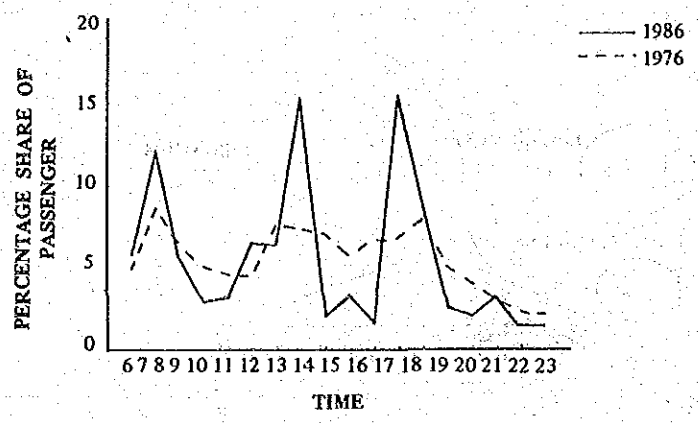


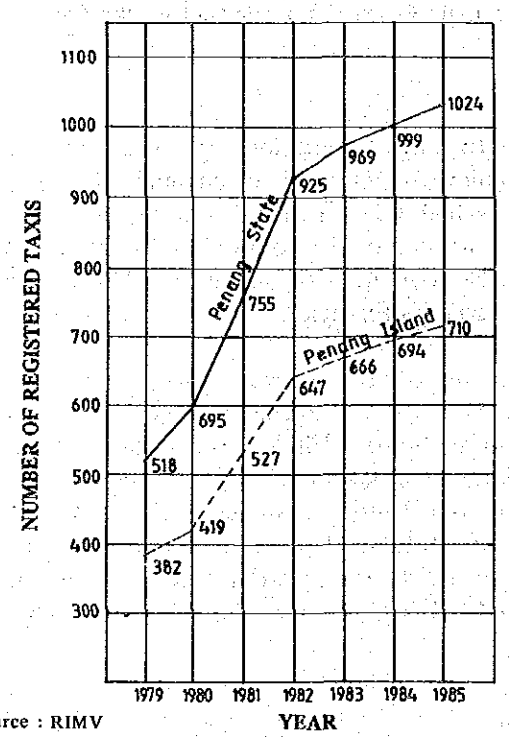
Figure 2.4.11 : Fluctuation of Daily Passenger Volume of City Council Buses on one of its major route

2.4.2 Taxi

A. Number of Taxi

Taxi services registered by the Road Transport Department (formerly known as RIMV) comprise Taxi Cabs and Hire and Drive Cars. The majority of taxi services in Penang State is Taxi Cab Service which constituted about 92% of all taxi vehicle registrations.

Figure 2.4.12 illustrates the trend of registered taxi number in both Penang State and Penang Island for the period 1979 to 1985. In 1985, the number of taxis registered were 1,024 and 710 in Penang State and Penang Island respectively.



Source : RIMV

Figure 2.4.12 : Trend of Registered Taxis in Penang State and Penang Island

B. Characteristics of Taxi and its Movement

1. Taxi Ownership Pattern

About 63.8% of the registered taxis are in the hands of individuals. The remaining 36.2% of taxis are owned by companies or cooperatives.

Figure 2.4.13 illustrates the ownership period of taxis. 46.5% of the taxis are already more than four (4) years old. Another 31.5% are already three (3) to four (4) years old. Only 17.4% of the existing taxi fleet are less than three (3) years old.

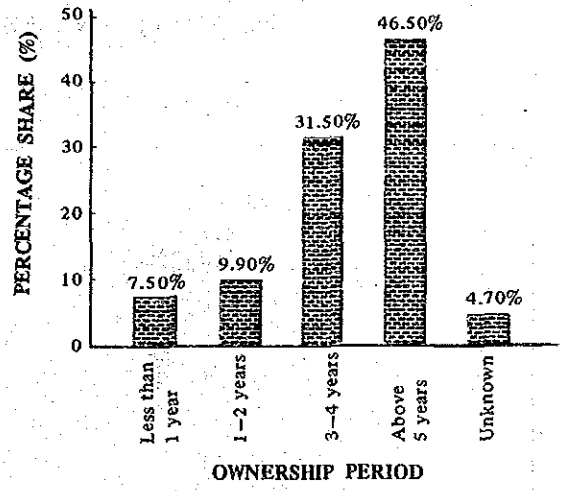


Figure 2.4.13 : Ownership Period of Taxis

2. Attributes Of Taxi Drivers

Majority of taxi drivers belongs to the middle age group. Figure 2.4.14 shows the taxi drivers by age. It shows that those in the 40–49 age group constitute 37.6% and 35.2% are in the 30–39 age group. About 20.2% are old drivers age fifty (50) years and above. Only 7.0% of the drivers are between 20–29 years old.

On the other hand, the distribution of the frequency of vehicle use per week is shown in Figure 2.4.15. More than 91% of the taxis are being used daily.

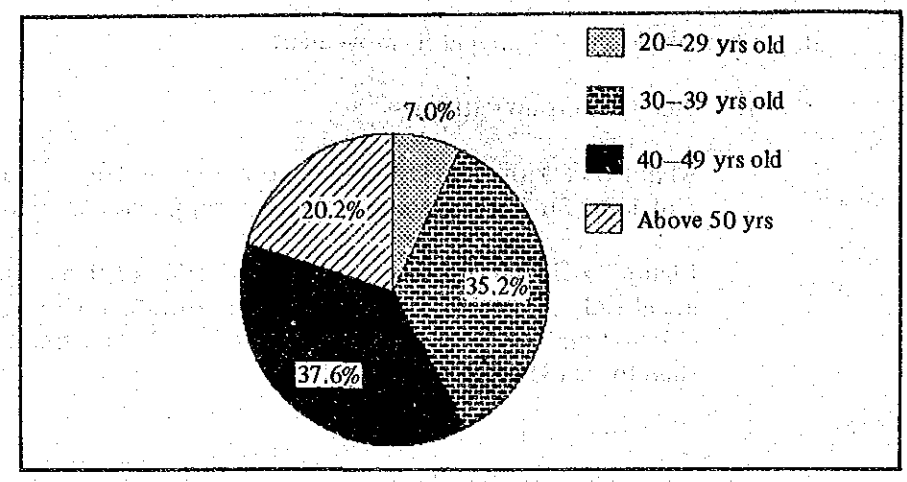


Figure 2.4.14 : Taxi Drivers by Age

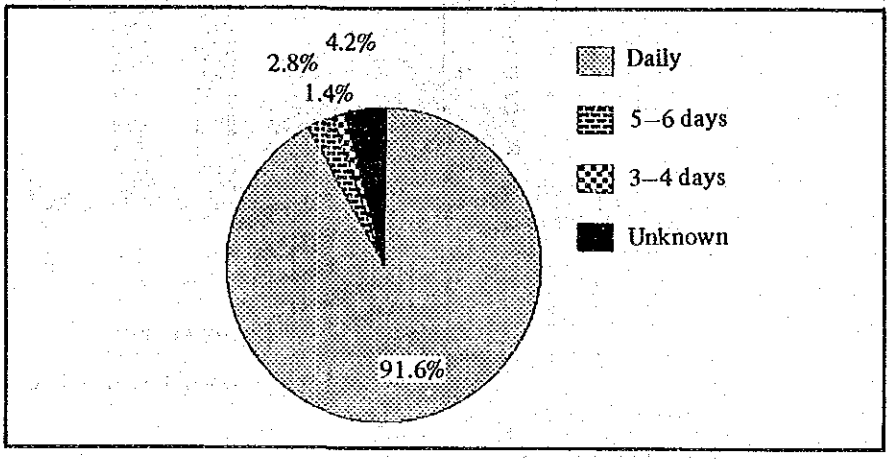


Figure 2.4.15 : Distribution of the Frequency of Vehicle Use per Week by Taxis

Figure 2.4.16 shows the distribution of average mileage travelled by taxis per day. The majority (53.5%) of the taxis in the Study Area travelled 50 miles (80 km) and above in a day. About 17.8% travelled 40–49 miles (64–78 km) per day.

Figure 2.4.17 shows the distribution of the number of trips made per day by taxis. The number of trips made per day varies from zero trips to more than eighteen (18) trips per day. However, 19.2% made only two (2) trips per day which is the most frequent response given by the taxi drivers interviewed. On the average, a taxi made about 6.6 trips per day.

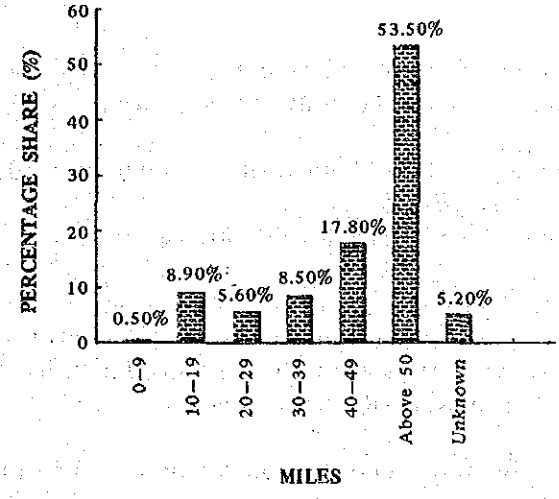


Figure 2.4.16 : Distribution of Average Mileage Travelled by Taxis

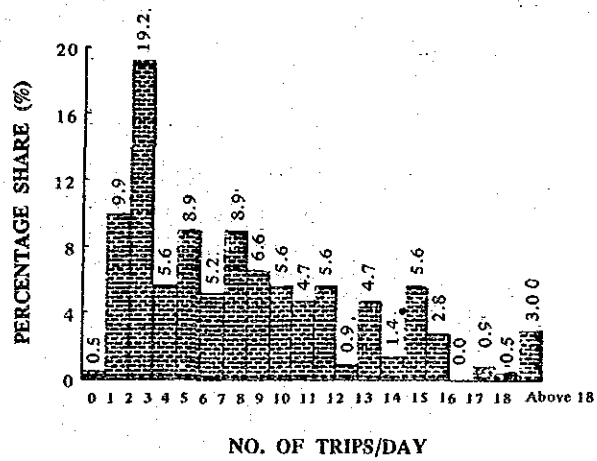


Figure 2.4.17 : Distribution of Number of Trips Made by Taxis per Day

C. Illegal Taxi

The presence of illegal taxi service in the Central Area is common knowledge to the local people in George Town and many of them make use of this illegitimate transport mode at their own risks because of the convenience provided.

The illegal taxis are passenger cars used mainly to pick up customers at bus stops and other busy points such as markets, schools, sightseeing locations, etc. Thus illegal taxis mainly operate along the bus routes. The fee charged is not fixed but is as much as that of bus fare.

2.4.3 Trishaw

According to MPPP's record, the number of registered and licensed trishaws in 1985 was 1,916 though the number is decreasing yearly.

Figure 2.4.18 shows the 12-hour trishaw volume on road network in George Town. As indicated, trishaws are mainly concentrated in the city centre, in particular, Prangin Road (1,240), Penang Road (930) and roads within the vicinity.

Figure 2.4.19 depicts the 12-hour trishaw volume at intersections. Among the intersections, high trishaw volume is recorded at Penang Road/Prangin Road intersection (2,005), Magazine Circus (1,945), Pitt Street/Chulia Street intersection (1,710) and Prangin Road/Ria Road intersection (1,671).

Although trishaw movements account for only 2–3% of the total traffic volume on the streets, their presence at the major intersections nevertheless impede smooth traffic circulation.

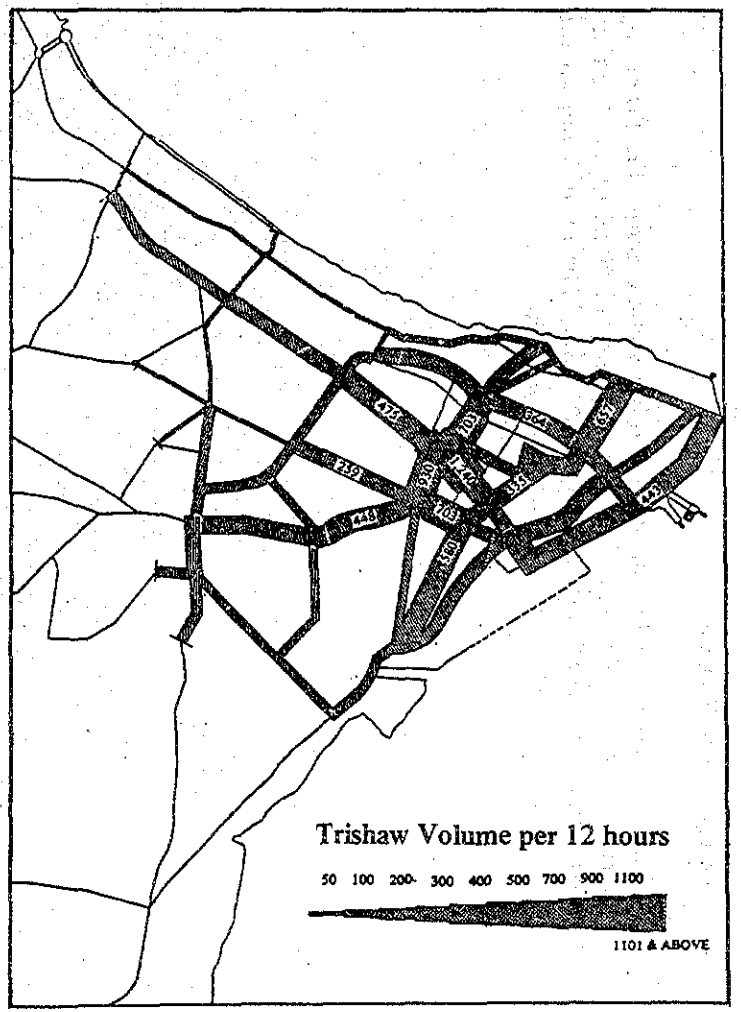


Figure 2.4.18 : 12-Hour Trishaw Volume on Road Network

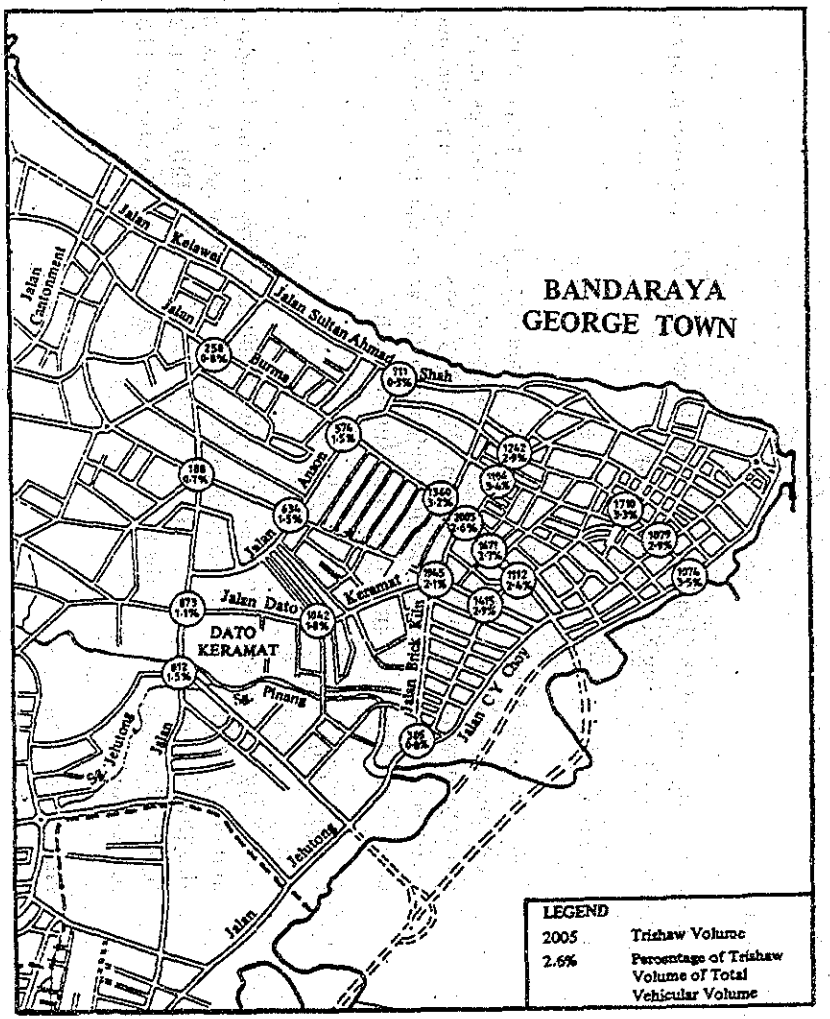


Figure 2.4.19 : 12-Hour Trishaw Volume at Intersection

2.4.4 Others

A. Ferry

Before the opening of the Penang Bridge in September 1985, the only means of transportation across the Straits was by ferry.

1. Number of Ferry

The ferry service is operated on a 24-hour basis by the Penang Port Commission. There are seven (7) passenger cum vehicular ferries and six (6) vehicular ferries. There are two (2) berths for passenger cum vehicular ferry vessels and two (2) berths exclusively for vehicular ferry vessels at each of the terminals in Penang and Butterworth.

2. Carrying Capacity

The carrying capacity of passenger cum vehicular ferry is four hundred and sixty (460) passengers on the upper deck and thirty-one (31) cars on the lower deck. For the vehicular ferry, it ranges from thirty-two (32) to thirty-six (36) cars on the upper deck and fourteen (14) to sixteen (16) lorries for the lower deck.

3. Number of Daily Trip

The ferries ply between the island and the mainland every nine (9) minutes from 6.00 a.m. to 10.00 p.m. After 10.00 p.m. the services are at intervals of fifteen (15) minutes till 12.00 midnight, thereafter it is half hourly till 6.00 a.m. Therefore, there are a total of 126 trips per day.

4. Yearly Traffic Volume

Figure 2.4.20 illustrates the yearly traffic volume across the Straits by ferry. The traffic volume dropped from 11,200,000 in 1984 to 10,500,000 in 1985 and 7,400,000 in 1986. The drop is due to the shifting of vehicular volume to the bridge linkage.

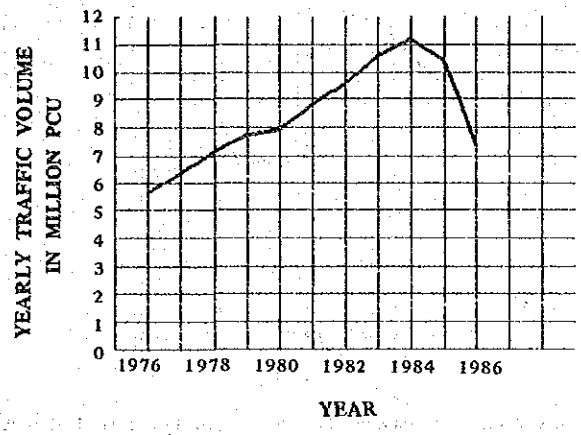


Figure 2.4.20 : Yearly Traffic Volume Across the Straits by Ferry

B. Airport

The Penang International Airport is located at Bayan Lepas.

1. Passenger Traffic

Figure 2.4.21 depicts the passenger traffic in Penang International Airport. After 1981, annual passenger traffic fluctuated around 1.1 million.

2. Cargo Traffic

Penang International Airport handled continuously an increasing international and domestic cargo volume from 1980 to 1984. Figure 2.4.22 shows the increasing trend of cargo loaded/discharged at the airport.

3. Aircraft movements

Figure 2.4.23 illustrates the aircraft movements at Penang International Airport. The total aircraft movements started to decrease after 1982.

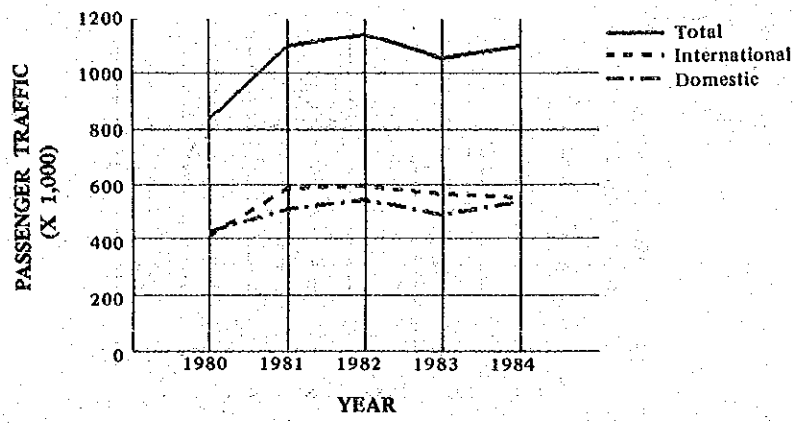


Figure 2.4.21 : Passenger Traffic at Penang International Airport

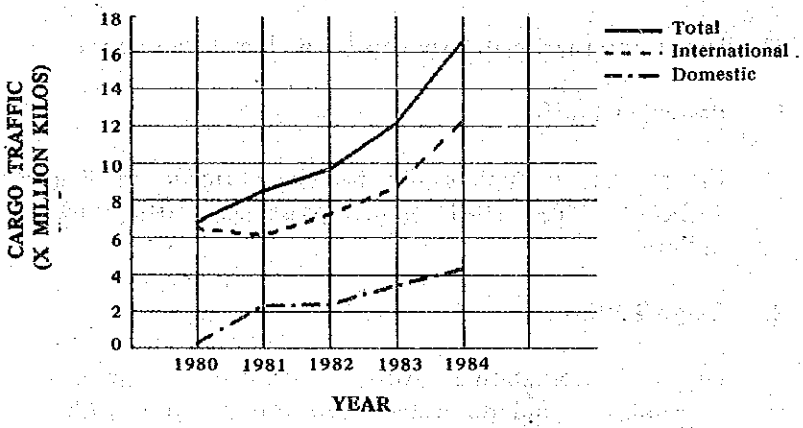


Figure 2.4.22 : Cargo Traffic at Penang International Airport

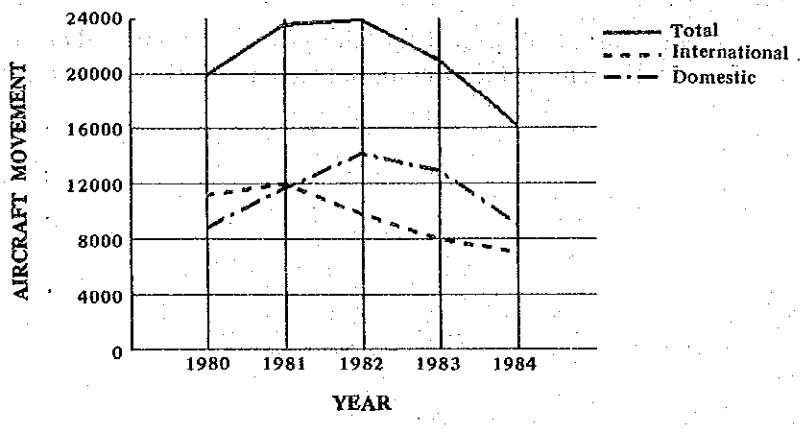


Figure 2.4.23 : Aircraft Movement at Penang International Airport

2.4.5 Problems on Public Transport

A. Bus

1. Irregularity of Bus Operations

The actual frequency of bus is about 75% of the scheduled frequency of bus trips. More than 50% of bus commuters have to wait more than 20 minutes for a bus.

2. Long Bus Travelling Time

The travelling time of a bus is longer than that of a private vehicle especially during peak hours; their difference is about 3.7 minutes along Dato Keramat Road from Magazine Circus to Green Lane where the distance is only 2.9 km.

3. Inadequate Bus Service

a. Inadequate bus route network

The area covered by buses is mostly along main roads only and the users have to walk to these main roads. Almost 43% of bus commuters have to walk more than 10 minutes to a bus stop.

b. Low frequency of bus service

The frequency of bus service is quite low on certain bus routes except those on the main roads.

4. Old Buses

30 percent of buses in the bus fleets are over 10 years old. This discourages users who wish to travel comfortably from using them. In addition, old buses frequently break down. As a result, the bus services are cancelled without notice to the users.

5. Inefficient Bus-stops

Most of the bus stops are poorly equipped except for a bus-stop sign at each bus-stop. Users have to wait for a bus that is often behind schedule under strong sunshine or heavy rain.

6. Inadequate Bus Terminal Facilities

There are two main bus terminals and one bus interchange in the CBD. The facilities at the bus terminals and interchange are inadequate from the functional point of view.

The following drawbacks have been observed :

(1) difficulty in changing to other buses especially those of another company's.

(2) insufficient bays for buses whenever departure times are adjusted.

(3) inefficient bus operation management

(4) danger for moving pedestrians and waiting commuters

(5) inconvenience and discomfort for bus commuters

B. Trishaw

Although trishaw movements account for only 2–3% of the total traffic volume on the streets, their presence at the major intersections nevertheless impede smooth traffic circulation. A peak hour volume of 217 trishaws trips had been observed at the intersection of Penang Road and Prangin Road.

C. Illegal Taxi

The illegal taxis are seen as depriving the bus and taxi operators of their rightful market share. While enforcement to weed out illegal taxis by the police is important, the sole measure of their enforcement will only cause the number to decrease to a certain extent during the enforcement period and at the same time the users will be much inconvenienced. In order to tackle the problem at the root, public transport services including taxi services have to be promoted and improved as soon as possible.

2.5 Pedestrian

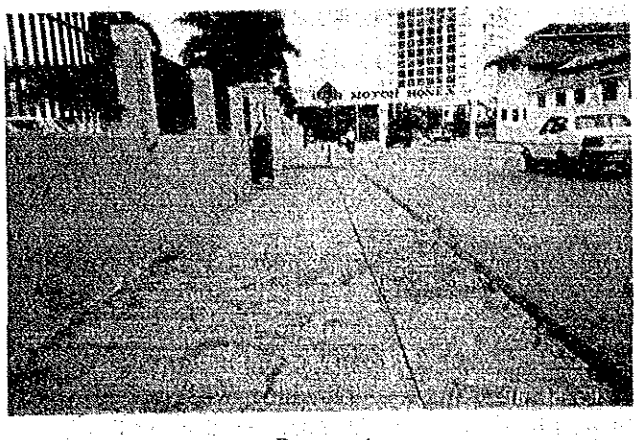
2.5.1 Existing Pedestrian Movement and Facility

The existing sidewalks in the city consist primarily of corridors (popularly known as five-footway in Malaysia) and pavements. The average effective width of corridors is about 1.0 meter whereas that if the pavement is between 1.0 and 3.0 meters. Figure 2.5.1 illustrates the existing types of pedestrian sidewalk in the Central Area of George Town.

Structurally, the corridor does not provide a pleasant pedestrian movement. Secondly, certain elements on the corridors obstruct the movement and the occasional unequal corridor levels cause much discomfort to the users. Occasionally, the pedestrians are forced to walk on the adjacent roadway upon approaching a narrow footpath, thus, endangering their safety. The narrowness is further hampered by the unlawful vehicle parkings on the sidewalks. Undoubtedly, 'jay-walking' has become a common sight in the city. One of the factors is the inadequate pedestrian crossing facilities at busy intersections and heavy trafficked roads. Another is the discontinuity of footpath in providing a continuous pedestrian access.

Figure 2.5.2 presents the pedestrian movement volume along major roads in the Central Area of George Town. Studies show that there is a comparatively large percentage of pedestrian movement at the KOMTAR periphery. The primary reason is that this area is boosted with numerous modern shopping complexes in addition to the integrated variety level of activities introduced by KOMTAR.

Total accident rate accounted for the year 1985 in George Town was approximately 4,563. Pedestrian accidents constituted 8% of the total accidents. Studies show that the average pedestrian accident number per kilometer along the major roadways in George Town is about 31 accidents/km. Figure 2.5.3 depicts the pedestrian accident rate along major roads in the Central Area of George Town. Five roadway sections have a high-frequency accident characteristics with a rate greater than 31 accidents/km. Prangin Road (between roadway sections of Ria Road and Carnarvon Circus) registers the highest accident rate at 125 accidents/km. Apparently, these sections coincide with areas having a large percentage of pedestrian trips.



Pavement

Corridor

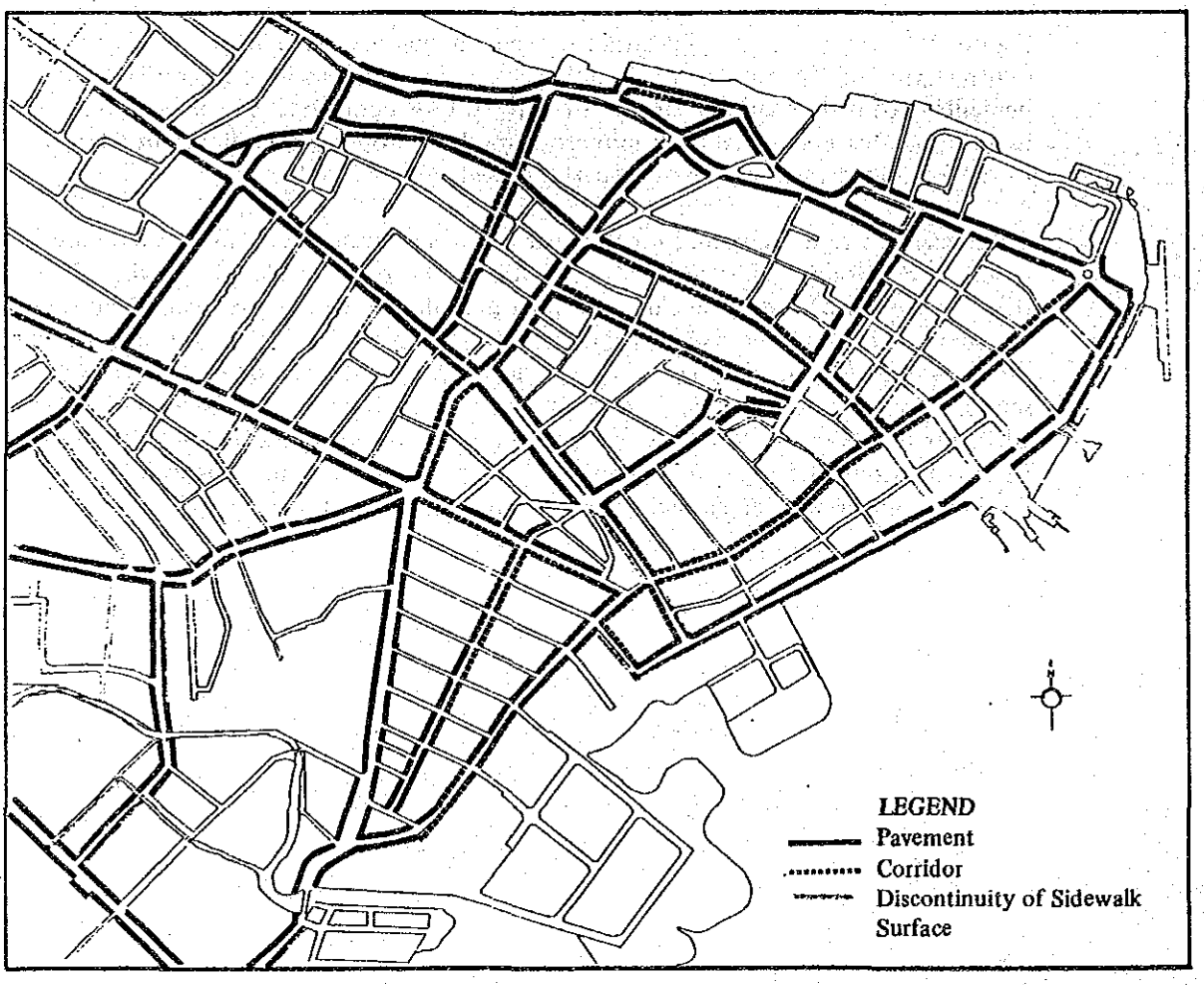


Figure 2.5.1 : Existing Types of Pedestrian Sidewalk in the Central Area of George Town

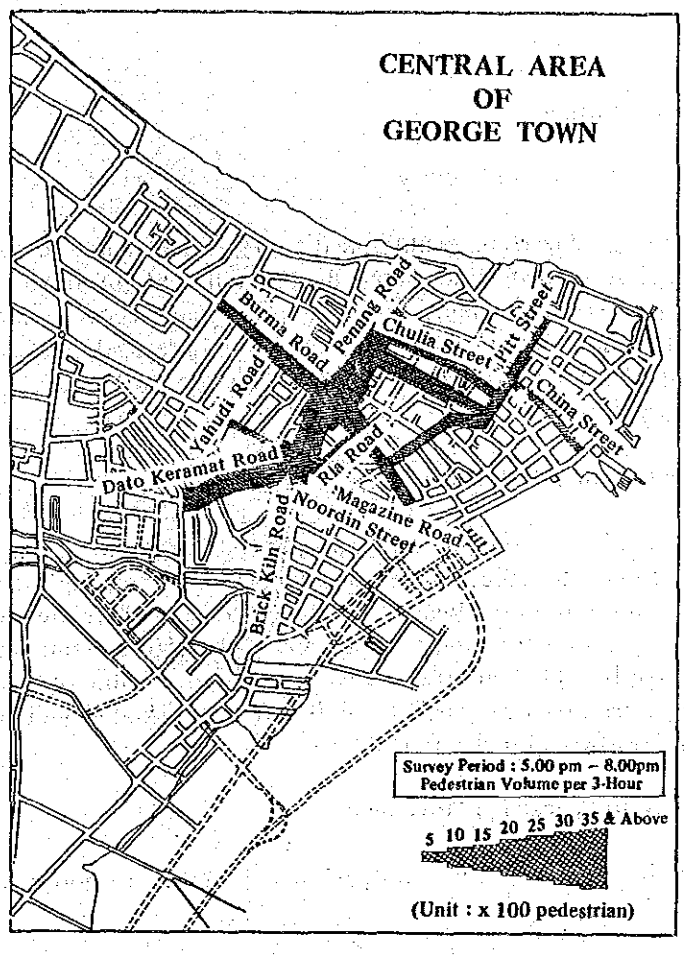


Figure 2.5.2 : Pedestrian Volume Along Major Roads in the Central Area of George Town

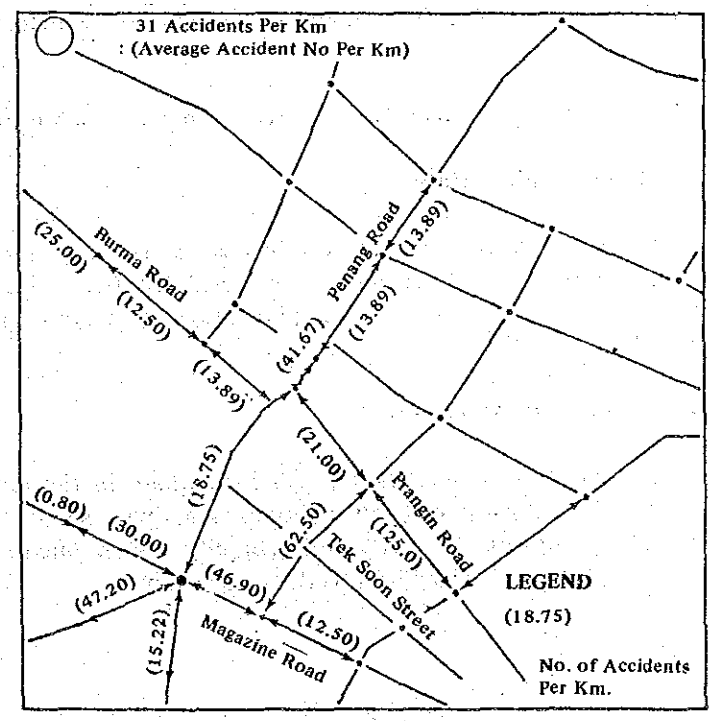


Figure 2.5.3 : Pedestrian Accident Rate Along Major Roads in the Central Area of George Town

2.5.2 Problems on Pedestrian

1. **Inadequate Pedestrian Facility**

The existing pedestrian facility in the city is inadeauate to accommodate the increasing urban pedestrian demand. Even in the Central Area where there is a high pedestrian movement, continual pedestrian access is non-existent. The existing corridors are too narrow to accommodate all the pedestrians who want to enjoy shopping along busy streets. This forces the pedestrians to walk on the carriageway.

2. **Low Pedestrian Safety Priority**

Jay-walking has become a common sight in George Town. The primary reason is attributed to the inadequate pedestrian crossing facilities at busy intersections and across heavily trafficked roads. There are stretches of street of about a kilometer long without any pedestrian crossing along them at all. Consequently, the pedestrians have inculcated a habit of crossing the street wherever they please. Such habit if left unchecked would pose a hazard to both the traffic and pedestrian alike.

3. **Hindrance to Pedestrian Movement**

Obstructions on pedestrian footpath which hinder a smooth pedestrian movement in the city include :

(1) Company merchandise being placed on the corridor.

(2) Structures such as fire-hydrant and street-light post which are sited on the pavement.

(3) Unlawful parking of cars and motorcycles on pedestrian footpaths.

4. **High Pedestrian Accident Rate**

Based on the 1985 traffic accident data in George Town, pedestrian accidents constituted 8% of the total accidents. Inadvertently, the accident prone areas coincide with areas having a large percentage of pedestrian trips at the periphery of KOMTAR.

5. **Inadequate Pedestrian Amenities**

The present pedestrian amenities are still inadequate in the city. Amenities such as city information panel, flower boxes, seats with shelters, special street lighting, water sculpture, etc. are rare in the city. Such amenities would give character to the pedestrian facilities to the pedestrians.

2.6 Parking

2.6.1 Parking Condition

A. Parking Facilities

Figure 2.6.1 shows the existing parking facilities in the Central Area whereas Figure 2.6.2 depicts the parking space and inflow car volumes. There exists a total parking capacity of about 18,000 parking lots of which 9,200 (51%) are on-street parking facilities while 8,800 (49%) are off-street parking facilities. There are relatively few places where on-street parking is prohibited.

According to the Vehicle Owner Interview Survey, 58.5% of parked cars use offstreet parking facilities whereas 41.5% of the cars are parked on on-street parking spaces.

Results from the parking duration survey reveal that on-street charged parking is well utilised during the day time whereby off-street parking is highly utilised in the afternoon.

About one-quarter of the parking spaces are occupied by commuters involve in various urban functions such as banking, shopping and retailing.

Results from the parking interview survey reveal that about 46% of parkers walk to their destination or from their origin for less than three (3) minutes while 11% walk for more than seven (7) minutes. Generally speaking, more than three-quarters of the drivers park within a walking distance of 400 metres.

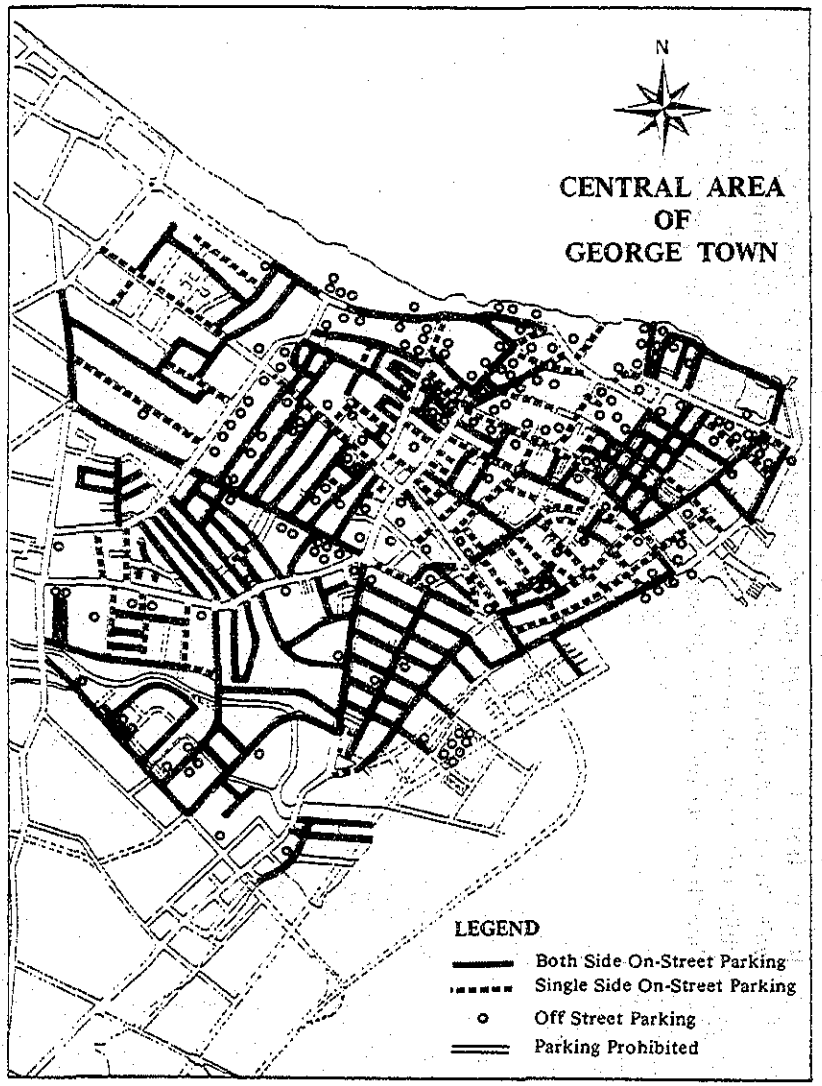


Figure 2.6.1 : Existing Parking Facilities in the Central Area of George Town

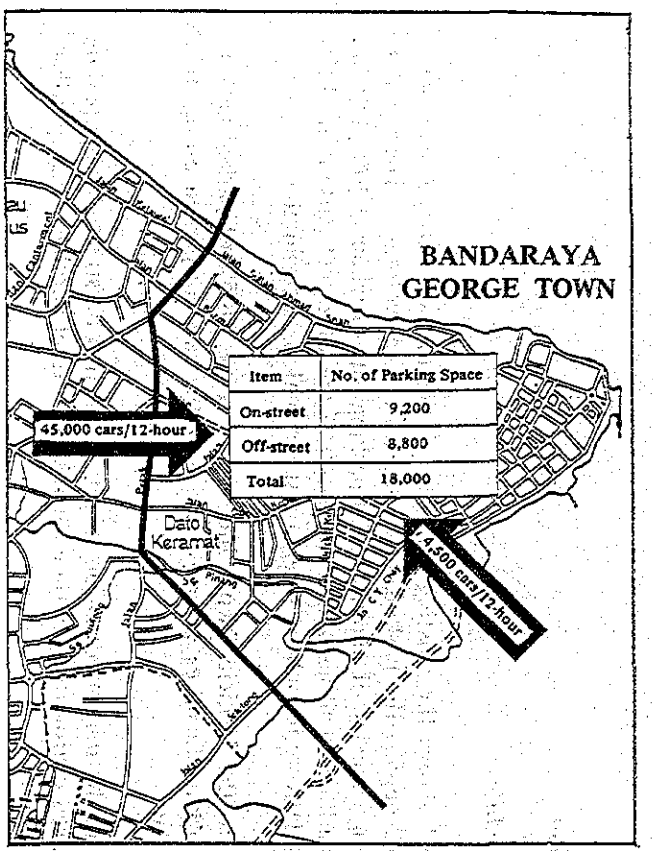


Figure 2.6.2 : Parking Space and Inflow Car Volume

B. Parking Demand Characteristics

Figure 2.6.3 shows the estimated hourly variation of parking demand by car trips attracted into the Central Area. The peak hour parking demand is 16,100 beginning from 10.00 am. This implies that the overall parking demand can be satisfied by the existing total parking capacity in the Central Area. However, a more detail analysis into the supply and demand of parking condition in each specific area reveals that there is some disparity in the parking supply and demand situation as shown in Figure 2.6.4.

For example, in the Central Business District (CBD), the area boxed by Pitt Street, Light Street, Beach Street and Chulia Street shows a parking demand which is more than three (3) times the available capacity. Another commercial area in the vicinity of Campbell Street and Kimberley Street also shows a parking demand which is about three (3) times the available capacity. The commercial area between Beach Street and Weld Quay has a parking supply deficiency ranging from between 14% to 80% at peak hour. However, in other areas the utilisation rate of parking facilities at peak hour varies from 18% to 80%.

Therefore, the issue which is clearly seen here is the need to encourage a more efficient utilisation of existing parking facilities and at the same time to increase the supply of off-street parking facilities in the CBD.

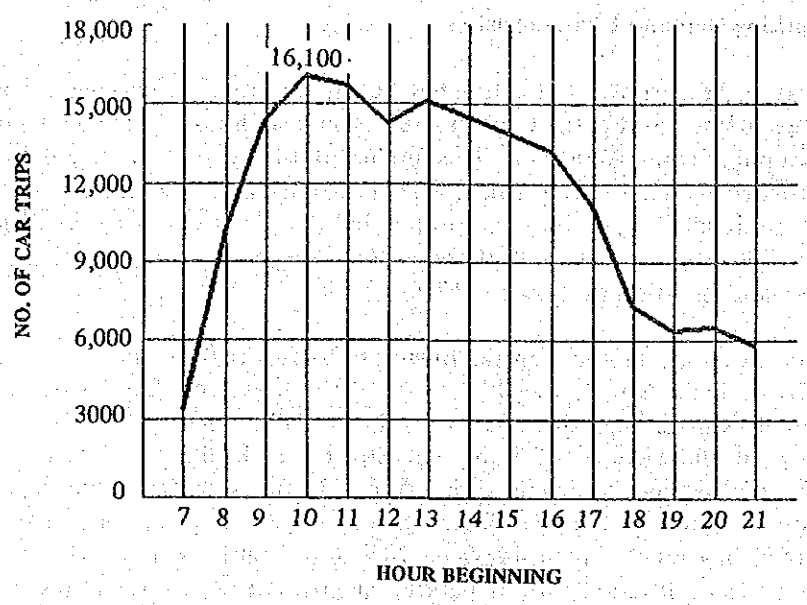


Figure 2.6.3 : Hourly Demand of Parking by Car Trips Attracted into Central Area of George Town

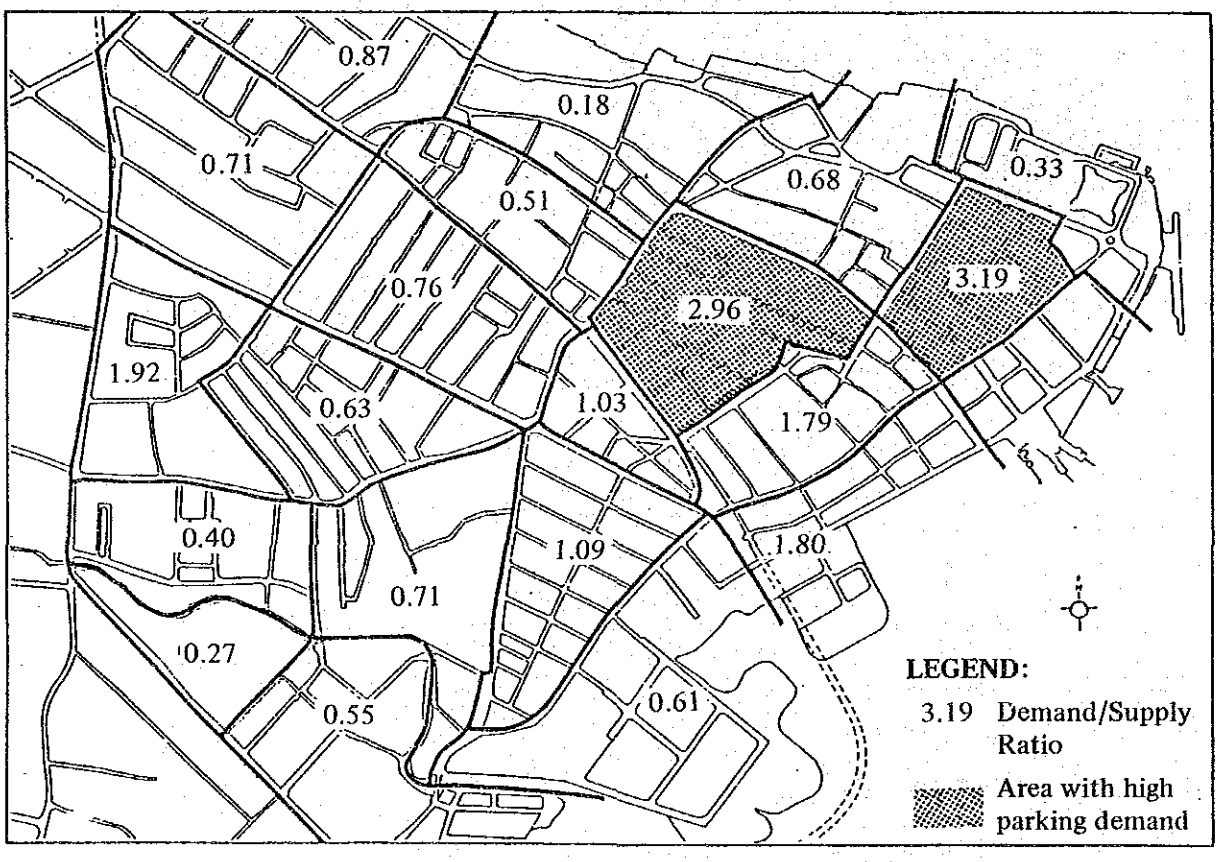


Figure 2.6.4 : Existing Parking Situation (Demand/Supply Ratio)

2.6.2 Problems on Parking Condition

1. Imbalance in the Use of Parking Areas in Specific Areas

The average utilization rate varies from 23.4% to 99.3% depending on the landuse in that area. Business and commercial area utilization rates are higher than that of other areas. However, according to the Parking Interview Survey results, approximately 18% of the drivers have to walk more than 5 minutes to their destinations from their parked vehicles. According to JICA's report (Technical Report 06) in 1979, only 7% of the drivers had to walk more than 5 minutes to their destinations. In short, walking distance from the parked vehicle to the respective destination tends to increase yearly.

2. Illegal Parking and Stopping

Kerbside parking and on-street waiting vehicles (especially on a busy roadway) reduce the effectiveness of the carriageway's width. This creates not only inconvenience to the road users but also causes roadway congestion. For instance, loading and unloading of merchandise actively take place along the commercial area of Beach Street. Such activities pose a hazardous problem to the traffic movement.

3.0 TRAFFIC DEMAND PROJECTION AND FUTURE TRAFFIC SITUATION UNDER DO–NOTHING CASE

3.1 General

Traffic demand projection in the 'Do-Nothing' situation is to simulate the future traffic demand assuming that no improvement to the existing transportation system is undertaken. Such simulation provides some information or controls in formulating the future Transportation System Management Plan.

In this section, the procedure for the traffic projection is outlined first followed by the forecasted transport conditions in the 'Do-Nothing' case. Simultaneously, the future transport management related problems and issues are identified.

3.2 Procedure for the Traffic Projection

Traffic demand data were obtained from the Vehicle Owner Interview Survey (VOIS). The conceptual procedure for the traffic projection used in this study is illustrated in Figure 3.2.1, which involves five main steps.

3.2.1 Establishment of a Traffic Projection Framework

The frameworks for the traffic projection are as follows :

(1) Population, Household Number and Income, Vehicle Ownership, etc.

(2) Population and Employee Distribution in each zone.

The forecast of these frameworks (exclusive of vehicle number) is mainly based on the Penang Island Structure Plan (PISP) data. The vehicle number is forecasted in this study.

3.2.2 Estimation of Trip Production

Estimation of the trip production is based on the unit trip production of each vehicle type derived from the home interviews in the Vehicle Owner Interview Survey (VOIS).

The traffic volume does not necessarily increase in linear proportion to the increased number of vehicles. Inadvertently, the number of vehicles per household will increase in the future with the increasing household income. As a result, the number of trips per vehicle will decrease inevitably. For instance, the unit trip production per private car was 3.98 trips per day in 1979 as compared to 3.78 trips per day in 1986. The decrement of the unit trip production per car is caused by an increment of car ownership since 1979.

3.2.3 Estimation of Trip Generation and Attraction in each Zone

Total trip production in the Study Area is sub-divided into trip generation and attraction in each small zone.

The methodology involved refers to the usage of the regression equation which is derived from the Vehicle Owner Interview Survey.

The variables used in the regression equation are primarily the sizes of population and employee in each study zone obtained from the PISP data and the VOIS data.

3.2.4 Forecasting of Trip Distribution

Estimation of the trip distribution is based on the Present Pattern Method which uses the growth rate of the trip generation and attraction of each small zone.

In this manner, the Origin-Destination Table (O–D Table) by each vehicle type is obtained.

3.2.5 Traffic Assignment on Road Network

Traffic assignment is the process of finding the path which is taken by a driver, and the forecast of the traffic volume along a particular section of a road.

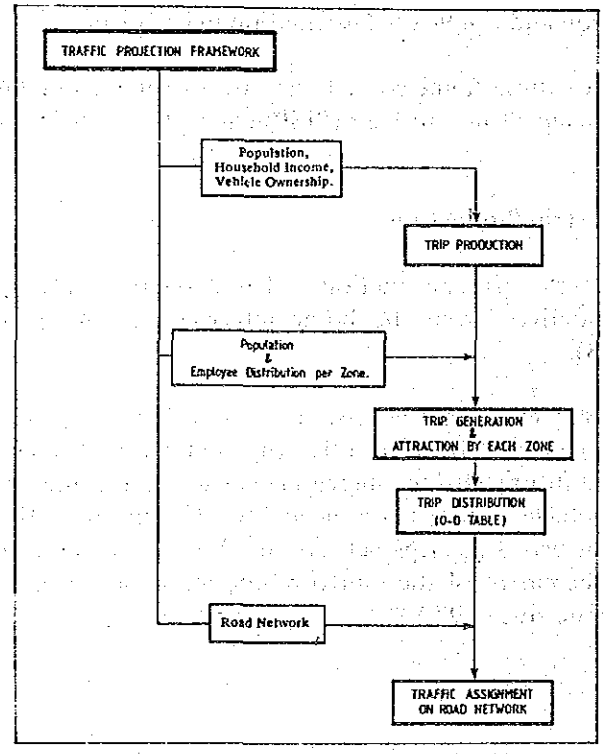


Figure 3.2.1 : Traffic Projection Flow Chart

3.3 Traffic Projection Framework

3.3.1 Economic Framework

A. Gross Domestic Product

The economic framework serves as a premise in forecasting the traffic projection framework.

Malaysia sustained a moderate economic growth between 1980–1984 at about 6.5% per annum. Growth between 1984 and 1985, however, has dropped drastically to only 2.8%, due to the world economic recession.

Table 3.3.1 shows the gross domestic product by industry of origin in 1985 and 1990.

The economy in the country is projected at 5.0% per annum under the Fifth Malaysia Plan. To provide an impetus to the economy growth rate, development policies and strategies and a more efficient utilization of the resources in the country would have to be adopted.

In Penang State, the economic growth rate between 1981–85 was 4.4% per annum as compared to the national annual average of 5.8%. Under the Fifth Malaysia Plan, its growth rate is expected at 4.9% per annum.

Table 3.3.1 : Gross Domestic Product by Industry of Origin, 1985 and 1990 ($ million in 1978 prices)

	Malaysia				Penang State			
	1985	1990	Average annual growth rate (%)		1985	1990	Average annual growth rate (%)	
			1981–85	1986–90			1981–85	1986–90
Primary	18,052	20,702	4.2	2.8	249	252	0.7	0.2
Secondary	14,405	19,509	5.5	6.3	1,856	2,468	2.8	5.7
Tertiary	26,138	34,982	7.9	6.0	2,178	2,759	6.0	4.8
GDP at purchaser's Value	59,344	75,599	5.8	5.0	4,325	5,493	4.4	4.9
Per Capita GDP ($)	3,758	4,229	3.1	2.4	4,120	4,848	2.5	3.3

Source : Fifth Malaysia Plan 1986–1990.

B. Household Income

It is predicted and assumed that there will be a moderate growth in labour productivity of about 3.5% per annum over 1980 to 2000 and income growth will be fairly uniform across all income categories.

The expected household income distribution pattern in the years 1990 and 2000 under the uniform growth assumption and the final adjusted household income distribution trend based on the above assumption is shown in Table 3.3.2.

Table 3.3.2 : Projected Household Income Distribution, Penang Island (1983–2000)

Monthly Household Income	Year		(a) uniform growth assumption				(b) likely pattern	
			2.4% p.a.		4.4% p.a.		3.4% p.a.	
	1976	1983	1990	2000	1990	2000	1990	2000
below $500	52	30	22	13	20	10	22	12
$ 500–1000	27	32	34	31	35	26	33	25
$1000–1500	9	12	12	18	12	21	14	22
$1500–2000	5	5	8	8	7	8	8	10
$2000–3000	–	7	7	9	8	11	7	11
$3000–4000	7	6	5	5	5	6	5	5
$4000+	–	8	12	16	13	18	11	15
Total	100	100	100	100	100	100	100	100
Mean Income	774	1,335	1,443	1,823	1,590	2,214	1,520	2,020

Source : PISP

3.3.2 Population Framework

A. Population Targets and Distribution in the Study Area

The procedure used in establishing the future population framework for the Study Area is based on the population targets set by the Penang Island Structure Plan (PISP) to the years 1990 and 2000. Table 3.3.3 illustrates the future population. The 1986 population is obtained through an interpolation procedure.

Table 3.3.3 : Future Population

Area	Year				Average Annual Growth Rate (%)		
	1980[1]	1986[2]	1990[1]	2000[1]	1980–90	1980–2000	1990–2000
Penang Island	489,500	535,200	568,000	667,400	1.50	1.56	1.63
Study Area	404,100	437,200	460,900	517,600	1.32	1.25	1.17
George Town	260,200	256,800	254,600	283,500	–0.22	0.43	1.08

Note : 1. Penang Island Structure Plan
2. Study Team's modification based on Structure Plan

B. Future Demographic Characteristics

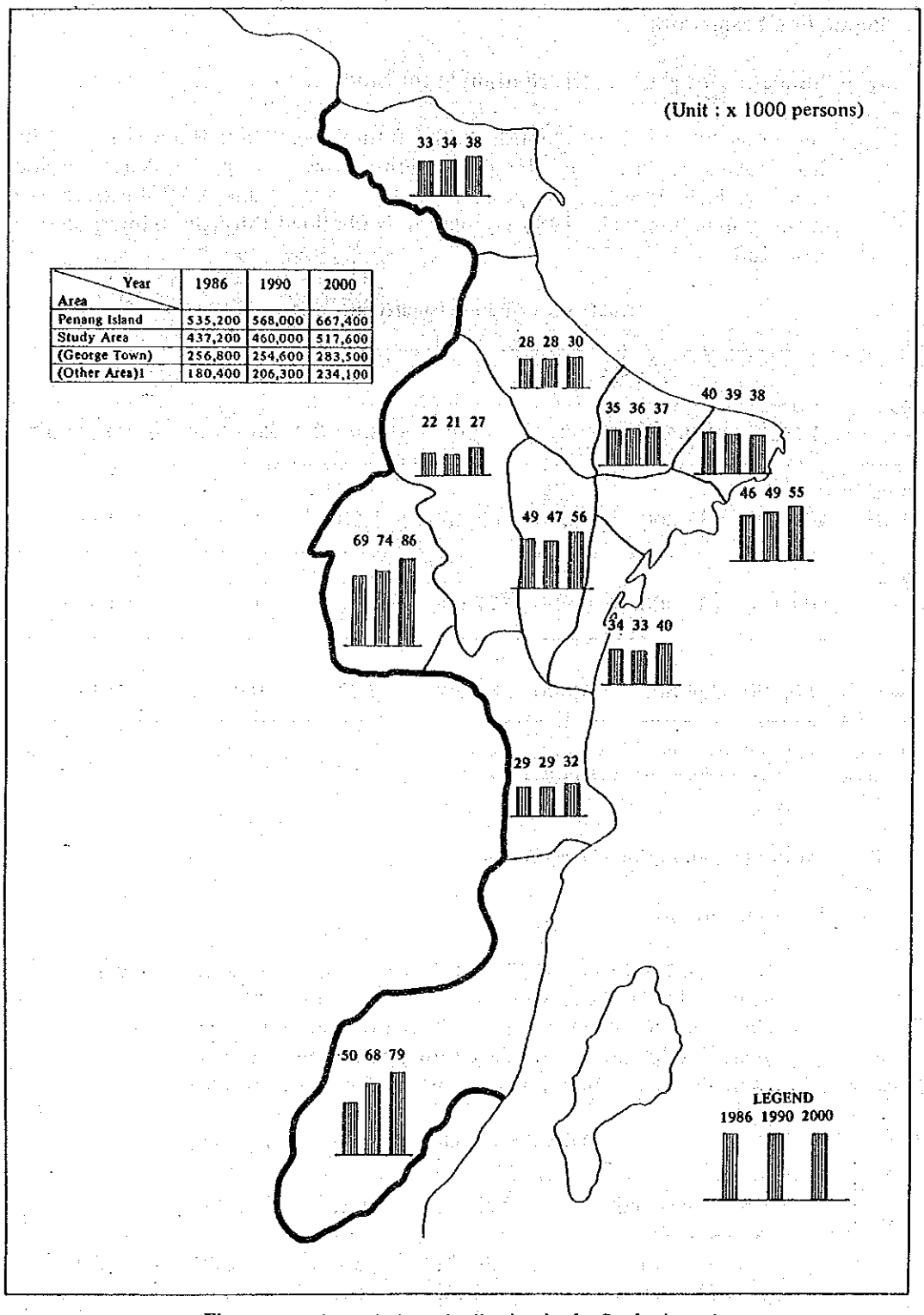
1. Age Group

Based on the Structure Plan, it appears that the age group category for 60 years old and above will increase slightly from 1986 to the year 2000. However, the other categories show a very nominal change for each target year. Table 3.3.4 shows the future population by age group. Figure 3.3.1 presents the future population distribution in the Study Area.

Table 3.3.4 : Future Population by Age Group

Age Group	1980	1986	1990	2000
0 – 14	30.7%	30.4%	30.2%	29.4%
15 – 59	61.9%	61.6%	61.4%	61.5%
60 and above	7.4%	8.0%	8.4%	9.1%
Total	100.0%	100.0%	100.0%	100.0%

Source : Penang Island Structure Plan (PISP).



Area \ Year	1986	1990	2000
Penang Island	535,200	568,000	667,400
Study Area	437,200	460,000	517,600
(George Town)	256,800	254,600	283,500
(Other Area)1	180,400	206,300	234,100

Figure 3.3.1 : Population Distribution in the Study Area

2. Household Size

Changing social phenomena and life style has resulted in a decline of household size. In the Study Area, the household size declines from 5.6 pph (persons per household) in 1986 to 5.4 pph in 1990 and 5.0 pph in 2000. Table 3.3.5 depicts the household size.

Table 3.3.5 : Household Size

		1980	1986	1990	2000
Penang Island	Household Size	5.8	5.6	5.3	4.8
	Population	489,500	535,200	568,000	667,000
	Household	84,900	95,600	107,200	139,000
	Housing Unit	73,600		102,600	136,500
Study Area	Household Size	5.9	5.6	5.4	5.0
	Population	404,100	437,200	460,900	517,600
	Household	68,500	78,100	85,400	103,500
George Town	Household Size	5.9	5.7	5.5	5.1
	Population	260,200	256,800	254,600	283,500
	Household	43,900	45,100	46,300	55,600
	Housing Unit	35,400		38,800	45,900

Note : 1. Figures in the year 1980 are based on the National Census and PISP.

2. Number of housing unit is projected by PISP.

3. Number of household size is estimated by the Study Team based on relationship between population and housing unit.

3.3.3 Employment Framework

Table 3.3.6 shows the projected sectoral pattern of employment in Penang Island.

The total number of employment in Penang Island is projected to increase to about 216,000 in 1990 and 260,000 by the year 2000.

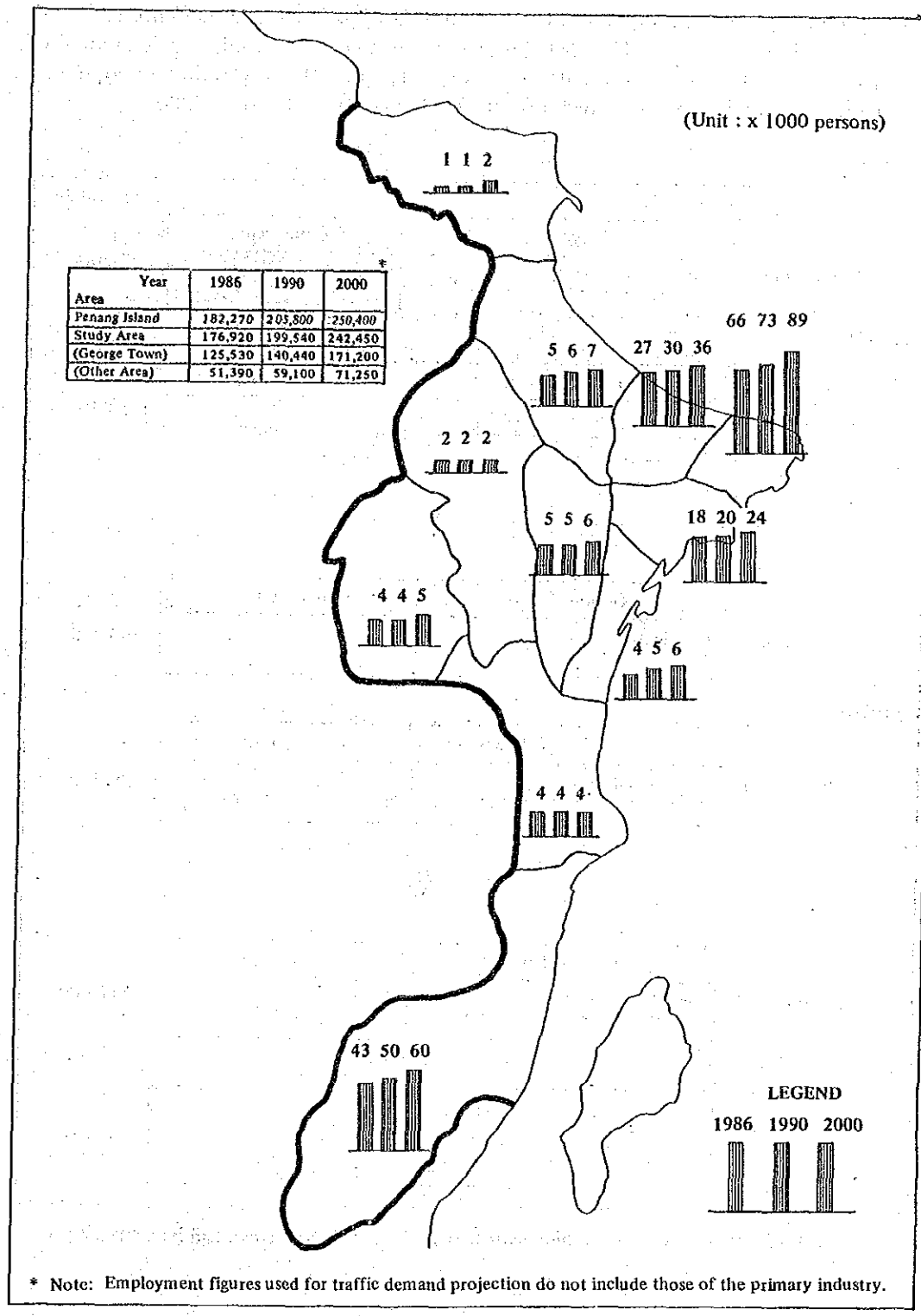
The percentage of white collar jobs is projected to increase, whereas the marketing sector will decline slightly as well as the agricultural sector. However, the percentage in the production-related field will increase.

Table 3.3.6 : Projected Sectoral Pattern of Employment, Penang Island (1980 – 2000)

	1980		1990		2000	
Employment Sector	**No.**	**%**	**No.**	**%**	**No.**	**%**
Primary	13,200	7.0	10,200	4.7	9,600	3.7
Manufacturing	49,100	27.0	64,100	29.7	78,000	30.0
Construction	10,900	6	12,200	5.7	13,800	5.3
Transport	8,000	4	10,200	4.7	13,800	5.3
Wholesale, Retail, Hotel & Catering	41,100	23	48,900	22.6	58,700	22.6
Wholesale & Retail	(27,900)	(16)	(33,100)	(15.3)	(39,500)	(15.2)
Hotel & Catering	(13,200)	(7)	(15,800)	(7.3)	(19,200)	(7.4)
Finance, Insurance, Real Estate & Business Service	6,300	4	12,200	5.7	18,200	7.0
Govt. & Community Services & Utilities	37,700	21	41,700	19.3	48,100	18.5
Personal & other Services	13,800	8	16,500	7.6	19,800	7.6
Total	181,100	100%	216,000	100%	260,000	100%

Source: PISP

Figure 3.3.2 shows the estimated future number of employment in the Study Area based on the PISP (exclusive of the employees in the primary industry sector). The number of employment in the Study Area will increase to approximately 242,000 by the year 2000 from 177,000 in 1986.



Year / Area	1986	1990	2000
Penang Island	182,270	205,800	250,400
Study Area	176,920	199,540	242,450
(George Town)	125,530	140,440	171,200
(Other Area)	51,390	59,100	71,250

* Note: Employment figures used for traffic demand projection do not include those of the primary industry.

Figure 3.3.2 : Employee Distribution in Study Area (Exclusive of the Primary Sector)

The population and employment distribution in George Town and its Central Area is shown in Figure 3.3.3. The distribution shows that the population is gradually spreading towards the outer part of George Town. However, the employment distribution trend does not reflect any subtle changes from 1986 to 2000.

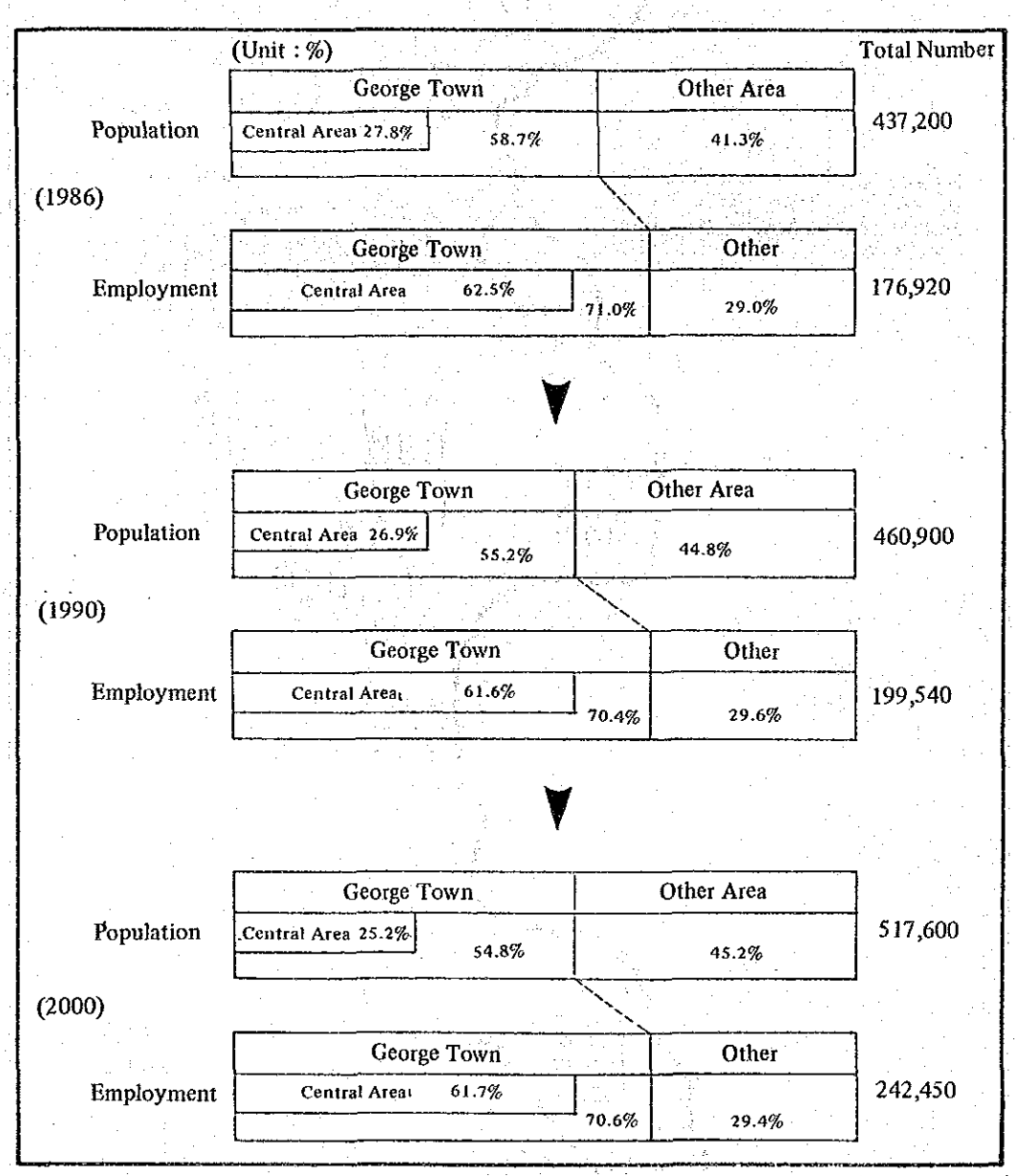


Figure 3.3.3 : Population and Employment Distribution in George Town and its Central Area

3.3.4 Vehicle Ownerships

Vehicle ownerships in Penang State which are registered with the RIMV show a rapid growth since 1970. Table 3.3.7 illustrates the registered vehicle number in Penang State.

Table 3.3.7 : Registered Vehicle Number in Penang State

	Year						Average Annual Growth Rate (%)		
	1970	1975	1979	1981	1983	1985	1985–1970	1985–1975	1985–1981
Car	28.3	45.6	68.7	83.4	100.1	115.0	9.8	9.7	8.4
Lorry	5.5	8.5	12.1	14.5	16.9	19.4	8.8	8.6	7.6
Taxi	0.3	0.4	0.5	0.8	1.0	1.0	8.4	9.6	5.7
Bus	0.5	0.8	1.1	1.3	1.5	1.6	8.1	7.2	5.3
Sub-total	34.6	55.2	82.4	100.0	119.5	137.0	9.6	9.5	8.2
M/C	47.4	89.3	129.9	161.6	212.4	251.0	11.8	10.9	11.6
Total	82.0	144.5	212.3	261.6	331.9	388.0	10.9	10.4	10.4

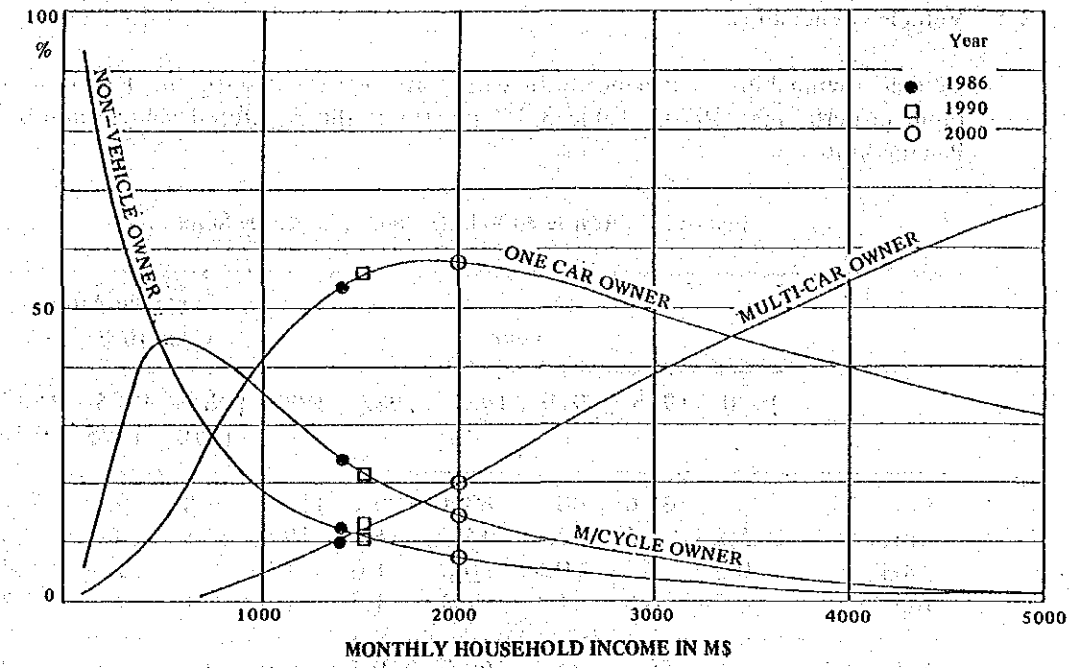
Unit : x 1000 vehicles

Note : The number of vehicles given against the state and vehicle types are cumulative totals from previous years.

source : RIMV & Year Book of Transort Statistics, Malaysia

Using the registered vehicle number, the estimated car and motorcycle ownerships per household in the Study Area were 1.16 and 1.79 respectively in 1985. Ownership rates in the Study Area were higher as compared to the Klang Valley's, 0.50 and 0.54 respectively in 1985, though their mean monthly household incomes were almost similar. Moreover, from the analysis of the number of road tax disks issued, car and motorcycle number registered with the RIMV appeared to be 30% higher than the current total number on the road.

Therefore, the study team estimated the number of car and motorcycles both existing and future, based on relationship between Vehicle Ownership and Household Income. This relationship was established in the Klang Valley Transportation Study (JICA 1985). Figure 3.3.4 shows the Klang Valley's vehicle ownership curves in 1985.



Source: HIS, Klang Valley Transportation Study, 1986

Figure 3.3.4 : Vehicle Ownership Curves, Klang Valley, 1985

Pertaining to the other vehicle type such as lorry, taxi, van, and bus, the following premise is set in projecting their future number.

The average annual growth rate for these vehicles between 1981 and 1985 was obtained from the registration records at the RIMV. Assuming a similar growth rate between 1986 and 1990, the vehicle number in 1986 and 1990 can be determined. However, the annual growth rate between 1990 and 2000 is set to be approximately 75% of the 1981 to 1985 growth rate.

The result of the estimation is shown in Figure 3.3.5 and Table 3.3.8. It appears that beyond the year 1990, the car ownerships show a rapid growth rate as compared with the motorcycle, primarily due to an increase in the mean monthly household income, hence the number of cars will be very close to the number of motorcycles in the year 2000.

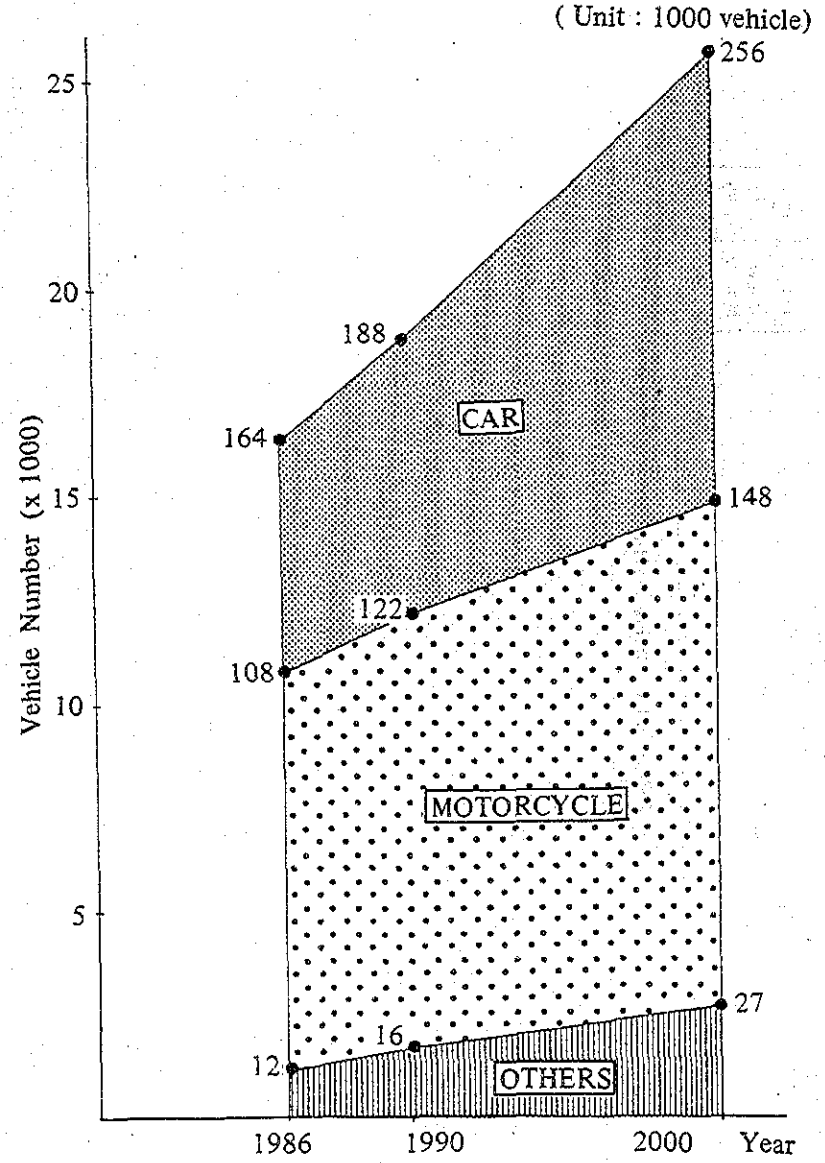


Figure 3.3.5. Trend of Vehicle Number

Table 3.3.8 : Vehicle and Population Number

		1986	1990	2000	Average Annual Growth Rate 1986-1990	Average Annual Growth Rate 1990-2000
Car	Private	53,500	63,000	102,100	4.2	4.9
	Company	2,940	3,400	5,400	4.2	4.9
	Sub-Total	56,440	66,400	107,500	4.2	4.9
M/c	Private	90,400	100,300	115,300	2.6	1.4
	Company	4,760	5,300	6,100	2.6	1.4
	Sub-Total	95,160	105,600	121,400	2.6	1.4
Taxi		750	940	1,440	5.7	4.3
Van		1,580	2,120	3,690	7.6	5.7
Lorry		8,560	11,480	19,990	7.6	5.7
Bus	Schedule	210	260	390	5.3	4.0
	Other	840	1,040	1,540	5.3	4.0
	Sub-Total	1,050	1,300	1,930	5.3	4.0
Total		163,540	187,840	255,950	3.5	3.1
Population		437,200	460,900	517,600	1.3	1.2
Vehicle/ Population		0.37	0.41	0.49		

Note : Figures modified by the Study Team from the analysis of the number of road tax disks issued.

3.4 Future O–D Distribution

Estimated future O–D distribution is based on the future population/employment distribution, future vehicle ownerships, and on the present O–D table.

Figure 3.4.1 illustrates the major traffic flow in Penang. The most frequent number of trips occur within George Town. In the years 1986, 1990, and 2000 the trips made are approximately 280,200, 326,000 and 462,900 pcu/day respectively.

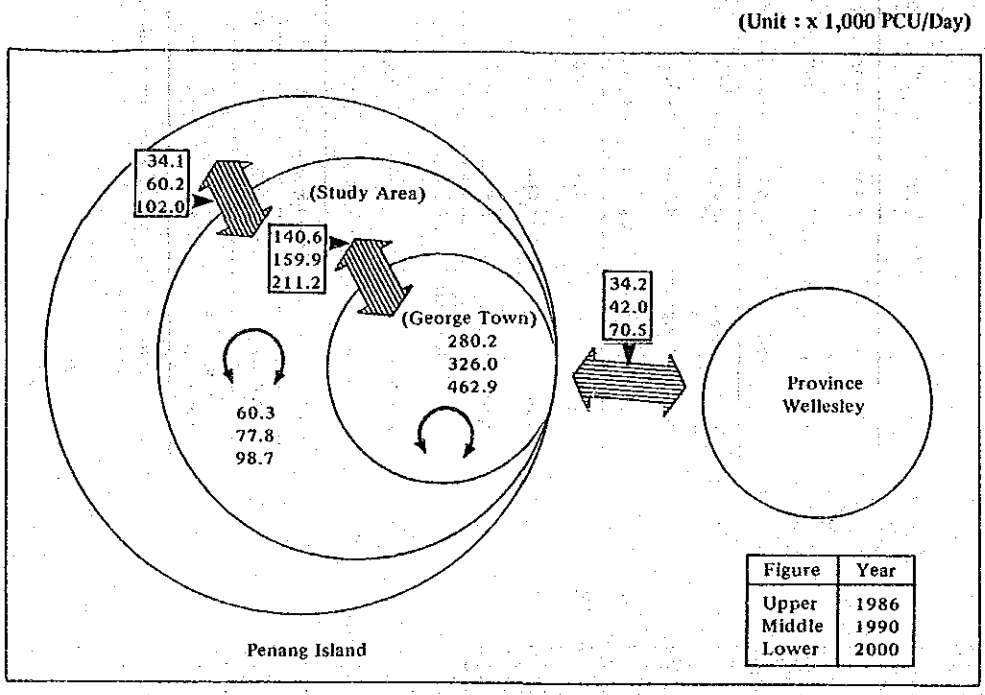


Figure 3.4.1 : Major Traffic Flow in Penang

3.4.1 Future Trip Production Pattern

Figure 3.4.2 illustrates the future trip production pattern in 1986, 1990 and 2000 (in terms of PCU).

The number of internal trips per day is estimated to be 481,100 in 1986, 563,000 in 1990 and 772,800 in 2000. Thus, the growth rates between 1986–1990 and 1990–2000 are 4.0% and 3.2% per annum respectively.

Growth rates of 10.5% and 5.2% are forecasted for the period between 1986–1990 and 1990–2000 for external trip.

In the case of through trip, it is estimated to increase at a rate of 18.4% and 10.3% between 1986–1990 and 1990–2000 respectively.

Generally, the total trip production was 553,100 in 1986 which will then increase at a rate of 5.1% per year to 673,500 in 1990. However, the annual rate will decrease to 3.7% between 1990–2000 whereby there will be 965,900 trips per day in 2000.

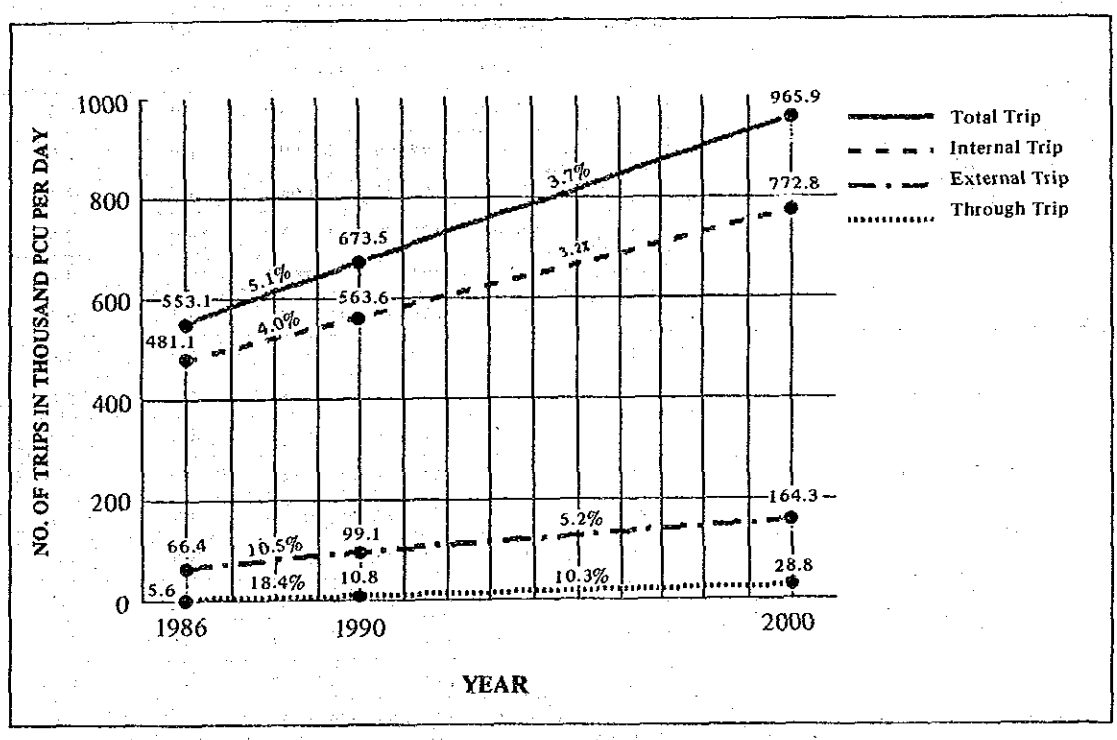


Figure 3.4.2 : Future Trip Production Pattern (1986, 1990, 2000)

3.4.2 Future Trip Generation and Attraction

Table 3.4.1 shows the present and future vehicular trip generation and attraction for all purposes by traffic zones in 1986, 1990 and 2000.

Table 3.4.1 : Present and Future Trip Generation and Attraction (1986, 1990 and 2000)

Unit : PCU

Zone Area			Large Zone Code	1986	1990	2000	Average Annual Growth Rate	
							1990/1986	2000/1990
Study Area	George Town	Central Area	0	227708	257700	355149	3.1	3.3
			1	124890	144125	191182	3.6	2.9
			2	71797	105879	171830	10.1	5.0
			Sub-total	424395	507704	718161	4.7	3.5
		Outer Part of Central Area	3	96434	105653	135048	2.4	2.5
			4	106077	118779	150904	2.9	2.4
			5	56222	70196	135923	5.7	6.8
			6	55852	62675	80131	2.9	2.5
			Sub-total	314585	357303	502006	3.3	3.5
				738980	865007	1220167	4.0	3.5
	Outer Part of George Town		7	54540	60920	78934	2.9	2.6
			8	87353	94306	126002	1.9	2.9
			9	58155	69885	86049	4.7	2.1
			10	90561	136679	193674	10.9	3.5
			Sub-total	290609	361790	484659	5.5	3.0
				1029589	1226797	1704826	4.4	3.3
Outer Part of Study Area	Outer Part of Study Area in Penang Island		11	9952	12197	18807	5.3	4.4
			12	18868	23494	41352	5.7	5.8
			13	14179	16628	26372	4.0	4.7
			14	0	26275	63546	–	9.2
			Sub-total	42999	78594	150077	5.1*	6.7
	Outer Part of Penang Island	Ferry	15	20245	24499	28335	4.9	1.5
		Penang Bridge	16	15329	17716	42662	3.8	9.2
			Sub-total	35574	42215	70997	4.4	5.3
				78573	120809	221074	4.7*	6.2
Grand Total				1108162	1347606	1925900	4.4*	3.6

Note : * Excluding Zone 14

Figure 3.4.3 shows the future daily traffic volume across the straits by ferry and bridge projected on the assumptions that ferry service condition and toll charges do not undergo major change. The share of bridge usage is expected to increase from 41.2% in 1986 to 60% in 2000.

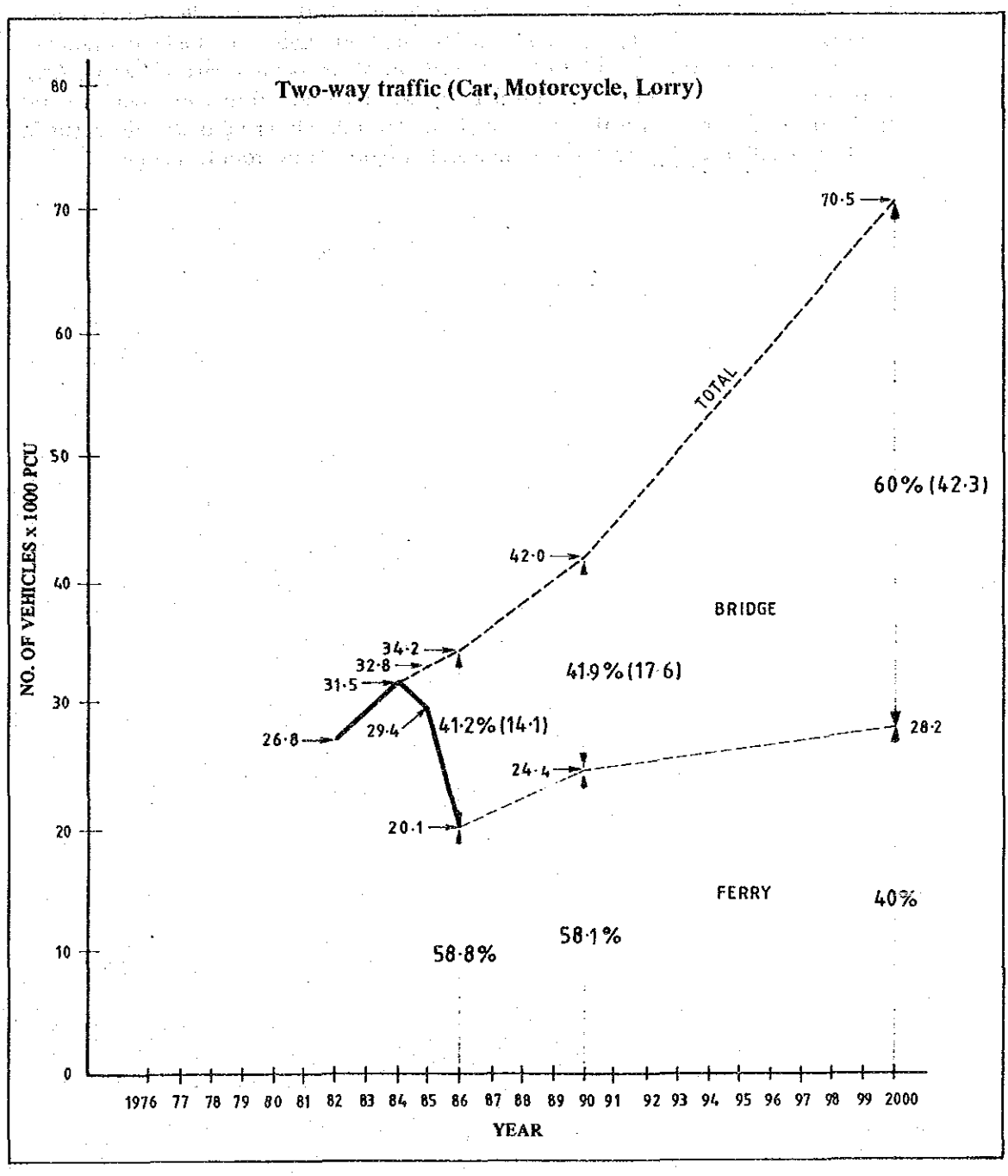


Figure 3.4.3 : Daily Traffic Volume Across the Straits by Ferry & Bridge

3.4.3 Future O–D Distribution Pattern

Table 3.4.2 shows the all vehicles O–D distribution matrix in 1986, 1990 and 2000 whereas the all vehicles O–D distribution pattern in 1990 and 2000 are shown in Figures 3.4.4 and 3.4.5. For clear illustration, only the desire lines with more than 3,000 trips per day are shown.

Compared with the O–D distribution in 1986, the Central Area still has the highest internal trip of 133,900 in 1990 and 191,800 in 2000. Likewise, the largest number of trip movement is projected to be on the Central Area-Outer part of Central Area corridor where the number of trips per day will be 120,800 in 1990 and 168,800 in 2000. In contrast with that in 1986, Zone 14, a developing growth area exists in 1990 and 2000 thereby creates incoming and outgoing trips from this zone.

Table 3.4.2 : Present and Future All Vehicles OD Distribution Matrix (1986, 1990 and 2000)

Unit : PCU

Zone Area	Study Area						Outer Part of Study Area						Trip Generation and Attraction
	George Town		Outer Part of Goerge Town				Outer Part of Study Area in Penang Island				Outer Part of Penang Island		
	Central Area	Outer Part of Central Area									Ferry	Penang Bridge	
Large Zone Code	0,1 & 2	3,4,5 & 6	7	8	9	10	11	12	13	14	15	16	
0, 1 & 2	109,178	105,918	17,316	28,181	14,397	18,281	3,737	3,902	2,163	0	9,445	2,699	424,395
	133,910	120,777	18,890	29,892	16,566	24,167	4,442	4,642	2,296	4,536	11,324	2,958	507,701
	191,840	168,806	25,160	40,461	20,998	33,797	6,397	7,117	2,999	10,622	12,681	6,799	718,161
3,4,5 &6		65,115	13,369	19,739	14,899	14,390	1,907	3,013	1,610	0	4,935	4,675	314,585
		71,299	14,553	20,304	16,744	18,750	2,437	3,859	2,044	3,406	6,000	5,505	357,303
		102,228	18,338	26,173	20,867	25,445	3,677	6,106	2,803	7,620	6,721	12,601	502,006
7			8,059	1,500	822	1,490	2,008	265	31	0	1,136	485	54,540
			9,370	1,613	857	1,551	2,400	319	47	170	1,363	481	60,920
			11,758	2,156	964	1,866	3,597	504	47	321	1,525	1,112	78,934
8				11,468	1,841	3,839	763	4,783	1,578	0	1,293	900	87,353
				12,220	1,881	4,872	909	5,484	1,724	588	1,547	1,032	94,306
				15,807	2,189	6,150	1,368	8,600	2,353	1,178	1,733	2,353	126,002
9					7,242	8,593	162	435	518	0	588	1,416	58,155
					8,137	10,622	196	498	568	3,345	682	1,476	69,885
					9,007	11,842	290	787	780	5,527	764	3,382	86,049
10						15,400	543	2,690	4,024	0	1,814	3,937	90,561
						26,629	641	3,176	4,413	8,118	2,074	4,498	136,679
						36,904	967	5,027	6,033	17,283	2,323	10,272	193,674
11							91	193	56	0	334	67	9,952
							132	274	73	63	472	61	12,197
							294	653	151	174	796	213	18,807
12								507	1,497	0	367	583	18,868
								813	1,953	299	477	801	23,494
								2,037	4,218	855	846	2,897	41,352
13									1,014	0	189	485	14,179
									1,224	204	234	566	16,628
									2,279	501	355	1,768	26,372
14										0	0	0	0
										2,541	227	222	26,275
										9,110	456	903	63,546
15													20,245
													24,499
													28,335
16													15,329
													17,716
													42,662

Note :

Figure	Year
Upper	1986
Middle	1990
Lower	2000

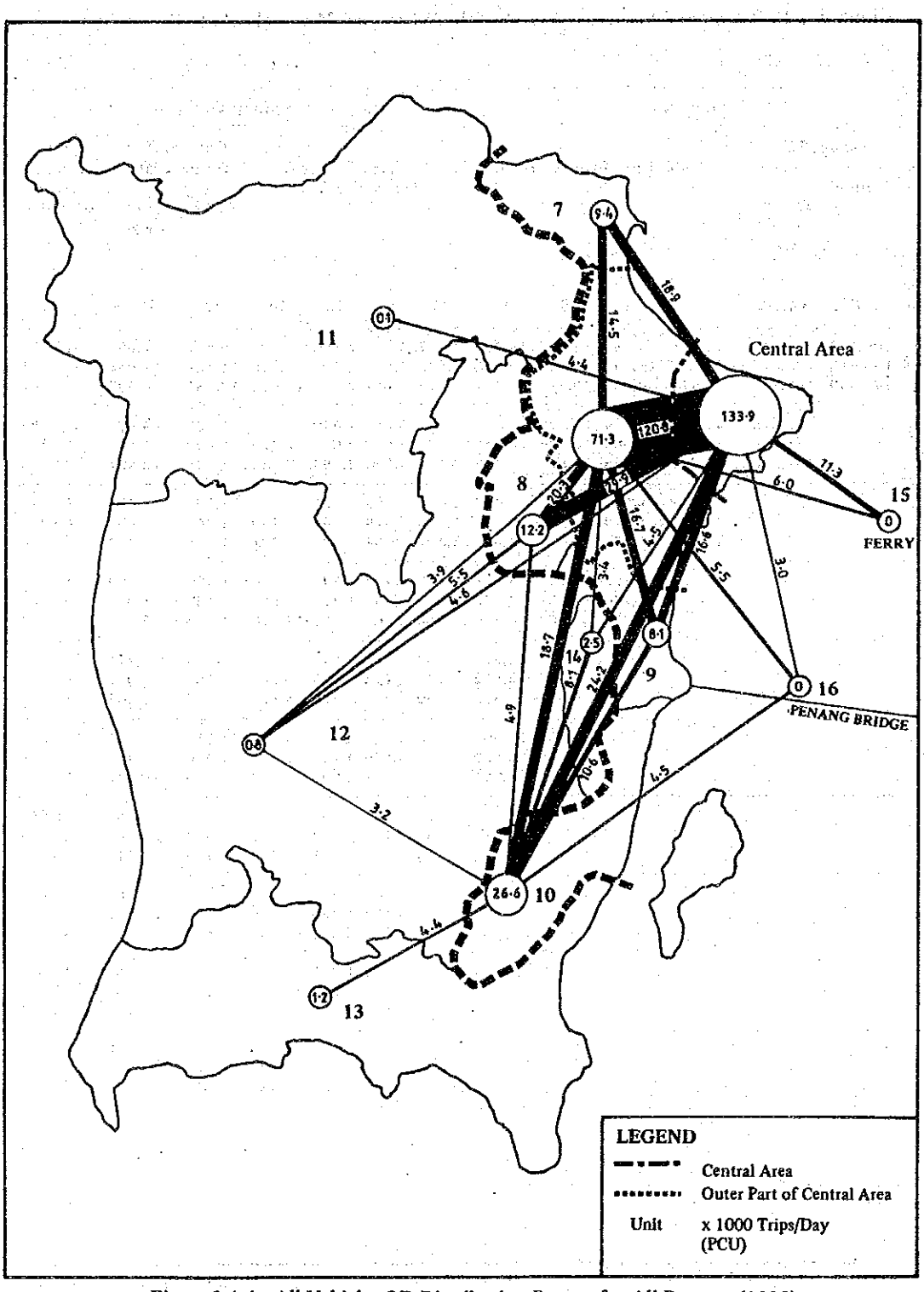


Figure 3.4.4 : All Vehicles OD Distribution Pattern for All Purpose (1990)

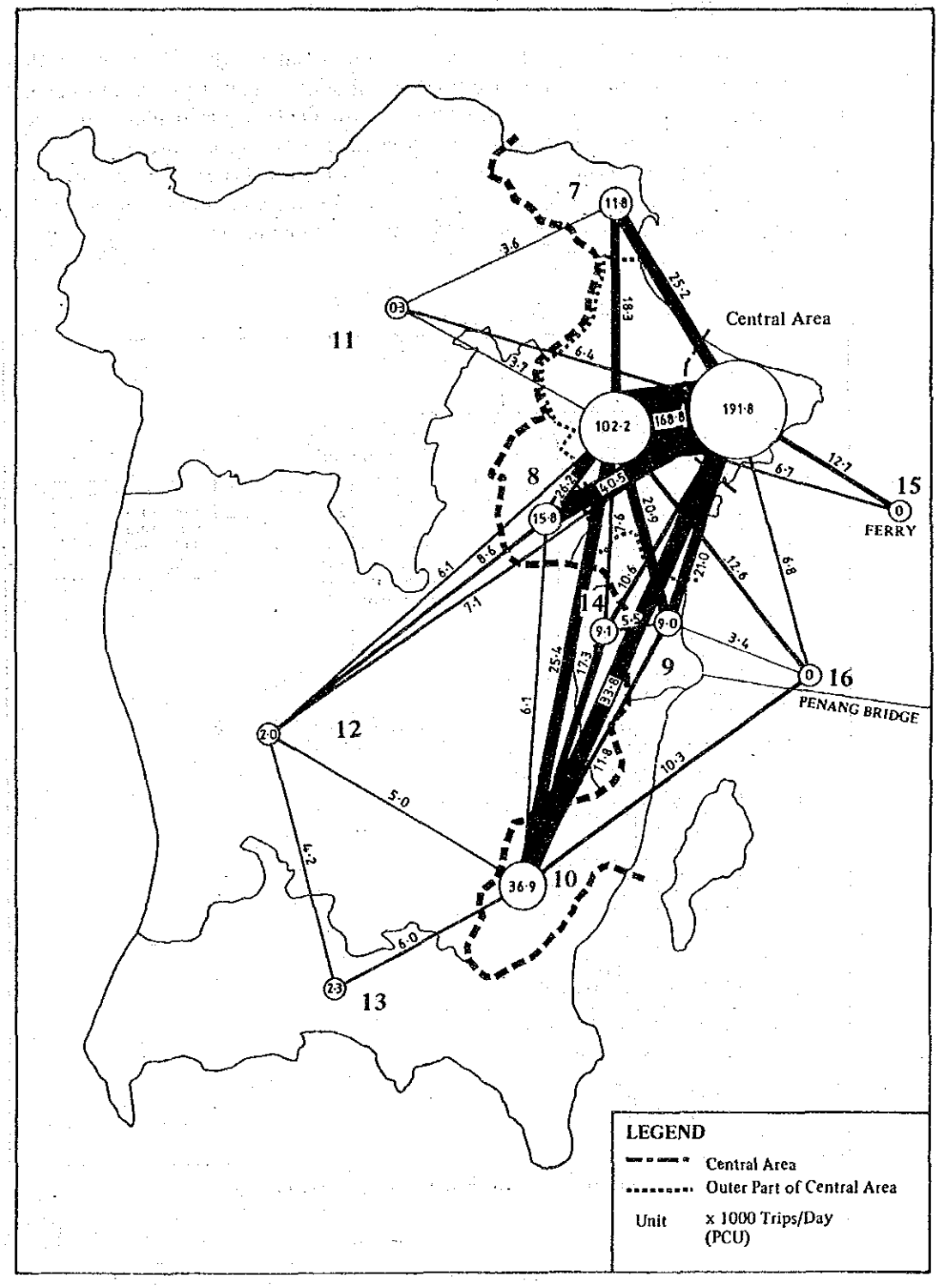


Figure 3.4.5 : All Vehicles OD Distribution Pattern for All Purpose (2000)

3.5 Traffic Assignment

The methodology used for the traffic assignment is called 'All or Nothing Method' with capacity constraint. 'All or Nothing' means assigning all trips from i to j to the shortest path between i and j. In this process, the O–D trip is divided into 5 equal portions, and thus this procedure is repeated 5 times. This procedure will determine the traffic volume on each road. Figure 3.5.1 illustrates the procedure of traffic assignment. The traffic assignment for motor cycles and other vehicles will be executed separately considering their different functional usage.

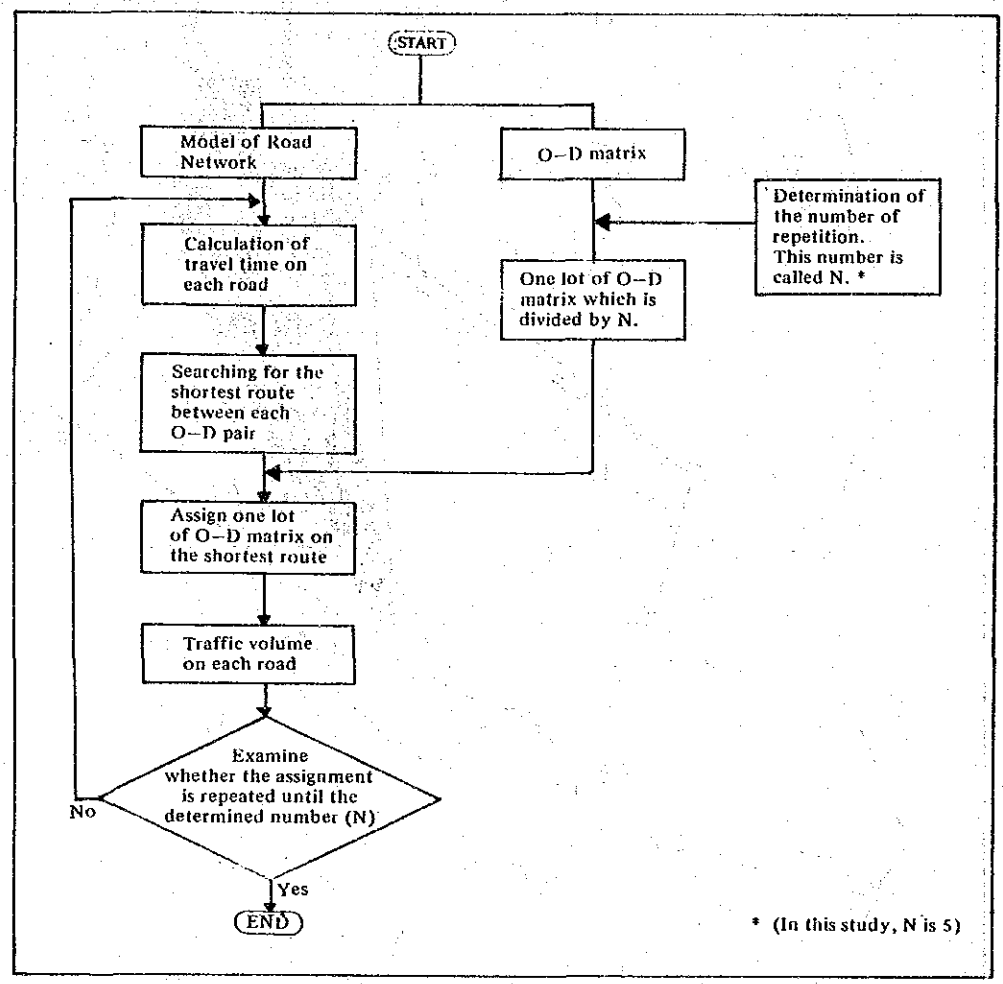


Figure 3.5.1 : Procedure of Traffic Assignment

Figure 3.5.2 and Table 3.5.1 present the Q–V Formula and the average daily traffic capacity respectively used in this study.

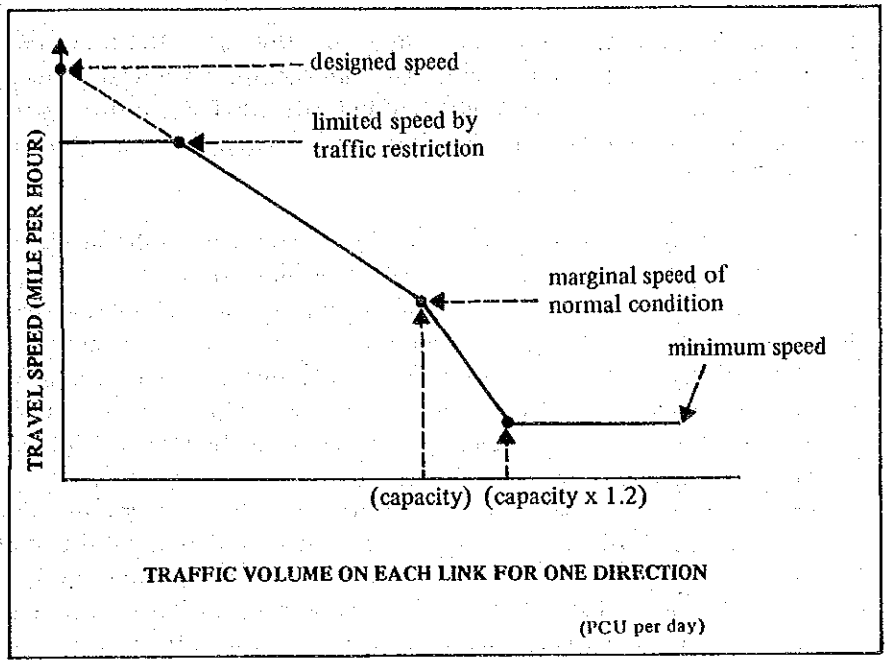


Figure 3.5.2 : (Q – V) Formula Used in Traffic Assignment

Table 3.5.1 : Average Daily Capacity for Both Directions

	No. of lane	2-lane			4-lane		6-lane
	Effective width of carriageway in feet	20'	22'	24'	44'	48'	72'
A	Urban Motorway	–	–	–	–	59,000 11,700 61,700	75,000 11,700 86,700
B	All purpose road with no standing vehicles permitted & negligible cross traffic	16,700 6,700 23,400	18,300 8,300 26,600	20,000 10,000 30,000	36,700 8,300 45,000	40,000 10,000 50,000	60,000 10,000 70,000
C	All purpose street with no restriction by junctions	10,000 5,000 15,000	13,300 6,700 20,000	16,700 6,700 23,400	28,300 6,700 35,000	33,300 8,300 41,600	–
D	All purpose street restricted by junctions	5,000 3,300 8,300	8,300 5,000 13,300	11,700 6,700 18,400	22,500 5,000 27,500	25,000 6,700 31,700	–

Upper : Motorcar (PCU)
Middle : Motorcycle (PCU)
Lower : Total (PCU)

3.6 Forecasting Traffic Conditions Under Do-Nothing Situation in 1990 and 2000

In this section, the OD traffic volumes for 1990 and 2000 are assigned on the existing road network (that is under the Do-Nothing Case which includes on-going projects). These assignment results will indicate what the future traffic conditions will become if no new road project is undertaken and where and how traffic bottlenecks will occur.

Table 3.6.1 shows a summaryof the traffic assignment results in traffic volumes in 1986, 1990 and 2000. In terms of vehicle kilometers taking the value in 1986 as 100, the values for 1990 and 2000 will become 127 and 186 respectively. However the corresponding values of vehicle hours for same years are 100, 140, 252 respectively, that is, compared to the vehicle kilometers, there will be a more drastic increase in vehicle hours. This is a manifestation of increase in travel time due to traffic congestion on the roads. The congestion degree in 1986 is 1.22 which indicates that the existing road capacity has already been exceeded. In 1990, the congestion degree is expected to worsen to 1.35. In the computer simulation, the road capacity established for traffic assignment describes an ideal condition for free flow of traffic. In reality, traffic flow is permissible to some level of congestion degree. Therefore, from the traffic survey results, it can be judged that the established road capacity can actually manage a capacity of 1.2–1.5 time.

That is, under the Do-Nothing case, until the year 1990 it is considered possible to cope with the traffic demand through an efficient use of the existing road network and to undertake only minor road improvements to alleviate some of the traffic bottlenecks. However, by the year 2000, the existing road network will not be able to cope with the demand and new road construction projects would be necessary to increase the overall road capacity.

Table 3.6.1 : Summary of Traffic Assignment in 1986, 1990 and 2000

	Existing	Do-Nothing Case	
	1986	1990	2000
Vehicle Kilometers ('000 PCU Km)	2,485 (100)*	3,157 (127)*	4,630 (186)*
Vehicle Hours ('000 PCU Hr)	104 (100)*	146 (140)*	262 (252)*
Capacity Kilometer ('000 PCU Km)	2,236	2,334	2,334
Average Velocity (Km/Hr)	23.9	21.7	17.6
Congestion Degree	1.22	1.35	1.93

*Growth Index where 1986 value is taken as 100.

Next, looking at the roads in George Town, the traffic flow on each link for 1990 and 2000 is shown in Figures 3.6.1 and 3.6.2 respectively. High concentration of traffic flow is observed on the primary roads, especially on the two Middle and Inner Ring roads (Green Lane and Perak Road) and the three radial roads (Northam Road, Dato Keramat Road and Jelutong Road). Among them, the congestion on Jelutong Road is the most severe.

As for the intersections, heavy concentration of traffic is observed at the intersections of Dato Keramat Road/Perak Road, Ayer Itam Road/Green Lane and Jelutong Road/Green Lane. At the latter two intersections, construction works for grade-separated intersections are on-going and congestion at these two points will be alleviated when these works are completed.

Next, traffic flow pattern indicates that traffic with the same OD avoids the narrow road sections and takes different detours.

For example, from the CBD to Bayan Lepas in the south (and vice versa), traffic seems to avoid the congested Jelutong Road by detouring to Green Lane via Dato Keramat Road or Macalister Road or Burma Road.

This is manifested as a complicated traffic flow which increases the turning movements at the intersections of Macalister Road/Anson Road, Burma Road/ Anson Road and Macalister Road/Perak Road. Various patterns of movements are expected for traffic flow with different OD pairs depending on the time and traffic congestion conditions.

Without having to say, the most complex traffic circulation is observed in the city center around KOMTAR. The road network around KOMTAR including the one-way circulation system is developed for KOMTAR which leads to more concentration of traffic there and by the year 2000 it can be expected that very serious traffic congestion will develop.

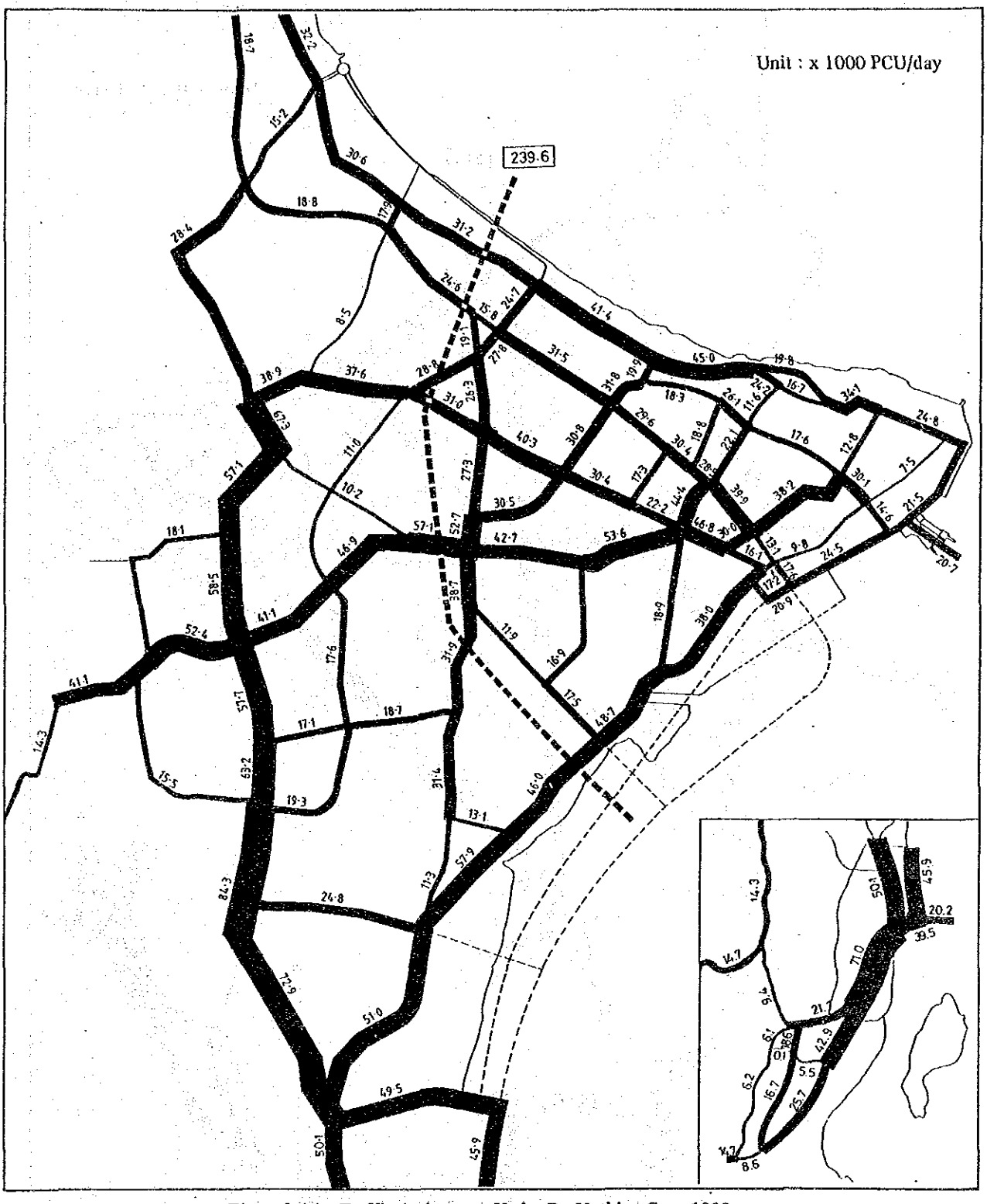


Figure 3.6.1 : Traffic Assignment Under Do-Nothing Case, 1990

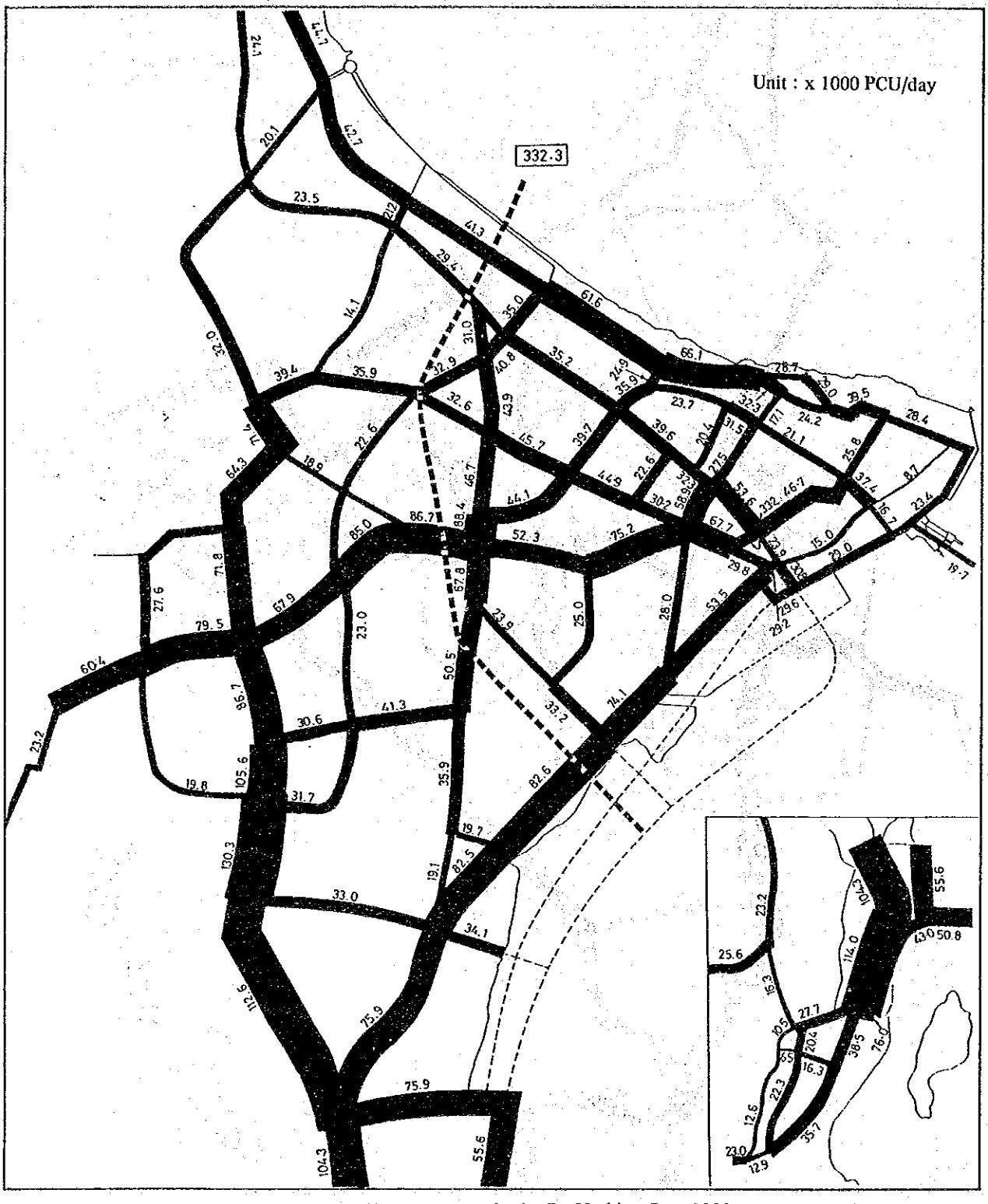


Figure 3.6.2 : Traffic Assignment Under Do-Nothing Case, 2000

3.7 Forecasting Public Transport Demand Under Do-Nothing Situation in 1990 and 2000

Figure 3.7.1 shows the number and composition of vehicles and passengers by transportation mode entering and leaving the Central Area (1986).

As shown in Figure 3.7.1, in the Vehicle Passenger Occupancy Survey (7:00 – 19:00) conducted by the Study Team, out of 343,000 person trips crossing the Central Area Screen Line (both directions) about 23% or 79,900 person trips were made by buses (Stage Bus and Factory and School Bus).

The change to the share of bus users due to increase in private vehicle usage brought about by the increase in private vehicle ownership estimated earlier will be forecasted in this section.

The number of bus users will be forecasted on the basis of the following assumptions :

(1) The increase in person trips moving into and out of the Central Area will be proportionate to the growth rate of employment within the Central Area.

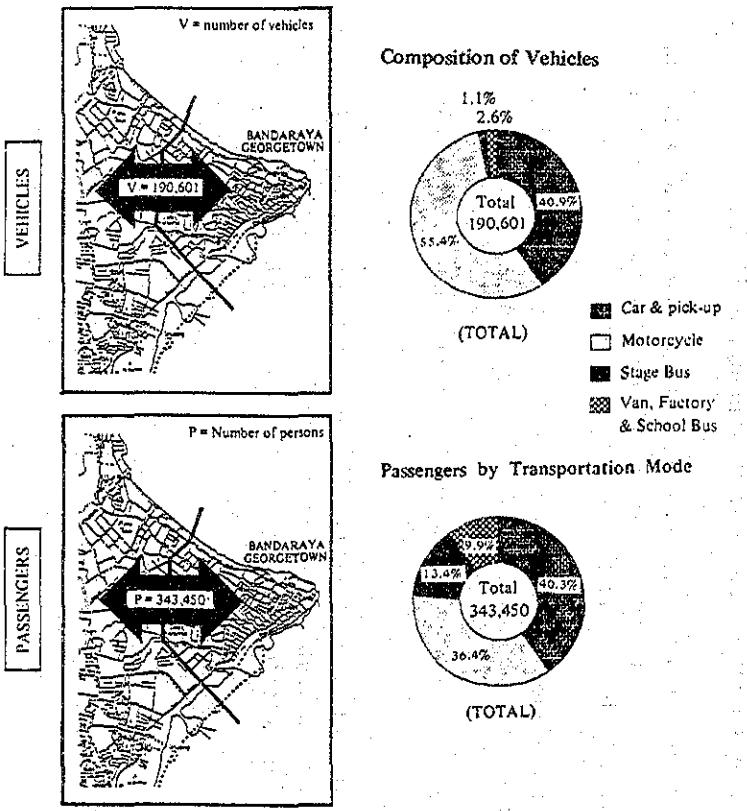
(2) The growth rate of vehicular traffic volume based on the number of car and motorcycle described in section 3.6 will be used.

(3) The occupancy of car and motorcycle will be estimated using the existing observed values adjusted by the rate of decrease in household size.

(4) The number of bus users going into and out of the Central Area will be estimated as the difference between the total number of person trips and the number of person trips by car and motorcycle.

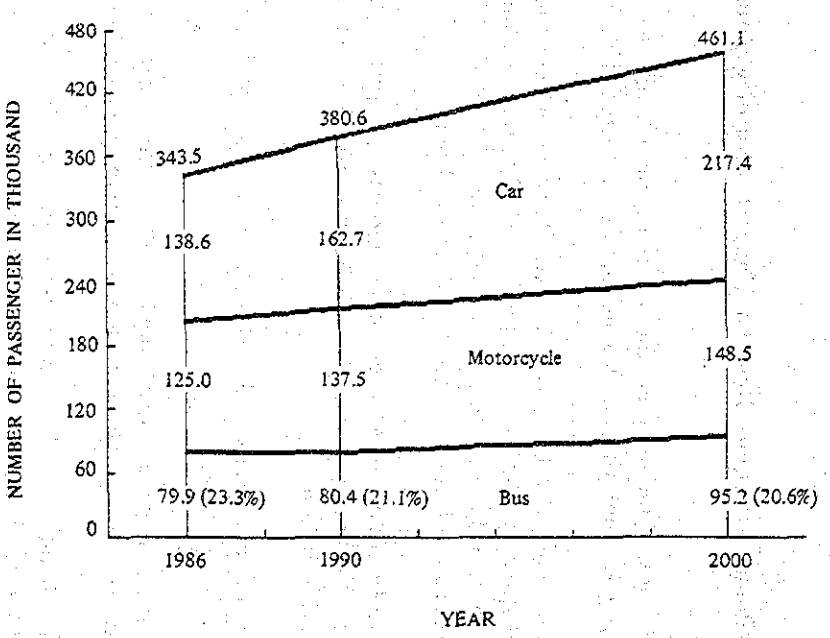
The result of the public transport demand forecasted is shown in Figure 3.7.2. In the future, the total number of bus users across the Central Area Screen Line could not be expected to differ much from the existing value. Moreover, in terms of composition by mode, bus users' share is expected to decline from 23.3% in 1986 to 21.1% and 20.6% in 1990 and 2000 respectively.

The bus users value forecasted above includes Factory and School bus users besides stage bus users. Therefore in the 'Do-nothing' situation, the financial difficulties which would be faced by stage bus operators in the future could be foreseen clearly.



Direction of Traffic	Transportation Mode									
	Car and Pick-Up		Motorcycles		Stage Bus		Factory & School Bus, Van		Total	
	Vehicle	Passenger	Vehicle	Passenger	Vehicle	Passenger	Vehicle	Passenger	Vehicle	Passenger
Inbound	41,548	74,667	52,524	62,665	1,052	23,865	2,540	17,250	97,664	178,447
Outbound	36,485	63,890	53,028	62,315	1,075	22,055	2,349	16,743	92,937	165,003
Total	78,033	138,557	105,980	124,980	2,127	45,920	4,889	33,993	190,601	343,450

Figure 3.7.1 : Number and Composition of Vehicles and Passengers by Transportation Mode Entering and Leaving the Central Area (1986)



Note : ( ) figures show the bus users share

Figure 3.7.2 : Passengers by Transportation Mode (1986, 1990 & 2000)

3.8 Future Parking Supply and Demand

Future parking supply under 'Do-Nothing' situation is estimated based on two assumptions : that on-street parking facilities will not be increased and that off-street parking provisions in new development or redevelopment areas would grow at the same rate as the employment growth rate in the Central Area.

Future parking demand is estimated based on the growth rate of the number of cars attracted into the Central Area for the year 1990 and 2000.

The result of these projections illustrated in Figure 3.8.1 reveals that by 1990 there is a supply of 19,000 parking lots against a demand for 18,800 parking lots. However by 2000 there is only a supply of 21,000 parking lots against a demand for 29,000 parking lots. That is, a deficiency of 8,000 parking lots would be expected.

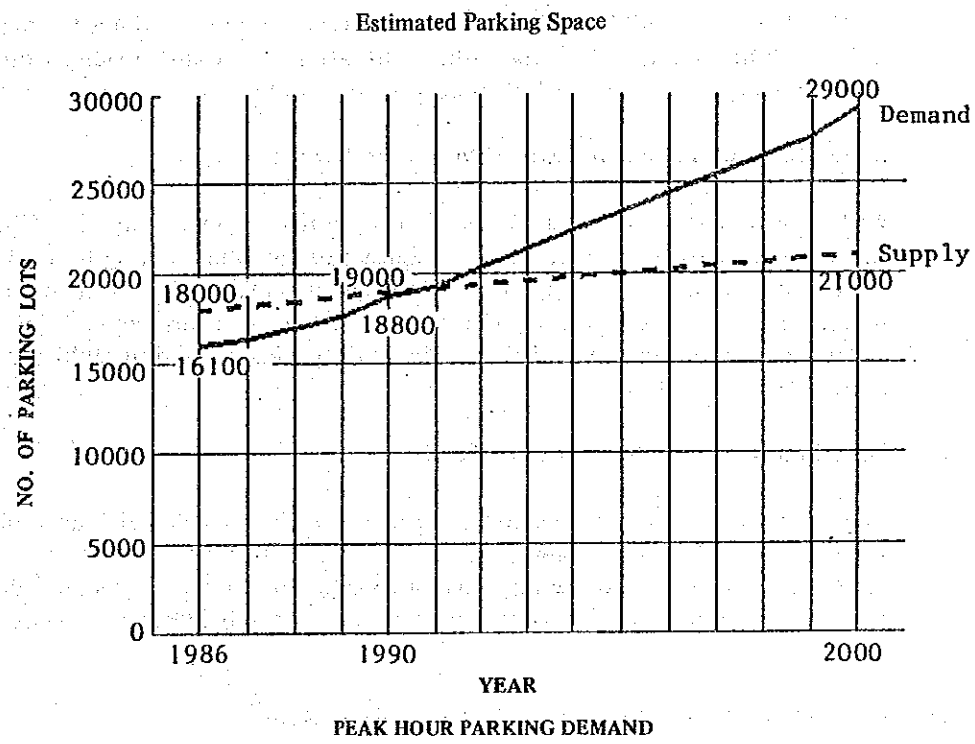


Figure 3.8.1 : Projections of Parking Supply and Demand at Peak Hour in the Central Area of George Town

3.9 Future Transport Problems

Existing transportation problems in the Study Area would be expected to worsen in magnitude and intensity in the future under the 'Do-Nothing' case as a result of increasing pressure from traffic demand on the limited capacity of transport facilities. The following future problems are further identified from the forecasted future traffic conditions.

A. Aggravation of Traffic Congestion

Severe traffic congestion will be expected on many primary roads in 1990. Especially, the congestion on Jelutong Road and Northam Road will become even more severe than before. Traffic bottlenecks will be observed at the intersection of Dato Keramat Road/Perak Road and the intersections in the vicinity of KOMTAR.

Traffic demand in 2000 is projected to increase by about 1.7 times the existing traffic volume. Under the 'Do-Nothing' situation, the road capacity would be severely insufficient to meet this impending demand.

B. Increasing Complexity of Traffic Movement Pattern

With the congestion on Jelutong Road, traffic flow from the CBD to the southern part will be expected to detour to the Middle Ring Road (Green Lane) via various routes. Such traffic movements create complexed circulation pattern and increased turning movements at intersections which aggravates traffic congestion on road. This problem will be manifested in 1990 and even more severely in 2000.

C. Deterioration of Public Transport Service

Together with traffic congestion on the roads, bus speed will inevitably be further reduced and bus service become more irregular. If left alone, bus service level will deteriorate and bus patronage will inevitably decline further. Woes of the public transport will become chronic and illegal taxi service will perpetuate.

D. Congestion of Road Space and Decline in Road Safety

With the road space occupied by a mixture of cars, motorcycles, hawkers, trishaws and pedestrians, the increase in traffic demand will make it more and more difficult to secure road safety. The continuous presence of the admixture of fast and slow moving vehicles on the same carriageway will further aggravate traffic congestion and road safety. At the same time the functionality of the street vista become vague and unpleasant.

E. **Inadequate Supply of Parking Space**

While the overall parking supply in the Central Area is tolerable to meet the demand until 1990, drastic increase in parking demand in 2000 and the consequences of regulating on-street parking to increase road capacity will cause a major strain in the parking space supply. Unnecessary and wasteful travelling to find an empty parking lot will become chronic.

3.10 Major Transport Issues

Major transport issues are identified from existing and future transport problems. Figure 3.10.1 shows inter-relationship between problems and issues.

Major transport issues are :

A. **Alleviation of Traffic Congestion**

Geometric improvement on the bottleneck roads and intersections together with proper traffic management will effectively serve as remedial measures to alleviate traffic congestion.

Another measure will be the improvement of circumferential roads around the Central Area such as Perak Road and Anson Road to ease the traffic congestions which usually occur on bottleneck radial roads and roads around KOMTAR. This is because the circumferential roads will effectively disperse through traffic away from the Central Area.

In addition, implementation of an innovative traffic management system, including an improvement and modification on the existing traffic control devices, especially on the signal system, and the traffic circulation system in the Central Area, are essential to alleviate traffic congestion.

B. **Encouraging Usage of Bus Services**

Buses need to be run on time and according to schedule so that commuters will continue to use them. Schedules should be drawn up in such a way that operations will not be affected by congestion on roads. This will encourage more people to use buses.

C. Enhancing Traffic Safety

Traffic safety education and facilities will be required to enhance the traffic safety.

Regarding to education, traffic safety programs must be carried out to educate the public. This includes the clear definition of the driver's and pedestrian's duties and responsibilities.

In addition to the education regarding road-use in the traffic safety education system, adequate information campaigns are equally important. Application of proper traffic engineering methods is not only self-enforcement but also self-education to a certain extent. For example, drivers tend to drive within a lane when lane-markings are painted on street. Through driving on the streets with lane markings, drivers pick up the habit of not weaving too frequently.

As one of the traffic safety programs, traffic accident analysis system is required for improvement of traffic operations. However, statistics of accidents and analytical reports are not always availale to the City Engineering Department, educational institutions and other agencies concerned with road safety.

On the other hand, traffic safety facilities must be discussed in consideration of the problems observed in existing traffic conditions, which involve the mixture of transportation modes, such as car, motorcycle, trishaw and pedestrian on the same roadway.

D. Measures to Parking Problems

There are three issues regarding parking in George Town. Firstly, the parking demand will exceed the parking capacity in future, so that new parking space will be required. Moreover, there is imbalance in the use of parking area. Another is to control the parking space from the view points of alleviation of traffic congestion, which is contrary to the second issue.

E. Creation and Improvement of Pedestrian Facilities

Pedestrian facilities must be created and improved to safeguard the pedestrians and their movements. Efforts are to be made to provide a comfortable and conducive walking environment which will encourage pedestrians to walk a longer distance to shop and get to the bus-stops and parking lots. In addition, such amenities enhance business at shopping centres, increase the number of bus commuters, and provide availability of parking lots.

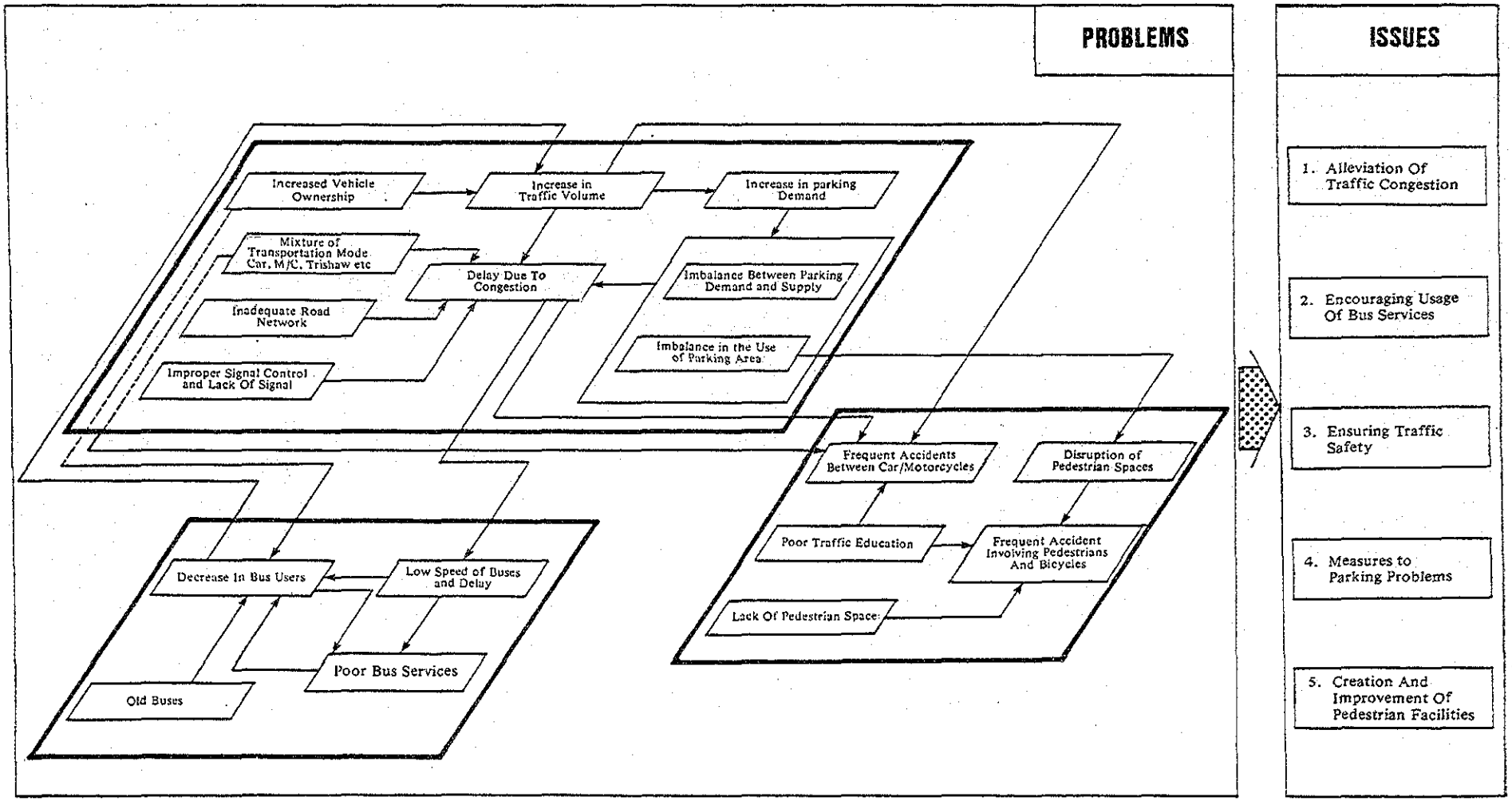


Figure 3.10.1 : Inter-Relationship Between Problems and Issues

4.0 PROPOSED TRANSPORTATION SYSTEM MANAGEMENT PLAN

4.1 Introduction

In this Chapter, a proposed Transportation System Management (TSM) Plan for the Study Area is prepared based on an inventory of the existing transport situation and foreseeable problems already discussed in the preceding Chapters 2 and 3 respectively. Figure 4.1.1 shows the planning process adopted by the Study Team. As shown in the flow-chart, suggestions for individual countermeasure to mitigate each of the transport problems identified are made; these countermeasures (separate plans) are then consolidated as the proposed TSM Plan.

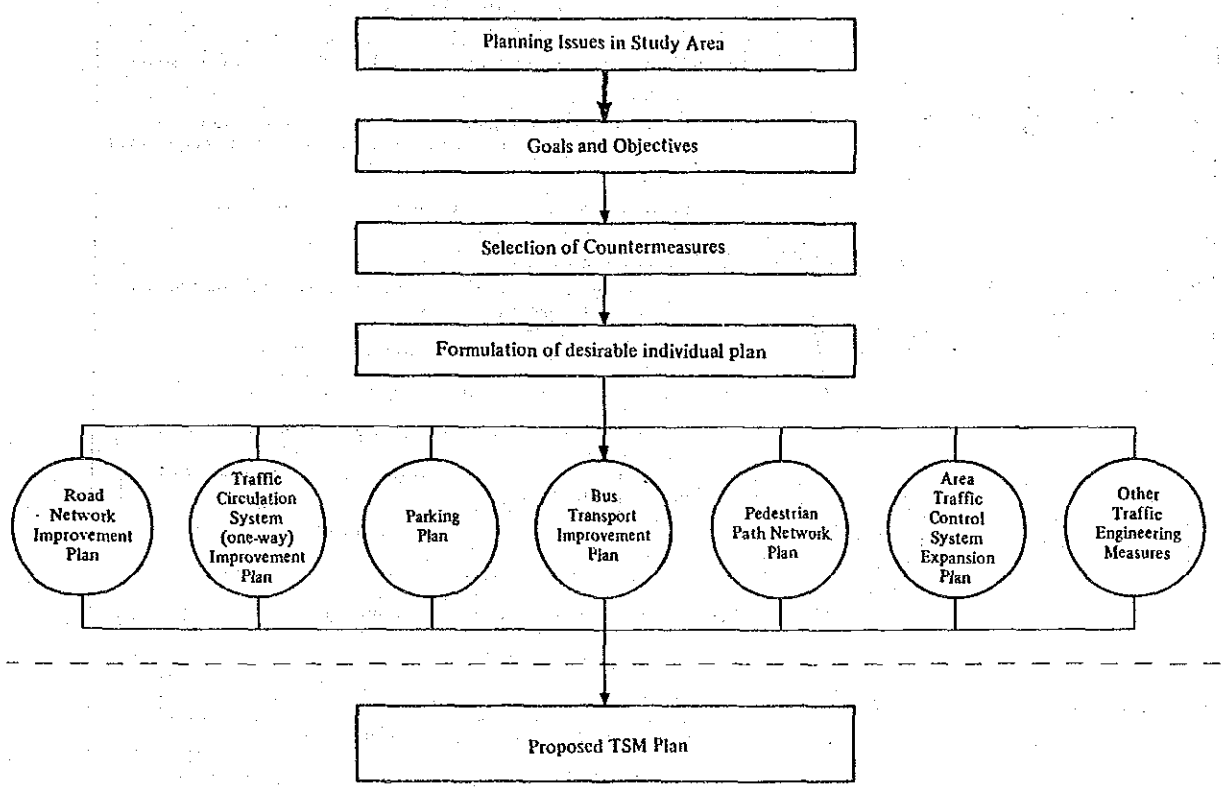


Figure 4.1.1 : Planning Process

4.2 Planning Issues, Goals and Objectives

The Study Team has identified five (5) major planning issues for the Study Area, i.e. :

(1) Alleviation of traffic congestion
(2) Encouraging the usage of bus services
(3) Ensuring traffic safety
(4) Measures to parking problems
(5) Creation and improvement of pedestrian facilities

Corresponding to these five (5) major planning issues, five (5) goals and thirteen (13) objectives have been established and depicted in Figure 4.2.1.

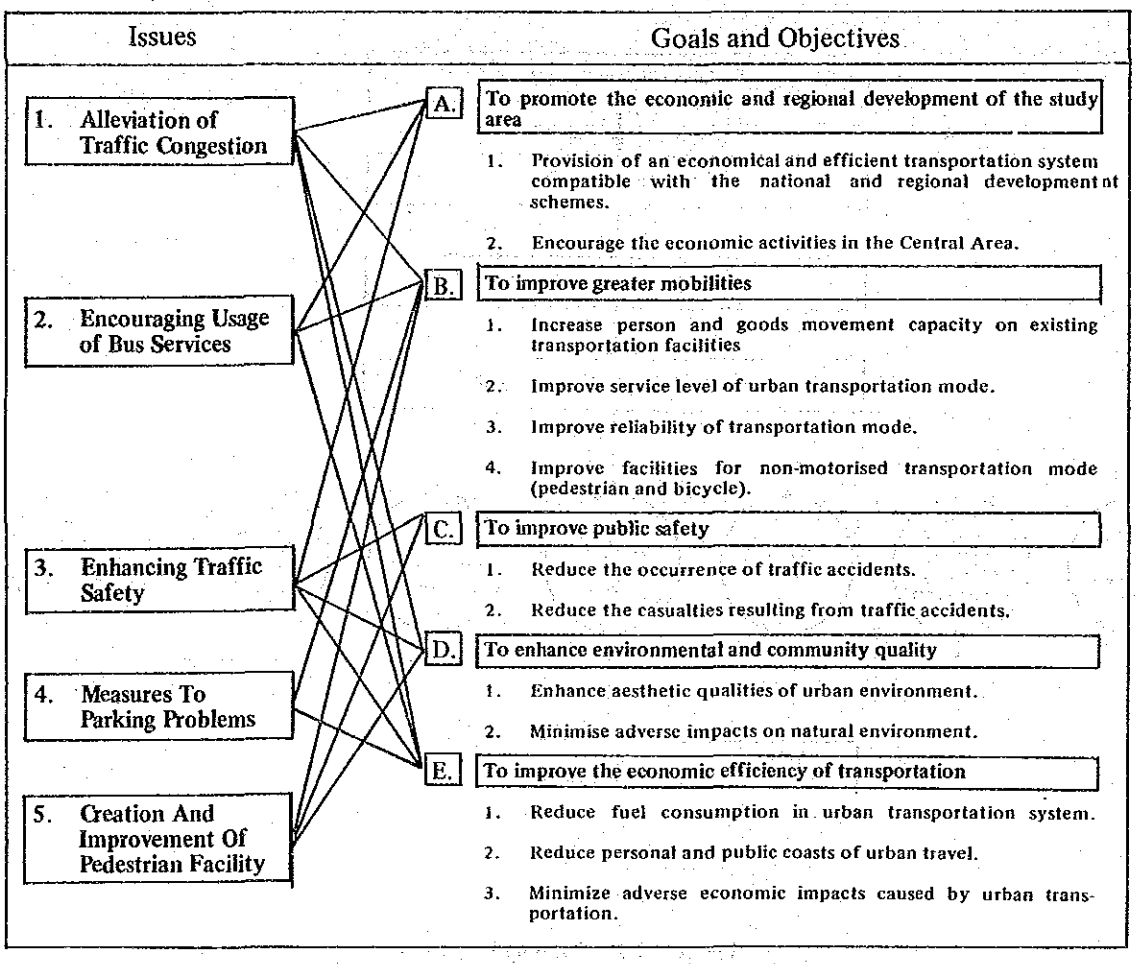


Figure 4.2.1 : Planning Issues, Goals and Objectives es

4.3 Selection of Countermeasures

4.3.1 Selection of TSM solutions

A wide range of possible solutions to the transport problems as seen from various viewpoints can be adopted to achieve the final goals and objectives of the TSM Plan for the Study Area. These solutions can be collectively categorized into the following four (4) approaches.

A. Supply Augmentation Approach

The supply augmentation approach advocates for the improvement of existing road network or the introduction of new bus services, etc. to increase the absolute capacity of transport facilities.

B. Demand Modification Approach

The demand modification approach advocates for the changes to travel pattern of people and goods, such as by means of landuse planning or staggered working hours, etc. in order to reduce the absolute transport demand or the peak hour demand.

C. Transit Operating Modification Approach

The transit operating modification approach advocates for the shift to transit usage by reorganizing bus routes or implementing various control measures; or to ensure the convenience of each mode in order to increase the efficiency and smoothness of traffic flow.

D. Beautification and Presentation Program

The beautification and preservation program advocates for the improvement of aesthetic qualities and traffic safety in the urban environment by measures such as the facilitation of street furniture and pedestrian path network.

A checklist of possible TSM solutions in the abovementioned classification of approaches is tabulated in Table 4.3.1. In consideration of the transport characteristics of the Study Area, those solutions which are suitable to mitigate the identified transport problems have been selected for the formulation of the proposed TSM Plan.

Table 4.3.1 : Checklist of All Possible TSM Solutions

A. Supply Augmentation Approach	**C. Transit Operating Modification Approach**
1. Road Network	**1. Operational Improvements**
Construction and improvement of road network ●	Bus route modifications ●
Improvement of intersection approach facilities ●	Bus schedule modifications ●
2. Crossing and Entry Control	**2. Mode Transfer**
Signal timing optimization ●	Bus stop and terminal relocation ●
Signal installation and renewal ●	Park-and-ride facilities —
Computerized signal control system ●	Station and stop amenities improvement ●
Circulation system ●	Simplified transfers ●
One-way street ●	
Reversible lanes —	**3. Effective Usage of Vehicle**
No Turning movement —	
Grade-separated crossings for pedestrians ●	Share-riding —
	Car pool/Van pool —
3. Public Transport	High Occupancy Vehicle (HOV) Lane —
	Taxi deregulation —
Frequent Bus Service ●	Bus Incentives —
Bus fleet improvement ●	Goods distribution system —
New concept of bus system ●	
Introduction of an innovative transit system —	**4. Control**
4. Non-motorized modes	Parking control ●
	Speed control ●
Pedestrian path network ●	Landuse control —
Bicycle paths —	Turning movement control ●
Sidewalk widening ●	Trishaw movement Control ●
	Illegal taxi control ●
5. Parking	
	5. Information services
Off-street parking —	
Parking supply reduction or restraint ●	Information on bus departure time ●
CBD fringe parking —	Changeable message sign on street ●
Suburban park-and-ride facilities ●	Roadside radio information ●
6. Goods	
Terminal consolidation —	
Increase in truck lot sizes —	
Off-street loading facilities —	
B. Demand Modification Approach	**D. Beautification/Preservation Programme**
1. Modification of demand distribution by time	**1. Beautification Program**
Staggered working hours —	Street furniture ●
Flexible time —	Pedestrian malls & pathways ●
Shortened workweek —	Plantings, trees ●
	Bus stop amenities improvement ●
2. Modification of demand frequency	
	2. Preservation Program
Substitution of communications for transportation —	
	Sidewalk widening ●
3. Modification of spatial location	Zone system —
	Traffic cell system —
Land use changes —	

Note : ● TSM Measures selected as solutions to transportation problems in the Study Area.

4.3.2 Formulation of Proposed Individual Plan

The TSM measures selected in the preceding sub-section 4.3.1 can be reorganised into seven (7) separate plans for study. This process consists of the formulation of proposed individual plan for various transport facilities. Thus, these seven (7) proposed plans will introduce the following measures into the Study Area, i.e:

1. **Road Network Improvement Plan**

   - Construction and improvement of road network
   - Improvement of intersection approach facilities

2. **Traffic Circulation System (one-way) Improvement**

   - Circulation system
   - One-way street

3. **Parking Plan**

   - Off-street parking
   - Parking supply restraint
   - CBD fringe parking
   - Parking control

4. **Bus Transport Improvement**

   - Frequent bus service
   - Bus fleet improvement
   - Bus route modifications
   - Bus schedule modifications
   - Bus stops and terminal relocation
   - Terminal and bus-stop amenities improvement
   - Simplified transfers
   - Information on bus departure time
   - New concept of bus system

5. **Pedestrian Path Network Plan**

   - Pedestrian path network
   - Sidewalk widening
   - Grade-separated crossings for pedestrians
   - Street furniture
   - Pedestrian malls & pathways
   - Plantings, trees

6. **Area Traffic Control System Expansion Plan**

   - Signal timing optimization
   - Signal installation and renewal
   - Computerized signal control system
   - Changeable message sign on street
   - Roadside radio information

7. Other Traffic Engineering Measures

- Speed control
- Turning movement control
- Trishaw movement control
- Illegal taxi control

In the process of formulating the individual plan, the spatial area of concern for each plan can be broadly divided into two regions. That is, plans such as 'Road Network Improvement Plan', 'Area Traffic Control System Expansion Plan', 'Bus Transport Improvement Plan' and 'Other Traffic Engineering Measures' are formulated for the whole region under the Study Area; while plans such as 'Traffic Circulation System (one-way) Improvement Plan', 'Parking Plan', 'Bus Transport Improvement Plan' and 'Pedestrian Path Network Plan' are mainly concerned with the transport problems in the Central Area of George Town.

Thus, the spatial area of concern for each plan is different as shown in Figure 4.3.1. And in the following sections each plan will be examined separately and its proposed components will be introduced.

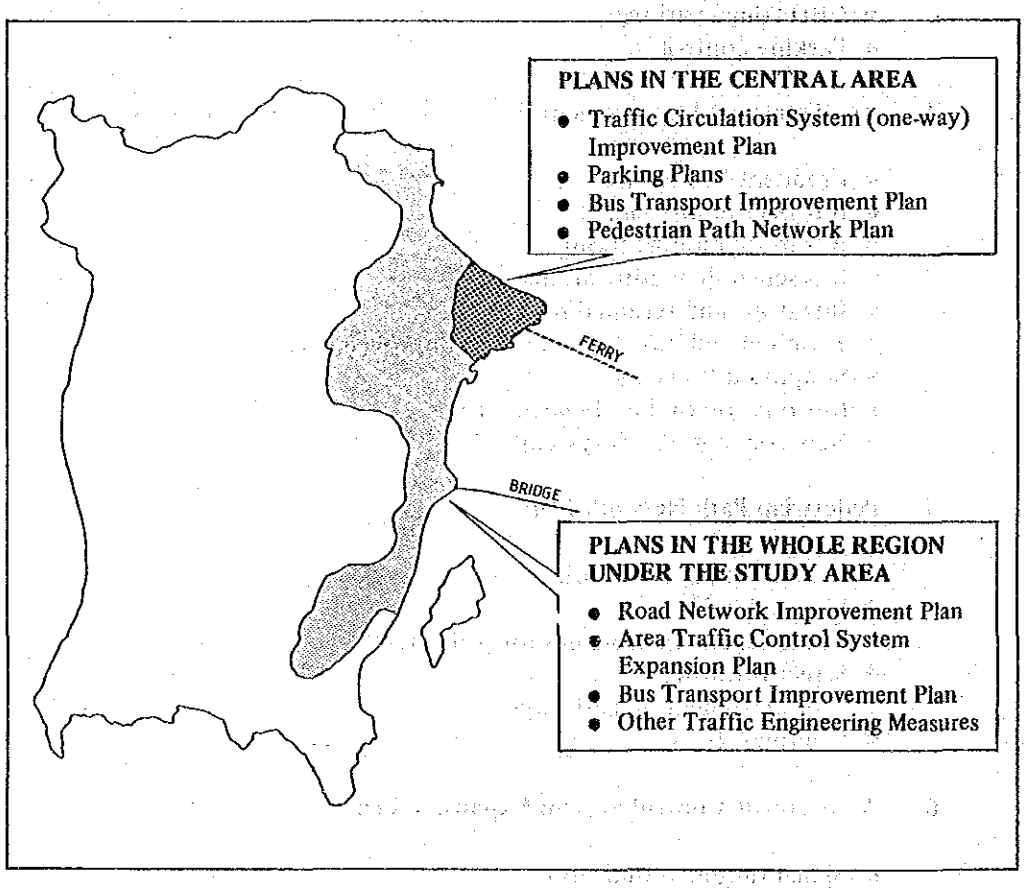


Figure 4.3.1 : Spatial Area of Concern For Each Plan

4.4 Road Network Improvement Plan

4.4.1 Basic Guideline

The rapid increase in car and motorcycle ownership is expected to continue in the future. The Study Team estimated that the total vehicle ownership in 2000 will increase to 1.6 times that of the 1986 value. As a result, vehicle trips will also grow rapidly in proportion to the growth rate of vehicle ownership. For example, vehicle trips across the Central Area Screen Line in 2000 is estimated to increase by 1.7 times of the 1986 volume.

In order for the roads in the existing road network which are already congested to cope with the large impending traffic volume, the following positive measures are proposed, that is :

(1) Construction of new roads, improvement of roads and intersections;

(2) Establishment of a road network hierarchy.

In particular, because the road network hierarchy in George Town has not been clearly established, it appears that the network is incapable to handle the traffic demand. Therefore it can be expected that with the simultaneously construction of the Coastal Road and improvement of the road network to form a radial and circumferential network, the following results can be achieved :

(1) Increase in road network capacity,

(2) Ensurance of smooth traffic flow.

In this section, the road network which would form the basis for the Transportation System Management Plan will be established.

4.4.2 Evaluation of Alternative Plan

A, Road Network Plan

The Alternative Road Network Plan are tabulated in Table 4.4.1.

Table 4.4.1 : Road Network Plan

Year	Alternative Plan		
1990	Present		
2000	Alternative 1	Alternative 2	Alternative 3

Outline of these alternative plans are as follows :

The base for the road network in 1990 is the existing road network with all the on-going road projects completed.

In 2000 a tremendous increment in traffic volume is expected. It will become near impossible for the 1990 road network capacity to meet this impending demand. In this section, the formulation of new plans for construction of roads will consider those proposals made by JICA Study in 1980, the MPPP, the State and the Federal Government.

Here, a few alternative plans will be formulated by combining selected projects considered effective in alleviating traffic congestion from among those existing proposals. These alternative plans will then be evaluated by the results of traffic demand forecasting and analysis on the cost-effectiveness of each plan. From these examinations the road network which will be the premise for the Transportation System Management Plan in 2000 will be established.

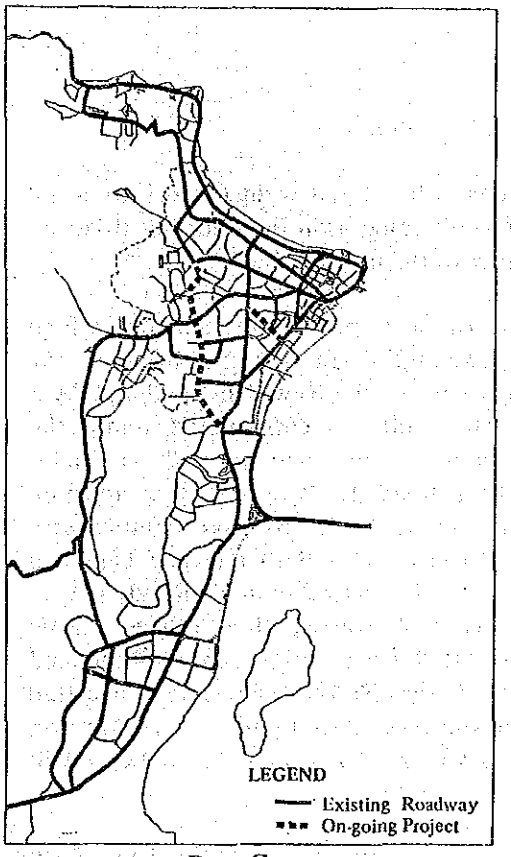
The road network alternatives are outlined as follows :

(1) Alternative 1 : Base Case with Coastal Road and Weld Quay Extension. This plan will alleviate congestion on Jelutong Road by diverting traffic flow to the new roads.

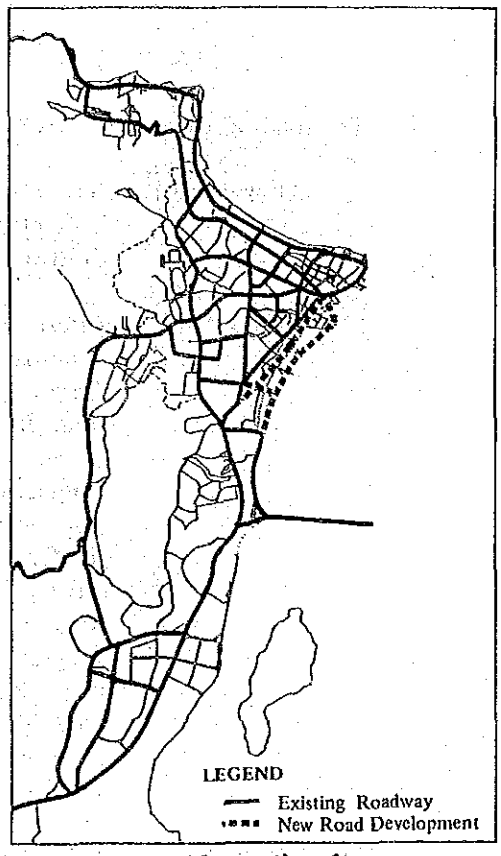
(2) Alternative 2 : Alternative 1 and other improvement schemes which comprise the South Coastal Road (from the Bridge to the Airport), two roads namely the New Pair Road and Ayer Itam By-pass which would be constructed under the housing schemes and a new road of 1.7 kilometer connecting Hamilton Road to Weld Quay Extension. This new road and the Ayer Itam By-pass together with the flyover at Hamilton Road – Batu Lancang Lane will serve as an alternative to Dato Keramat Road –Ayer Itam Road for east-west traffic, thus relieve traffic congestion on Ayer Itam Road, Free School Road and Perak Road. Overall, this plan will alleviate congestion on Jelutong Road and Ayer Itam Road. Congestion on the access roads to George Town and Bayan Lepas will also be alleviated.

(3) Alternative 3 : This plan includes the construction of Outer Ring Road in addition to those in Alternative 2 to relieve traffic congestion on the urban streets of George Town by diverting through traffic away from them.

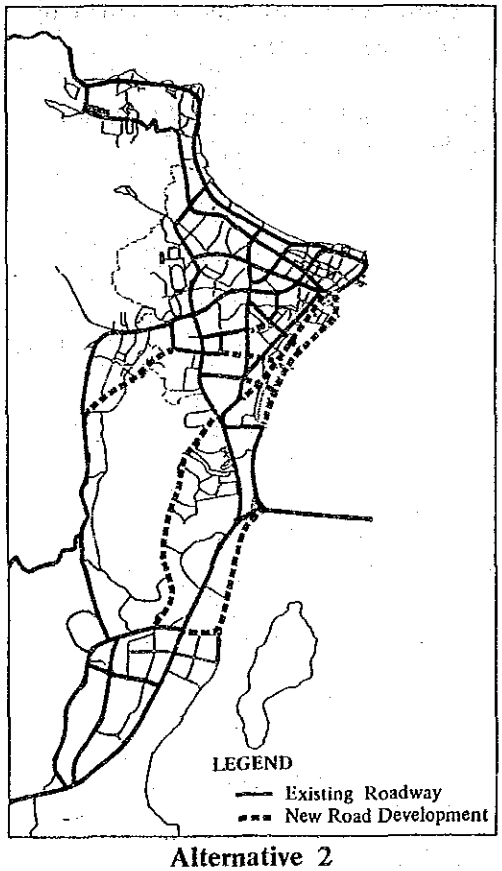
Cases of these road network plans including the base case in 2000 (which has been discussed in Section 3.6) are shown in Figure 4.4.1.



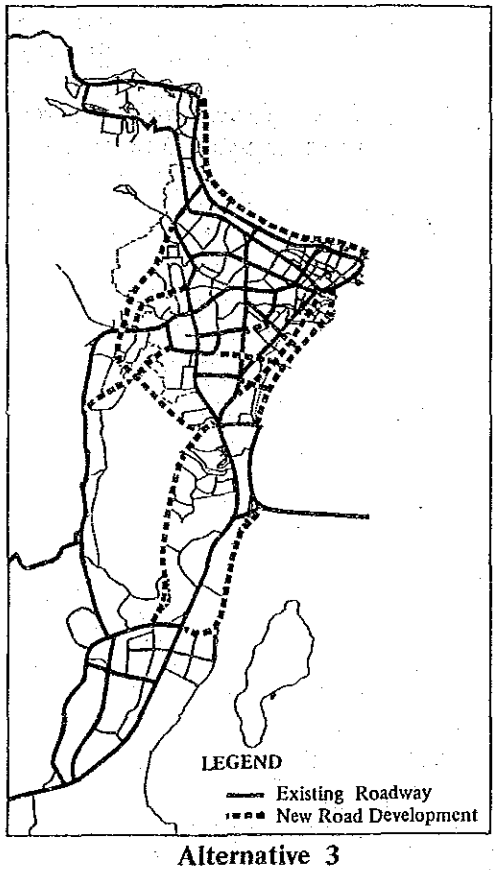
Base Case



Alternative 1



Alternative 2



Alternative 3

Figure 4.4.1 : Alternative Road Network Plans in 2000

B. Evaluation of Alternative Plans

Table 4.4.2 shows the summary of traffic assignment results for the above-mentioned three (3) cases of road network in year 2000. A congestion degree* of 1.5 is taken as the threshold value for which new road construction is deemed necessary to increase the total road capacity. On this basis, the road capacity in Alternative 1 will be considered insufficient. At the least, the amount of road improvement proposed in Alternative 2 will be desirable. Alternative 3 with a congestion degree of 1.1 shows a vast improvement in the traffic condition.

Table 4.4.2 : Summaryof Traffic Assignment in 2000

Indicators	Base Case	Alt. 1	Alt. 2	Alt. 3
Vehicle Kilometers ('000 PCU Km)	4,630	4,493	4,509	4,625
Vehicle Hours ('000 PCU Hr)	262	228	196	167
Average Velocity (Km/hr)	17.6	19.7	23.1	27.8
Congestion Degree	1.93	1.61	1.40	1.10

* Base Case is discussed in Section 3.6.

* Interpretation of congestion degree

Congestion Degree	Traffic flow condition
Less than 1.0	Saturation time is zero, Q/C is less than 1.0, throughout the 12 hour daylight, roads are not congested. Smooth and free flow can be observed. Traffic jam and delay due to it are almost non-existent.
1.00 – 1.25	Saturation time at most road sections is usually below 1 – 2 hours. For most road sections, Q/C is less than 1.0. During the 12 hour daylight, traffic congestion may be observed on some roads for 1 – 2 hours (peak hours). Continuous traffic jam for many hours are very rare.
1.25 – 1.75	Saturation time is from 0 – 12 hours. 10–15% of the time Q/C is greater than 1.0. High possibilityof observing traffic jam lasting for many hours especially during peak hours. At the extreme ends, traffic congestion periods may vary from just during peak hours to a continuous situation throughout the day.
Above 1.75	Zero saturation time is almost non-existent. 50% of the time Q/C is greater than 1.0. The situation is one of chronic traffic congestion.

In this study, comparison of the observed data on traffic flow and the calculated road capacity suggested that the existing road network would be able to manage a simulated congestion degree of 1.5. Therefore a congestion degree of 1.5 can be taken as the threshold value for the requirement of further road improvement.

Figures 4.4.2 to 4.4.4 depict the traffic flow in the Study Area for each of the assignment case.

On the other hand, Table 4.4.3 shows the tabulation of single year benefit/cost ratio in 2000 for the road network alternatives. Among the three alternatives, Alternative 2 shows the highest cost effectiveness with a benefit/cost ratio of 2.1.

Therefore, Alternative 2 is proposed as the road network in 2000.

Table 4.4.3 : Single Year Benefit/Cost Ratio in 2000

	Alt. 1	Alt. 2	Alt. 3
Project Cost (M$ million)	133	195	397
Annualised Cost at 12% (M$ million)	17.5	24.9	52.0
Annual Benefit (M$ million)	28.9	51.4	89.2
B/C Ratio	1.7	2.1	1.7

4.4.3 Proposed Road Network Plan

A. Proposed Road Network Plan

Figures 4.4.5 and 4.4.6 illustrate the proposed road network configuration in 2000 for the Study Area and George Town respectively. Roads are classified into three (3) categories according to their function. The following are the definitions of the categories.

1. Urban Primary Road

   These roads are designed to provide a high level of service and a large traffic capacity since they are used to distribute long trip, inter-city and intra-city traffic. All long distance traffic to, from and within the town should be channelled to these roads.

2. Urban Secondary Road

   These roads distribute traffic within the main residential, industrial and business districts of the town while forming the link between the primary network and the roads within the surrounding areas. It performs a vital function of accommodating maximum traffic movement during peak periods and serves the general circulating and land service functions of the community during off-peak periods.

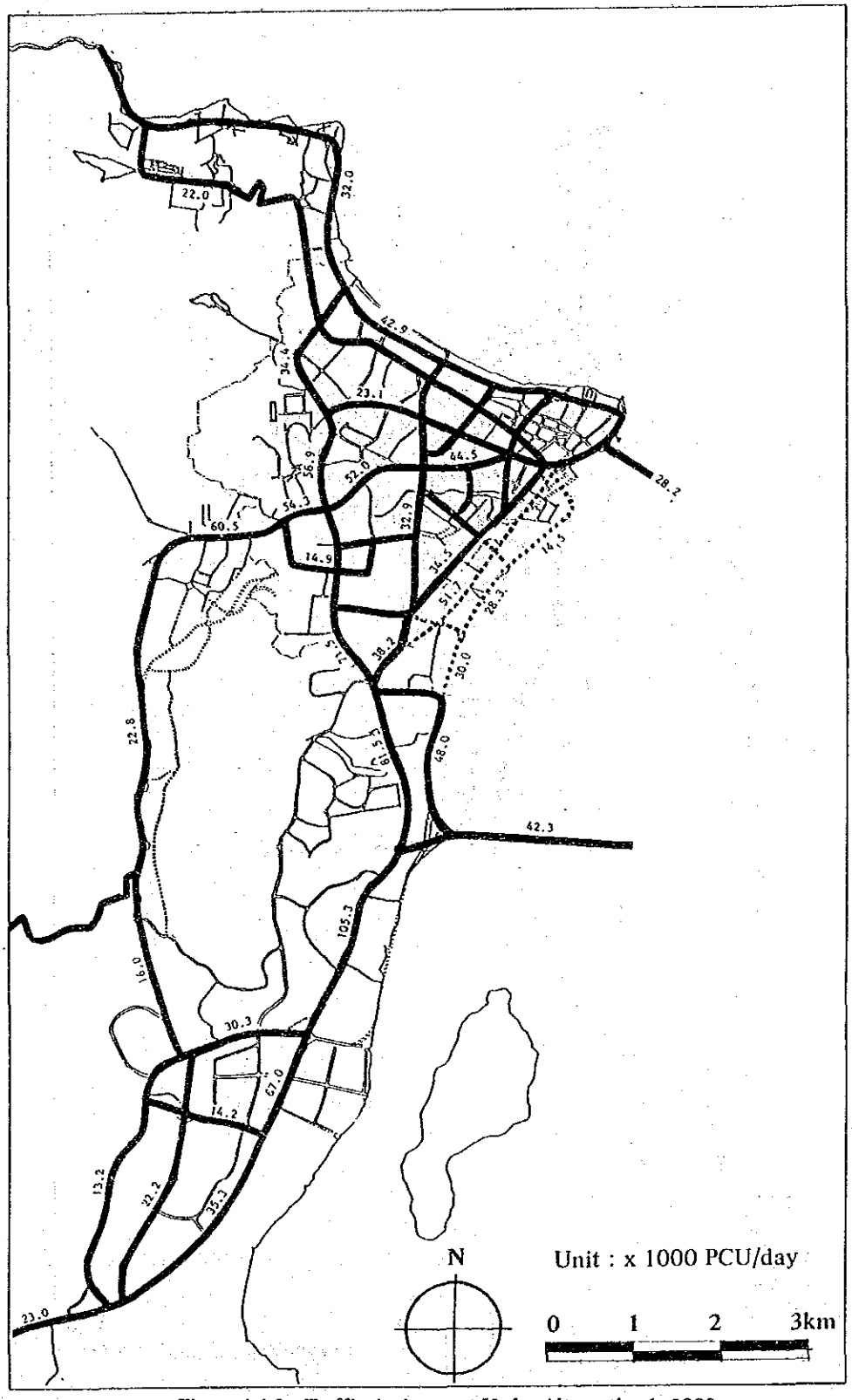


Figure 4.4.2 : Traffic Assignment Under Alternative 1, 2000

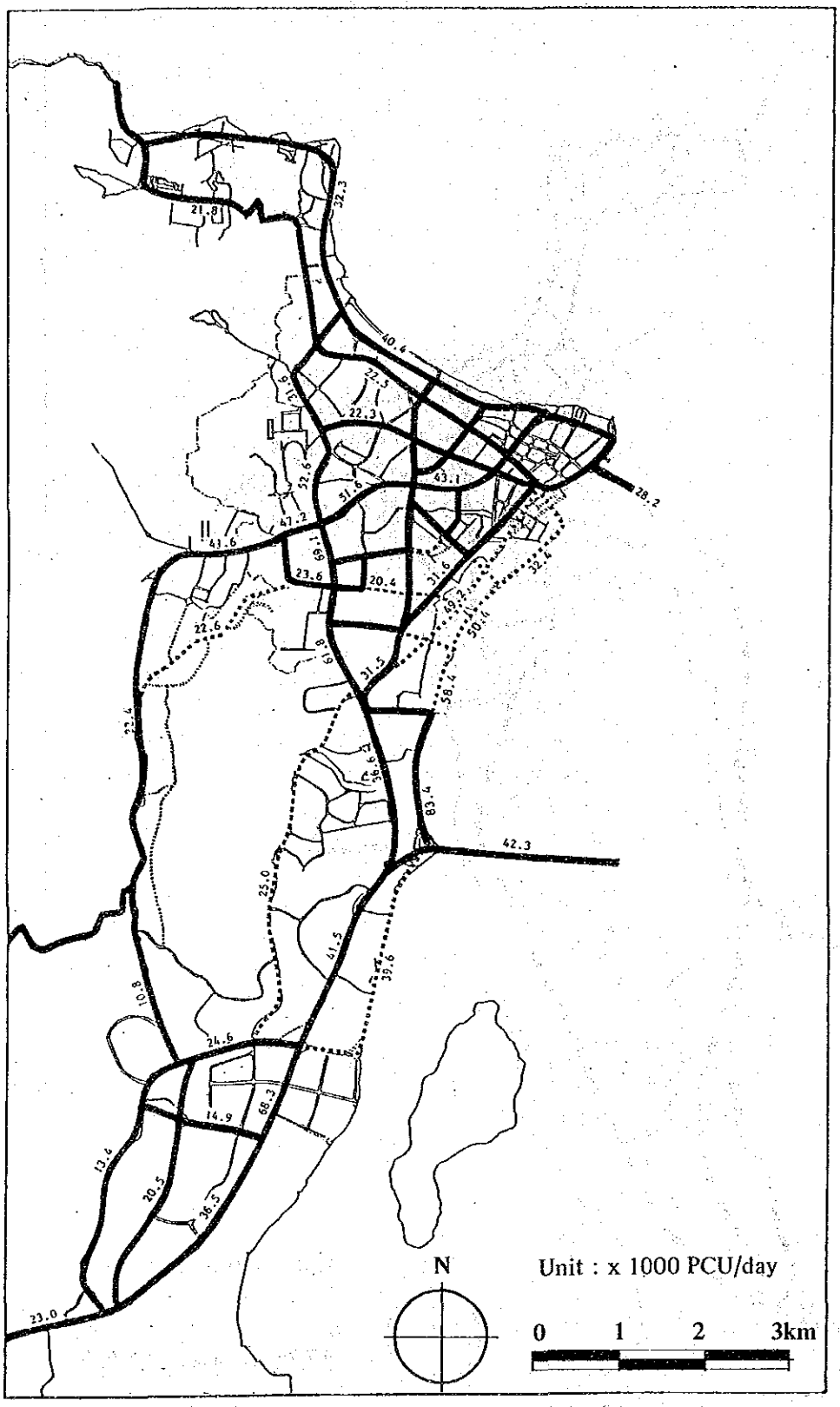


Figure 4.4.3 : Traffic Assignment Under Alternative 2, 2000

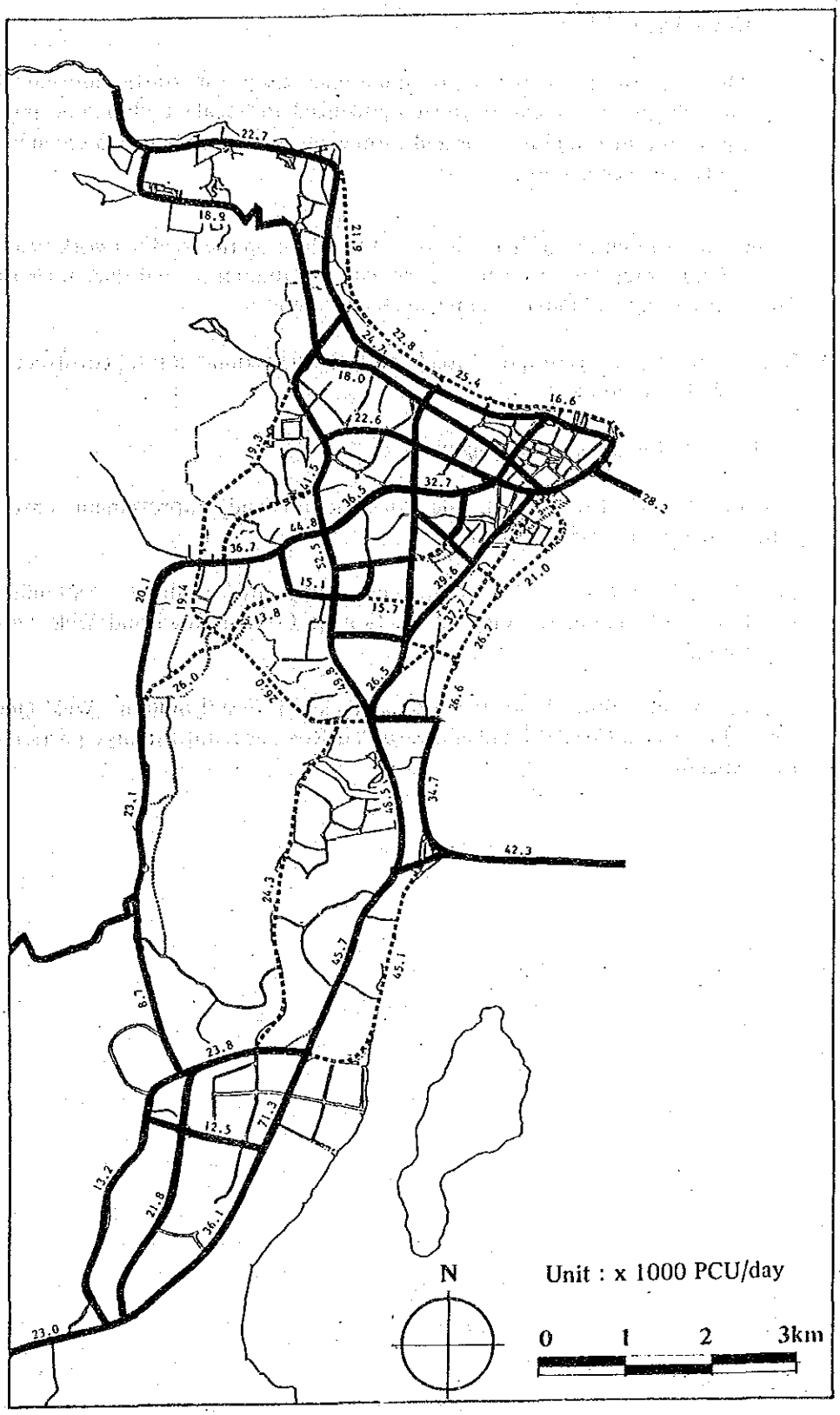


Figure 4.4.4 : Traffic Assignment Under Alternative 3, 2000

3. Urban District Road

Although these roadways are sometimes used for traffic movements through the city, they are generally utilized for local circulating purposes within the surrounding areas and form a necessary link between secondary roads and access roads.

Under this configuration, it is aimed to fully develop the road network system in the Study Area into a radar road network configuration and that of George Town into a ring and radial road network configuration.

In order to attain this proposed road network, the estimated total construction cost is M$195 million.

Table 4.4.4 illustrates the staging plan.

For the period 1988–1990, the construction and improvement cost is estimated at about M$16 million.

For the period 1991–1995, the total cost is estimated at about M$89 million which is used mainly for the construction of Coastal Road and Weld Quay Extension.

For the period 1996–2000, the estimated cost is M$90 million. Weld Quay Extension, South Coastal Road and New Pair Road account for large portion of this expenditure.

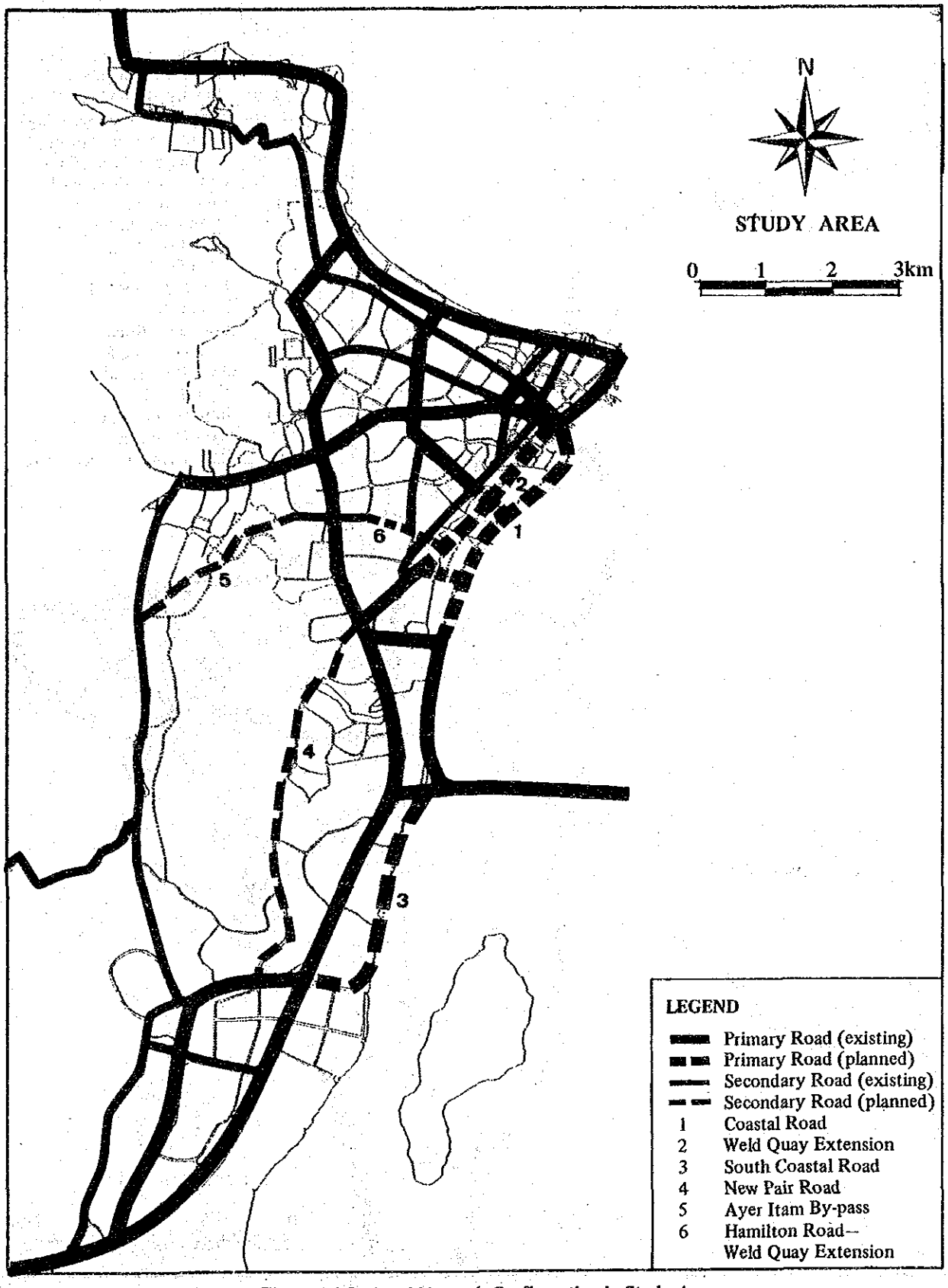


Figure 4.4.5 : Road Network Configuration in Study Area

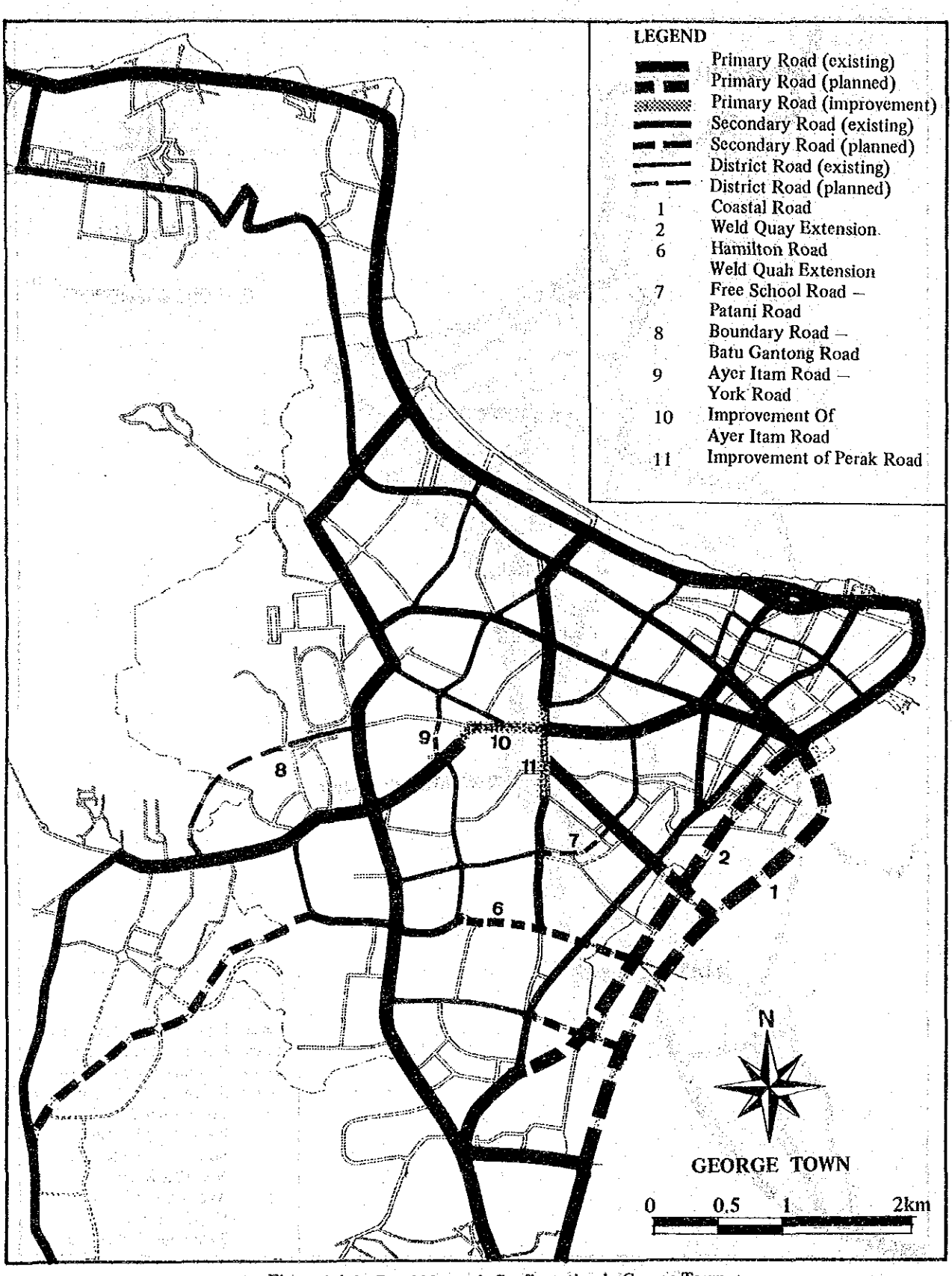


Figure 4.4.6 : Road Network Configuration in George Town

Table 4.4.4 : Staging Plan

	Construction Cost (M$ million)	1988–1990	1991–1995	1996–2000
1. Coastal Road	70.00		******	
2. Weld Quay Extension	60.00	(5.0) ******	(30.0) ******	(35.0) ******
3. South Coastal Road	23.00			******
4. New Pair Road	25.00			******
5. Ayer Itam By-Pass	3.70		******	
6. Hamilton Road – Weld Quay Extension	6.60		(3.0) ******	(3.6) ******
7. Free School Road – Patani Road	2.36			******
8. Boundary Road – Batu Gantong Road	1.80		******	
9. Ayer Itam Road – York Road	1.41			******
10. Improvement of Ayer Itam Road	0.48	******		
11. Improvement of Perak Road	0.55	******		
Total Cost	194.90	(6.03)	(98.50)	(90.37)

Note : Numerals in brackets ( ) indicate the cost in each phase.

B. Other Considerations

1. Intersection Improvement

Intersection improvement involves:

(1) simplification of intersection configuration
(2) provision of additional lane, such as right turn and left turn lane
(3) geometric modifications of intersection, such as curve radius, etc.

The purpose of simplifying intersection configuration is to convert the turning movement of main traffic flow, (both right turn and left turn), to through traffic flow taking into consideration the road network configuration.

There are a lot of intersections in need of improvement due to the present complicated configuration of road network in George Town. These improvement must be done together with the expansion plan of the Area *Traffic Control System*.

2. Improvement of Functional Usage of Roadway Cross-section

Motorcycle constitutes over 50% of the transport mode share in the Study Area. It is observed that many trishaws are operating on busy traffic roadways as well.

Apparently, the traffic conditions on existing roadways depict a confusing fashion due to an admixture of cars, motorcycles, trishaw and pedestrians on the roadway. Consequently, the road capacity is reduced and the traffic safety is affected. Therefore, it would be desirable to have a separate provision of sidewalk and motorcycle lane and also to control the trishaw movement. Figure 4.4.7 illustrates the concept of an improved carriageway.

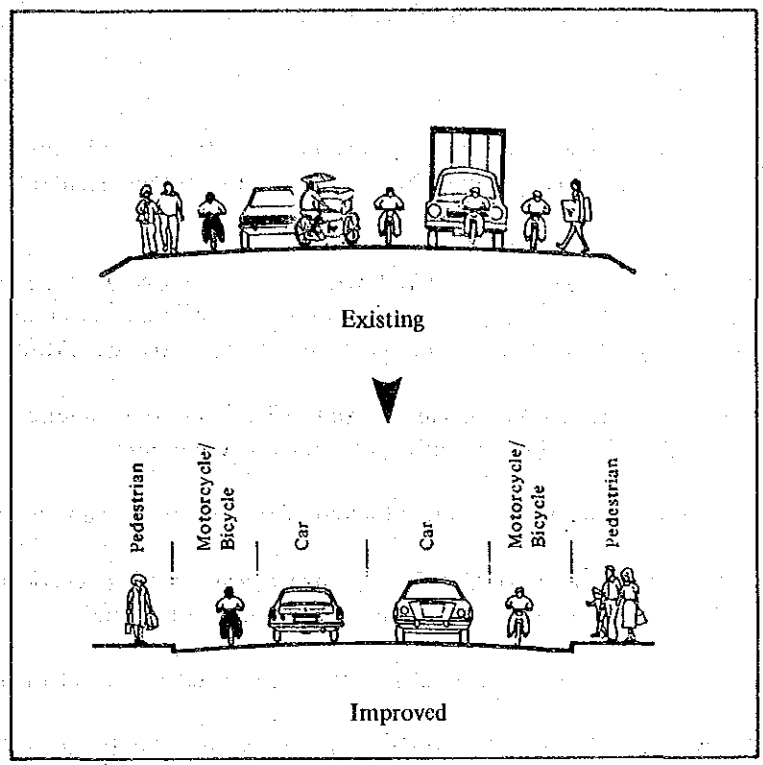


Figure 4.4.7 : Concept of an Improved Carriageway

3. Coping with Transport Problems Beyond Year 2000

Future traffic problems will not be completely mitigated by this proposed Road Network Improvement Plan. In order to cope with the further increase in traffic volume beyond the year 2000, the road network must be improved further.

By the year 2000, the road network configuration in George Town is a step closer to the ring and radial pattern.

After this, for the development of Penang Island beyond year 2000, it is necessary to construct the Outer Ring Road.

4.5 Traffic Circulation System Improvement Plan

4.5.1 Basic Guideline

A good circulation system provides a more efficient and smoother traffic flow. It is widely used as a traffic management technique especially in a heavy trafficked urban areas.

A circulation system is created when two or more adjacent streets carry an unidirectional traffic flow. It is composed of a single circulating traffic flow or is formed by an interlocking network of one-way streets. Among its advantages are :

(1) intersection control can be simplified and its efficiency improved because of reduced number of conflicting traffic movement;

(2) co-ordination between adjacent signal systems can be made more effective;

(3) unidirectional traffic flow carries less serious carriageway's obstructional impact compared to an opposing two-way flow, and

(4) reduction of 'frictional' resistance imposed by street on its traffic movement.

Analysis on the existing traffic conditions and the future vehicle OD distribution pattern shows that the circulation system around KOMTAR is expected to face a serious traffic congestion in the future. The attributory factor is that most of the traffic circulation within the Central Area is concentrated in the periphery of KOMTAR. Hence, remedial measures are desirable to improve the existing circulation system to upgrade traffic flow, road safety, and to increase carriageway/ intersection capacity.

4.5.2 Traffic Circulation Alternatives

At this juncture, one alternative short term plan (1990), and two alternative long term plans (2000) are considered for the future one-way circulation system.

The conceptual strategy is to (a) provide a more efficient and smoother traffic flow, (b) reduce the traffic volume in the periphery of KOMTAR, and (c) increase the carriageway and intersection capacity and furthermore (d) improve or construct pedestrian pathways. The basic feature of the existing system and these alternatives are briefly enlisted hereunder. Figure 4.5.1 depicts the traffic circulation alternative plans in 1990 and 2000.

A. Existing Circulation System

Under the existing circulation system, the major traffic control features are:

(1) One-way north-bound on Penang Road between Prangin Road and Magazine Circus, one way south-bound on Ria Road as a pair;

(2) One-way west-bound on Magazine Road between McNair Street and Magazine Circus, one way east-bound on Prangin Road from Penang Road to Ria Road;

(3) One-way south-bound on Penang Road between Chulia Street and Prangin Road, one-way north-bound on Transfer Road;

(4) Basically, a series of one-way loops (combined loopsystem) is adopted in the Central Area of George Town, that is, the one-way loop formed by the roads as mentioned in the above items (1) and (2) is connected at the intersection of Penang Road and Prangin Road with another one-way loop formed by Burma Road, Transfer Road and Phee Choon Street.

B. Short Term Alternative

Alternative S–1 : To a certain extent, the circulation of this alternative plan is identical to the existing system. Major changes involve conversion of some major roads into one-way and reversal in traffic flow of some existing unidirectional streets. Planning of this circulation is based on the anticipated fact that the new Coastal Road will not be in operation by 1990.

C. Long Term Alternatives

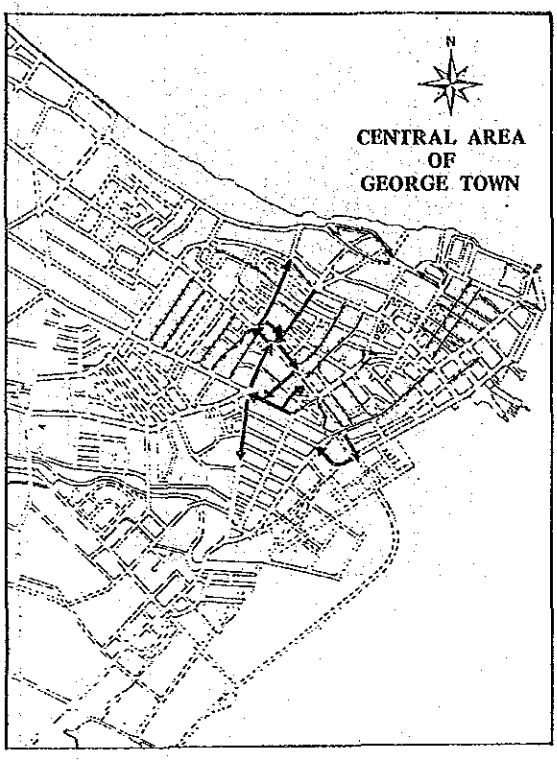
The usage of main roads and some buildings around KOMTAR have been decided under the KOMTAR Project. According to the decision, Prangin Road will be operated as one-way for east-bound traffic, while Magazine Road will be controlled as one-way for west-bound traffic. These roads will be directly connected to the new Coastal Road.

Therefore, the following Alternatives L–1 and L–2 are considered under the KOMTAR Project plan.

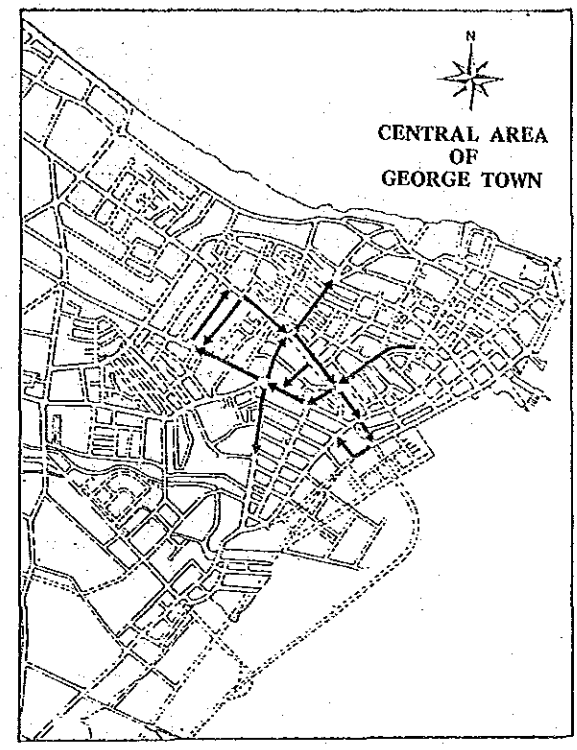
Alternative L–1 : Basically, the circulation plan in this alternative is identical to the existing system involving some minor changes. This circulation shall accommodate the traffic impacts introduced by the new Coastal Road, presumably to be in operation by 2000.

Alternative L–2 : The circulation plan in this alternative is identical to Alternative S–1, which involves some major changes from the existing system in view of the impending traffic impacts introduced by the new Coastal Road by the year 2000.

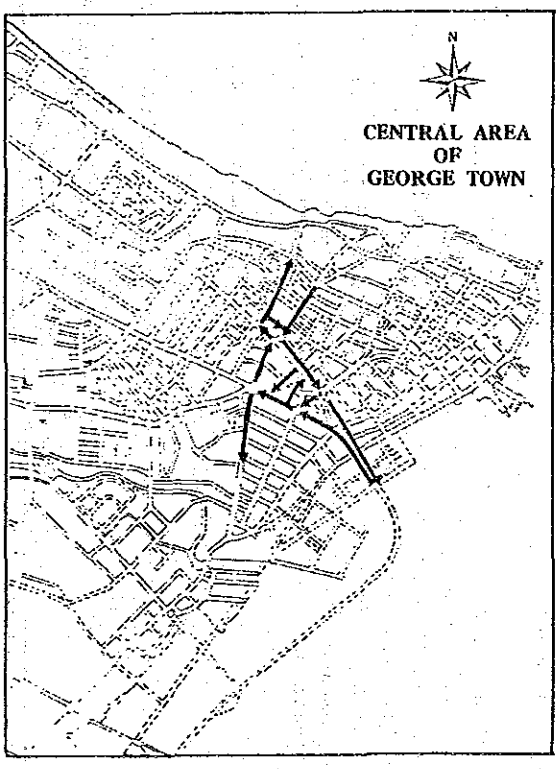
Further details are presented in Table 4.5.1.



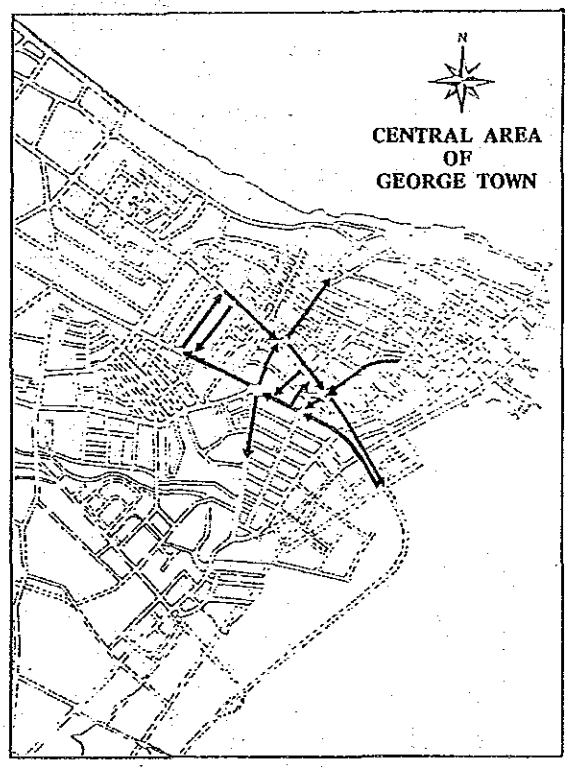
Existing System Plan (1987)



Alternative S–1 (1990)



Alternative L–1 (2000)



Alternative L–2 (2000)

Figure 4.5.1 : Traffic Circulation Alternative Plans

Table 4.5.1 : Examination of the Traffic Circulation System Alternatives

Traffic Circulation System Alternatives	Circulation Features	Remarks
EXISTING SYSTEM PLAN (1990)		
The conceptual strategy is : • to deter through traffic in the centre of town by making many turn-movements through a longer trip distance	• One-way northbound on Penang Road (between Prangin Road & Magazine Circus), one-way southbound on Ria Road as it's pair • One-way westbound on Magazine Road (between McNair Street & Magazine Circus), one-way eastbound on Prangin Road (between Penang Road and Ria Road) • One-way southbound on Penang Road (between Chulia Street & Prangin Road), one-way northbound on Transfer Road	• A series of one-way loops (combined loop system) is adopted in the CBD, that is, the one-way loop around KOMTAR is connected at the intersection of Penang Road & Prangin Road with another one-way loop formed by Burma Road, Transfer Road & Phee Choon St. • Most of the traffic from outside CBD is concentrated in the circulation loops, then by using them, the traffic is distributed to each destination in the CBD, and vice versa. • There are some congestions on short weaving sections
ALTERNATIVE S–1 (1990)		
The conceptual strategy is : • to ease traffic promptly from the centre of town through a shorter trip distance using signals • to promote pedestrian safety, walking conditions by providing pedestrian pathway	Conversion of some major roads into one-way streets • Burma Road (between Steward Lane and Penang Road) • Carnarvon Street (between Leboh Acheh and Carnarvon Circus) • Macalister Road (between Penang Road and Yahudi Road) Reversed traffic direction of the existing unidirectional street • Penang Road (between Burma Road and Chuila Street) Conversion of Transfer Road (between Argyll Road and Burma Road) into two-way street	• With the conversion of Macalister Road, Burma Road & Carnarvon Street into one-way streets, traffic congestions along Burma Road & Carnarvon Street would be palliated • Elimination of the weaving problems on the section of Penang Road between Phee Choon St and Prangin Road with the introduction of the reversed traffic along the existing unidirectional Burma Road and Penang Road • Weaving problems on the section of Magazine Road between Ria Road and Penang Road would still be present

Table 4.5.1 : Examination of the Traffic Circulation System Alternatives (cont'd)

Traffic Circulation System Alternatives	Circulation Features	Remarks
ALTERNATIVE L–1 (2000)		
The conceptual strategy is : • to deter through traffic in the centre of town by making many turn-movements through a longer trip distance • to ease access from the new coastal road to KOMTAR and vice versa.	Circulation system is identical to the existing except with some minor changes involving • Non-provisional traffic access from Carnarvon Circus to KOMTAR through Prangin Road • Outbound of the new Coastal Road connects Prangin Road and the inbound connects Magazine Road	• Accommodation of impact introduced by the new coastal road by providing a smooth and continuous thoroughfares from/to the southern traffic corridors • Weaving problems on the section of Prangin Road between Rope Walk and Carnarvon Street will appear
ALTERNATIVE L–2 (2000)		
The conceptual strategy is : • to ease traffic promptly from the centre of town through a shorter trip distance using signals • to ease access from the new coastal road to KOMTAR and vice versa • to promote pedestrian safety, walking conditions by providing pedestrian pathway	Circulation system is identical to Alternative S–1 except with some minor changes involving • Non-provisional traffic access from Carnarvon Circus to KOMTAR through Prangin Road • Outbound of the new Coastal Road connects Prangin Road and the inbound connects Magazine Road	• Same as Alternative S–1 in addition to a provision of traffic access from/to southern traffic thoroughfares

4.5.3 Traffic Conditions under the Traffic Circulation Alternatives

This section examines the traffic conditions under each traffic circulation alternatives. For this purpose, the traffic volume in the periphery of KOMTAR are estimated using the traffic assignment simulation method. Figures 4.5.2 to 4.5.5 illustrate the traffic volumes under the traffic circulation alternative plans.

This examination is discussed under three (3) factors:

(1) total trip distance, total travel time and average speed
(2) level of traffic congestion on road sections
(3) level of traffic congestion at intersections

A. Total Trip Distance, Total Travel Time and Average Speed

Table 4.5.2 shows the total trip distance in vehicle kilometers, total travel time in vehicle hours and average speed in kilometer per hour in the Central Area of George Town in 1990 and 2000.

Table 4.5.2 : The Comparison of Vehicle-kilometers, Vehicle-Hours and Average Speeds in 1990 and 2000

Indicator	Traffic Circulation Alternatives			
	1990		2000	
	Existing System Plan	Alt.S–1	Alt.L–1	Alt.L–2
Vehicle Kilometers ('000 PCU Km)	209.4	208.5	287.9	284.2
Vehicle Hours ('000 PCU Hr)	11.0	11.0	17.5	17.0
Average Speed (Km/Hr)	19.0	19.0	16.5	16.7

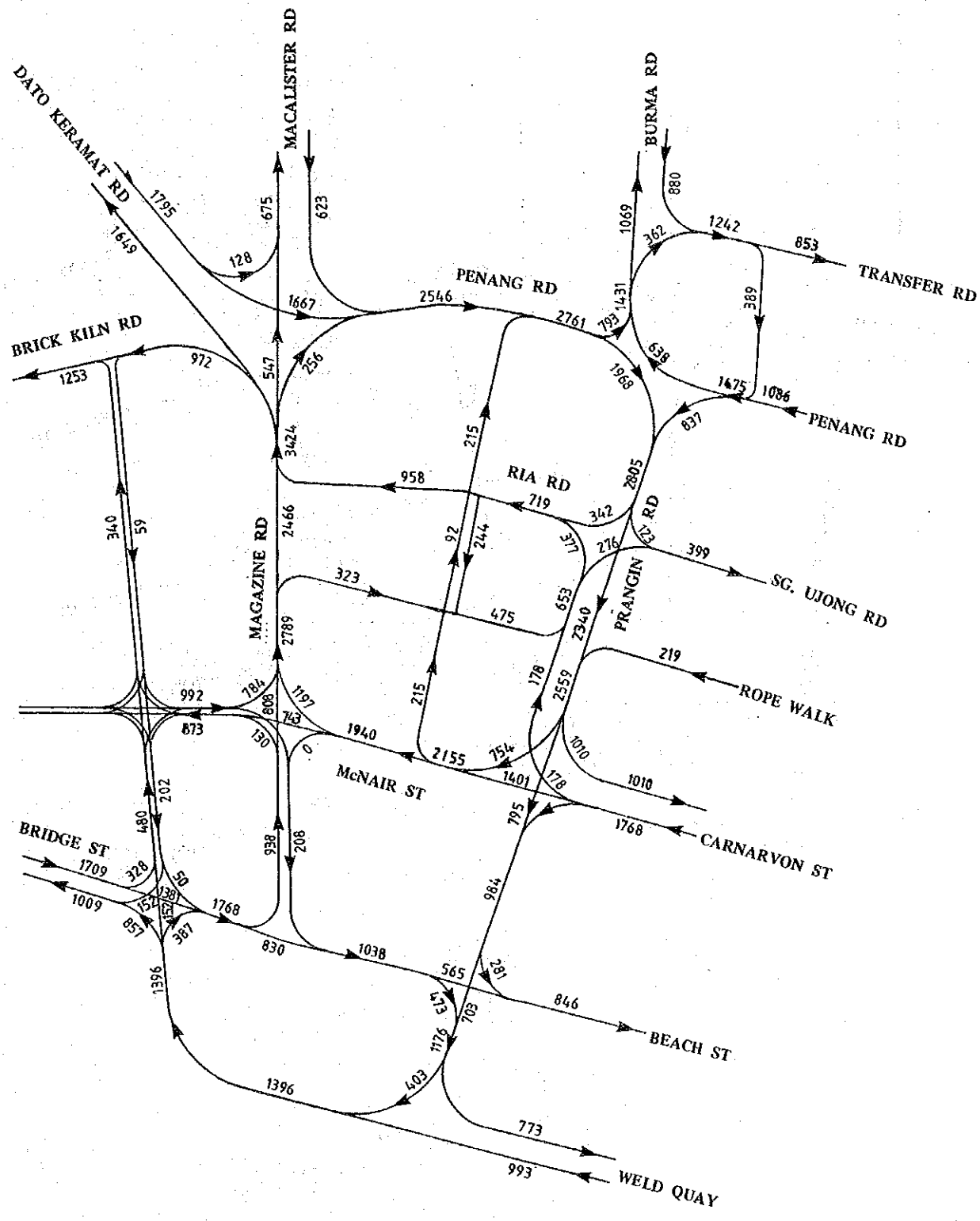


Figure 4.5.2 : Traffic Circulation Alternative Plan (Existing System Plan) and Traffic Volume in 1990

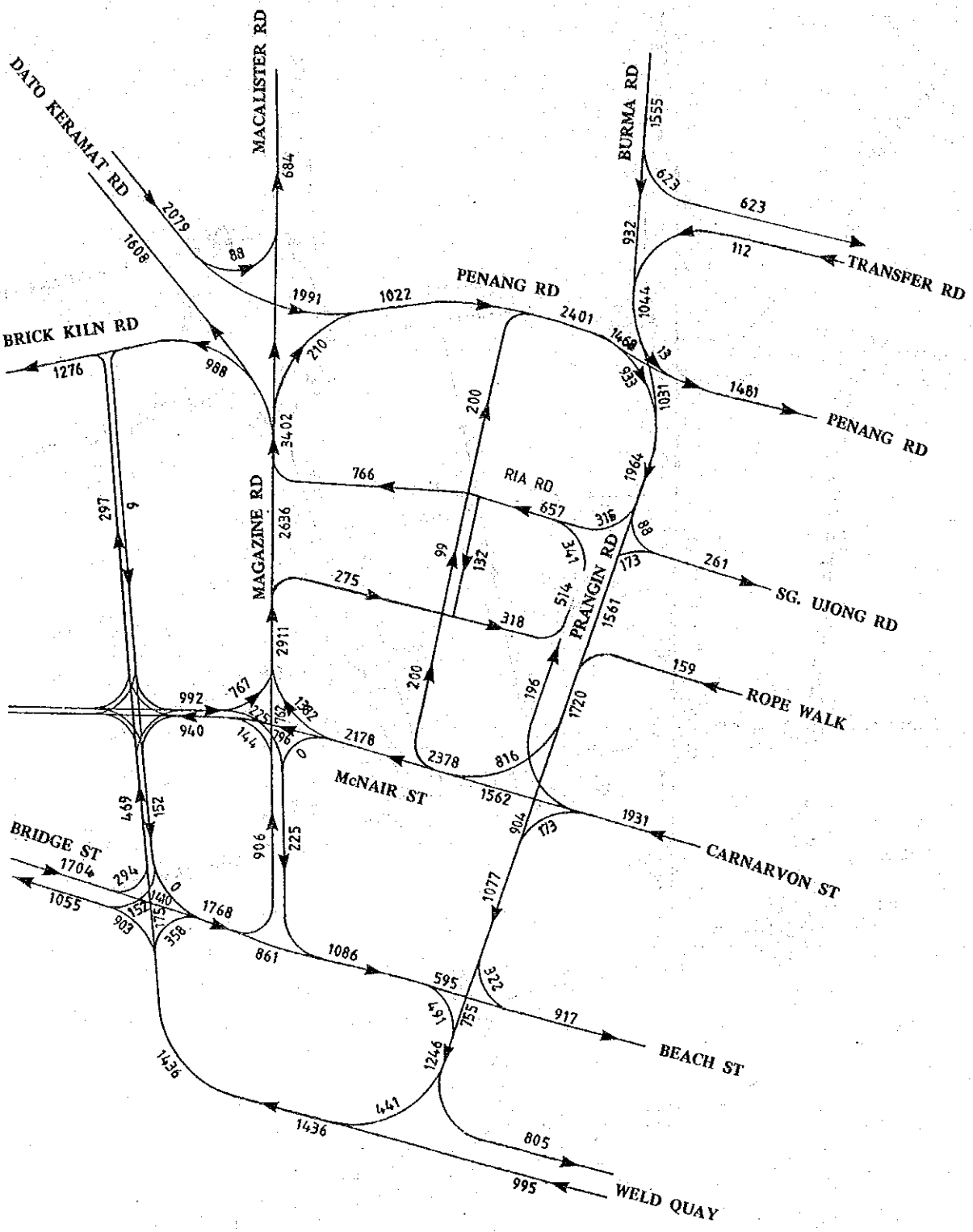


Figure 4.5.3 : Traffic Circulation Alternative Plan S–1 and Traffic Volume in 1990

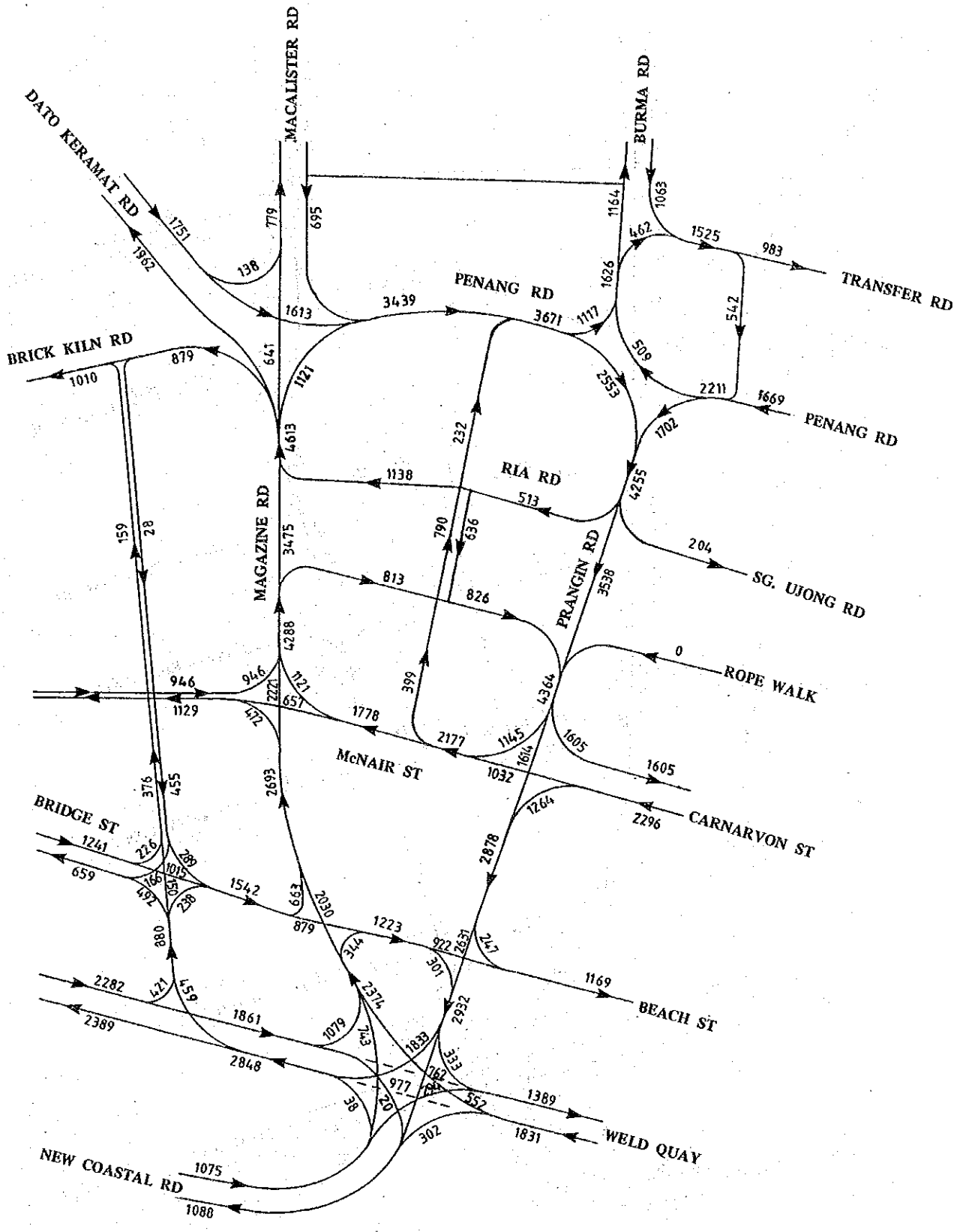


Figure 4.5.4 : Traffic Circulation Alternative Plan L–1 and Traffic Volume in 2000

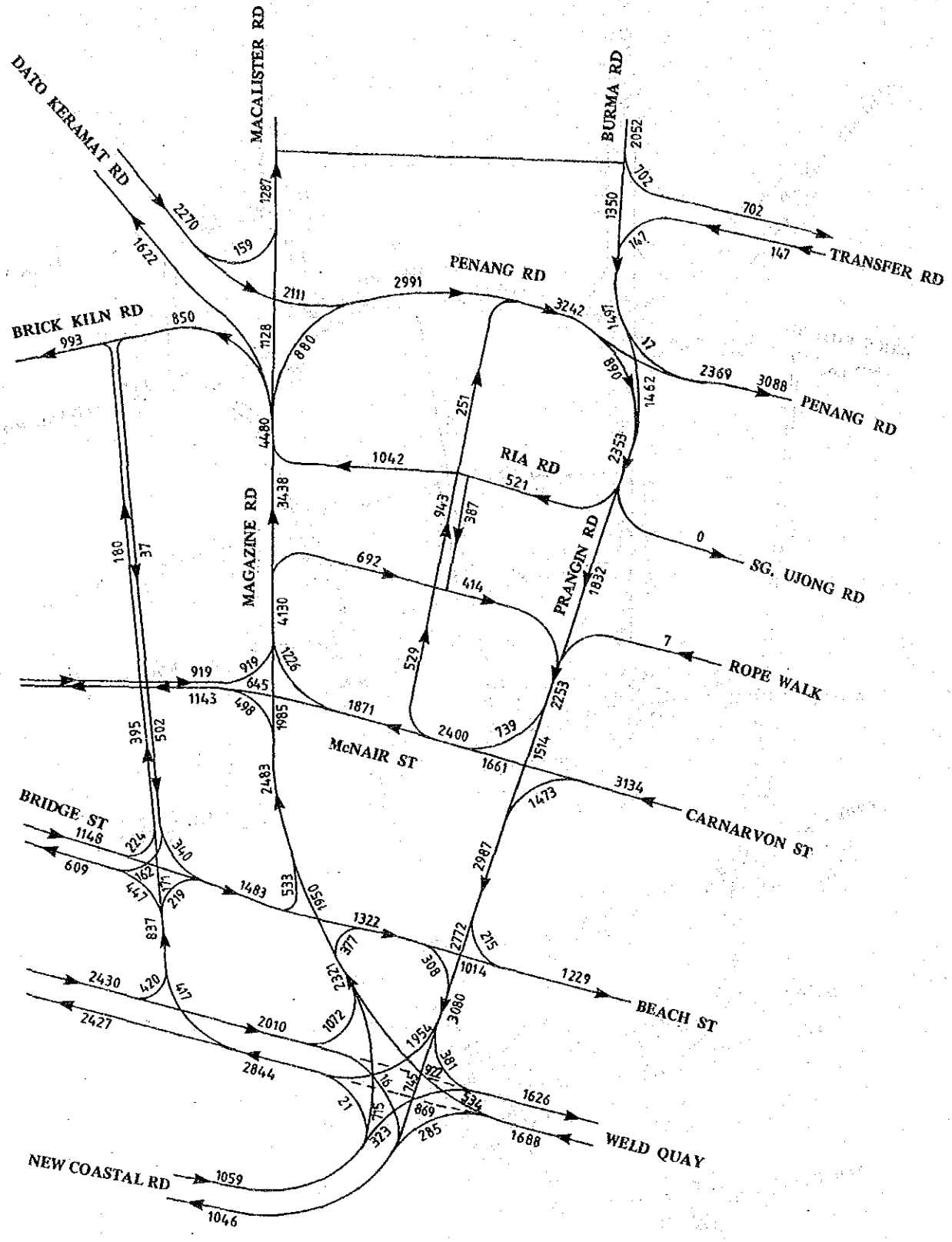


Figure 4.5.5 : Traffic Circulation Alternative Plan L–2 and Traffic Volume in 2000

The comparison between the Existing System Plan and Alternative S–1 in 1990 shows that the values of each factor are almost similar in both cases. However, the value of vehicle-kilometers runned under the Existing System Plan is slightly higher than that of Alternative S–1.

In 2000, the values of vehicle-kilometers and vehicle-hours under Alternative L–1 is larger than those under Alternative L–2, that is, motorists will make longer trip length and travel time in the case of Alternative L–1. This is illustrated by the slower average speed in this case than in Alternative L–2.

B. Road Capacity and Traffic Volume

The comparison between road capacity and traffic volume is made as follows :

Table 4.5.3 depicts the road capacity and traffic volume.

Table 4.5.3 : Road Capacity and Traffic Volume

Road Name	Capacity	Traffic Circulation Alternative			
		1990		2000	
		Existing System Plan	Alt.S–1	Alt.L–1	Alt.L–2
Weld Quay	4,800	1,766 (0.37)	1,800 (0.38)	3,220 (0.67)	3,314 (0.69)
Prangin Road (East)	2,400 7,200**	1,176 (0.49)	1,426 (0.52)	5,306** (0.74)	5,401** (0.75)
Prangin Road (West)	3,600	2,805 (0.78)	1,964 (0.55)	4,255 (1.18)	2,353 (0.65)
Carnarvon Street	3,200 3,600*	2,778 (0.87)	1,931* (0.54)	3,901 (1.22)	3,134* (0.87)
Bridge Street	1,600 2,000	2,718 (1.36)	2,759 (1.38)	1,900 (0.95)	1,757 (0.88)
Penang Road (North)	3,600	1,475 (0.41)	1,481 (0.41)	2,211 (0.61)	2,369 (0.66)
Penang Road (South)	3,600	2,761 (0.77)	2,401 (0.67)	3,671 (1.02)	3,242 (0.90)
Magazine Road	3,600	3,424 (0.95)	3,402 (0.95)	4,613 (1.28)	4,480 (1.24)
McNair Street	3,600	2,155 (0.60)	2,378 (0.66)	2,177 (0.60)	2,400 (0.66)
Dato Keramat Road	3,200	3,444 (1.07)	3,687 (1.15)	3,713 (1.16)	3,692 (1.22)
Macalister Road	2,000 2,400*	1,298 (0.65)	684 * (0.29)	1,474 (0.74)	1,287* (0.54)
Burma Road	2,000 2,400*	1,949 (0.97)	1,555* (0.65)	2,227 (1.11)	2,052* (0.86)

Note : * One-way Operation
** Capacity or traffic volume of Prangin Road and Magazine Road extension to be newly constructed
( ) = Volume/Capacity

Under the traffic circulation alternatives in 1990, roads expected to have congestion are fairly similar in both alternatives. They are, Bridge Street, Dato Keramat Road, Burma Road and Magazine Road. However, the congestion in Burma Road will be expected to be relieved when it becomes a one-way street as in Alternative S–1.

Under Alternatives L–2, the traffic conditions on Carnarvon Street and Burma Road will be congestion free under one-way operation. In addition, Prangin Road between Penang Road and Ria Road will also be congestion free.

In both alternatives in 2000, the demand on Magazine Road and Dato Keramat Road will exceed the road capacity, and on Penang Road between Prangin Road and Tek Soon Street, the demand will be near to its capacity.

C. **Intersection Capacity and Traffic Flow**

Five main intersections which may have some traffic problems are discussed: Magazine Circus, Prangin Road/Penang Road, Magazine Road/McNair Street, Prangin Road/Carnarvon Street and Prangin Road/Weld Quay.

The first three intersections has been signalized, and the others will be signalized by the opening of the new Coastal Road. It is assumed that a flyover will be built on Weld Quay above the intersection of Prangin Road/Weld Quay.

Table 4.5.4 shows the congestion degree at intersections under the traffic circulation alternative plans in 1990 and 2000.

In 1990, the intersections of Prangin Road/Penang Road and Prangin Road/ Carnarvon Street will have slight congestion in case of the Existing System Plan, while in case of Alternative S–1, congestion will not appear, but Magazine Circus will become slightly crowded.

In 2000, under Alternative L–1, the intersections at Prangin Road/Penang Road and Prangin Road/Carnarvon Street will have serious congestion. On the other hand, under Alternative L–2, Magazine Circus will have heavy congestion.

Since the intersection of Prangin Road/Carnarvon Street is not improved yet, it is necessary to carefully design it.

Table 4.5.4 : Congestion Degree at Intersections

Intersection Name	Traffic Circulation Alternatives							
	1990				2000			
	Existing System Plan		Alternative S–1		Alternative L–1		Alternative L–2	
	Volume/ Hour	Volume/ Capacity	Volume/ Hour	Volume/ Capacity	Volume/ Hour	Volume/ Capacity	Volume/ Hour	Volume/ Capacity
Magazine Circus	5,840	0.79	5,481	0.91	7,059	0.89	6,250	1.32
Prangin Road/ Penang Road*	4,236	1.08	3,445	0.67	5,882	1.53	4,729	0.93
Magazine Road/ McNair Street	3,870	0.77	4,076	0.76	5,687	0.77	5,273	0.68
Prangin Road/ Carnarvon Street**	4,327	1.02	3,651	0.72	6,660	1.53	5,387	1.05
Prangin Road/ Weld Quay***	–	–	–	–	5,960	1.13	6,046	1.13

Note : (1) * In the case of three lane operation in one direction on Prangin Road
** In the case of signalization at Prangin Road/Carnarvon Street
*** In the case of a flyover on Weld Quay above this inter

(2) Each estimated value should be lessened by 11% due to lower PCU for motorcycle.