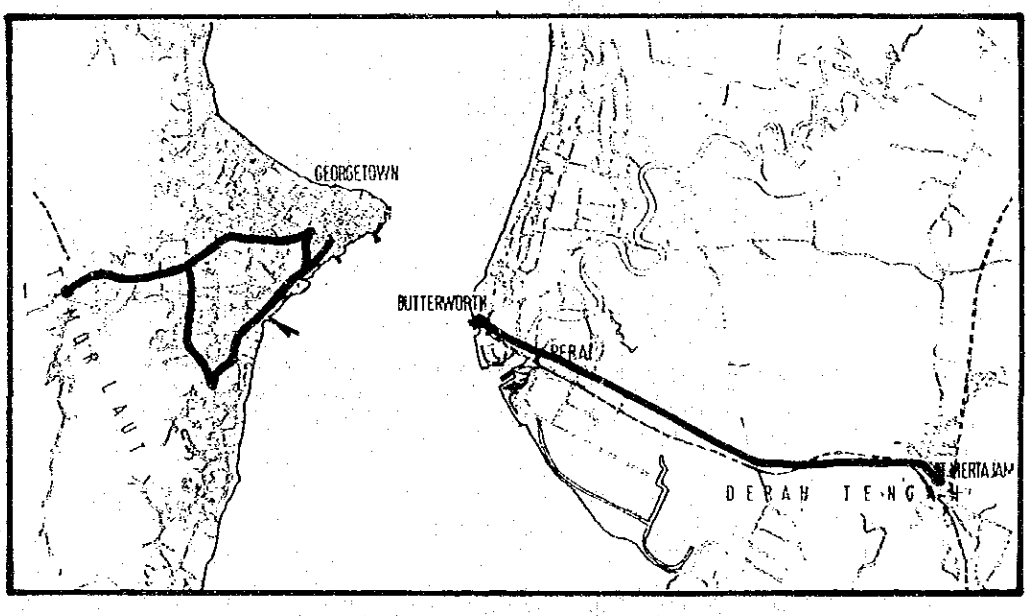

Fig. 4.6 LOCATION OF EXCLUSIVE BUS LANES

Strategy B. Introduction of New Transport System

If a more effective public transport system than the present bus service is necessary, then the new transport system will be introduced. The team proposed the following routes for the New Transport System.

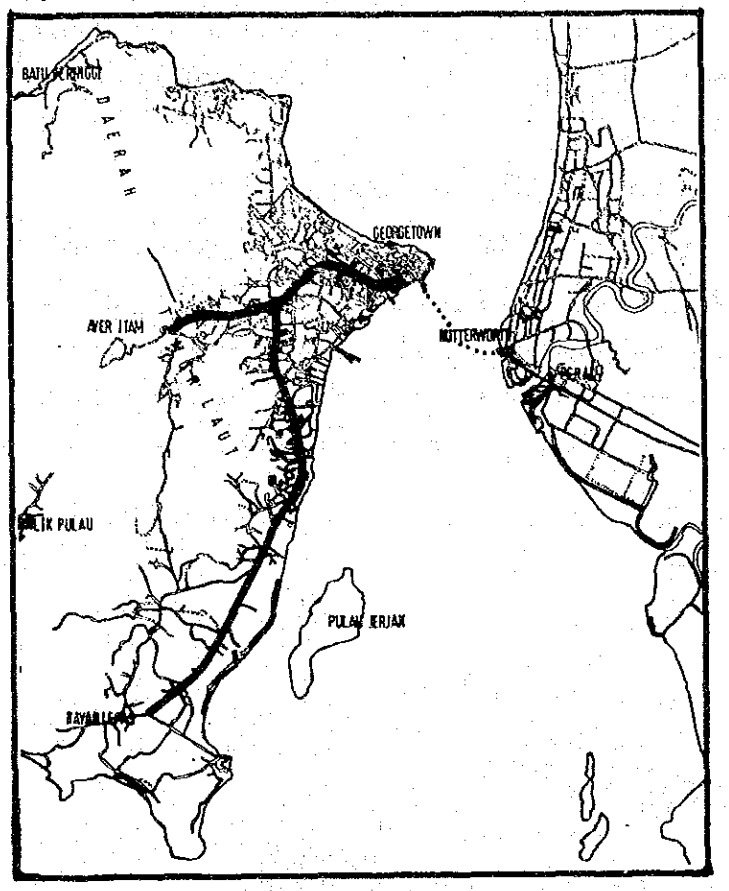

Fig. 4.7 LOCATION OF NEW TRANSPORT ROUTES

2. Demand Control Strategies

Strategy A. Parking Control

Prohibition of on-street parking is mainly aimed at achieving a smooth and safe traffic flow and providing space for sidewalks. However, regarding control of parking capacity in the C.B.D., the team assumed a situation where the total parking capacity in the year 2000 during peak hours in spite of increase in off-street parking due to the sharp decrease of on-street parking capacity.

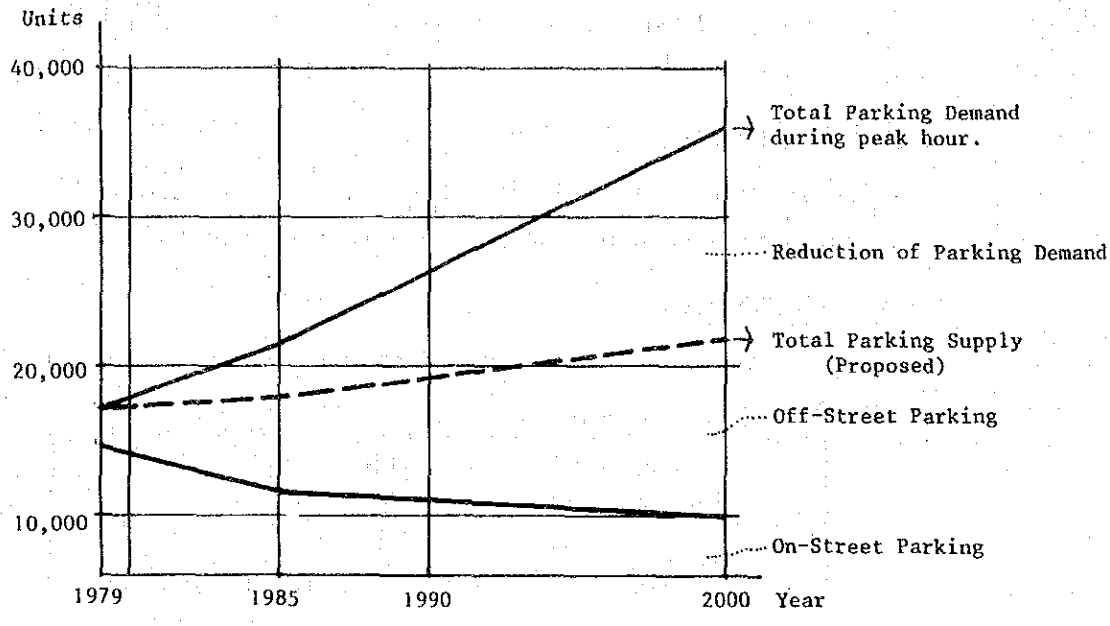

Fig. 4.8 PARKING DEMAND AND SUPPLY

Strategy B. Car Pooling System

The car pooling system is devised in order to prevent traffic congestion caused by private cars entering the C.B.D.

The system as planned by the team is as follows:-

The objective area ---------- the C.B.D. of George Town.
Average number of passengers --- 3 persons including drivers.

4.3.3 Alternatives

Many alternatives are prepared from the combination of the road network and the strategies mentioned earlier. In addition to these combinations, two (2) situations, i.e. the termination of the ferry service after 1985 and the continuation of this service after 1985 are included in the alternatives.

1. Combination Plan for Road Network

Existing road network plan (present)

The road network of this plan is composed of only the existing roads.

Intended road network plan (base case)

The road network of this plan is composed of the existing roads, the Penang Bridge, the New Federal Route I, the traffic dispersal roads and the supporting roads of the East-West Highway.

Plan 1 (on-going)

In addition to the road network plan, the road network is composed of some new roads which have been proposed earlier.

Plan 2 (Proposed)

The following new roads proposed by the team are added to the road network.

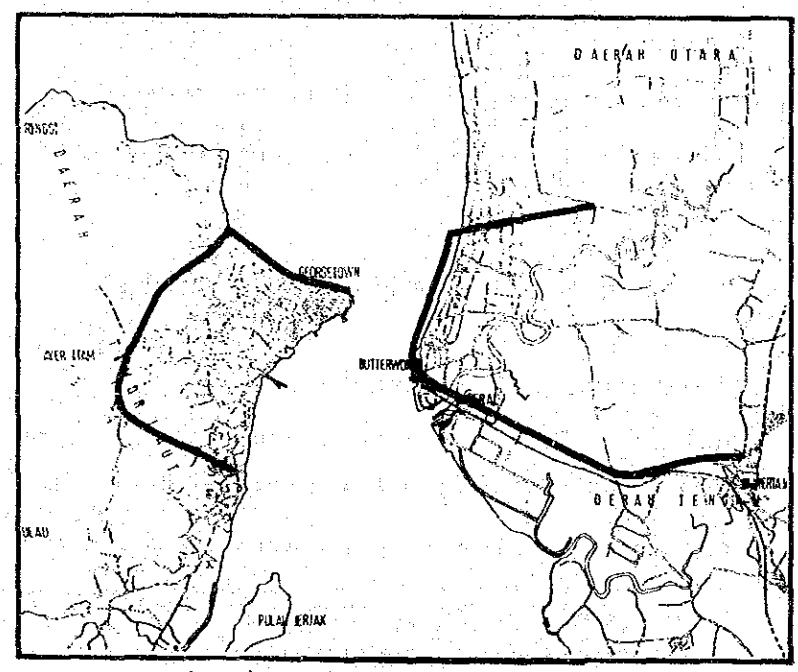

Fig. 4.9 LOCATION OF NEW ROADS

Plan 3 (on-going and proposed)

The road network of this plan consists of Plans 1 and 2.

Plan 4 (Ultimate)

In this road network some roads are added to Plan 2 so as to form the ultimate road network. Besides, this plan is divided into three (3) sub-plans due to the difference in the usage of the ferry service.

Regarding the continuation of the ferry services, Plans 3 and 4 include both cases of with ferry and without ferry.

2. Combination Plan for Demand Control (Public Transport Plan included)

Plan A

No improvements to the public transport and no introduction of demand control.

Plan B

A combination of parking control and exclusive bus lane.

Plan C

A combination of parking control, exclusive bus lane and the introduction of the New Transport System.

Plan D

A combination of parking control and car pooling system.

3. Transport Alternatives

From the combination of the road network plans and demand control stratagies, the alternatives of the future transport system are prepared for evaluations.

Table 4.1 Transport Alternatives

Road Network Plan \ Demand Control Plan	Plan A: Existing Situation	Plan B: Parking Control Exclusive Bus Lane	Plan C: New Transport System Parking Control Exclusive Bus Lane	Plan D: Parking Control Car Pooling
(Present)	(1979)			
Base Case	1985 2000			
Plan 1 Under Planning	1985			
Plan 2 Proposed	1985			
Plan 3 Under Planning & Proposed	1985 2000	1985 2000		
Plan 4 Ultimate	2000	2000	2000	2000

Figures in boxes show the projected years.

In addition, regarding the evaluation of the continued existence or termination of the present ferry system, the following cases are also computed.

1985 With and without ferry system in case of Plan 3 - A

2000 With and without ferry system in case of Plan 4 - B

5. 各比較案の交通量予測

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5.1 予測手法

第4章で設定された各比較案ごとに、フローチャートの流れに沿って主要道路の区間交通量を推定した。

5.2 将来交通需要の推計

第3章では自然すう勢型の交通需要を推計したが、ここでは駐車規制やカープーリング等の自家用車に対する規制やバスに対する優先策、新交通システムの導入といった公共交通の整備の影響も含め検討している。

5.2.1 前　提

駐車規制による都心流入交通量の減少、公共交通整備による自家用車からの転換およびカープーリングによる自動車交通量の減少を計量する。

5.2.2 発生・集中交通量の推計

各比較案ごとの推計結果はここに示される通りである。

5.3 交通量の配分

5.3.1 配分手法

各道路リンク毎にQ－V条件を設定し、各O－Dペアはその最短ルートを選定するとする"オール・オア・ナッシング法"を使用した。

5.3.2 配分結果

現況を始め1985年では5ケース、2000年では7ケースの13ケースについて配分を行った。

5.4 フェリー交通量予測

フェリー利用の交通量は、架橋の影響を直接に受けるので、架橋完成前と完成後とに分けてそれぞれ推計した。

5.4.1 架橋完成前（フェーズA）

経済活動の活発化に伴ない、自動車交通量は年率10～15%の伸びで増加すると予測される。

5.4.2 架橋完成後（フェーズB）

架橋の料金等、未確定な要素を仮定して推定すると、架橋利用の交通量のシェアは

１９８５年で８３％、2,０００年で７７％と推計された。

5.5 バス旅客需要の推計

現況のバス網を基本に将来のバス需要を推定した。特に政策を構じない場合は１９８５年で２５万人／日、2,０００年で３０万人／日の需要が見込まれる。

5.5.1 バス専用レーンの効果

バス・レーンの設置やパーキング規制によるバス旅客需要の増加は１９８５年で約８％、2,０００年で２０％と予測された。

5.6 新交通システムの需要予測

ペナン島において、C.B.D.とバヤン・レパスおよびエアー・アイタムを連絡する新交通システムを想定し需要を予測した。

5.6.1 需要推計

いくつかの仮定に基づいた推計の結果は、２２㎞の総延長に対し、９2,５００人／日、７４2,１００人・キロとなった。

5. TRAFFIC PROJECTION OF ALTERNATIVE PLANS

5.1 Procedure

After the future traffic demand is calculated, the alternative plans in the Study Area already selected in Chapter 4, are taken into consideration. According to these alternative plans, two (2) major estimations will be executed in this chapter.

1. To bring the modal split of the O-D table, already estimated in Chapter 3, in accordance with the intentions of the alternative plans and to complete the O-D table by alternative policies.
2. To apply the O-D table to the alternative road network and to estimate the traffic volume on each road.

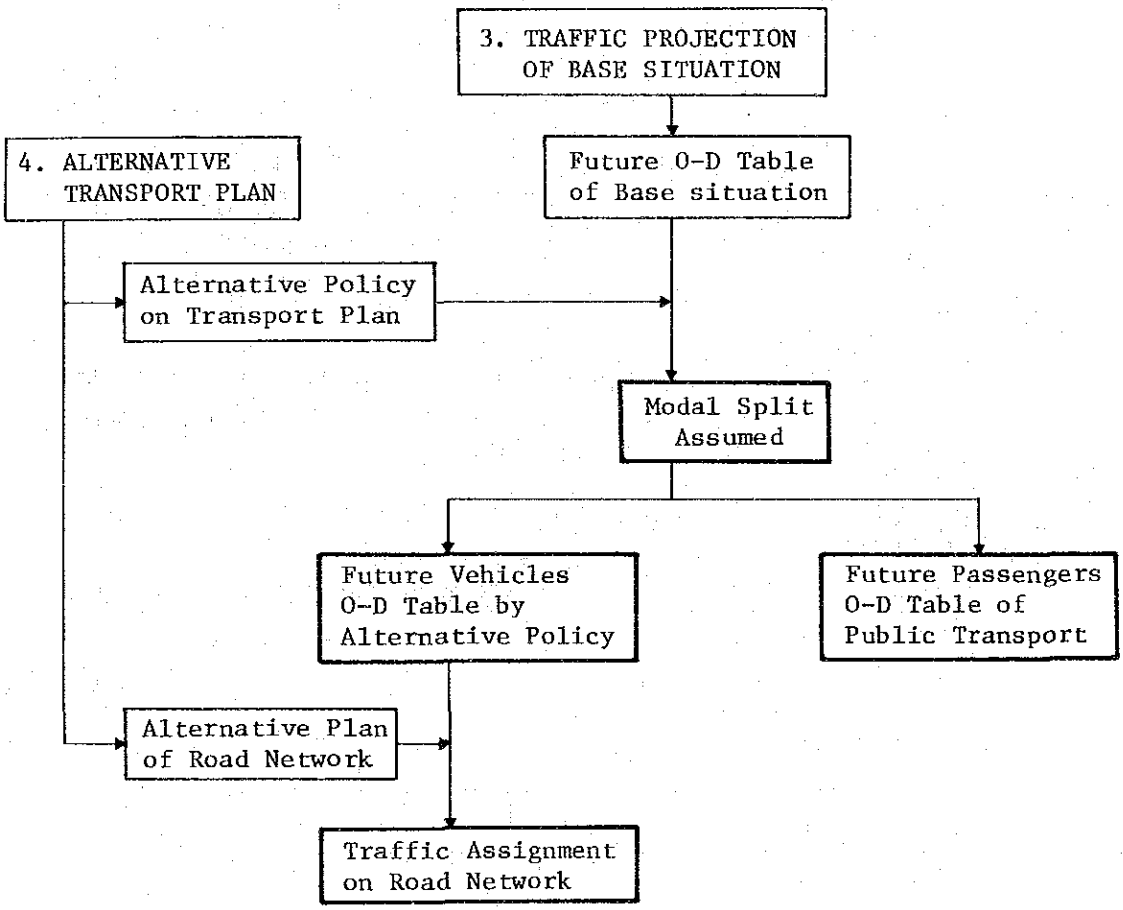


Fig. 5.1 PROCEDURE OF TRAFFIC PROJECTION

5.2 Estimation of Future Traffic Demand by Alternative Plans

The future O-D table described in Chapter 3 is estimated according to the demand of vehicles. However, this actual appearance of the traffic volume is affected by many restrictions and by any alternative transport, that is, if there are no parking areas, vehicle traffic will decrease and if there is some superior mode of transport faster than vehicles, some vehicle owners will divert to this new mode of transport.

In this chapter, the concept of modal split is introduced and future traffic demand is re-calculated by alternative plans.

The content of the alternative plans is already formed along the following four (4) alternatives:

1. Plan A

   There are no changes from the present situation. The estimation is already conducted in a previous chapter.

2. Plan B

   In this plan, the control of parking demand and the alternative transport, which is represented by exclusive bus lanes, are considered.

3. Plan C

   In this plan, a new transport system which is imagined as the Lightway Rail System is considered of Penang Island in addition to Plan B.

4. Plan D

   In this plan, the control of parking demand and the car pooling system are considered.

The estimations are executed as follows;

Year	Plan - B	Plan - C	Plan - D
1985	execute		
2000	execute	execute	execute

5.2.1 The Premises for Calculation

For the purpose of estimating the traffic demand by alternative plans, the following three (3) premises must be introduced first:

1. Control of Parking Demand
2. Diversion to Public Transport.
3. Car Pooling System.

1. Control of Parking Demand

The premises for calculation are as follows;

1) The object area of parking control is limited to C.B.D. in George Town (that is zone 111, 121, 131).

2) The differences in volume between the parking demand and the parking supply are to be controlled and diverted to the public transport.

3) These differences are subtracted from the traffic volume to C.B.D. whose purpose is 'going to work' by private car, and the equal amount is subtracted from the travel volume whose purpose is 'going home' by private car.

4) For the parking ratio and the average number of passengers the present figures which were obtained through the traffic survey are used.

5) There are no restrictions concerning motor-cycles.

6) The average number of passengers with the trip purpose "going to work' in each car, obtained from the present traffic surveys is 1.4.

The calculation will be executed according to the following flow cahrt.

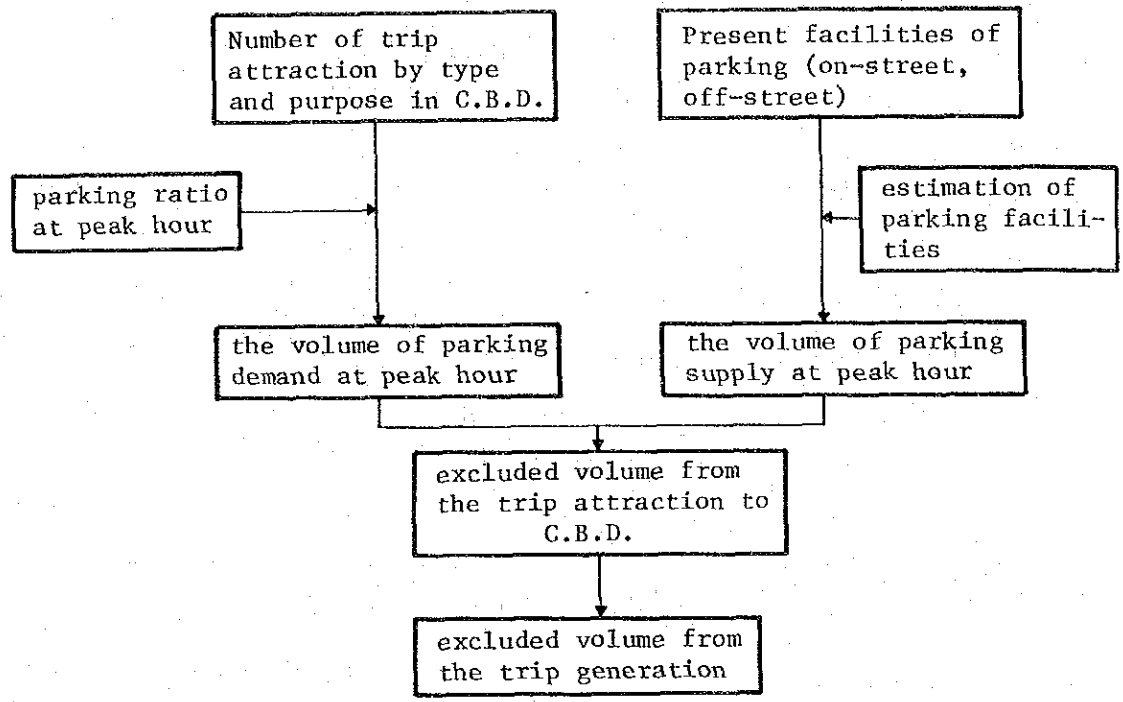


Fig. 5.2 THE FLOW CHART OF CONTROL OF PARKING DEMAND

According to this flow chart, the excluded volume due to control of parking demand is calculated as follows;

(a) Parking demand

The parking demand at peak hours is as follows:-

Table 5.1 PARKING DEMAND AT PEAK HOUR IN C.B.D.

(Unit : trip end)

year		1979	1985	2000
Car	To Work	12440	15010	24410
	On Business	1880	2320	3930
	Private	1290	1690	3030
	Home	540	680	980
Lorry		1300	1600	3300
Total		17450 (100)	21300 (122)	35650 (204)

(b) Parking supply

The volume of parking supply is estimated by our parking survey as follows:-

Table 5.2 THE VOLUME OF PARKING SUPPLY

(Unit : vehicles)

year	1979	1985	2000
On-street	14133	11500	10000
Off-street	3491	6500	11000
Total	17624	18000	21000

From Table 5.1 and Table 5.2, the excluded volume due to the shortage of parking supply is calculated as follows;

Table 5.3 THE EXCLUDED VOLUME BY CONTROL OF PARKING

(Unit : 1000 trip end)

year	1979	1985	2000
demand volume	17.5	18.0	21.0
supply volume	17.6	21.3	35.7
difference	+0.1	-3.3	-14.7
excluded volume	-	-6.7	-29.3

2. Diversion to Public Transport

People who live in urban areas always choose a suitable mode of transport according to their own judgement. Various factors play a role in this choice, but generally these factors can be classified under the concept of distance from place of origin to destination.

The concept of distance means, of course, actual distance, time distance and economic distance which includes the travel fee.

In the "URBAN TRANSPORT POLICY AND PLANNING STUDY FOR METROPOLITAN KUALA LUMPUR", the diversion curve and the time differences between alternative periods of transport are chosen as the determining factors for the modal-choice model. As there is no other modal-choice data available for our study area, the

above-mentioned data is used for the estimation of diversion from vehicle traffic volume to public transport.

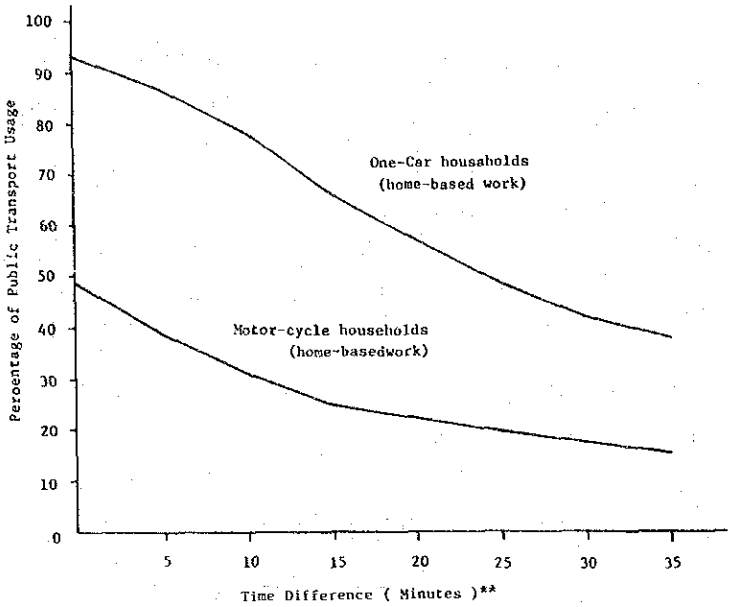


Fig. 5.3 MODAL CHOICE MODEL *

* SOURCE : URBAN TRANSPORT POLICY AND PLANNING STUDY FOR METROPOLITAN KUALA LUMPUR.

** (Public - Private transport)

The following premises have to be taken into consideration.

1) The object areas for diversion are limited to those areas which are directly related to the alternative public transport plans.

2) Since the calculation of diversion for "going to work" purpose by private car or motro-cycle, is the same as for the "going home" purpose by private car or motor-cycle, this calculation will suffice.

3) The ratio of diversion is calculated by means of the reduction time provided by means of the alternative public transport plan and the diversion curve of the above-mentioned study.

4) Travel time is calculated as follows:-

	BUS		N.T.S.
Schedule speed	25 Km/h	(Exclusive lane)	30 Km/h
	15 Km	(Urbanized area)	
	20 Km	(other area)	
Operation internal	5 min.	(Urbanized area)	10 min.
	10 min.	(other area)	
Approach distance to stops	250 m	(Urbanized area)	500 m
	500 m	(other area)	

5) Average passenger numbers of cars and motor-cycles with the trip purpose "going to work" are 1.4 and 1.2 respectively.

The volume of diversion from car and motor-cycles to public transport is shown in the following table.

Table 5.4 THE VOLUME OF DIVERSION BY TRANSPORT PLANS

(Unit : 1000 trips)

Year		In Penang Island		In Province Wellesley	
		Car	M/C	Car	M/C
1985 Caused by Bus exclusive Lane	internal trips	221.9	273.7	71.8	151.6
	volume of diversion	2.3	3.6	0.5	1.2
2000 Caused by Bus Exclusive Lane	internal trip	424.0	241.8	215.1	193.8
	volume of diversion	3.5	3.6	1.7	2.1
2000 N.T.S.	internal trip	424.0	241.8	-	-
	volume of diversion	12.9	9.1	-	-

3. Car Pooling System

The Car Pooling System is devised in order to prevent traffic congestion which is caused by private cars entering the C.B.D.

As a result of this system whereby cars are enforced to carry a minimum amount of passengers, the number of cars, hence the traffic volume will decrease.

The premises are as follows;

1) The enforcement area of the car pooling system is limited to the C.B.D. in George Town.

2) By imposing an additional charge on the cars which have few passengers, the average number of passengers will increase from 1.65 to an average of 3.0.

3) All cars entering or leaving the C.B.D. are subject to the Car Pooling System, irrespective of trip purpose ("going to work" or "private").

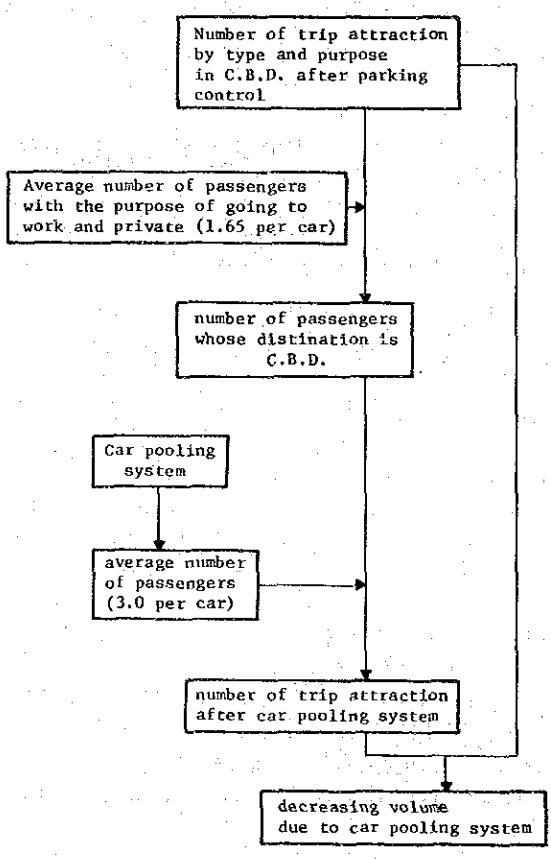


Fig. 5.4 FLOW CHART OF CALCULATION FOR THE YEAR 2000

The number of trip attraction in the C.B.D. after parking control is as follows;

Table 5.5 NUMBER OF TRIP ATTRACTION IN C.B.D.

(unit : 1000 trip ends)

		trip attraction
Car	To work	43.4
	On Business	28.0
	Private	43.3
	Home	24.4
Lorry		23.6
Taxi		7.5
Bus		5.9
Sub-total		176.1
Motor-cycles		95.5

From this table, the number of passengers whose trip purposes are "going to work" "private" total 143,100 persons (86,700 cars x 1.65 persons).

After the car pooling system is executed, there will be a decrease in the number of cars as follows.

Table 5.6 DECREASING VOLUME DUE TO CAR POOLING SYSTEM

(Unit : 1000 trip ends)

	number of trip attraction	number of passengers	average number of passengers
before car pooling system	86.7	143.1	1.65
after car pooling system	47.7	143.1	3.0
decreasing volume on one way direction	39.0		
decreasing volume on both way	78.0		

5.2.2 Estimation of Traffic by Alternative Plans

The total traffic volume related to the Study Area is estimated as follows:

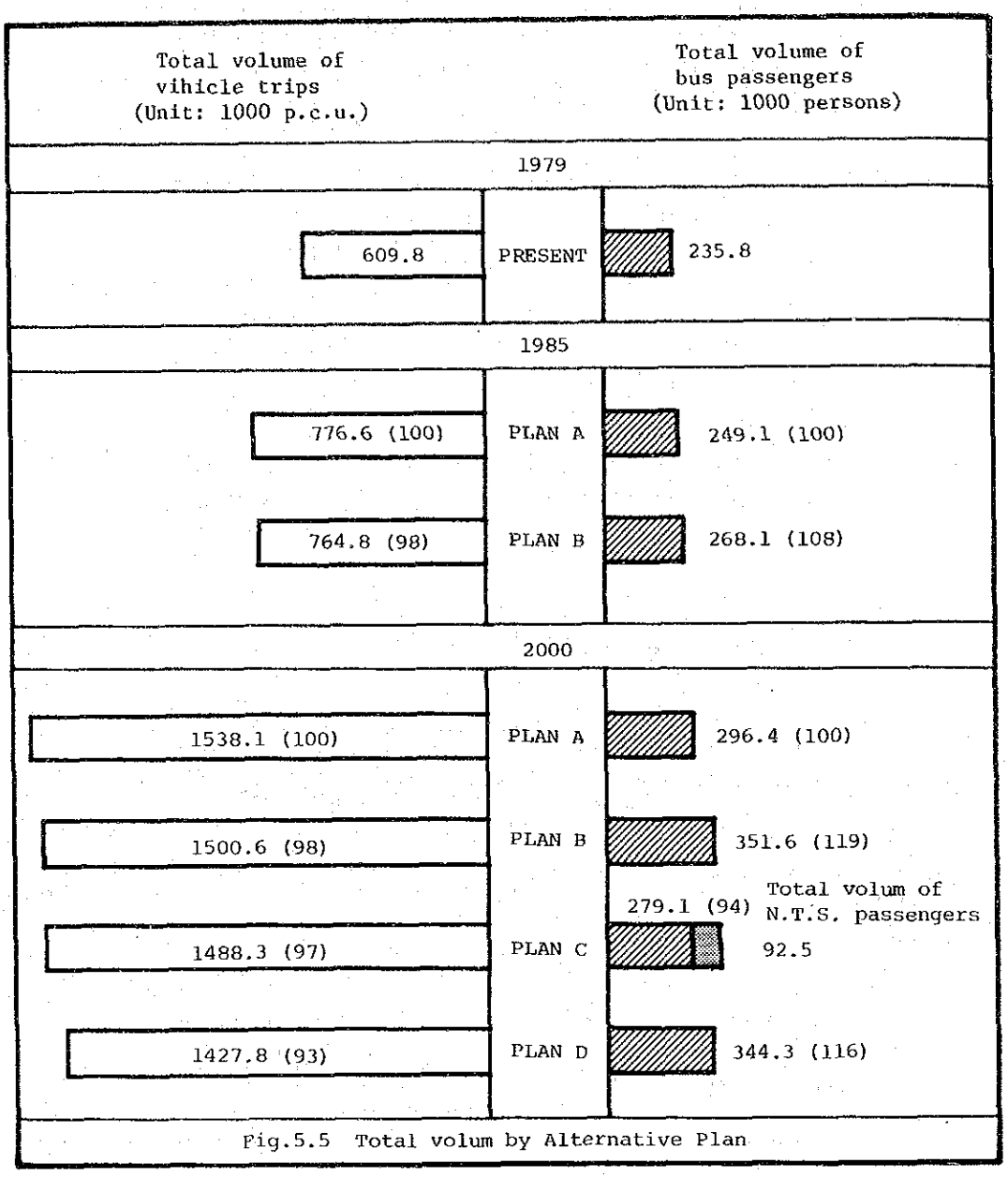


Fig.5.5 Total volum by Alternative Plan

Table 5.7 SUMMARY OF TOTAL VOLUME BY ALTERNATIVE PLANS

- 1985 - (Unit : 1000 trips, p.c.u., persons)

		Vehicle (trips)	Motor-cycle (trips)	C.P.U.	Bus passenger
	PLAN A	440.0	465.3	776.6	249.1
PLAN B	control parking demand	-6.7	-	-6.7	+9.4
	exclusive bus lane	-2.8	-4.7	-5.2	+9.6
	Total trips	430.5	460.5	764.8	268.1

- 2000 - (: 1000 trips, p.c.u., persons)

		Vehicle (trips)	Motor-cycle (trips)	C.P.U.	Bus passenger	N.T.S. passenger
	PLAN A	1044.9	477.9	1538.1	296.4	-
PLAN B	control of parking demand	-29.3	-	-29.3	+41.0	-
	exclusive bus lane	-5.2	-5.7	-8.0	+14.2	-
	Total trips	1010.4	472.2	1500.6	351.6	-
PLAN C	control of parking demand	-29.3	-	-29.3	+41.0	-
	N.T.S.	-12.9	-9.1	-17.5	-63.4	+29.1 +63.4
	exclusive bus lane	-1.8	-2.1	-2.8	+5.1	-
	Total trips	1000.9	466.6	1488.3	279.1	92.5
PLAN D	control of parking demand	-29.3	-	-29.3	+41.0	-
	car pooling system	-78.0	-	-78.0		-
	exclusive bus lane	-	-5.7	-2.9	+6.9	-
	Total trips	937.5	472.2	1427.8	344.3	-

(1) Comparison of Alternative Plans

(a) Comparison by trip generation and attraction

Execution of the transport plans is particularly related to the C.B.D. area in George Town because these plans are devised to prevent traffic congestion around the C.B.D. area. Trip generation and atraction of the C.B.D. area (zone 111, 121, 131) by alternative plans are compared as follows:-

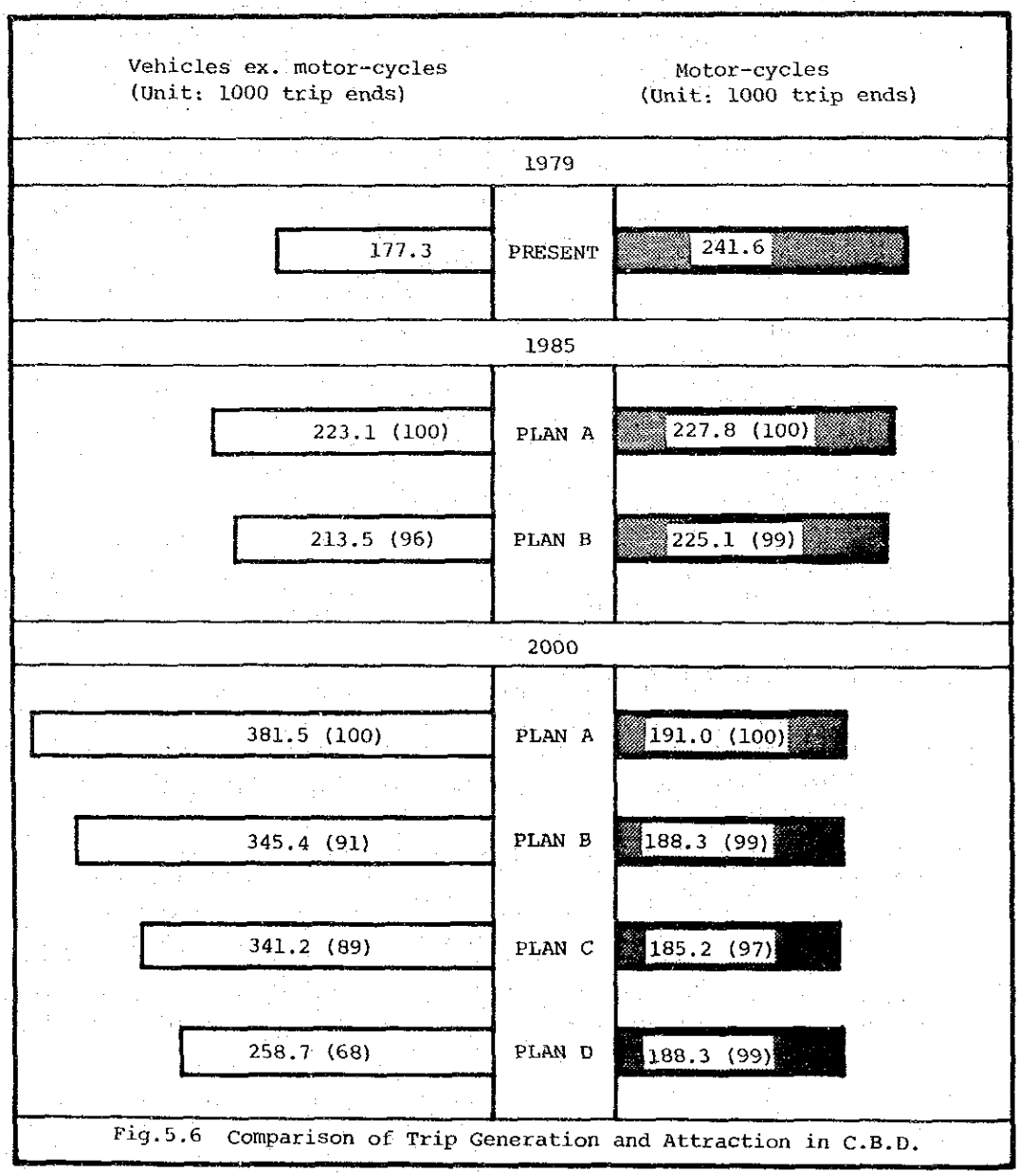


Fig.5.6 Comparison of Trip Generation and Attraction in C.B.D.

(b) Comparison by desired assignment

All transport plans, if executed, will increase the demand of vehicle trips. The effects are particularly notable on the cordon line of middle zone 11. The figures are shown as follows:-

Table 5.8 COMPARISON OF THE TRAFFIC DEMAND

(Unit : 1000 p.c.u.)

		Traffic demand on the cordon line of zone 111		Trassif demand on the line between George Town and Bayan Lepas	
1985	Plan A	127.7	-	105.7	-
	Plan B	165.6	-7.1	103.7	-2.0
2000	Plan A	293.9	-	239.1	-
	Plan B	272.1	-21.8	230.7	-
	Plan C	267.5	-26.4	255.5	-13.6
	Plan D	223.8	-70.1	212.0	-27.1
1979		147.9		62.9	

Note: The differences are subtracted from Plan A.

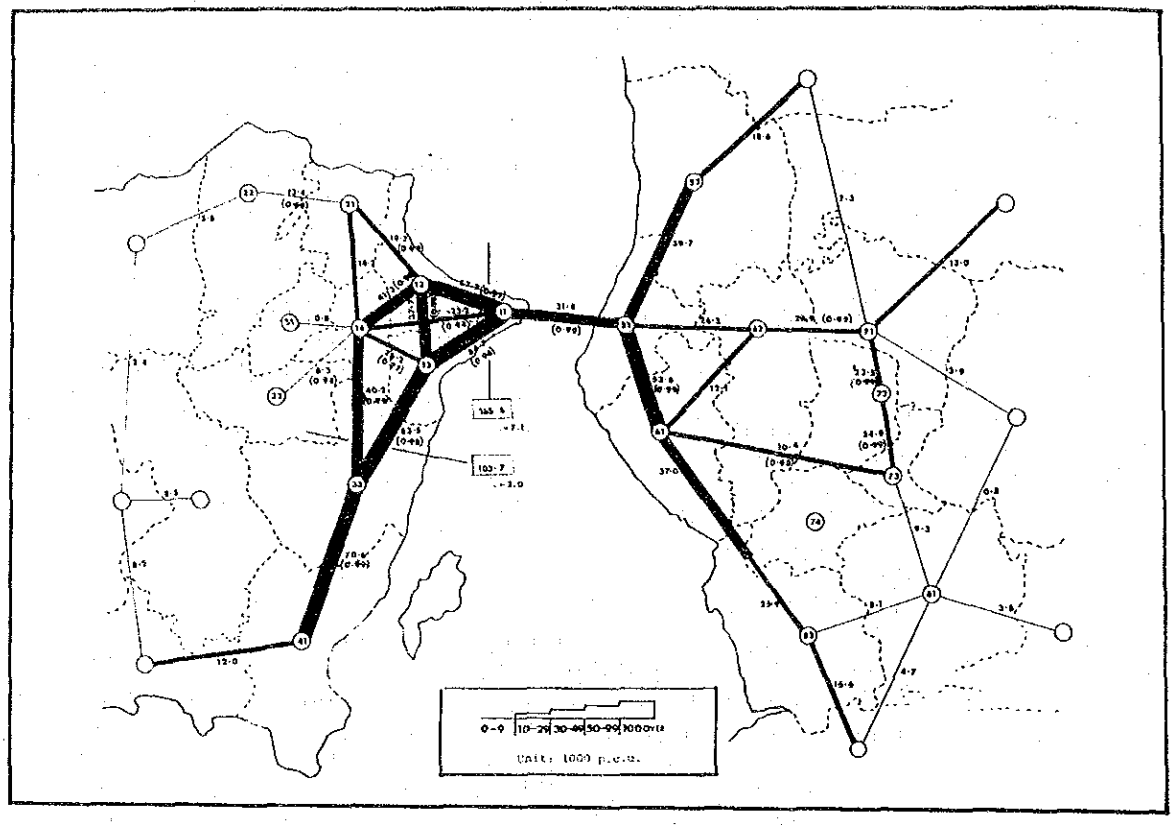


Fig. 5.7 Desired Assignment by Plan B (1985)

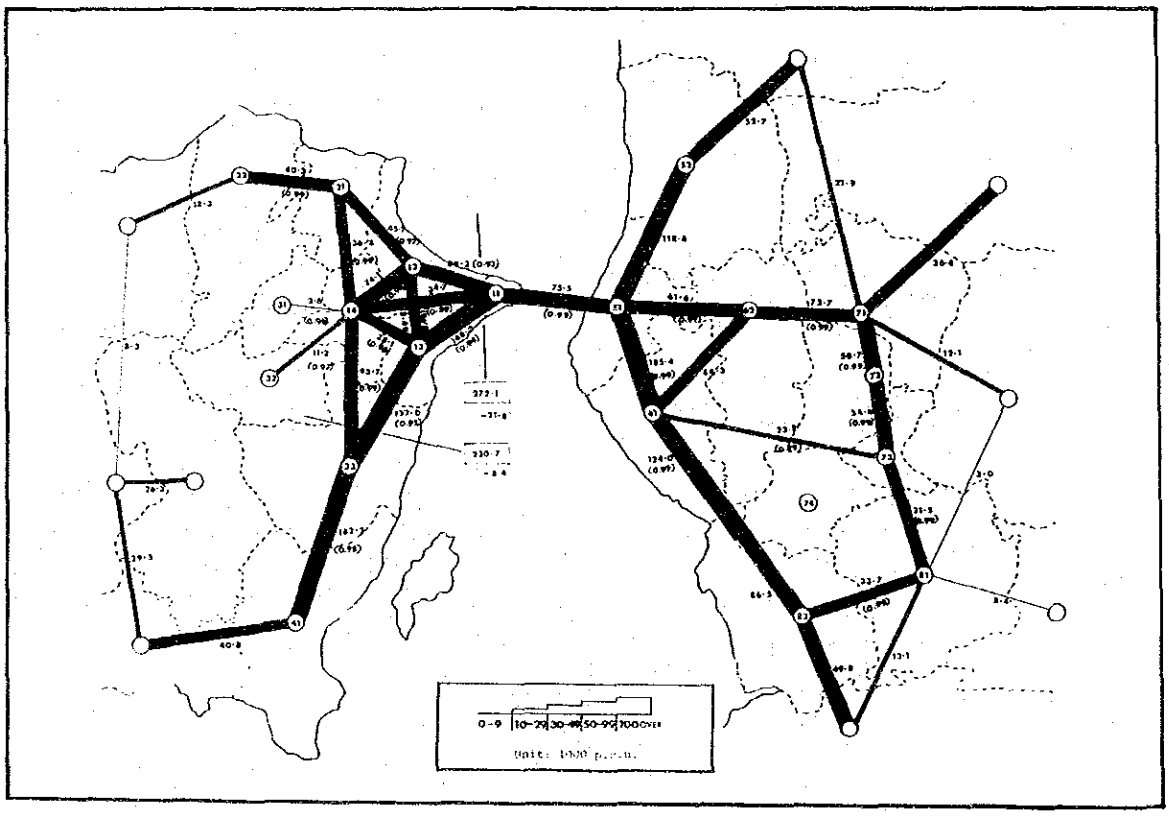


Fig. 5.8 Desired Assignment by Plan B (2000)

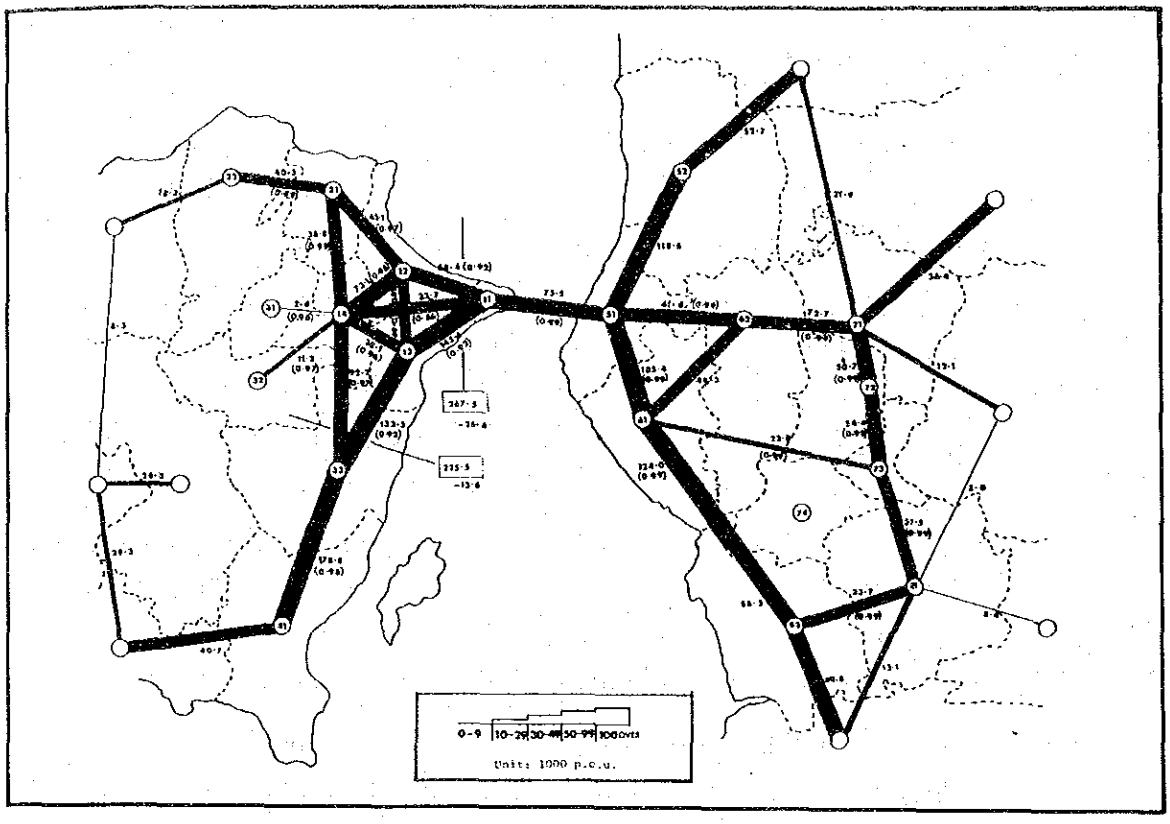


Fig. 5.9 Desired Assignment by Plan C (2000)

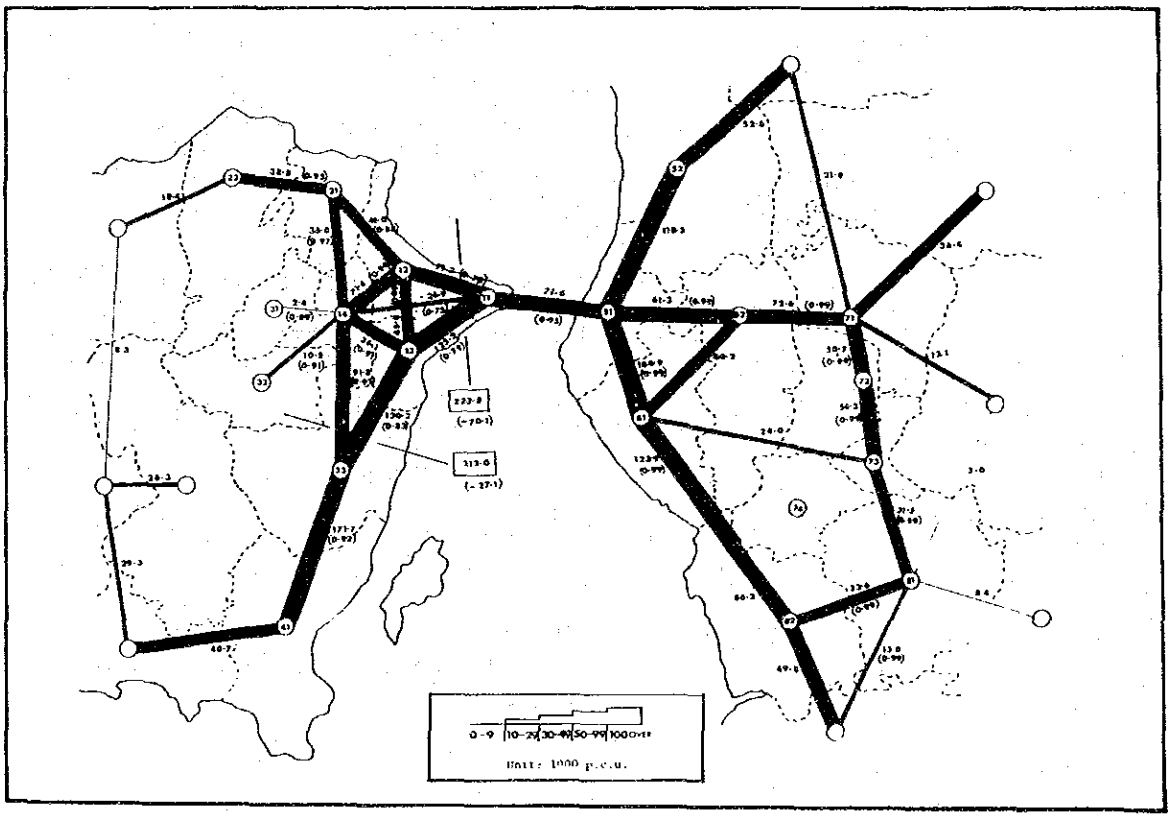


Fig. 5.10 Desired Assignment by Plan D (2000)

5.3 Estimation of Future Traffic Demand on Road Network

5.3.1 Procedure for Traffic Assignment

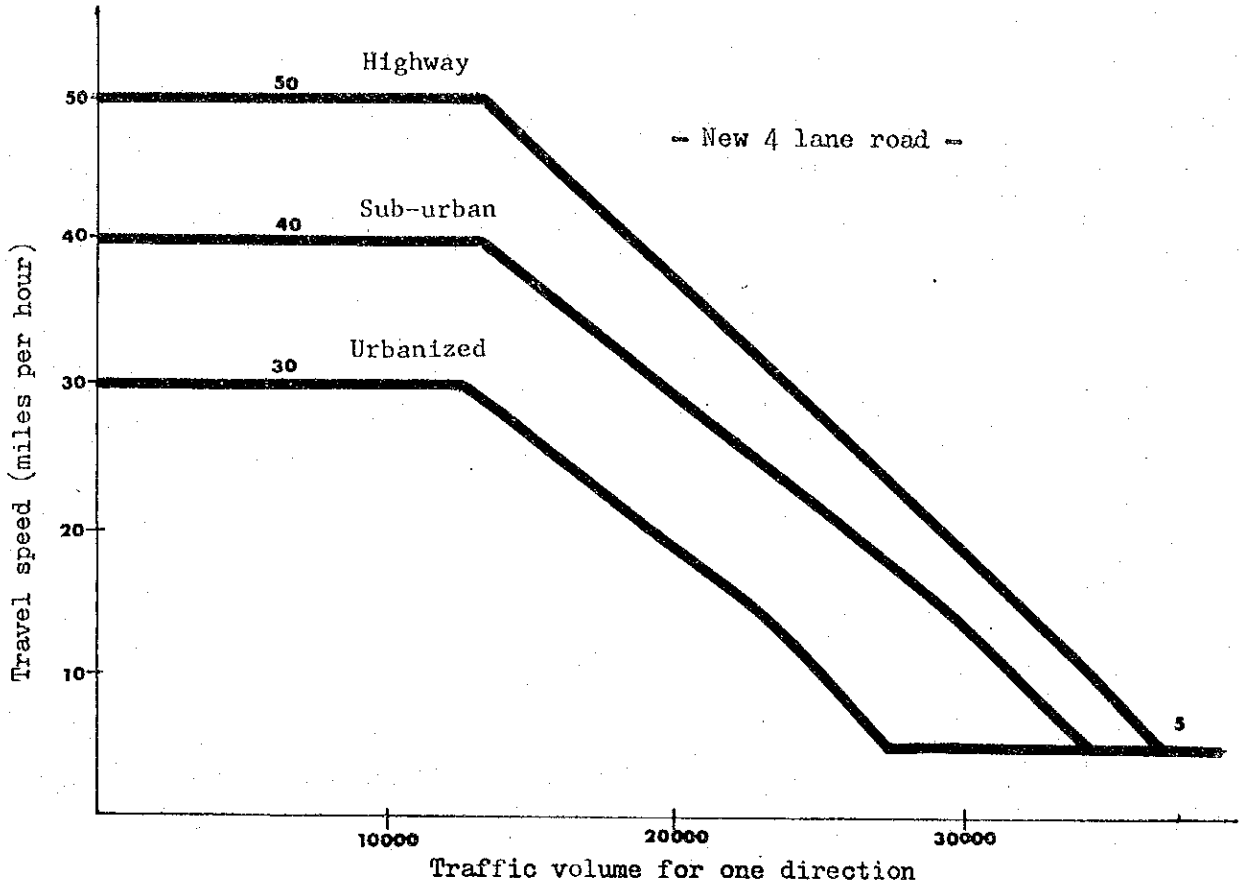
The traffic volume on each road is estimated through traffic assignment, the procedure of which is explained below.

1. Each link of the road network has its own relationship between the traffic volume and the travel time, i.e. the travel time increases with respect to the increase in the traffic volume already assigned. The travel time increases very rapidly as the traffic volume approaches the road capacity.

2. The traffic demand of each O-D pair is assigned to the shortest route in relation to the travel time decided upon by the above relationship.
   The so-called "all or nothing" method is used.

3. The traffic demand of O-D pairs is divided into several lots and the travel time is calculated repeatedly according to the traffic volume on a link at the assignment of each lot. The shortest route is obtained by the above calculations. The above procedure is repeated until all the lots of each O-D pair are assigned. Therefore, it rarely happens that the traffic demand of a particular O-D pair concentrates on a particular route.
   The relationship between the traffic volume and the travel time is calculated from the Q-V formula.

4. The Q-V formula expresses the relationship between the traffic volume and the travel time. It is known that the more the traffic volume increases, the more the travel speed decreases. Therefore, the Q-V formula is determined by type of road as follows:-



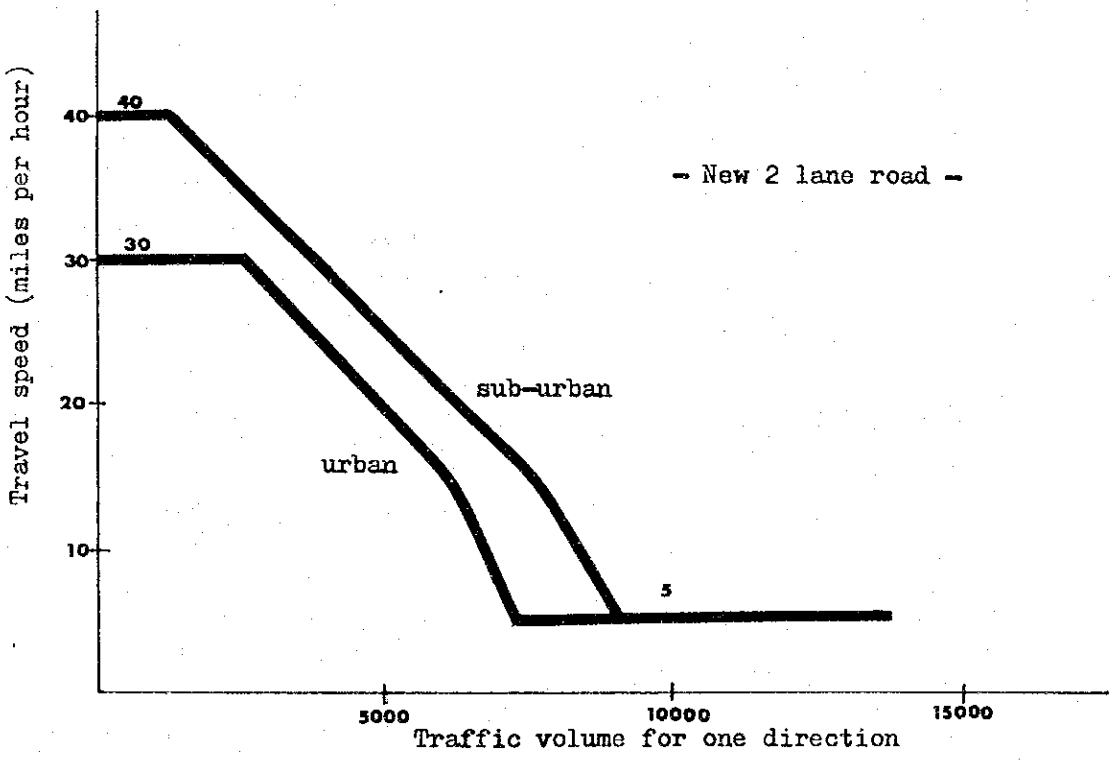


Fig.5.11 Example of Q-V Formula