2) Industrial base

Industrial land use took up an area of 3,345ha, which is 6% of main island area. By the end of the fiscal year 1988/89, the total land area managed by JTC reached 6,729.51ha.

3) Commercial use

Shops, offices, hotels and restaurants occupy a land area of 2% of total area of the mainland. Currently, 70% of commercial activities are concentrated in the city centre. However with the aggressive decentralization of program by HDB, commercial activities in the Central Business District (CBD) will be expected to decrease to 50% by 2000.

Several New Town developments such as Woodlands, Punggol, Jalan Kayu, Kangkar and Seletar New Towns together with the MRT Extension Programmes and expressways will contribute to the increase in commercial use outside the CBD area.

2.4.5 Registered Vehicles

Fiscal measures taken on the number of car ownership have controlled motor vehicle growth. The Government's action is a national policy to avoid traffic congestion which generates various urban transportation problems. The Government has set up the following procedures.

1) Bidding of certificates of entitlement

Bidding is conducted monthly for people who intend to buy any kind of car in a category opened by the Government. If the bid is lost, one is able to obtain a licence from other bidders or car dealers.

2) Fiscal measures

There is a dual pricing system for the purchase of new cars: PARF and ARF.

PARF is the trade in system for used cars (age 10 years or less). The import duty of the car to the owner is 175% of the car price. The system suppresses the increase in the number of cars.

ARF is the price to purchase a car without a used car. 220% of import tax is borne by the owner.

The import tax includes related miscellaneous charges and fees and road tax categorized by the displacement of the car engine is collected biannually. A car tax system does not exist in Singapore.

The number of vehicles registered between 1983-1989 are shown in Table 2.9.

The number of registered vehicles in 1986 and 1987 was a result of the economic recession of 1985. The increase in taxis and goods vehicles were slower as compared with private cars. Due to the slow response in the change of economic climate, late reinvestment was reflected in 1988.

Table 2.9 Number of registered vehicles

	1983	1984	1985	1986	1987	1988	1989
Total	476,288	491,322	486,760	473,659	471,124	491,808	520,357
Private	202,092	271,119	221,279	220,566	222,487	237,801	257,371
Taxi	14,841	15,221	14,971	13,991	13,633	13,613	13,787
Bus	7,985	8,283	8,717	8,638	8,733	8,924	9,126
Truck	105,090	111,259	109,596	105,643	104,938	106,477	113,671
Others	146,280	139,440	132,197	124,821	121,333	124,993	126,582

Source: DOS

Existing socio-economic indexes are summarized in Table 2.10.

Table 2.10 Existing socio-economic indices

INDEXES	UNIT	1983	1984	1985	1986	1987	1988	1989
1. Population	thousand	2,502.0	2,529.1	2,558.0	2,586.2	2,612.8	2,647.1	2,685.4
2. Employment	thousand	1,167.6	1,174.8	1,154.3	1,149.0	1,192.9	1,238.5	1,277.3
1)Primary		11.8	8.8	8.1	9.6	10.4	6.2	6.5
2)Secondary		410.7	423.9	339.9	390.9	411.0	443.7	461.3
3)Tertiary		743.5	739.3	744.8	746.7	769.9	786.8	808.3
4)Others		1.6	2.8	2.4	1.8	1.6	1.8	1.2
3 GNP (At Current Mkt Pr)		36.56	40.82	40.33	39.55	43.19	50.36	56.35
4. GDP 1985 (At Current Mkt Pr)	billion S$	36.54	39.57	38.92	39.64	43.39	48.22	52.68
5. GDP/Capita	S$ (US$)	14,604	15,646	15,215	15,328	16,606	18,216	19,617
6. Trade Balance	billion S$	-13.35	-9.79	-7.64	-6.56	-8.15	-9.18	-9.74
1)Export		46.15	51.34	50.18	48.99	79.05	79.05	87.12
2)Import		59.5	61.13	57.82	55.55	88.23	88.23	96.86
7. Industrial Prods.	billion	36.73	40.05	38.92	38.65	42.61	49.37	55.31
1)Primary	S$(GDP)	0.33	0.4	0.29	0.22	0.20	0.19	190.0
2)Secondary		13.25	14.94	13.41	14.87	17.76	19.38	19,385.4
3)Tertiary		23.15	24.77	24.50	26.81	31.40	35.73	35,734.7
8. Tourisia Incomes								
1)Visitors Arrival	thousand	2,853.6	2,991.4	3,031.0	3,191.0	3,678.9	4,186.1	4,830.0
2)Expenditure per person/day	S$	890.0	760.0	750.0	750.0	810.0	830.0	850.0
3)Total Incomes	billion S$	2.5	2.3	2.3	2.4	3.0	3.5	4.1
4)Collected Cess	million S$		3.8	34.6	33.4	38.2	45.6	56.0
9. Registration of Vehicles	no.	476,288	491,322	486,760	473,659	471,124	491,808	520,537
1)Private		202,092	217,119	221,279	220,566	222,487	237,801	257,371
2)Taxi		14,841	15,221	14,971	13,991	13,633	13,613	13,787
3)Bus		7,985	8,283	8,717	8,638	8,733	8,924	9,126
4)Truck		105,090	111,259	109,596	105,643	104,938	106,477	113,671
5)Others		146,280	139,440	132,197	124,821	121,333	124,993	126,582

SOURCE : DEPARTMENT OF STATISTICS

CHAPTER 3

ROAD TRANSPORT

CHAPTER 3 ROAD TRANSPORT

The urban transport system in Singapore is served by a well established road and bus route network. The MRT started operations in December 1987 and became fully operational in July 1990. The MRT network is 67 km; 22km of the North-South Line, 39km of the East-West Line and 6km of the Branch Line.

According to the MRT study, the MRT serves 40% of the city's commercial and industrial areas. It is expected to provide service within 10-minutes' walking time to 30% of the inhabitants of new towns. The MRT will transport 941,000 persons a day and will account for 1/3 of the utilization of total public transportation in 2000 according to SDPS.

However, in spite of the MRT, road transport is expected to play an increasingly major role in total person trips. The mode share in public transport is forecasted to decrease from 44% in 1981 to 38% in 2000 according to LTS.

3.1 Road Classification

As Singapore is a city state, all the roads are managed under the National Road Network and classified under the following three categories:

(1) Expressways : These roads form the primary network of Singapore and provide for continuous, high speed (max. limit of 80km/h) and long distance travel.

(2) Arterials : (1) Semi-expressways
(2) Major Arterials
(3) Minor Arterials
These complement the expressway network and serve to distribute traffic between residential, industrial and business districts of Singapore. They form the links between the expressway network and roads within the local areas.

(3) Primary Access: These roads distribute traffic within the local areas. They link the arterial roads with the local access roads.

(4) Local Access : These roads give direct access to buildings and land within local areas.

The present total length of roads in Singapore is 2,836 km.

Expressways	102km	(3.6%)
Arterials	512km	(18.1%)
Primary Access	242km	(8.5%)
Local Access	1,980km	(69.9%)
Total	2,836km	(100.0%)

Among the total 2,836km, 2,752km (97.0%) are paved and 84km (3.0%) are unpaved.

3.2 Road Network

Table 3.1 shows the development of the road network in Singapore, and Fig. 3.1 shows existing road network. Despite the development of the MRT System, the dependence on road transportation is expected to increase, therefore, the authorities are prompted to study the prospects of future road development. From 1978 to 1989 the total length of expressways was increased by 3.6 times (an increase of 74km), arterial roads by 1.9 times (an increase of 247km), collector roads by 1.7 times (an increase of 100km) and local roads by 1.1 times (an increase of 152km). The development of expressway and arterial roads has been the main focus of the development during the period as shown in Table 3.1.

Table 3.1 Development of road network (Unit:km)

	Paved Road				Unpaved	Total
	Express ways	Arterial Roads	Collector Roads	District Roads	District Roads	
1978	28	265	142	1,473	355	2,263
	(1.2)	(11.7)	(6.3)	(65.1)	(15.7)	(100.0)
1979	28	280	144	1,509	328	2,289
	(1.2)	(12.2)	(6.3)	(65.9)	(14.3)	(100.0)
1980	39	313	157	1,539	308	2,356
	(1.6)	(13.3)	(6.7)	(65.3)	(13.1)	(100.0)
1981	54	345	188	1,611	285	2,483
	(2.2)	(13.9)	(7.6)	(64.9)	(11.4)	(100.0)
1982	54	373	199	1,671	236	2,533
	(2.1)	(14.7)	(7.9)	(66.0)	(9.3)	(100.0)
1983	57	387	211	1,714	199	2,568
	(2.2)	(15.1)	(8.2)	(66.8)	(7.7)	(100.0)
1984	57	408	208	1,761	163	2,597
	(2.2)	(15.7)	(8.0)	(67.8)	(6.3)	(100.0)
1985	73	435	202	1,797	138	2,645
	(2.8)	(16.5)	(7.6)	(67.9)	(5.2)	(100.0)
1986	77	458	210	1,828	113	2,686
	(2.9)	(17.1)	(7.8)	(68.0)	(4.2)	(100.0)
1987	83	490	227	1,855	105	2,760
	(3.0)	(17.8)	(8.2)	(67.2)	(3.8)	(100.0)
1988	96	500	238	1,891	85	2,810
	(3.4)	(17.8)	(8.5)	(67.3)	(3.0)	(100.0)
1989	102	512	242	1,896	84	2,836
	(3.6)	(18.1)	(8.5)	(66.9)	(3.0)	(100.0)

Source: Yearbook of Statistics, 1989,
Department of Statistics

Generally, the road network in the southern half of the island is denser than that of northern half. In the central area of island the road network pattern by the ring road and radial road is being formed, whilst a mesh pattern of networks is being formed in the south-east and south-west part of island.

The present expressway network is composed of 7 expressways. PIE (35km) and ECP (19km) were completed in 1981, BKE (11km) in 1985 and AYE (14km) in 1989. Part of CTE, TPE and SLE are now being used even though they are currently under construction.

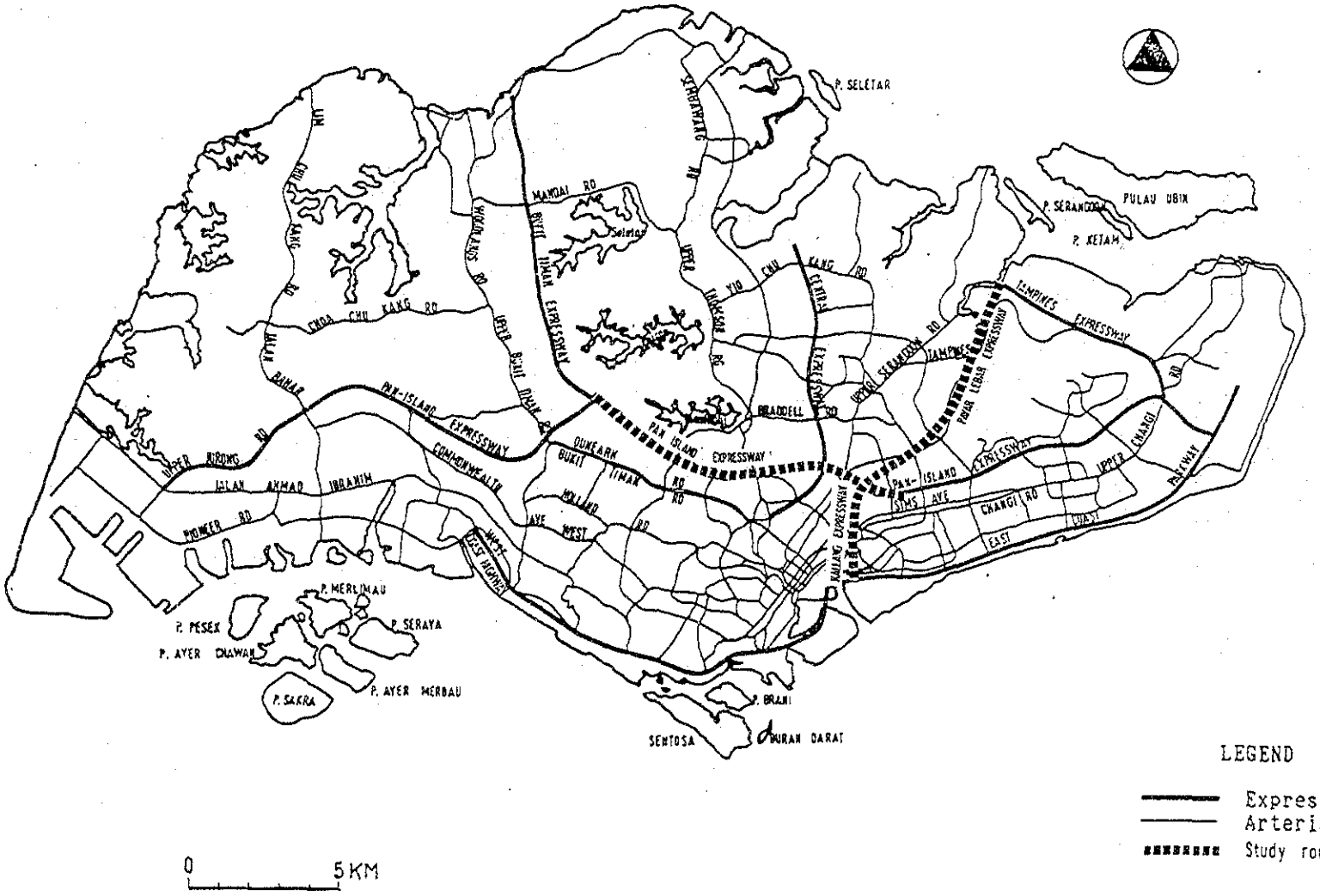


Fig. 3.1 Existing road network

3.3 Traffic Volumes at Major Locations

In order to prevent traffic congestion in the afternoon (4.30 pm - 7 pm), the evening ALS (Area Licence Scheme) was introduced on 01 June, 1989. The traffic count to examine its effects was conducted in May 1989 (before implementation) and July/August 1989 (after implementation) by PWD.

The roads were classified into 4 types for the traffic surveys:

(1) Roads within the RZ (Restricted Zone).
(2) Radial Roads fanning out from the RZ into the suburbs.
(3) Inner and outer ring roads skirting the RZ.
(4) Expressways.

The traffic volumes on these roads for the two hours from 5 pm to 7 pm are shown below.

(1) City Roads (Within RZ)

Road	Before May 89	(After Aug 89)
1. Orchard Road	7,300	(3,557)
2. South Bridge Road	3,993	(2,567)
3. Bras Basah Road	7,303	(4,191)
4. Victoria Street	4,198	(3,030)

(2) Radial Roads

	Before (After) to City May 89 (Aug 89)		Before (After) away from City May 89 (Aug 89)	
1. Mountbatten Road	1,044	(1,939)	2,022	(1,851)
2. New Upper Changi Road	2,249	(2,236)	2,527	(1,820)
3. Macpherson Road	1,591	(2,010)	2,679	(1,943)
4. Upper Serangoon Road	1,863	(1,380)	3,573	(2,691)
5. Thomson Road	3,348	(3,839)	4,813	(4,422)
6. Bukit Timah Road/Dunearn	4,631	(4,534)	5,298	(4,529)
7. Holland Road	3,855	(3,280)	3,391	(2,569)
8. River Valley Road	2,678	(2,506)	3,159	(2,597)
9. Alexandra Road	3,339	(2,892)	2,784	(2,661)
10. Telok Blangah Road	5,272	(4,897)	2,998	(3,150)

(3) Ring Road

		Before May 89	(After Aug 89)
Inner Ring Road			
1. Lavender St	to Balestier Road	5,266	(4,594)
	to Kallang Road	3,781	(3,588)
2. Scotts Road	to Orchard Road	5,965	(5,011)
	to Newton Circus	6,399	(7,912)
3. Outram Road	to Cantonment Road	3,464	(2,902)
	to Tiong Bahru Road	3,837	(2,108)
Outer Ring Road			
4. Paya Lebar Road	to Up. Serangoon Rd	3,931	(3,976)
	to Sims Ave	3,815	(3,656)
5. Adam Road	to Lornie Road	5,621	(4,934)
	to Holland Road	4,164	(3,954)
6. Queensway	to Alexandra Road	3,266	(2,880)
	to Farrer Road	3,950	(4,183)

(4) Expressways

Expressways		Before May 89	(After) (Aug 89)
1. Pan Island Expressway	to Jurong	11,308	(8,588)
	to Changi	9,535	(10,874)
2. East Coast Parkway	to Keppel Road	6,708	(6,968)
	to Changi	10,324	(6,914)
3. Central Express	to Kampong Java Road	7,949	(7,591)
	to Yio Chu Kang Road	8,497	(7,379)
4. Ayer Rajah Expressway	to Keppel Road	9,151	(11,847)
	to Jurong	7,594	(7,123)
5. Bukit Timah Expressway	to PIE	2,009	(1,970)
	to Woodlands	2,845	(3,917)

3.4 Traffic Accident on Expressways

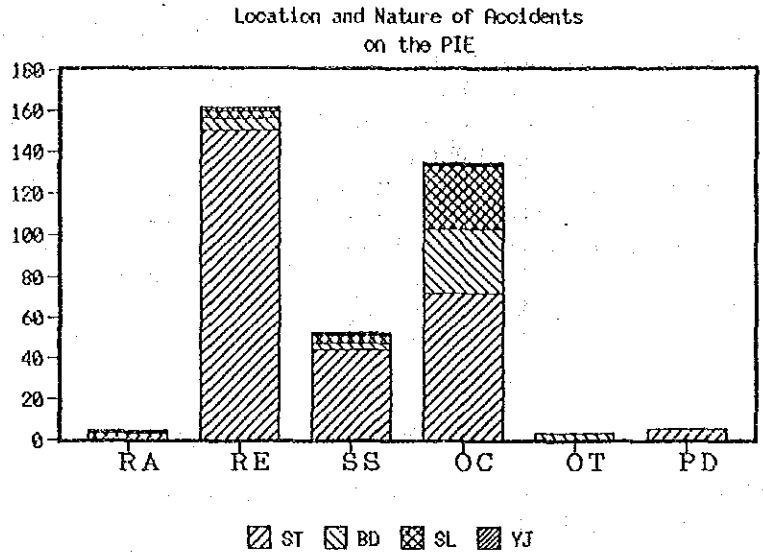
The number of accidents which occurred between 1988 and 1990 on the existing expressways is shown in Table 3.2.

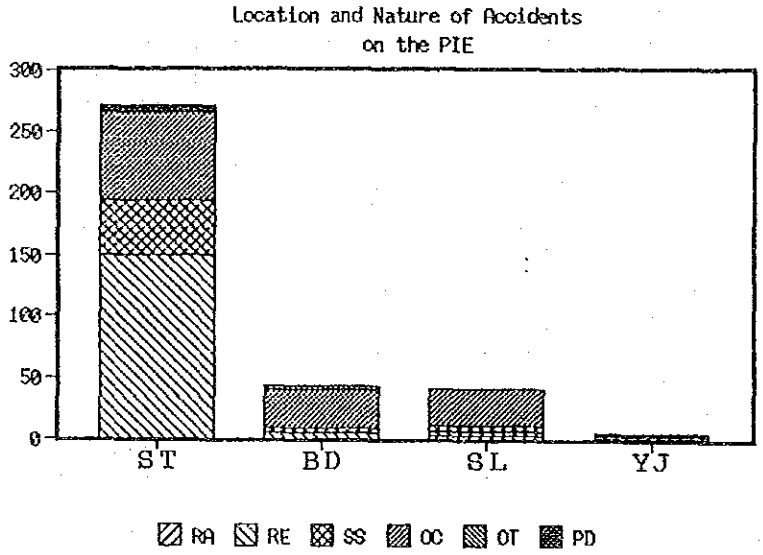
Table 3.2 Number of accidents on major expressways

	a. Number of accidents (frequency/ 3 years)	b. Route Length (km)	c=a/b rate of accidents (frequency/km)
PIE	376	35	10.7
BKE	52	11	4.7
CTE	61	16	3.8
ECP	195	19	10.2
AYE	110	14	7.9

The number of accidents which occurred on PIE totaled to 376 during the past three years. This is the highest among all the existing expressways. Besides, even if it is compared in terms of number of accidents per unit kilometer (accident rate), the accident rate on PIE is still the highest. However, accident rate should originally be compared with the number of accidents based on number of usage (vehicle) * kilometer. Since there isn't any data on detailed traffic volume, the accident rate based on per unit kilometer was used to compare the rates among different expressways.

Besides, Fig. 3.2 shows the cross totaling of the road interval - accident type of the accidents which occurred on PIE. For accident type, most of the accidents are tailgating accidents (of a vehicle) and mishandling. Tailgating accidents usually happen on straight roads while the probability of accident caused by mishandling is high on straight, bending and slip roads. Looking to the fact that the route lengths of bending roads and slip roads are shorter as compared to the route length of straight roads, we can conclude that for the case of accidents caused by mishandling, the number of accidents which occurred per unit kilometer on bend roads and slip roads are rather high.





Nature of Accident	
Right angle collision	– RA
Rear end collision	– RE
Sideswipe	– SS
Out of control	– OC
Overturned	– OT
Pedestrian	– PD

Location Type	
Straight	– ST
Bend	– BD
Slip Road	– SL
Y-Junction	– YJ

note: based on data from 1988 to 1990

Fig. 3.2 Traffic accident condition

CHAPTER 4

SOCIO-ECONOMIC FRAMEWORK

CHAPTER 4 SOCIO-ECONOMIC FRAMEWORK

4.1 Configuration of Socio-Economic Indicators for Traffic Volume Forecast

4.1.1 Population Forecast

Forecasts of future national population growth are based on the studies of DOS, MND, MOH and previous forecasts by DOS, MND and PMRTA. These forecasts were based on the results of the census conducted in 1980. The main objective of the study of population was to review the existing studies and establish the appropriate forecast with the latest information.

As the first step of the review, the population in 1990 was estimated from that of 1989 (2,685,400) by examining the natural increase rate from 1983 to 1989. As a result of the examination, it was estimated to be 2,717,356 which is close to that forecast in the Master Plan (2,708,200). Therefore the population of 1990 used for future forecasts was established to be 2,708,200.

The strong influence of the government's "Family Planning" is apparent by the sudden decrease in the age group 10-14 and is because of the policy pursued during the 1966-75 period. According to a study of MOH, the average number of children per household was estimated to be 1.57 in 1989.

The population of children in the age group of 10-14 showed a sharp decrease in 1989 and it is the smallest number among all age groups, followed by the age group of 5-9 years. The decrease in the female population within the age group of 10-14 was 94,900, within the 5-9 age group it was 96,400. Since the government changed its population policy in 1988 and promoted population growth, the population within the age group 0-4 increased. But in spite of a baby boom during the Golden Dragon Year in 1988, the population within the 0-4 age group was not as high before the "Family Planning" campaign.

On the other hand, females in the age group 25-39 born during the sharp population increase will gradually change with the following decreased age groups in 1995 and 2010. The composition of female age groups in 1989 is shown in Table 4.1.

Table 4.1 Comparison of female population by age group

	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Person	106.7	96.4	94.9	108.7	119.6	141.9	140.2	119.6
(%)	(8.1)	(7.3)	(7.2)	(8.2)	(9.1)	(10.8)	(10.6)	(9.1)

Source: DOS (Unit: thousands of persons)

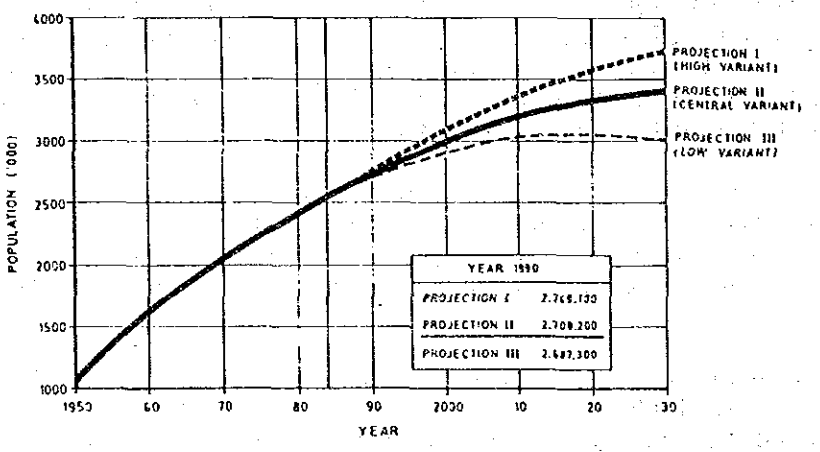
Considering the stable sex ratio of 1.06 and stable death rate of about 5.2, population growth excluding migration will be negative and will gradually decrease by 1995 and 2010.

In addition to the above, the rise in marriageable age due to the

popularisation of higher education and job opportunities for females is expected to continue and act as a negative factor in efforts to increase the number of children. All females will have to have at least 2 children to maintain the present population growth. However, MOH has forecast the average number of children per household to be 1.45 in 1995 and 1.1 in 2030.

According to these studies, the Study Team calculated the future population to be 2,856,300 in 1995, 3,020,900 in 2000 and 3,229,400 in 2010.

These figures were compared with the approximate forecasts prepared by MND and PMRTA, and it is judged that the Population Projection II in Master Plan is the most reasonable projection as adopted for the basis of our forecast because of similar forecast figures. (Fig. 4.1)



Source: Master Plan

Fig. 4.1 Population forecast

Analyzing other forecasts conducted by DOS/NUS, MOH and PMRTA, the following forecast was prepared by our study. (Table 4.2)

Table 4.2 Population forecast

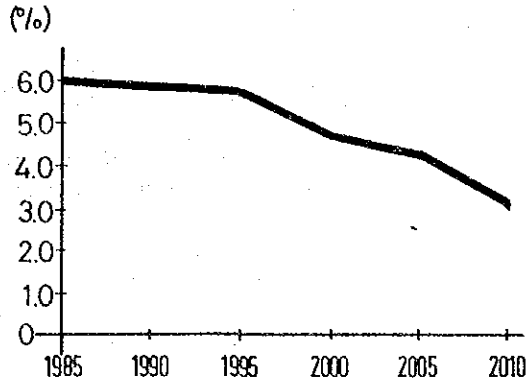
	1990	1995	2000	2005	2010	2030
Population	2,708.2	2,865.0	3,000.0	3,125.0	3,225.0	3,391.4
Increase/5 years	(5.89)	(5.80)	(4.71)	(4.17)	(3.20)	(1.27)

Source: Worked by JICA Study Team (Unit:thousands of persons)

The change in population per five years growth is shown in Fig. 4.2.

4.1.2 Employment

The forecast of employment in 1995 and 2010 was based upon a review of forecasts conducted by PMRTA and NUS. The population forecasts by MTI, DOS and MOL and discussions with JTC, HDB and URA were taken into



Source: JICA Study Team

Fig. 4.2 The change in population growth per five years

account. Through these studies, the future directions of employment structure were assessed as follows:

(1) The role of primary industries has continuously decreased in the employment market (1.2% in 1989). Accordingly, it has been categorized as 'miscellaneous' since 1986. Due to the progress of urbanization, activities in this sector will be negligible in 1995 and 2010.

(2) The decrease in population growth and higher education opportunities threaten the supply of manpower in the manufacturing sector. In order to maintain a constant growth rate in this sector, reform of the industrial structure is being undertaken to raise productivity. The proportion of employed persons in this sector will decrease in the labour market. But employment in this sector will continue to grow as a basic supporting industry of the country.

(3) The miscellaneous sector is the most productive sector in Singapore and is generating a big proportion of employment. This sector includes the financial and service industry sectors. It is playing a specially important role in this country, which has few natural resources.This sector is promoted by the government as a major industry in the next century.

The recent rapid growth of NIC countries in the ASEAN area will increase the role of Singapore as a free financial and business centre because of its location and well-established industrial and business infrastructure.

(4) In the city centre, the redevelopment of shop-house areas to large scale shopping centres will also decrease employed persons in the area. Therefore, employment in this sector will grow slowly in spite of its active expansion.

(5) The number of tourists visiting Singapore was to 4,800,000 in 1989, it is estimated to exceed 5,500,000 in 1990. Employment in tourism and related service industries will expand.

According to the prospect of economic development patterns and population growth of Singapore, the forecast of PMRTA (2000 and 2030)

was adopted as the framework of the study.

Employment of 1990 was estimated from the data of 1989. Forecasts in 1995, 2005 and 2010 were estimated by the data of 1981, 2000 and 2030.

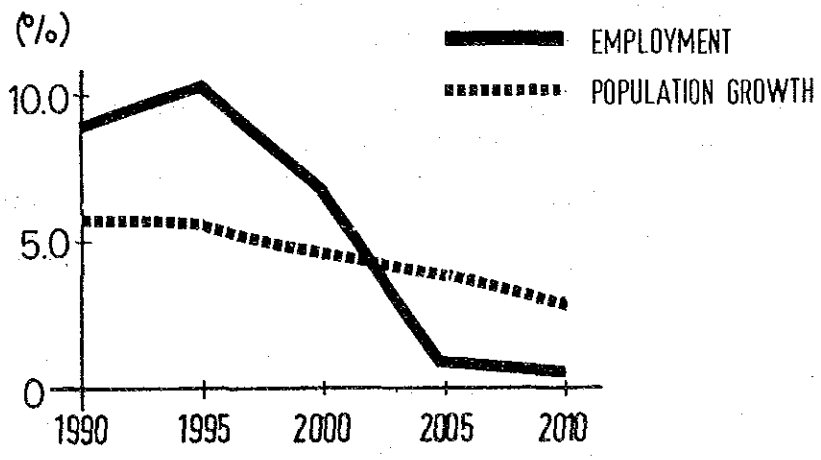
In line with these basic conclusions, a forecast of future employment was prepared as shown in Table 4.3 (Employed persons are of 15 years and above).

Table 4.3 Forecast of employed persons

	1990	1995	2000	2005	2010	2030
Total	1,258.0	1,386.5	1,481.8	1,493.3	1,504.2	1,550.6
(1) Manufacturing	373.2	399.2	429.7	430.5	431.2	434.2
(2) Retail	131.2	135.5	140.8	140.7	140.5	139.6
(3) Others	753.6	851.8	911.3	922.2	933.1	976.8

Source: JICA Study Team (unit: thousands of persons)

The change in growth of employment is as Fig. 4.3.



Source: JICA Study Team

Fig. 4.3 Change in growth of employed persons

4.1.3 Gross Domestic Product

The forecast of Singapore's GDP was based on a study of the following:

- -Statistics by DOS
- -Forecast growth rates used in LTS
- -Economic reports by MTI
- -Economic news articles published in the newspaper

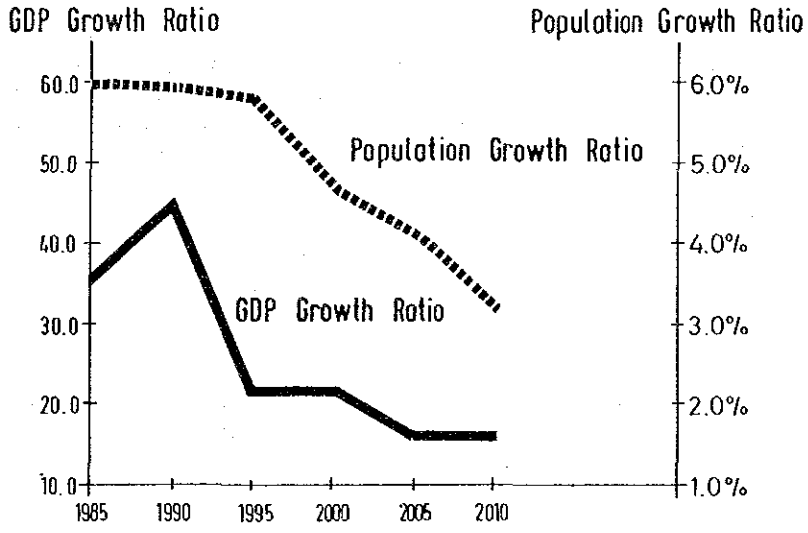
The growth rate in LTS was the latest reliable source. The MTI estimated the GDP of first quarter in 1990 as S$13,534 million, showing 10.1% growth comparing to the same period during previous year. The total GDP growth rate was estimated to be approximately 7% in 1990, GDP in 1990 was estimated to be S$56,370 million as a basis of the forecast.

GDP growth began a strong recovery in 1987 from the serious economic recession of 1985. The growth rates were 11.1% in 1988 and 9.2% in 1989. It is anticipated that the economy structure will change and growth pattern of the economy will be the same as in developed countries in 2000; until that time, high economic growth rate will continue.

After 2000, changed economic structures in Singapore will exhibit growth in the same pattern as developed countries, i.e. a slow but stable growth ratio of 2-3% p.a.

In addition to the changed economic structure, a decrease in population growth is considered to be a potential factor to the constraining economic developments.

The relation between population and GDP growth is shown in Fig. 4.4.



Source: JICA Study Team

Fig. 4.4 Relation between population and GDP growth

Based on the foregoing analysis of the country's economic prospects, the review of the projection of LTS (Land Transport Study) is until 2000. The growth after 2000 was estimated by the Study Team through discussion with the concerning departments.

The high growth rate of GDP in 1988 (11.1%) decreased to (9.2%) in 1989 and is anticipated to be 7% in 1990; this is considered to be a result of the changing economic structure of the country. An anticipated 4% average growth rate by 2000 is considered to be reasonable. The reason for the extremely high growth rate in 1990 was because of the speedy recovery from the economic recession of 1985

The growth rates adopted from the forecast are:

1990-1995	+21.70% (4%p.a.)
1995-2000	+21.70% (4%p.a.)
2000-2005	+16.00% (3%p.a.)
2005-2010	+16.00% (3%p.a.)

The growth of GDP and GDP per capita is forecast as shown in Table 4.4.

Table 4.4 Forecast of GDP and GDP per capita

	1990	1995	2000	2005	2010
GDP(million S$)	56,370	68,600	83,490	96,850	112,340
(%)	(44.83)	(21.7)	(21.7)	(16.0)	(16.0)
		(4%pa)	(4%pa)	(3%pa)	(3%pa)
GDP/Capita($)	20,815	23,944	27,830	30,992	34,834
(%)	(36.81)	(15.03)	(16.23)	(11.36)	(12.40)

Source: Worked by JICA Study Team

4.1.4 Registered Vehicles

In the case of Singapore, a forecast of registered vehicles cannot be conducted based on ordinary commercial market phenomena because of the government's control. The forecast of vehicle registration started from an estimation on the number of vehicles in 1990. Registered cars in the first half of 1990 and the number of vehicles up for bidding for "Certificate of Entitlement" announced in the newspaper were taken into account. Registered vehicles in 1990 were estimated as follows and used as a basis of the forecast:

-Private Cars	275,080
-Taxis	14,900
-Buses	9,200
-Goods Vehicles	121,630
-Motor Cycles	126,900
-Others	5,980
Total	553,690

The increase in the number of vehicles after 1990 was forecast considering the government's intention to control the quantity. The methods of forecasting of vehicles are as follows:

1) Private cars

The potential market for private cars is considered to be big in spite of the political and financial hurdles set up by the government. This was shown by the dramatic jump in the quota premium in the bidding for "Certificates of Entitlement" conducted in July 1990. Increases in population and income will broaden the potential market and demand for car ownership. The officially recognised life span of a car, 10 years, will be a subsidiary factor raising buying power. The growth rate on the number of cars for 1990-1995 is expected to be 6.7%, 1995-2000 is 5.5%, 2000-2005 is 4.6% and 2005-2010 is 3.6%.

2) Taxis

Since 1985 to 1988, the number of taxis has decreased by about 10%, i.e. 1,360 units. This was mainly due to the after effects of the economic recession that hit Singapore in 1985. Since 1989, new investment to increase the number of taxis has begun. The number recovered to 1,378 by the end of the year. The investment in new cars

in the taxi market in 1990 shows a visible difference, especially in the city area. Referring to the number of registrations during the first half of 1990, the number of taxis is estimated to be 14,900 by the end of 1990.

The population growth rate was used as a basis in forecasting the increase in taxis of which 5.8% is forecast for 1990-1995, 4.7% for 1995-2000, 4.2% for 2000-2005 and 3.2% for 2005-2010.

3) Buses

The number of registrations of buses seems to have been increasing steadily in accordance with purchasing schedules, approximately 200 units every year since 1987. Referring to the registered number of buses during the first half of 1990, the number of buses will continuously increase, but at a slow rate based on the increase in the number of passengers. Therefore, the population growth rate was also applied in this forecast. Results obtained were similar to those as that of taxis.

4) Goods vehicles

During 1985 to 1987, the number of registered goods vehicles continued to decrease. In spite of the strong and rapid recovery of the economy, the increase in goods vehicles has been too low to satisfy the market. Even in 1990, the supply of goods vehicles is regarded as too low to meet demand. The bidding price for quotas in this category jumped 4 times more in July than in May 1990 reflecting strong demand. The forecast for goods vehicles was based on growth of GDP and the trend of the population increase. A rate of 21.7% was anticipated for the years 1990-1995, 21.7% for 1995-2000, 7.7% for 2000-2005 and 7.7% for 2005-2010.

5) The category "others" includes road rollers, bulldozers, etc.

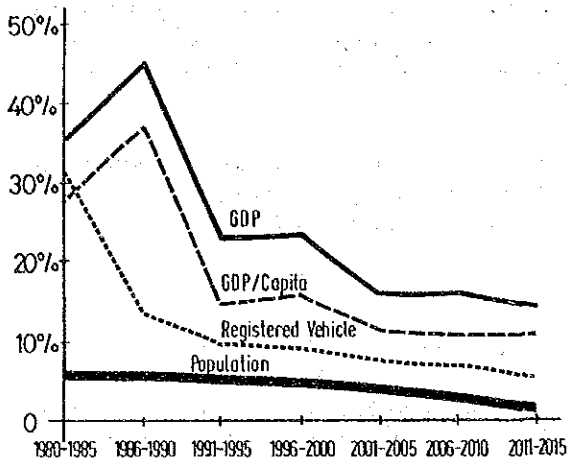
Generally, these vehicles are used for industrial purposes such as construction and warehouse activities, so the number was increased based on GDP growth. 21.7% for 1990-1995, 21.7% for 1995-2000, 16.0% for 2000-2005 and 16.0% for 2005-2010.

The forecast of each category of vehicles is summarised in Table 4.5 and the comparison between registered vehicles and socio-economic indexes is shown in Fig. 4.5.

Table 4.5 Forecast of registered vehicles

	1990	1995	2000	2005	2010
TOTAL	553,690	609,670	668,670	710,230	739,960
(1) Private Cars	275,080	293,510	309,650	323,890	335,550
(2) Taxis	14,900	15,760	16,500	17,190	17,740
(3) Buses	9,200	9,700	10,160	10,580	10,920
(4) Goods V.	121,630	148,020	180,140	198,870	209,030
(5) M.Cycle	126,900	135,400	142,850	149,420	154,800
(6) Others	5,980	7,280	8,860	10,280	11,920

Source: Work by JICA Study Team Department of Statistics



Source: JICA Study Team

Fig. 4.5 Comparison of registered vehicles and socio-economic growth

4.2 Socioeconomic Framework by Zones

The Study Team's zone map was originally prepared by the Provisional Mass Rapid Transit Authority (PMRTA) in 1980. This is still used as a basic material for traffic planning in PWD.

Singapore is divided into 17 traffic zones, 16 for main island and a 17th for Southern islands as shown in Table 4.6 and Fig. 4.6.

Table 4.6 Zoning system by PMRTA

Central Area	Sector	1	C.B.D	41
		2	Orchard	7
		3	Adjacent Orchard	6
Town Areas		4	Queenstown	40
		5	Toa Payoh	21
		6	Geylang	41
		7	Jurong/Clementi	21
		8	Jurong Industrial Estate	14
		9	Ang Mo Kio	29
		10	Changi	30
Outlying Areas		11	Tampines	12
		12	Hougang	27
		13	Yishun	16
		14	Bukit Batok	14
		15	Woodsland	20
		16	Lim Chu Kang	7
Off-shore		17	Islands	6
Sub-total				352
Others				64
Total				416

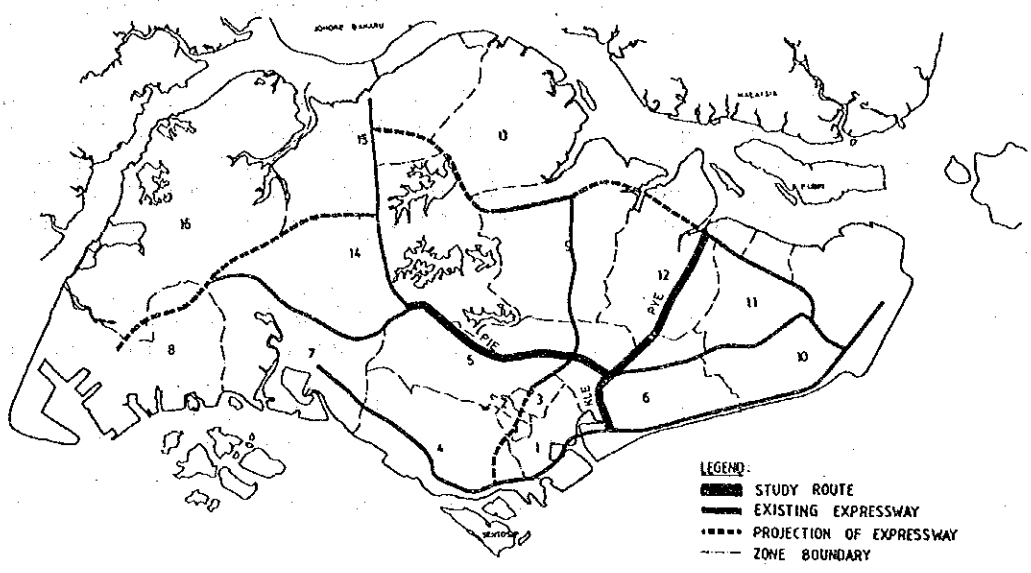


Fig. 4.6 Planning Sectors

Zones 5, 6 and 12 are directly related to the study. Recent large scale urban redevelopment and reconstruction of business centres and offices have push up land prices and accelerate urbanisation in these areas.

Zone 12 are currently planned for future development of New Towns and industrial estates by HDB and JTC respectively. Therefore large increases in population are expected in the future.

4.2.1 Zone Population Framework

This forecast presented is based upon the estimate by PMRTA formulated from the results of 1980 census.

At present, the commercial development in the central area (zones 1, 2 and 3) is well advanced and urban redevelopment is spreading to the surrounding area (zones 4, 5 and 6). The rise in land costs and the development of convenient public transportation facilities such as MRT, bus routes, expressways are accelerating the "Urban Exodus" everyday. And then, the non-inhabited area is expanding, leading to the "Donut Phenomenon", which is the after effect of economic-oriented urban development.

Many housing projects are being undertaken in the suburban area. New Town zones 11, 13, 14, 15 have a particularly high capacity to accept immigrants. According to the long range plan of HDB, four New Town projects are being studied in zones 9 and 12, such as;

(1) Seletar New Town	(zone 12)	139,250 residents
(2) Punggol New Town	(zone 12)	149,550 residents
(3) Kangkar New Town	(zone 9)	135,850 residents
(4) Jalan Kayu New Town	(zone 9)	68,850 residents
Total		493,500 residents

Seletar and Punggol New Towns will start after 1995 and be partly

inhabited in 2000. Kangkar and Jalan Kayu New Towns will start after 2010.

The existing towns in zone 12 are 80% complete and another 10,500 units are under construction in Hougang New Town. Therefore, the population of the New Towns in zone 12 will be approximately 150,000 in 2000. The inhabitants in Punggol and Seletar is expected to be about 61,500 in 2010. Therefore the population of zone 12 is forecast to be 211,500 in 2010.

Population of zones 5 and 6 are projected to decrease as mentioned above which is similar to that with the "Donut Phenomenon". The existing large scale urban redevelopment of these zones will continue to generate and attract large traffic volumes in spite of the decrease in population.

In general, population is moving from the central area to perimeter zones such as 11, 12, 13, 14 and 15. The zones with the jobs will strongly attract population

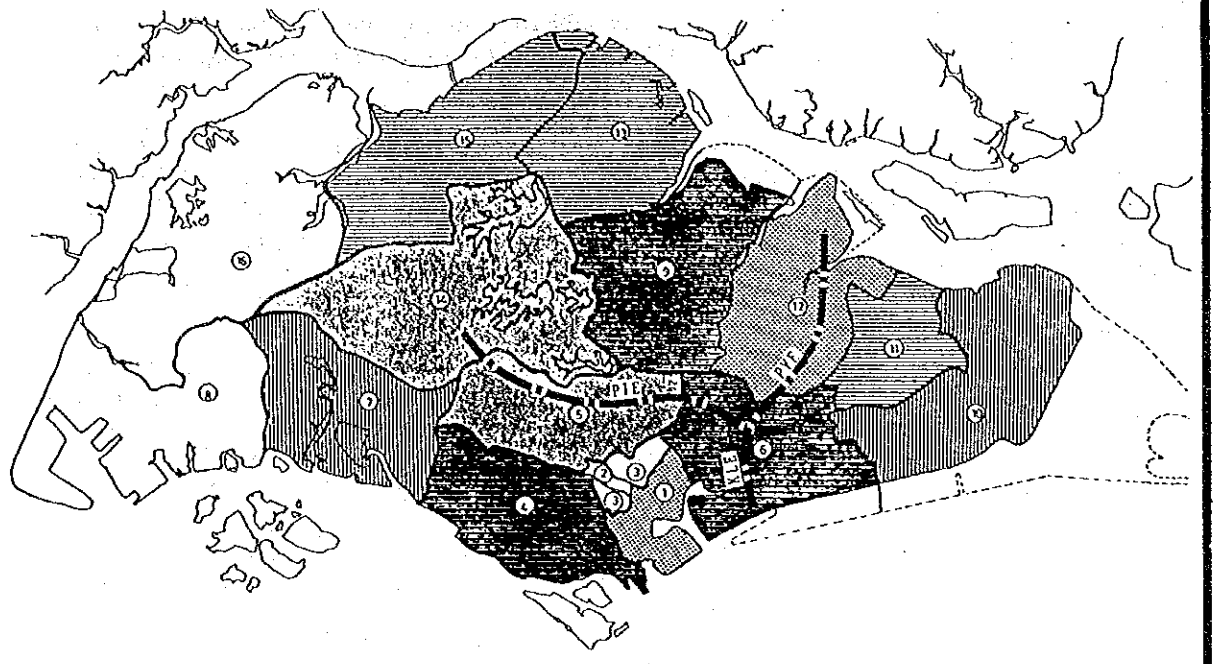
The populations of zones 5,6 and 12 are forecast as follows:

zone 5	Year1995	239,363	Year2010	375,797
zone 6		346,235		319,716
zone 12		127,864		211,419

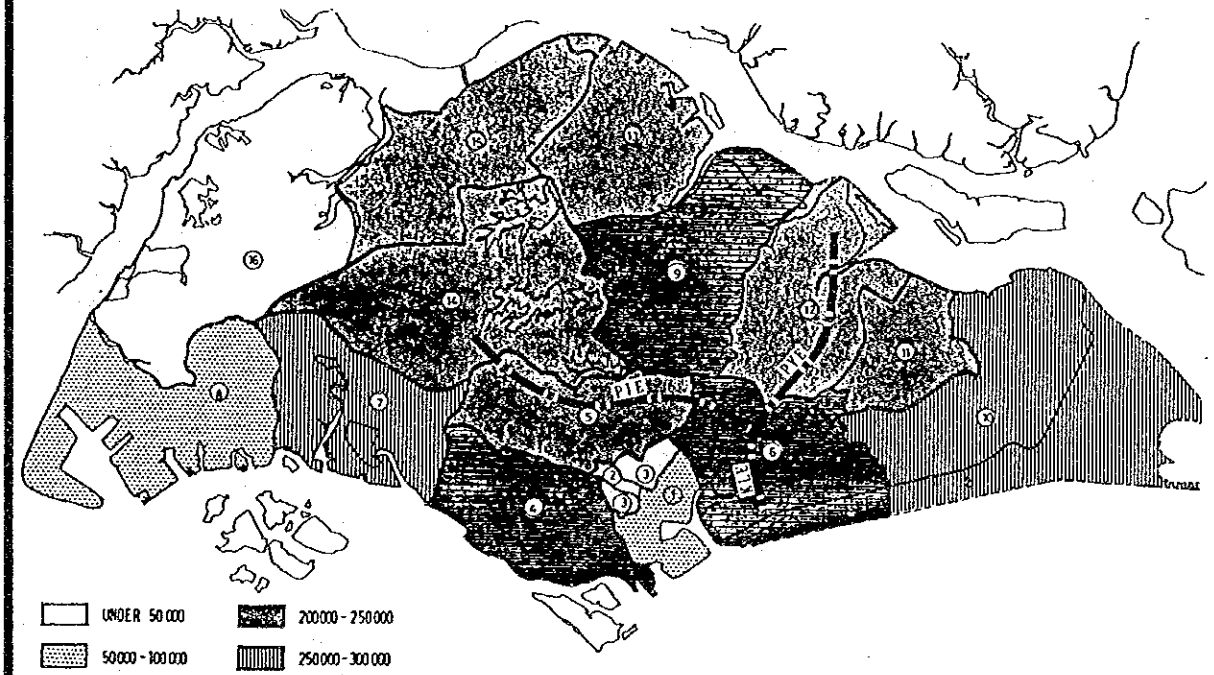
The framework of future populations by each zone is shown in the Table 4.7 and Fig. 4.7.

Table 4.7 Population framework by zone

Zone No.	1981	1995	2000	2010	2030
1	149,130	114,718	100,900	99,316	96,150
2	4,220	5,012	6,350	5,150	5,800
3	39,600	38,840	38,600	37,099	34,100
4	481,970	408,567	383,600	375,797	345,200
5	297,460	239,363	220,000	214,182	202,550
6	414,130	346,235	327,200	319,716	353,400
7	208,060	271,574	285,450	279,315	252,050
8	7,090	37,320	46,350	52,067	54,500
9	296,790	321,266	332,250	450,383	527,650
10	223,689	252,364	262,900	274,750	257,050
11	20,290	150,903	195,800	201,034	205,500
12	85,700	127,864	148,400	211,419	337,450
13	32,291	175,116	211,850	227,801	229,700
14	76,599	212,445	251,300	249,967	247,300
15	57,660	156,028	183,300	223,434	239,700
16	37,960	7,261	3,400	3,364	3,000
17	4,500	263	350	333	300
	2,437,139	2,865,149	3,000,000	3,225,127	3,391,400



POPULATION FRAMEWORK
BY ZONES, 1995



POPULATION FRAMEWORK
BY ZONES, 2010

Fig. 4.7 Population framework by zone

4.2.2 Zone Employment Framework

A review of the forecast prepared by PMRTA was conducted based on the anticipated future prospects of urban and socioeconomic developments in Singapore.

The manufacturing sector occupies the locations in the industrial estates prepared by JTC and HDB . They are in Jurong (zone 8), Clementi (zone 7), Sungei Kadut (zone 15), Kranji (zone 15), Woodland East (zone 15), Kallang Basin (zone 6), Loyang (zone 10), Changi North (zone 10) and Changi South (zone 10).

The retail sector consists of shopping complexes, mainly located in the Orchard area (zone 2) and traditional shop-houses in surrounding areas (zone 4,5 and 6) and urban centers and town centers (zones 7,9,10,11,12,13 and 14). Currently, the dealing amount in the central area is more than the new towns. However URA intends to increase the share of new towns to be 50% of the total dealing amount by 2000.

Other sectors including banking, financing and service industries are concentrated mainly in the central area (zones 1,2 and 3,). Since most government agencies are located in the central area, the area's locational advantage for the private sector will not change in future. Therefore, this sector will continue to attract employment in the central area.

Based on this analysis of future development directions,(zone 1) will play a major role in Singapore's economic and political activities. The potential employment capacity of this area is considered to be quite substantial.

Zone 10 (Changi Airport and the surrounding industrial estates) also has resources to generate employment. Changi Airport will be extended to accommodate the increase in visitors,(expected to be 5.5 million in 1990), and third terminal building is under planning now. In addition, to the industrial estates, the expansion of terminals and the airfield in reclaimed area will expand employment in this zone.

Zones 9,12 and 13 are areas where the HDB New Towns are actively being developed and therefore employment capacity is increasing . There are

31,500 units under planning in zone 9, 15,000 units in zone 12 and 15,000 units in zone 13. The future New Town Developments presented in 2.2.1,(2), (ii), are planned in zones 9 and 12. The developments will generate many industrial, commercial and supporting jobs in these areas.

The new towns in zone 15 are being developed slowly because of the poor public transportation linking this with other urban centers (only 260 units were completed during the 1988/89 fiscal year). But the extension of MRT and completion of JTC industrial estates program will generate many jobs in this zone. Therefore, the employment increase in zone 15 will be high.

In zone 16 there are only few primary industrial activities. Reserved military fields, scarce roads and poor public transportation are constraints preventing further economic development in this zone apart from military development. Due to the zone's location, near Jurong,

Sungei Kadut and Kranji areas, the labour force in this zone will be attracted to these neighbouring area (zones 8 and 15), resulting in a decrease in jobs in zone 16.

According to the decentralization policy, URA intends to encourage business and commercial activities in the new towns to be as equally important as those in the city centre by the target year 2000. Rapid development of convenient transportation will divide employment in two groups; those that are attracted to the city centre and those that are attracted to the urban centres. Therefore employment attraction in surrounding areas may be weaker than these two groups because of the attractive geographical location of the two centres.

It is foreseen that employment will increase until 2000, when most of the shop-houses are demolished by further urban redevelopment and the promotion plan by URA is realised. However beyond 2000, employment in the urban centres will be highly attractive because of shorter distances and no transportation problems. The service industries will increasingly attract more employment in the city centre, so that the employed persons in the surrounding area (zones 4,5 and 6) will gradually decrease.

Table 4.8 shows the summarized zone employment framework in 1995, 2000, 2010 and 2030.

Table 4.8 Employed person by zone

Zone No.	1981	1995	2000	2010	2030
1	230,680	294,395	319,300	343,499	391,900
2	41,590	67,422	74,700	75,232	73,300
3	17,610	23,622	26,050	24,900	22,600
4	155,930	162,069	164,350	152,373	128,400
5	96,560	83,824	79,700	74,631	64,500
6	143,869	172,004	194,550	181,519	175,450
7	83,530	111,699	120,800	112,966	97,300
8	81,200	90,664	95,500	92,533	85,600
9	58,904	62,580	64,900	70,454	83,550
10	68,810	97,855	106,050	122,533	155,500
11	5,530	21,355	27,650	26,382	25,050
12	27,440	39,341	41,850	50,700	68,400
13	12,608	33,081	38,900	42,282	49,050
14	27,608	45,535	49,500	47,050	42,450
15	36,957	53,607	60,050	60,149	60,350
16	18,110	6,869	15,550	14,850	13,450
17	5,640	10,605	12,400	12,150	11,650
Total	1,112,700	1,386,551	1,481,800	1,504,203	1,548,500

CHAPTER 5

TRAFFIC VOLUME FORECASTS

CHAPTER 5 TRAFFIC VOLUME FORECASTS

Future traffic volumes have been estimated by the method shown in Fig. 5.1. This approach, so-called four-stage estimation, is generally used in traffic forecasting. Vehicle traffic is specified and three-stage estimation with a straight line is used without a modal split model.

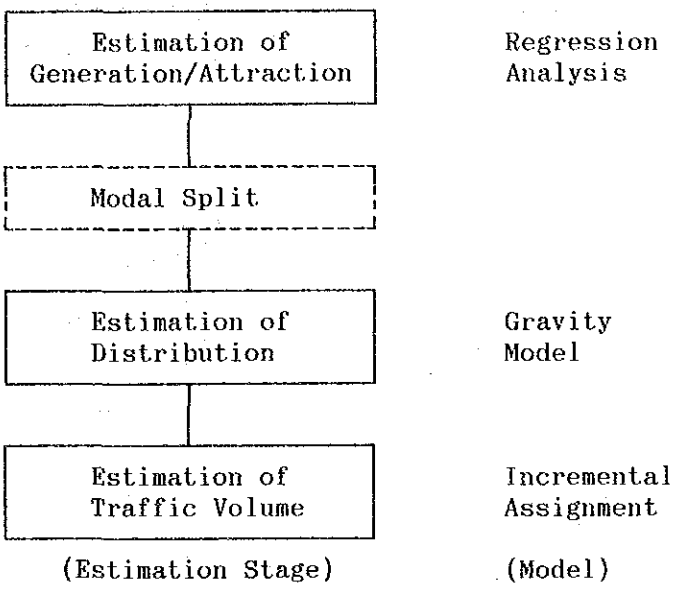


Fig. 5.1 Transportation models

5.1 Planning Forecasts and Assumptions

The reports and data provided by the PWD for projection of traffic volumes are as follows:

1) LTS (Land Transport Study)

Ministry of Communications and Information (1986)

(1) Final Report Appendices
Appendix 1. Assumptions for the Reference Forecasts
2. Design of Travel Schedule Behaviour Survey
5. Evaluation of Reference Forecasts
17. Documentation of Model Changes

(2) Network for 2000
Link data and Figure of Links

Link data design
1 Road Type
2 A-Node
3 B-Node
4 Distance (10m)
5 Time (0.01 min)
6 Capacity

(3) Traffic Assignment Volumes in 2000

AM/PM/Off Peak traffic volume at various time periods

2) Socio-economics

Projections of planning parameters were supplied by the Planning Department of the Ministry of the National Development based on the LTS. These parameters included population, number of households and number of school children by zone residence; numbers of jobs by employment type and school places by education level were furnished for zones where those activities are expected to be located. In addition, information was provided at the zone level on special traffic generators such as theatres, markets, hospitals and clinics.

3) OD table

The OD Tables from the LTS data were combined with the vehicle type OD Tables shown in Table 5.1 and transformed to passenger car unit.

Table 5.1 Vehicle type and passenger car unit

Vehicle Type	Passenger Car Unit
Motorcycles	0.75
Cars and Taxis	1.00
Light Goods Vehicles	1.00
Heavy Goods Vehicles	2.75
Small Buses	2.00
Large Buses	3.00

For the estimation of a future OD Table, Socio-Economic and OD Tables in the same year (normally the year of survey) are needed. Although an OD Table was not provided for this study, the zonal generations and attractions were aggregated from the LTS Traffic Assignment Volumes. Zonal generations were summed by the link volume from the zone centroid, attractions were summed by the link volumes to the zone centroid. These generations and attractions do not include intra-zonal traffic. Therefore, the estimation will be discussed without consideration of intra-zonal traffic.

5.2 Zoning

The zoning system used was the same as for LTS, it is sufficient for forecasting traffic volumes by direction at some interchanges. Zonal expansion into sub-zones was not done. The LST zoning system is composed of 416 analysis zones and 17 planning sectors, as shown in Table 4.6 and Fig.4.6.

The 416 analysis zones consist of 352 zones and 64 zones that include a traffic terminus (e.g.,MRT stations). Information on the 17 planning sectors is summarized in the following discussion.

5.3 Generation and Attraction Model

A generation and attraction Model is used to forecast traffic volumes by relation formulas obtained by analyzing the relations between generation and attraction traffic volumes and socio-economic indices.

Relation formula is linear equations and includes error between actual and estimated values, so any increase in socio-economic indices will be directly reflected as an increase in traffic volume. (see Fig. 5.2)

$$Yi = a\,Xi + b + ei$$

where,

Yi : traffic volume in zone i
a,b: parameter
Xi : socio-economic indices in zone i
ei : error between the actual traffic volume and estimated traffic volume

when socio-economic indexes change from Xi to Xi+x

$$a\,(Xi+x) + b + ei = a\,Xi + b + ei + a\,x = Yi + a\,x$$

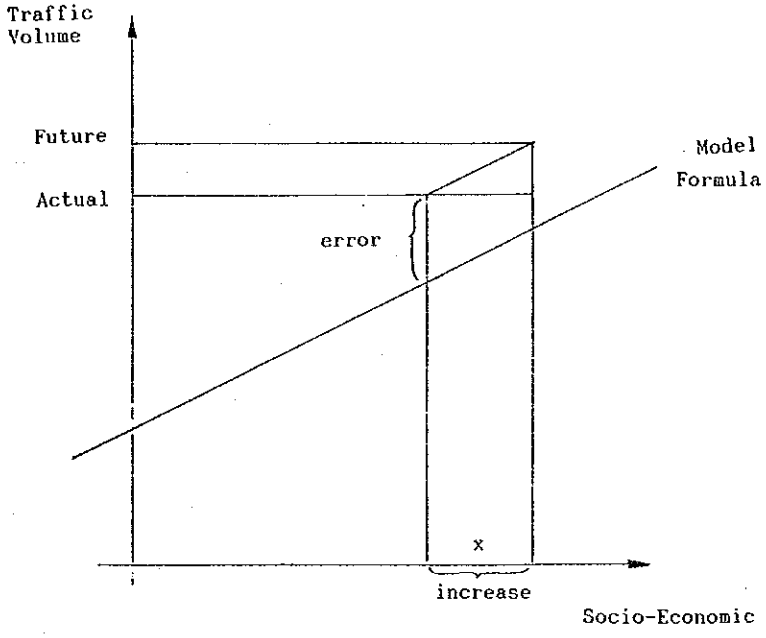


Fig. 5.2 Treatment of error between actual traffic and estimated traffic volume

If the error is not taken into account, forecasted traffic volumes may be lower than that at the time the model was established even though the value of socio-economic indices have increased.

This model formula was not directly used for projection of future traffic volumes but used only for the calculation of shares in future. If the traffic volumes in the model formula are applied directly, only socio-economic indices showing the same growth as traffic volumes can be used. Traffic volume is used as a control total.

The model will be explained by socio-economic indexes for 352 zones. These were classified into Central/Non-Central groups.

The correlation of socio-economic indices and traffic volumes by each

group is shown in Table 5.2. Based on the correlation, regression analysis was conducted to establish the model formula. The use of three statistics (population, households and school children) at the same time was avoided because of the strong inter-relation among these variables. And the use of the total and employment figures in a formula was also avoided because they are not independent of each other.

Table 5.2 Correlation factor of socio-economic indices

- Central Area -	Generation			Attraction		
	AM	PM	Off	AM	PM	Off
1 Population	-.1822	-.2105	-.1945	-.2170	-.1813	-.1941
2 Households	-.1735	-.2010	-.1844	-.2077	-.1720	-.1841
3 School Children	-.1847	-.2134	-.1971	-.2205	-.1839	-.1965
4 Enrollment	-.2245	-.2474	-.2453	-.2440	-.2296	-.2459
5 Employment	.6539	.6555	.6463	.6723	.6534	.6383
6 - Retail Trade	.3951	.4070	.4261	.3667	.4262	.4405
7 - Others	.6229	.6212	.6038	.6462	.5961	.5934

- Non-Central Area -	Generation			Attraction		
	AM	PM	Off	AM	PM	Off
1 Population	.6367	.2668	.4173	.0277	.6321	.4010
2 Household	.6368	.2669	.4174	.0277	.6322	.4011
3 School Children	.6363	.2663	.4169	.0272	.6316	.4005
4 Enrollment	.5960	.3740	.4733	.1394	.6379	.4730
5 Employment	.2843	.7310	.5978	.8218	.3375	.6054
6 - Retail Trade	.3737	.4439	.4513	.2928	.4651	.4574
7 - Others	.3063	.6465	.5359	.6122	.4108	.5485

The model selected based on a comparison of the statistics is summarised as shown in Table 5.3.

Table 5.3 Generation/attraction traffic volume model

Group	Generation Attraction	Time Period	Model Formula Constant	Variable 1		Variable 2	
Central Area	Generation	AM	141.1	Emp	0.083	-	
		PM	216.6	Emp	0.198	-	
		Off	41.0	E-R	0.540	E-O	0.117
	Attraction	AM	166.8	Emp	0.139	-	
		PM	18.1	E-R	0.470	E-O	0.113
		Off	-35.2	E-R	0.634	E-O	0.121
Non Central Area	Generation	AM	361.9	Pop	0.029	Enl	0.079
		PM	328.6	Emp	0.152	-	
		Off	134.5	Enl	0.108	Emp	0.092
	Attraction	AM	131.7	Emp	0.165	-	
		PM	399.1	Pop	0.039	E-R	0.605
		Off	120.5	Enl	0.106	Emp	0.091

5.4 Future Zonal Volumes

Traffic volume generations and attractions were forecasted in compliance with the following work flow shown in Fig. 5.3.

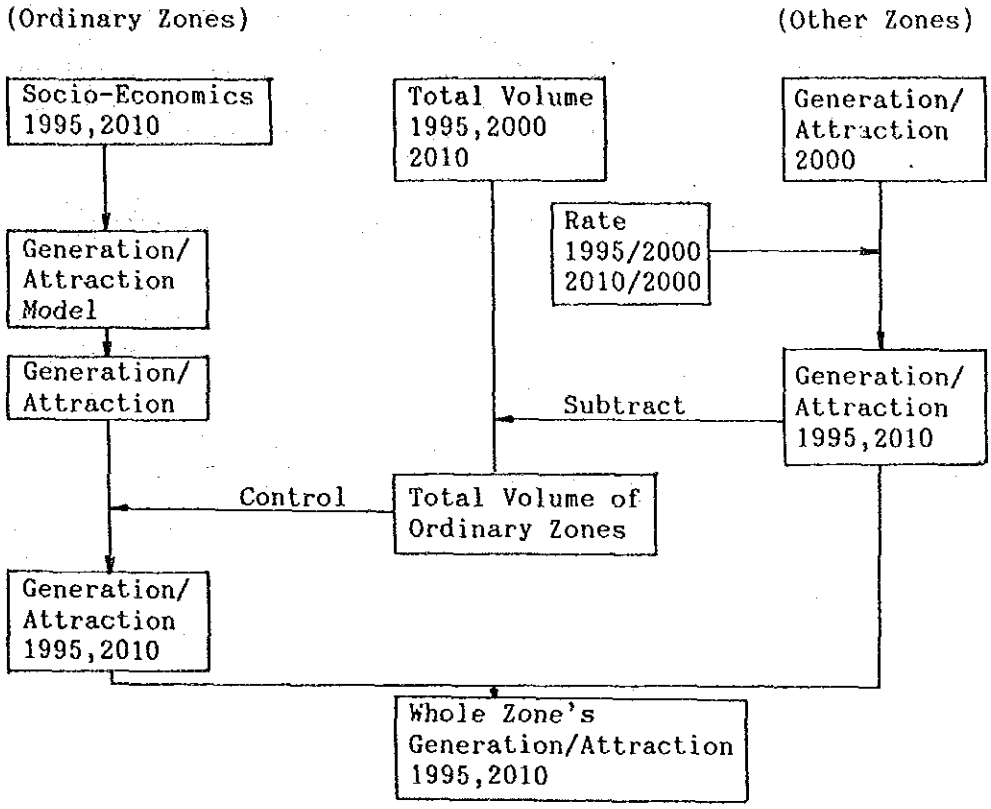


Fig. 5.3 Future zonal volume estimation

1) Establishment of total traffic volume

Based on the LST, the population and the number of person trips are as shown in Table 5.4. In this study, the population in 2010 was established to be 3225 (thousand) and the number of person trips in 2010 to be 8063-8224 (thousand) based on the assumption of 2.50-2.55 trip per person.

Table 5.4 Daily person trip in 1981,1990,2000 and 2010

	LTS			JICA
	1981	1990	2000	2010
Population (000)	2,433	2,708	3,000	3,225
Daily Trips(000)	4,384	5,361	6,837	8,063-8,224
Trips per capita	1.80	1.98	2.28	2.50-2.55
	-	(+0.19)	(+0.30)	(+0.22-0.27)

The number of trips by each traffic mode is shown in Table 5.5. The increase in auto drivers and auto passenger trips is remarkable. An increase in vehicle trips is expected in 2010.

The relation between person trips and vehicle trips will be as shown in Table 5.6. Since the increase in auto driver and auto passenger trips is remarkable, Table 5.5 among the traffic modes by the comparison of both trips, the same or a little less increase will be expected. If the growth rate is assumed to be 4.5%, the number of trips will be 4,765-4,860 (thousand) in 2010. These values are based on the current number of trips {4,815 (thousand)}, extended by a straight line from 1990 to 2010; the total traffic volume in 2010 was established as 4,815 (thousand).

Table 5.5 Daily person trips by mode of travel (LST)

	1981		1990		2000	
	Trips (000)	(%)	Trips (000)	(%)	Trips (000)	(%)
Auto Driver	974	(22.1)	1,312	(24.5)	1,978	(28.7)
Auto Passenger	652	(14.9)	889	(16.6)	1,288	(18.8)
Taxi	126	(2.9)	120	(2.2)	127	(1.9)
Motorcycle	308	(7.0)	359	(6.7)	426	(6.2)
School Bus	226	(5.2)	209	(2.9)	233	(3.4)
Company Transport	170	(3.9)	166	(3.1)	190	(2.8)
Public Transport	1,928	(44.0)	2,306	(43.0)	2,595	(38.0)
Total	4,384	(100.0)	5,361	(100.0)	6,837	(100.0)

Table 5.6 Daily vehicle trips

	LTS		JICA
	1990	2000	2010
(A) Daily Person Trips (000)	5,361	6,837	8,063-8,224
(B) Daily Vehicle Trips(000)	2,661	3,738	4,765-4,860
(B)/(A)	49.6%	54.7%	59.1%
		(+5.1%)	(+4.5%)

2) Forecast of socio-economic indices

The forecast of selected socio-economic indices, eg., population, school, enrollment, etc. was used for the generation and attraction model.

Socio-economic indices by zone were described by linear equations and controlled with the framework values for 1981, 2000 and 2030. (Fig. 5.4)

5.5 Distribution Model

Zone-to-zone trips were forecast by defining distribution patterns by time period using the gravity model according to the work-flow shown in Fig. 5.5.

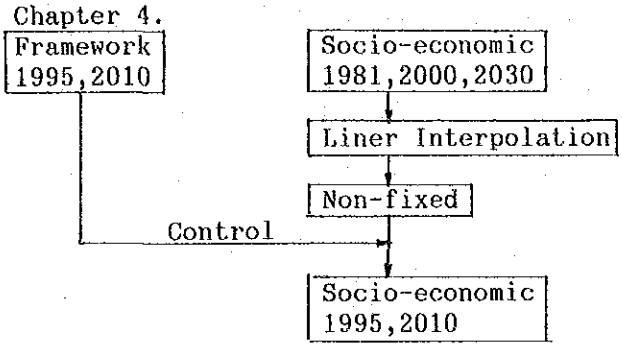


Fig. 5.4 Forecasting procedure of targeted year's socio-economic indicators

Note : The following two adjustments have been made in accordance with the framework prepared in Chapter 4.

- o 1995 is included as a target year.
  (1981)>0, (2000)=0 ==> (1995)=0
- o Land reclamation is assumed to be ongoing in 2010.
  (2000)=0, (2030)>0 ==> (2010)=0

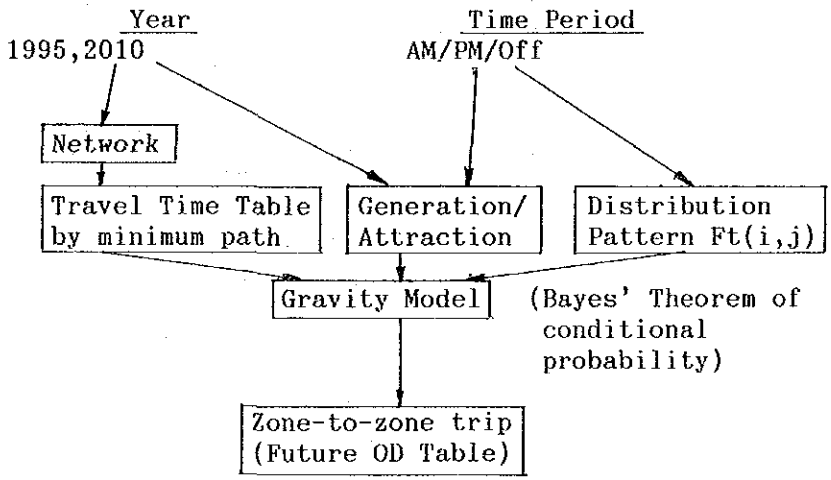


Fig. 5.5 Estimation of zone-to-zone trip

Bayes' Theorem of Conditional Probability was selected as the model for forecasting zone-to-zone trips from the possible gravity models. The formula is:

$$Tij = \frac{Gi\ Aj\ Ft(i,j)\ Kij}{Ax\ Ft(i,x)\ Kix}$$

where

- Tij : trips generated in zone i and attracted to zone j (analogous to gravitational force)
- Gi : trips generated in zone i (analogous to mass of body i)
- Aj : trips attracted to zone j

(analogous to mass of body j)

t(i,j) : travel time in minutes between zone i and zone j (analogous to separation between bodies i and j)

Ft(i,j): an empirically derived travel time factor that expresses the average area-wide effect of spatial separation on trip interchange between zones that are t(i,j) apart

Kij : a specific zone-to-zone adjustment factor to allow for the incorporation of the effect on travel patterns of defined social or economic linkages not otherwise accounted for in the gravity model formulation.

Ft(i,j) is generally established by the OD and Travel Time Tables. But because of a delay in the provision of the OD Table by PWD, it was defined by the work-flow shown in Fig. 5.6. A special value was not established for Kij.

The value of vehicle-km is set equal to the value used in the LTS by adjusting the distribution of Ft(i,j) in accordance with the comparison of vehicle-km. (Irrelevance of vehicle-km is small in the Model, the distribution area will broaden. When vehicle-km is large, the distribution area will be small.) (Table 5.7)

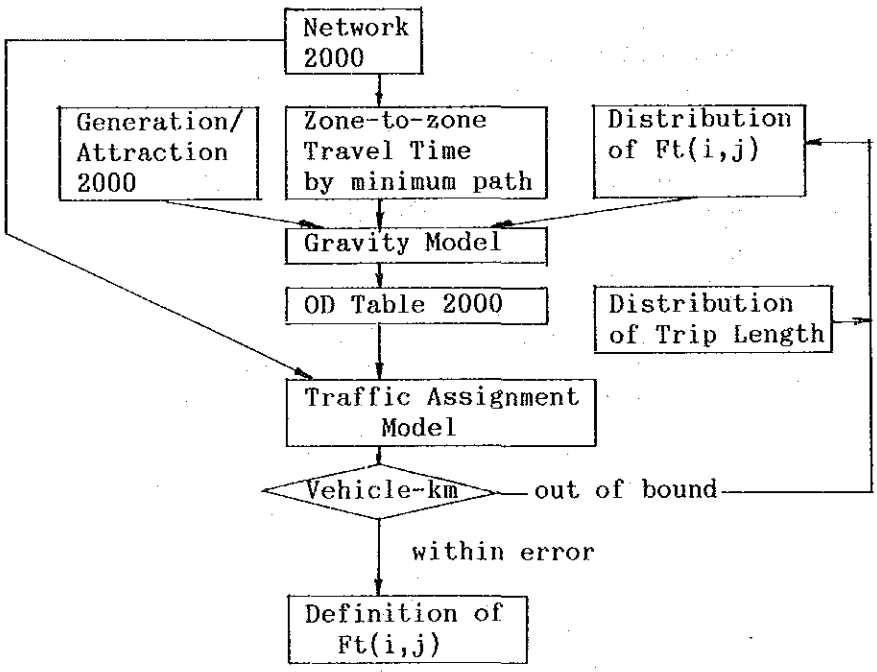


Fig. 5.6 Definition of Ft(i,j) in the Gravity Model

Table 5.7 Comparison of the assigned traffic volume in vehicle-km

Time Period	LTS in 2000 (A)	JICA in 2000 (B)	(B)/(A)
AM	4,191,855	4,150,038	0.99
PM	4,777,805	4,794,521	1.00
Off	3,532,179	3,503,614	0.99

5.6 Future OD Tables

OD Tables for both the AM and PM peaks in 2010 are as shown in Table 5.8 and 5.9, the strength of the linkage among zones is shown by the Desire Lines in Fig. 5.7. Since the OD traffic volumes have unique directions in each time period, the traffic volumes are shown by each direction.

Table 5.8 AM Peak OD table in 2010

Sector	1	2	3	4	5	6	7	8	9
1	5,543	2,848	559	13,918	5,142	13,094	4,633	543	3,446
2	3,204	42	43	3,540	1,168	3,746	1,288	137	1,278
3	967	51	16	867	183	797	293	25	292
4	17,447	4,069	685	7,134	3,162	4,538	6,792	1,876	1,267
5	10,378	2,295	286	4,925	1,137	4,053	2,202	299	1,545
6	19,265	4,564	691	5,157	2,923	5,690	585	48	2,273
7	5,419	1,443	226	6,918	1,449	645	5,045	9,181	369
8	199	44	10	761	74	18	3,150	5,695	10
9	11,702	3,887	656	3,249	2,916	6,478	755	59	2,324
10	8,104	1,306	267	897	1,114	7,346	53	14	794
11	2,862	553	109	203	541	4,692	22	8	647
12	7,046	2,173	357	1,313	1,672	5,435	89	14	2,311
13	1,356	541	137	194	990	1,022	152	87	5,195
14	2,266	1,316	254	3,466	1,986	1,118	7,222	4,326	728
15	497	484	109	627	1,147	370	3,230	1,687	1,507
16	11	6	1	15	9	6	365	847	2
17	243	106	17	250	215	76	756	643	283
Total	96,509	25,728	4,423	53,434	25,828	59,124	36,632	25,489	24,271

Sector	10	11	12	13	14	15	16	17	Total
1	4,323	1,200	2,520	187	1,003	103	21	371	59,454
2	639	238	729	96	512	86	6	94	16,846
3	182	61	181	31	157	46	3	20	4,172
4	522	104	493	31	1,770	186	33	386	50,495
5	1,074	408	1,008	244	1,363	399	21	90	31,727
6	5,919	2,118	2,560	162	430	77	16	95	52,573
7	32	14	46	30	3,275	1,325	875	1,069	37,361
8	5	1	3	4	863	397	975	596	12,805
9	1,378	737	2,844	2,625	869	880	20	137	41,516
10	11,785	3,222	2,429	125	34	19	4	426	37,939
11	7,317	1,241	1,931	157	17	12	2	178	20,492
12	2,918	1,425	1,586	733	99	77	6	47	27,301
13	376	329	1,751	6,487	1,035	6,373	64	636	26,725
14	57	21	108	374	2,387	3,338	1,177	504	30,648
15	49	22	169	4,880	3,872	6,057	859	863	26,429
16	4	0	0	7	263	261	846	35	2,678
17	193	22	23	873	894	1,883	115	6	6,598
Total	36,773	11,163	18,381	17,046	18,843	21,519	5,043	5,553	485,759

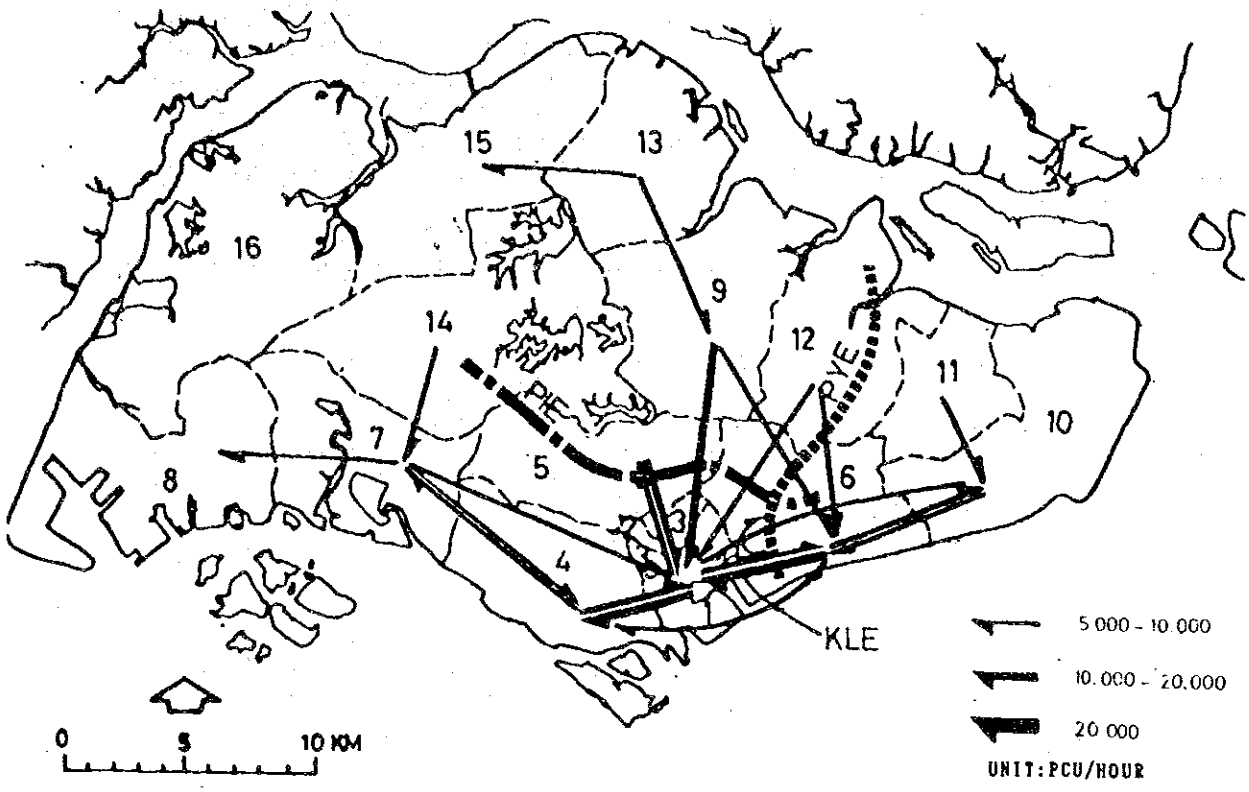
Generally, the AM peak hour shows the reverse characteristics, except for the link with Orchard.Concerning the PM peak, the strongest linkage is in the East-West direction connecting the CBD with Geylang and Queenstown. The next is the North-south direction connecting the CBD with Orchard, Toa Payoh and Ang Mo Kio.

Table 5.9 PM Peak OD table in 2010

Sector	1	2	3	4	5	6	7	8	9
1	22,156	11,248	1,985	23,872	14,140	27,132	5,500	119	12,420
2	10,607	291	223	6,867	4,492	5,951	1,535	28	5,189
3	1,372	142	29	793	427	743	193	5	714
4	21,939	6,676	1,001	12,352	5,608	3,688	7,529	421	2,727
5	9,211	2,804	370	3,703	2,465	4,163	1,540	51	4,781
6	20,047	4,950	815	3,238	4,666	9,781	402	14	5,842
7	3,919	1,187	171	7,941	2,248	390	10,031	3,326	758
8	257	70	9	1,303	165	54	8,581	5,981	67
9	5,205	2,091	416	1,278	2,907	3,227	364	14	5,877
10	4,650	786	165	396	904	7,773	52	7	1,280
11	961	197	40	53	275	2,557	11	1	747
12	3,200	1,109	221	443	1,418	3,555	44	3	4,988
13	170	77	14	29	206	138	24	6	3,597
14	893	620	136	2,098	1,754	423	6,071	896	1,149
15	95	95	31	169	462	70	1,186	240	1,025
16	35	17	2	33	22	17	701	665	30
17	382	82	11	365	57	56	908	538	83
Total	105,099	32,442	5,639	64,933	42,216	69,718	44,672	12,315	51,274

Sector	10	11	12	13	14	15	16	17	Total
1	8,057	2,919	7,059	759	2,007	272	30	273	139,948
2	1,195	520	2,345	421	1,264	235	10	76	41,249
3	170	76	316	77	230	74	1	15	5,377
4	562	124	869	129	3,248	341	22	205	67,441
5	1,183	598	2,154	750	1,937	644	11	88	36,453
6	9,685	4,704	6,619	422	562	122	10	39	71,918
7	48	28	78	102	10,260	2,639	365	551	44,042
8	26	12	25	86	3,472	1,395	920	649	23,072
9	846	603	4,433	5,999	774	1,330	11	188	35,563
10	17,786	9,294	3,408	275	65	73	3	273	47,190
11	6,729	2,591	1,984	208	17	24	0	28	16,423
12	2,582	1,935	3,514	1,405	70	99	5	14	24,605
13	112	116	833	11,252	385	5,758	11	474	23,202
14	55	22	118	787	6,166	5,374	379	654	27,595
15	28	18	76	6,503	4,440	9,043	282	1,790	25,553
16	9	4	13	57	1,059	847	1,026	63	4,600
17	397	101	19	381	410	1,020	30	6	4,846
Total	49,470	23,665	33,863	29,613	36,366	29,290	3,116	5,386	639,077

- AM Peak -



- PM Peak -

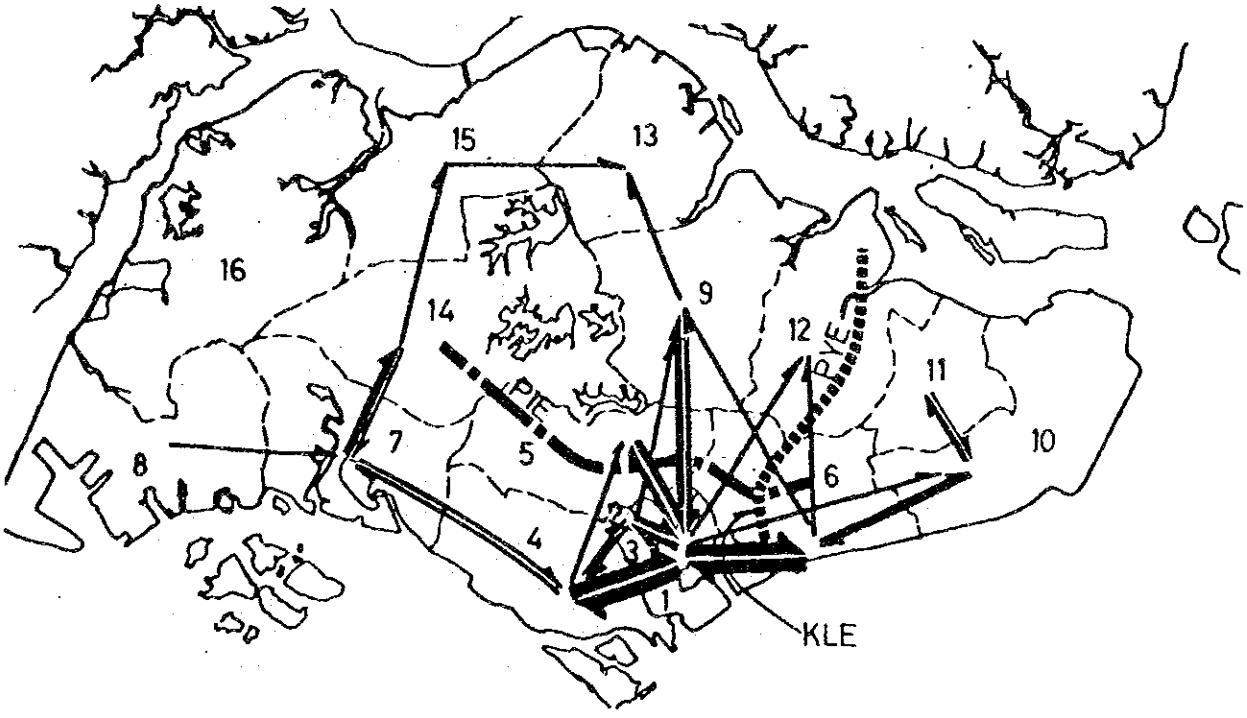


Fig. 5.7 Desired lines in 2010

5.7 Traffic Assignment Model

The Incremental Loading Method used in the LTS was adopted for the traffic assignment model. This method does not load all the traffic onto all of the network at the same time, but rather loads the traffic onto the shortest paths after a specified number of iterations. The shortest path is obtained by the recalculation of the speed on the link in accordance with the loaded volume. The speed on the link is calculated based on the traffic volume of the link and a delay function related with speed.

This model requires specification of the number of iterations and ratio and delay functions.

1) The number of iterations and its ratio

Since loading increases in proportion to the number of iterations specified, the number of iterations was set at 5 to obtain stable results with a minimum number of iterations. The ratio of each iteration will be 30%, 20%, 20%, 20% and 10%.

2) Delay function

Based on the results of traffic loading in the LTS and NESS (North-East Sector MRT Study), speed (time-on-link data) and capacity are given to each link. Link speed then decreases base on the ratio of loaded volume and capacity. The relationship is delay function, and these are shown by road type in Fig. 5.8.

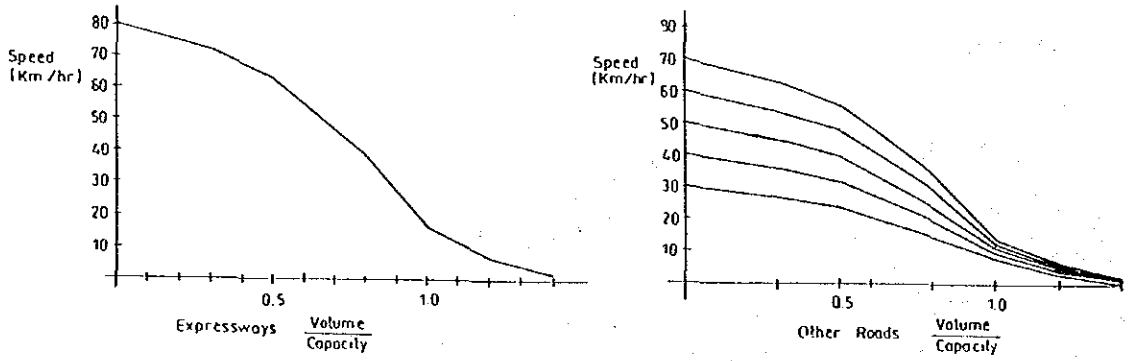


Fig. 5.8 Delay function on LTS

The ratio of current speed and initial speed (considering loaded volume and capacity) was adopted. The delay function is shown on Fig. 5.9, except for some links which do not show decrease in speed.

To check the replicability of the transportation models,the OD traffic volumes in 2000 are loaded on the network for 2000; then the loaded traffic volumes were compared with those found in the LTS. At the stage of OD Table generation, the index of vehicle-km had already been checked; the delay functions were adjusted to fit the vehicle-km on the expressways. The delay functions were separated into two, one for expressways and the other for ordinary roads.

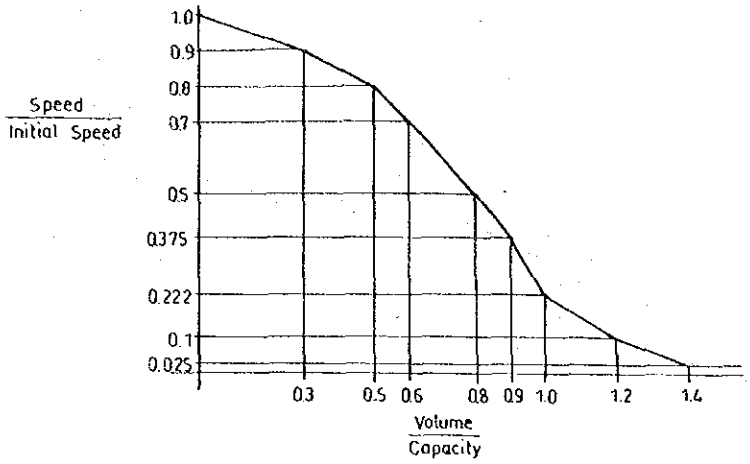


Fig. 5.9 Typical delay function on LTS

3) Replicability

The results for the PM time period in 2000 is shown in Table 5.10 and Fig. 5.10. The delay function adjustment was done only for expressways. Among the cases, Case 3 was the most suitable.

Table 5.10 Adjustment on expressways

Case	Vehicle-km	Ratio of LTS
1	1,688,136	0.877
2	1,699,734	0.883
3	1,842,392	0.958
4	1,834,536	0.953

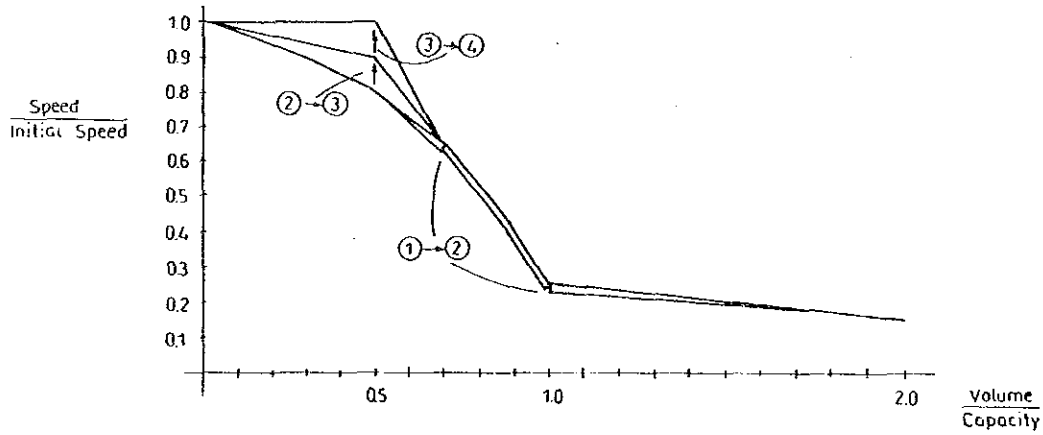


Fig. 5.10 Adjustment for expressways

The PWD carried out traffic counts in February 1990; traffic volumes at three interchanges and main streams of PIE were provided. These interchanges are the Thomson Road/Thomson Flyover, the Toa Payoh Circus/Toa Payoh Flyover and the Toa Payoh Lor. 6/Kim Keat Ave./JLN Toa Payoh.

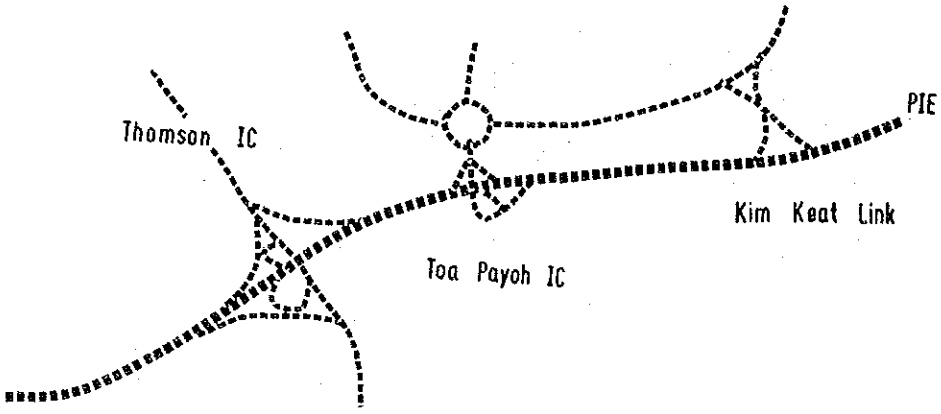
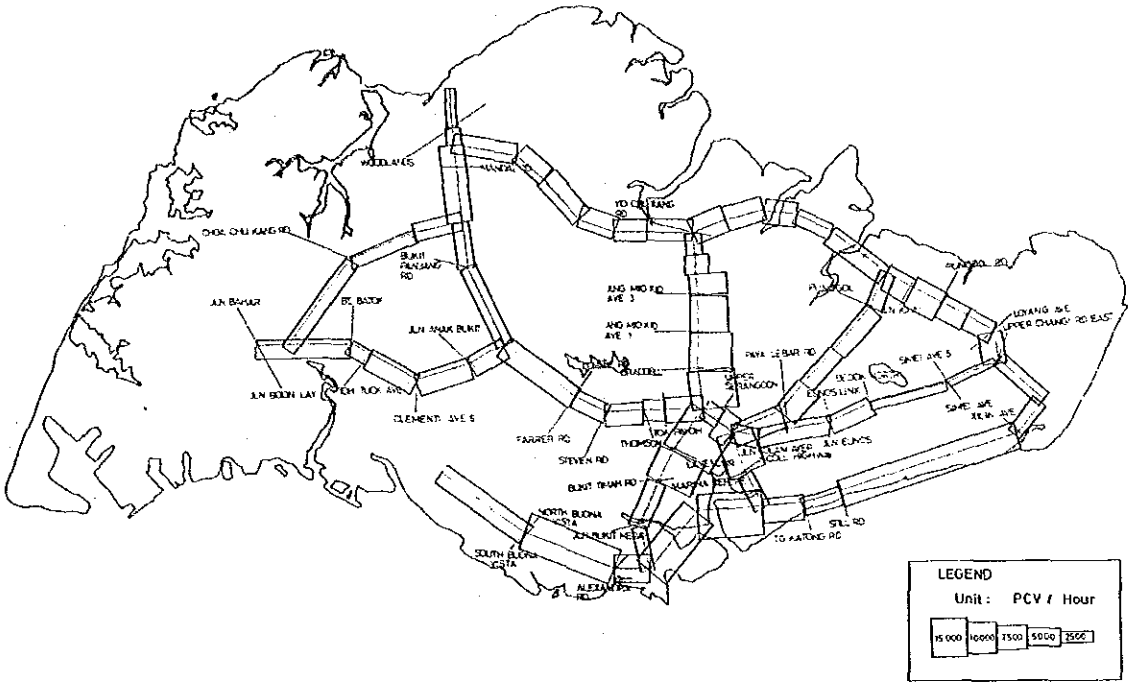


Fig. 5.11 The interchanges used for traffic volume adjustment

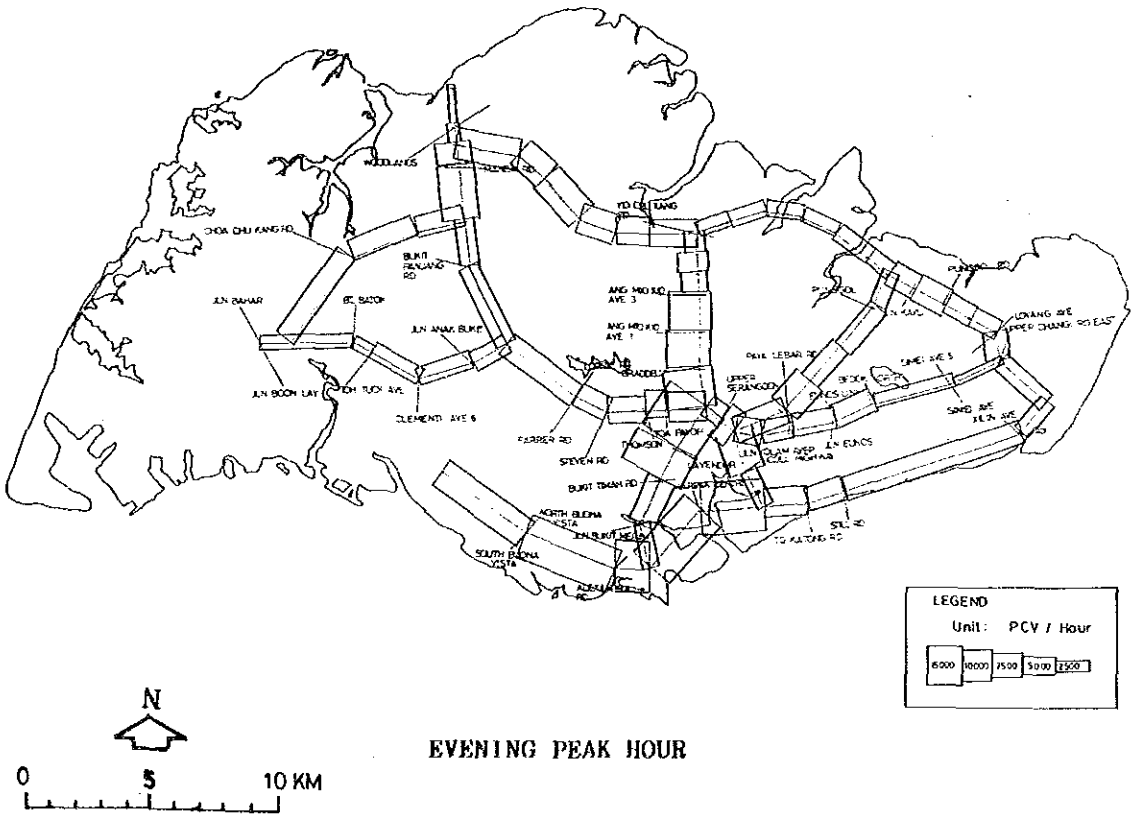
The OD traffic volumes for 1995 were loaded on the network based on the traffic counts; case 4 was deemed the most suitable case. Therefore, the delay function in case 4 was used for expressways and the same delay function as used in LTS was used for the other roads.

5.8 Future Traffic Volumes

In order to obtain future traffic volumes on the subject expressways, KLE, PYE and PIE, the OD traffic volumes in 2010 were loaded on the network. The traffic volume from the AM and PM peak hours on the three expressways are shown in Fig. 5.12.



MORNING PEAK HOUR



EVENING PEAK HOUR

Fig. 5.12 Future traffic volume in 2010

Source: Study Team

CHAPTER 6

ALTERNATIVE FORMATION

CHAPTER 6 ALTERNATIVE FORMATION

6.1 Basic Concept of Alternative Formation

The fundamental requirements for each alternative are as follows :

(1) Every alternative plan is independent of each other.
(2) Every alternative plan is competitive with each other.
(3) Every alternative plan has high feasibility.

The strategy of the alternative formation for improvement of the existing expressways and the construction of new expressways are as follows :

(1) To be feasible on the aspect of economics in Singapore.
(2) To ensure the expected traffic capacity and speed operation of the study expressway.
(3) To scheme the study route in good coordination with the land use of surrounding area.
(4) To use the structure and construction method that can be sufficiently substantiated judging from existing construction techniques.
(5) To ensure adaptability to changes, i.e., in the sense of value, land use policy and economic power in the future.

6.1.1 Improvement of Existing Expressway

There are eight interchanges with an average interval of 1.6 km between interchanges in a stretch of 11km. Besides these interchanges, there are also many slip roads to allow inflow-outflow traffic to and from PIE. As seen in such a situation, PIE functions as an expressway with emphasis on accessibility rather than speediness. The main factors for decreasing of traffic capacity in PIE is firstly due to insufficient length of some diverging and converging lanes and weaving stretches, and secondly the location of the bus stop at the outer lane of the expressway.

The route under study includes a stretch from Woodsville Interchange to PIE/CTE Interchange, both had their tenders conducted during the study period (June, 1990). The expressway stretch tendered is recognized as one of the provisions of the Study.

The factors to be incorporated in the alternative formation are as follows :

(1) Factors relating to horizontal alignment.
Separate line servicing, widening of existing route servicing.
(2) Factors relating to longitudinal alignment.
Flyover, ground level, semi-covered (including tunnel).
(3) Factors relating to the efficient usage of existing structures.
Preserve, reconstruct, demolish, partially reconstruct.
(4) Factors relating to various restrictions on land use.
Government owned land, private owned land.

Any proposal that fulfills the factors mentioned above is deemed to qualify as an alternative.

6.1.2 New Expressway Construction

1) KLE

Kallang Expressway starts from the reclaimed land of Marina East. After the connection at ECP, it passes across Geylang River, Kallang Park, Nicoll Highway, MRT and finally joins to PYE. As there is a development regulation of 40-50m width on the planned corridor of 1km in the new town, located southward of the interchange with PIE, horizontal alignment is less flexible. In the vertical alignment, the focus is on whether the layout of interchanges at the crossings with PIE, Nicoll Highway and ECP incorporating road structures such as tunnels, semi-covered, and flyovers, can be achieved.

2) PYE

The concept of PYE is to avoid as much as possible the concentration of traffic towards CBD. According to the original plan of PWD, this expressway was planned to pass through the Air Base by a tunnel. As the proposal was not favorably viewed by the Ministry of Defense, it is therefore desirable to examine other alternative routes.

There is a an industrial estate, which has a 30 year lease with HDB, on the western side of the Air Base. The lease for this piece of land will expire by the year 2010. This corridor can participate as one of the alternative routes. Apart from this, as Hougang Avenue passes in parallel with Defu Avenue, routing on this corridor is also one of the alternative plans.

In addition to the background described so far, the following items should be considered in the formation of alternative plans :

(1) Factors relating to horizontal alignment.
Restriction of land use: Government owned land, private owned land.

(2) Factors relating to longitudinal alignment.
Integrated use of land :Flyovers, at-grade, semi-covered(including tunnels).

(3) Location and type of interchange.
Structure, effectiveness and economical efficiency of road network.

Any proposal that fulfills the three fundamental factors mentioned above is deemed to qualify as an alternative plan.

6.2 Engineering Consideration

In order to establish the alternatives, route location, location of interchanges, and structure planning should be studied.

6.2.1 Route Location

The study of route location consists of the selection of horizontal alignment and vertical alignment in general. This technical item has a close relation to land use, where control point is normally defined by space or point to be avoided or targeted. Some examples of control points are as follow:

(1) Natural condition related :
river, lake, soft ground.
(2) Traffic facility condition related :
interchange with arterial road.
(3) Environmental condition related :
condominium, residential estate, school, hospital, park.
(4) Relevant Public Work and Public Facility Related :
urban development work, development of various traffic facilities.
(5) Cultural assets related :
temple, church, cemetery, tourist attraction, historical spot.

For the case of PIE, the basic horizontal alignment is already in place, while selection could only be allowed within limited space to widen the facilities to meet the traffic demand. On the other hand, although the route selection for KLE and PYE are limited by the width of the corridor, horizontal routing is still available for selection.

Vertical alignment basically accords to the ground profile. It is possible to utilise the space above, on and below the ground. All these should be evaluated together with the presence of various control points.

6.2.2 Location of Interchanges

The planning procedure for the allocation of interchanges is given in the Fig. 6.1.

The spacing between interchanges should be determined by considering the characteristics of the area where the route is located and the expected role of the study route. That is, for the case of urban expressways, traffic generating spots should be decentralised and the distance between interchanges should be slightly shortened when handling large volumes of traffic.

It is required to keep desirable distance between interchanges for the drivers so as to shift the lane safely. The location of the interchange depends basically on the presence of other main roads to need connection. However, in a new development area, future traffic demand should be taken care of by introducing appropriate interchanges.

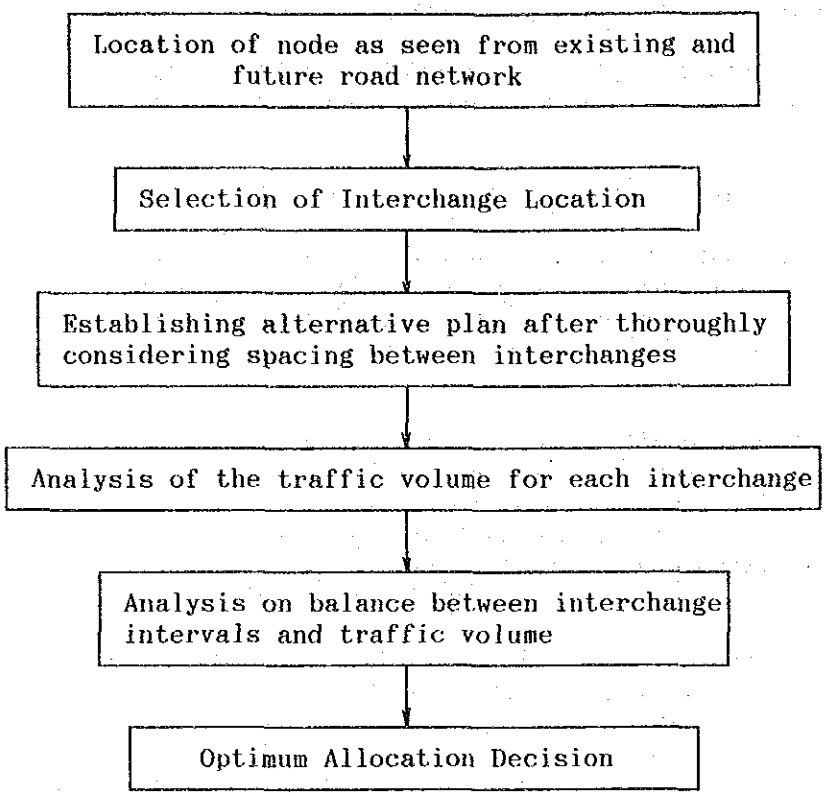


Fig. 6.1 Planning flow for Location of Interchange

Taking the existing road network into consideration, the most appropriate distance between interchanges will fall in the range of 1.5 to 2.5 km.

6.2.3 Structure Planning

In implementing the up-grading of PIE traffic capacity, structure planning is carried out based on the following principles:

(1) Scope of the structural planning in the alternative of widening at the same grade as the existing expressway covers modifications for the existing structures such as widening, demolition, and reconstruction, for interchanges, bridges, box culverts and ground level roadways.

(2) In the alternative for the up-grade counter measure by grade separation, i.e. a viaduct along the existing expressway, the existing roadway structures are free from modification activity. Instead, the alignment is required to take a close course to the existing highway in order to position supporting piers within the available space in the Right of Way.

Construction technique as close to the existing expressway as possible should not affect the existing structures in the vicinity and studies on structural types of viaduct, depressed including trough and semi-covered tunnels, and tunnels are included.

(3) As the widening works are carried out in the vicinity of the existing carriageway, consideration is taken to minimize the disturbance to traffic and the environmental impact. In particular, traffic lane control during construction, noise prevention and safety counter-measures require consideration.

(4) On both sides of the PIE, the roadway is furnished with abundant evergreens on the hilly sections. Therefore, widening work should avoid slope cutting to excessive depths.

In programming the new construction of KLE and PYE, structure planning is carried out based on the following principles:

(1) The KLE and PYE follow an urban course in most of the stretch. Consideration should be taken to minimize the environmental impact in the city area.

(2) Crossing many communication routes such as roads and MRT, the basic options of structural form are grade separation and underground facilities.

(3) Construction methods for viaduct superstructure will be by crane erection of Precast PC girder because they are easy to handle in accordance with speedy work during night hours. A substructure type is preferred to a single column pier because occupying space is saved.

(4) Types of depressed and tunnel structures are designed as single cell to accommodate both up-line and down-line carriageways to save the cost of temporary work.

(5) In Singapore, construction records of steel structures are very few. Almost all the expressway bridges are made of concrete because twice the cost incurred compared to a concrete bridge, unfavorable color of weather-proof steel in its aesthetics.

(6) Tunneling methods, in general, constitute 3 types, namely, open cut and cover, shielded tunneling and New Austrian Tunneling Method (in short NATM). Selection out of the 3 methods is based on the recorded construction cases to date and the state of technical art in Singapore.

(7) Planning of river crossing bridges should be based on the examination of the following points:

- Horizontal and vertical alignment of the route conveyed by the bridge.
- High Flood Level.
- Stability of stream center and waterway plan.
- Topography at bridge approaches.

6.3 Alternatives for PIE

6.3.1 Potential Alternatives

PIE is currently a single formation expressway with 3 lanes in one direction and a total of 6 lanes in both directions. Therefore, the possibility of having a separate route in horizontal alignment as an alternative is not a feasible one. For longitudinal alignment (i.e. road structure), there are possibilities of having an at-grade widening, constructing a flyover above the existing road and constructing a semi-covered (including tunnels) road below the existing road. Moreover, as shown in Fig.6.2, there are alternatives of either building viaducts or a semi-covered road in the middle of the existing road or on both sides.

In addition to the above combination, the location of the beginning and ending point of the grade-separation is also a problem. That is, if the interval between PIE/CTE IC and PIE/Toa Payoh IC is taken as the connection to the existing road, another connecting stretch would be either between PIE/Thomson IC and PIE/Mt. Pleasant IC or PIE/Eng Neo IC and PIE/BKE IC. Based on the above discussion the structural characteristics of at-grade, viaduct and semi-covered alternatives, the 5 drafts given in Fig. 6.3 can be considered as the basic configuration of the alternatives.

Next, in addition to the short distance between PIE/CTE IC and PIE/Thomson IC, heavy traffic volume and the co-existence of bus stops at the stretch between PIE/Toa Payoh IC and PIE/Kim Keat Slip Road contribute to traffic conflict in this area. The separation between fast and slow traffic or unification of existing ON/OFF ramps should be taken into careful consideration. A summary of the traffic flow at the targeted section is given in Fig. 6.4. In the direction towards Changi, the stretches between PIE/Thomson IC and PIE/Toa Payoh IC, PIE/Toa Payoh IC and PIE/Kim Keat IC, and PIE/Kim Keat and PIE/CTE IC have a potential of severe weaving phenomenon. For the direction heading towards Jurong, between PIE/Toa Payoh IC and PIE/Thomson IC also brings traffic conflict in this area. As such, the alternative plan of horizontal alignment of I-1 is further broken down and the idea of separating fast and slow traffic with the use of separators as well as the elimination and addition of ON/OFF ramps to streamline the traffic flow are added on as an alternative given in Fig. 6.5.

6.3.2 Necessary Number of Lanes

Necessary number of lanes is determined by the following formula by using the ratio of volume to capacity,

$$N = V / C$$ where N: Necessary number of lanes
V: Traffic volume (pcu/ hour)
C: Capacity (pcu/ hour / lane)

Fig. 6.6 indicates the future traffic volume in the year 2010 between PIE/BKE IC and CTE/PIE IC. Figure indication is divided into 3 hourly zones, i.e. morning peak hour (AM Peak), evening peak hour (PM Peak) and off peak hour (Off Peak).

Traffic capacity is specified in Table 6.1.

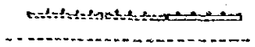
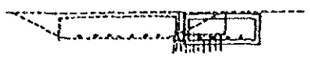
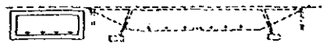
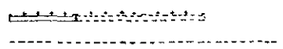
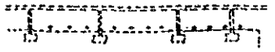
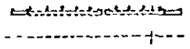
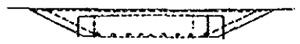
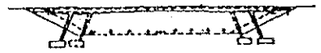
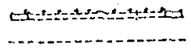
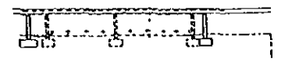
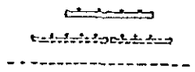
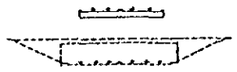
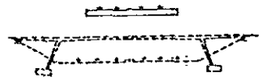
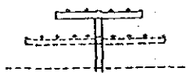
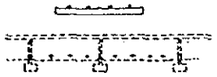
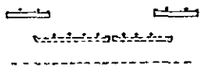
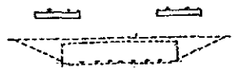
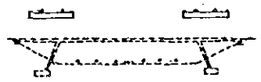
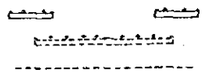
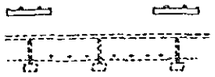
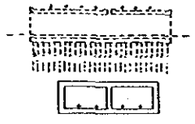
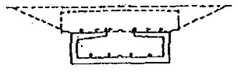
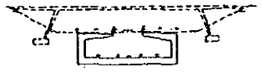
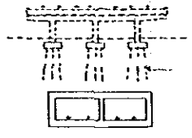
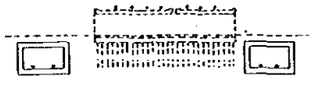
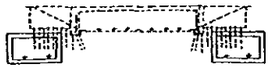
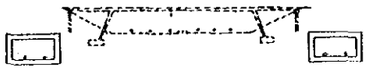
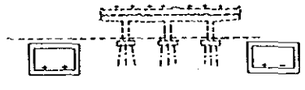
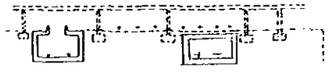
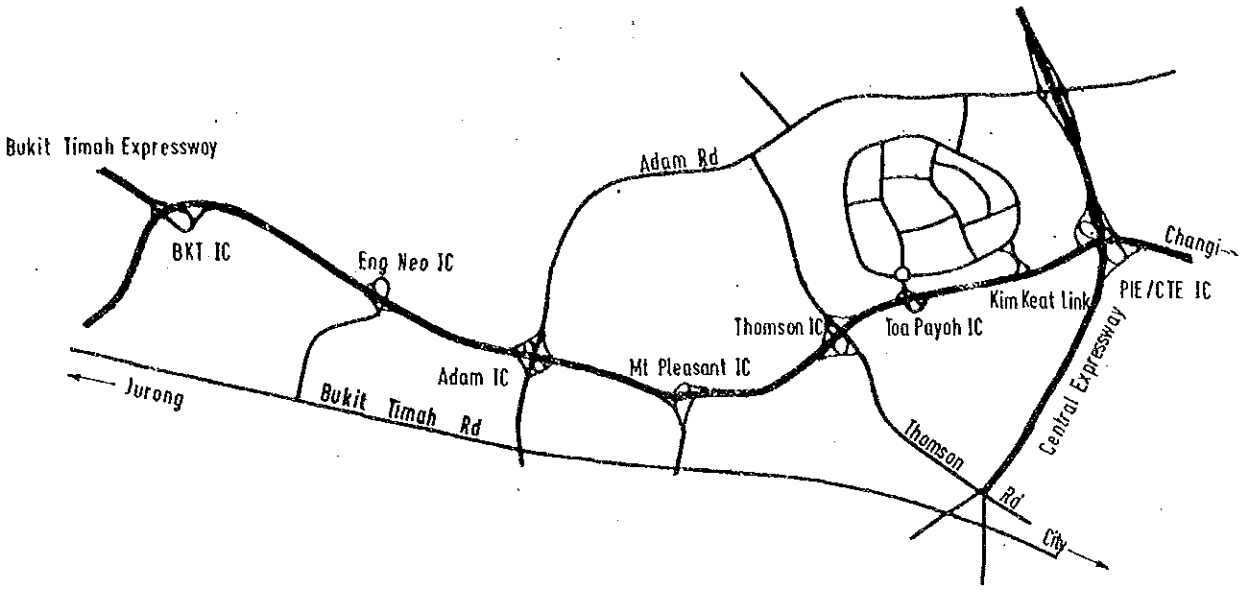
	Standard Section	Eng Neo FO	Adam FO	MT.Pleasant FO	Thomson FO	Toa Payoh FO
I	Additional 4 lanes at only one side of the existing expressway					
II	Widening of 1 lane at both sides of the existing expressway					
III	Construction of new viaduct with 4 lanes in the center of the existing expressway					
IV	Construction of new 2 lanes viaduct at both sides of the existing expressway					
V	Construction of new 4 lanes semi-coverd depressed type in the center and under the existing expressway					
VI	Construction of new 2 lanes semi-coverd depressed type at each side of the existing expressway					

Fig. 6.2 Improvement plans for interchanges on PIE



SYMBOL		P R O F I L E
Structure I (Plan)	I-1	BKT JC, ENG NEO IC, ADAM IC, Mt. PLEASANT IC, THOMSON IC, TOA PAYOH IC, CTE JC; 1; Additional 4 lanes at only one side of the exsting expressway
Structure II (Viaduct)	II-1	BKT JC, ENG NEO IC, ADAM IC, Mt. PLEASANT IC, THOMSON IC, TOA PAYOH IC, CTE JC; 2; 1
	II-2	Construction of new 2 lanes viaduct at the both sides of the existing expressway
Structure III (Depressed)	III-1	BKT JC, ENG NEO IC, ADAM IC, Mt.PLEASANT IC, THOMSON IC, TOA PAYOH IC, CTE JC
	III-2	2; 1

Fig. 6.3 Alternatives for Pan Island Expressway

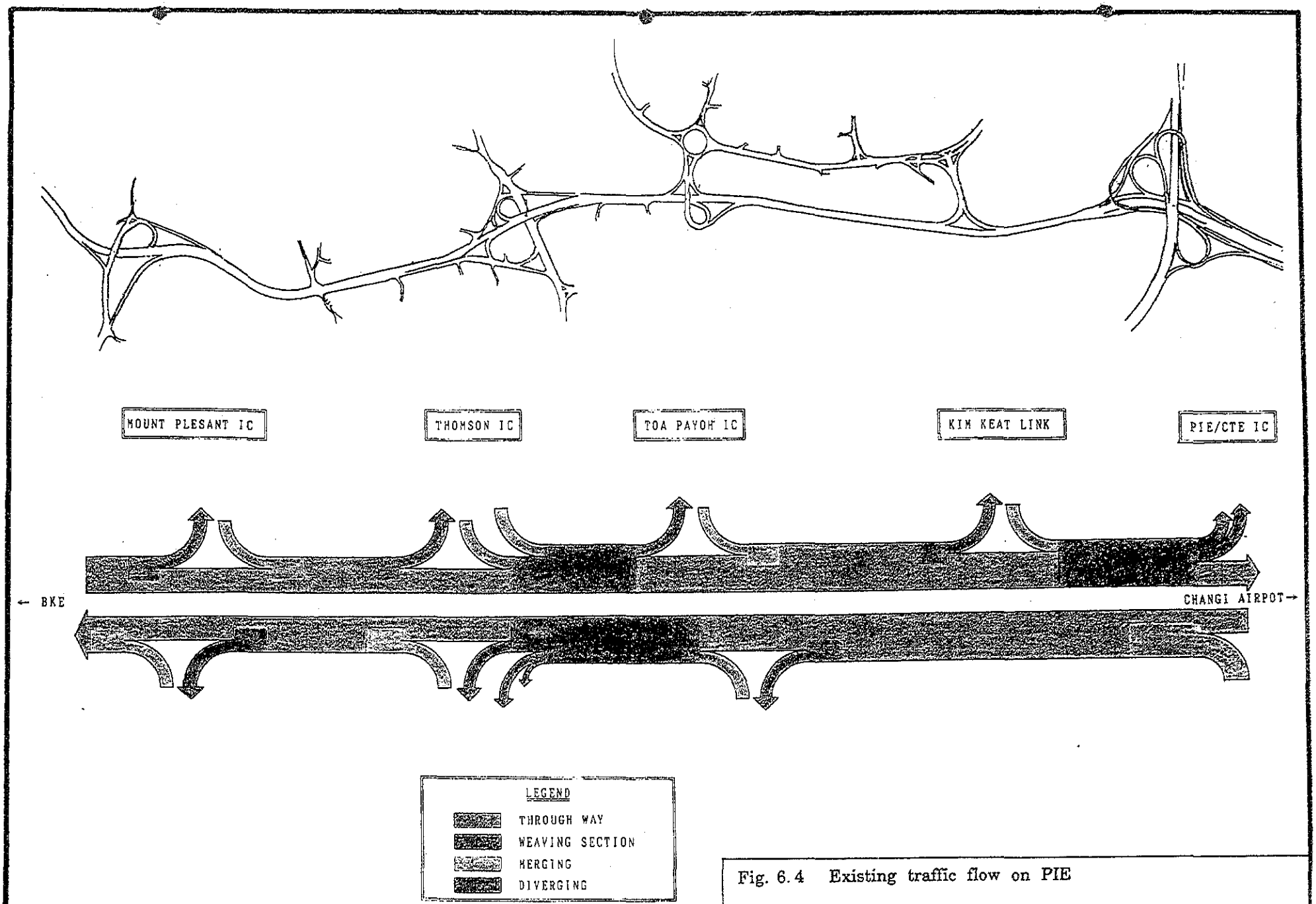
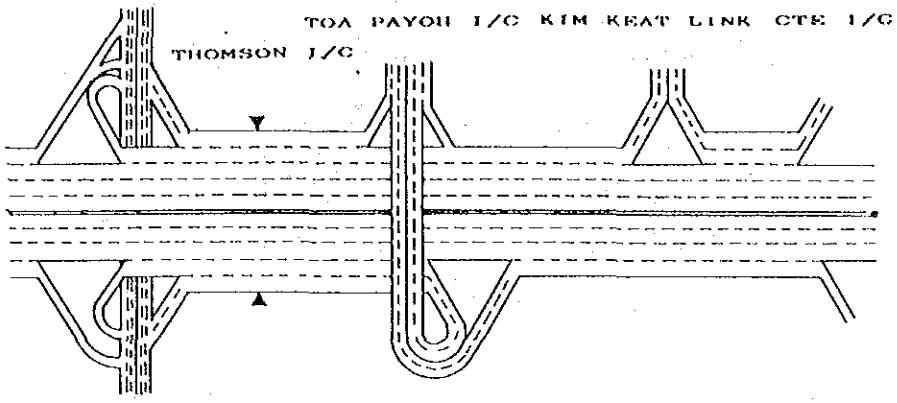
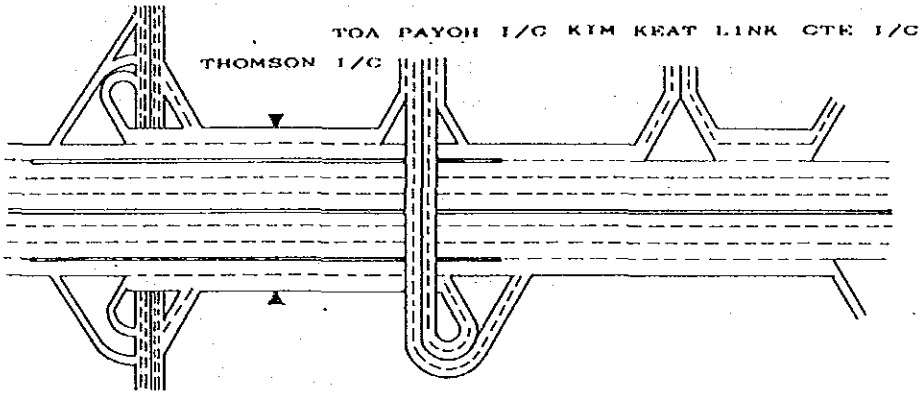


Fig. 6.4 Existing traffic flow on PIE

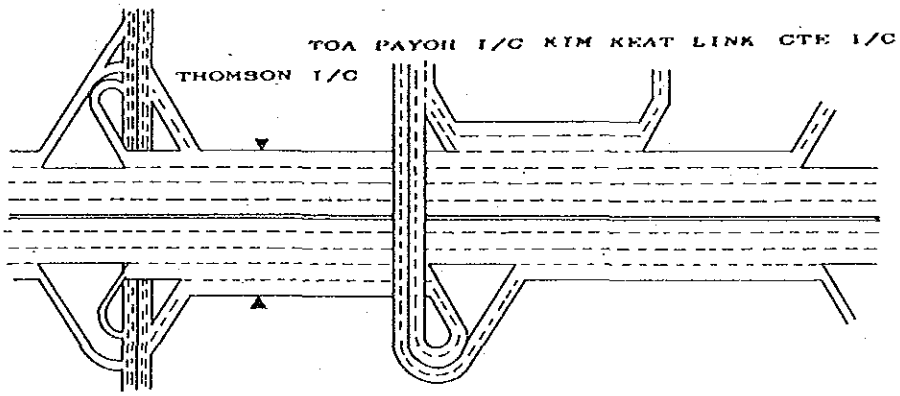
ALTERNATIVE I-1-a



ALTERNATIVE I-1-b



ALTERNATIVE I-1-c



ALTERNATIVE I-1-d

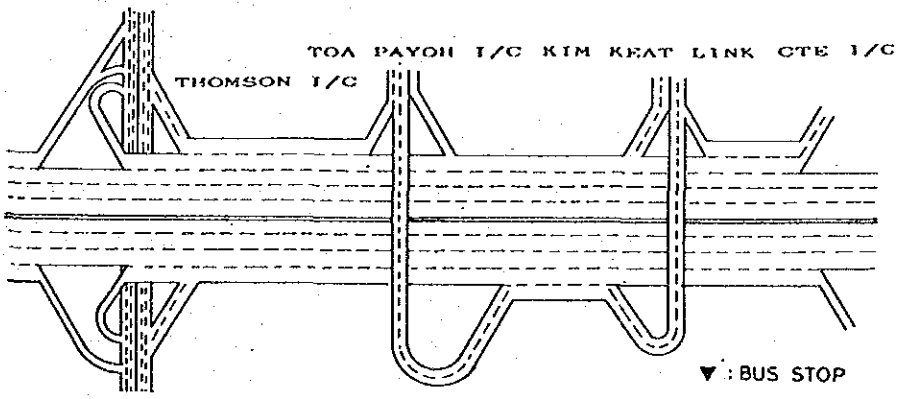


Fig. 6.5 Alternatives for the stretch between Thomson IC and PIE/CTE IC

Table 6.1 Traffic capacity

Section	Capacity
Freeway segments	2,200
Slip ramps	1,800
Loop ramps	1,600

unit: pcu/hour/lane

Fig. 6.7 indicates the necessary number of lanes derived from the formula described above. The necessary number of lanes for PIE is 4 lanes in each direction as clarified from the same figures. As for the stretch from PIE/Thomson IC to PIE/CTE IC where on-ramps and off-ramps repeatedly merge in considerably short intervals, an additional lane to connect the adjacent ramps is recommended to be installed, resulting in a partial stretch of 5 lanes.

6.3.3 Geometric Conditions

The work on PIE should be done on the existing 6 lanes. Although certain areas along this expressway do not meet the geometric standard for expressway, this situation is, however unavoidable. The geometrical aspect of the possibility of establishing alignment for the existing infrastructure on plane, the construction of new viaducts or semi-underground structures will be addressed in this section.

1) Widening of existing road

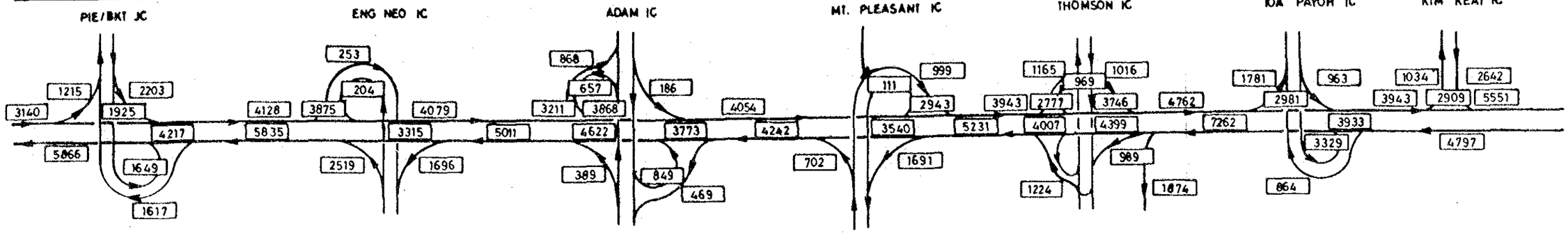
The existing landmarks along this road, which have become the control points for the targeted stretch are shown in Fig. 6.9. The areas with strict land usage limitation for setting of road alignment are given below with PIE/BKE IC as the starting point.

- South of PIE/Adam IC : Private land including Japanese Association
- PIE/Mt.Pleasant IC - South of PIE/Thomson IC : Catholic Junior College
- PIE/Thomson IC Vicinity : Police Academy at the north-west corner, Chequer's Hotel at the north-east corner, a building under construction at the southeast corner.
- PIE/Kim Keat-North of PIE/CTE IC : Apartments and Chinese Temple

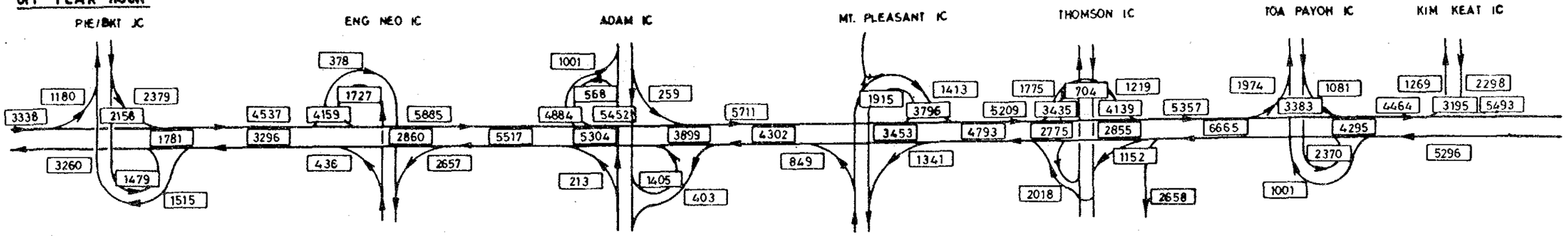
2) Viaduct and semi-covered proposal

For these two proposals, the main concern is whether the transition to ground level from viaduct grades or under-ground level enables proper alignment or not. The concept of the longitudinal alignment for the targeted stretch is shown in Fig. 6.8. Both proposals have a gradient of 4%, which is the standard minimum longitudinal gradient for the main road, and can be connected to the existing PIE. Both alternative II and III are applicable from the alignment view point.

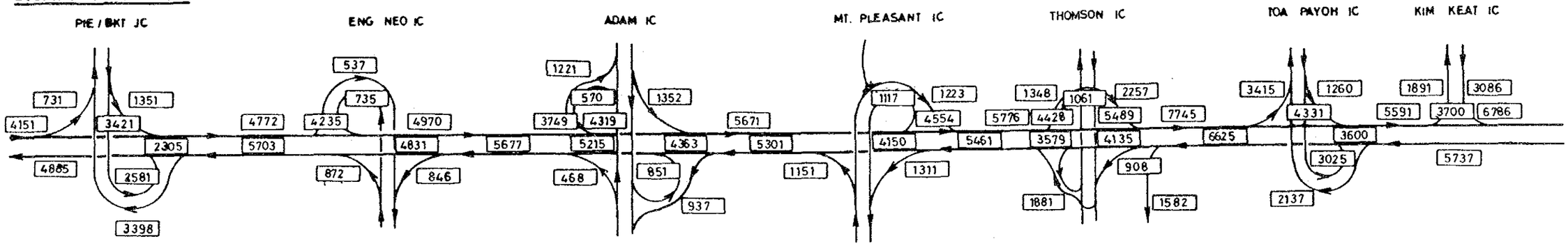
MORNING PEAK HOUR



OFF PEAK HOUR



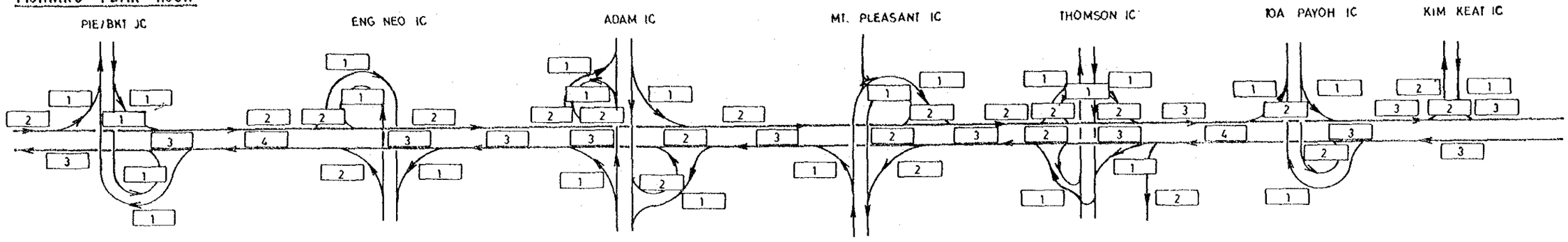
EVENING PEAK HOUR



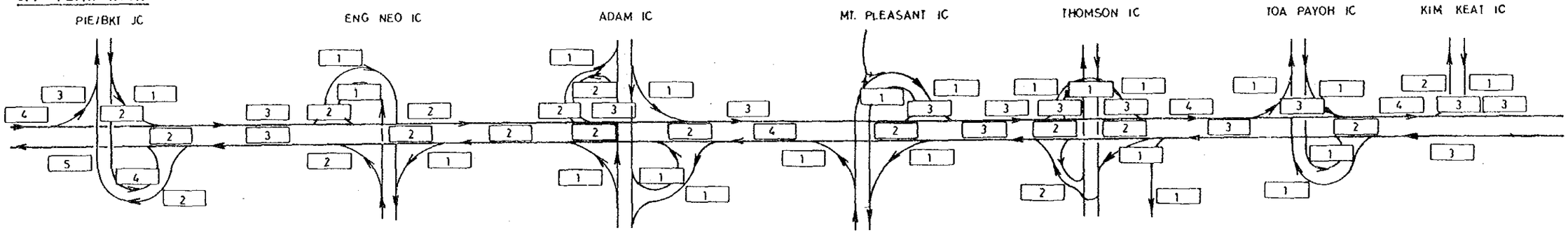
UNIT : PCU / HOUR

Fig. 6.6 Future traffic volume in 2010

MORNING PEAK HOUR



OFF PEAK HOUR



EVENING PEAK HOUR

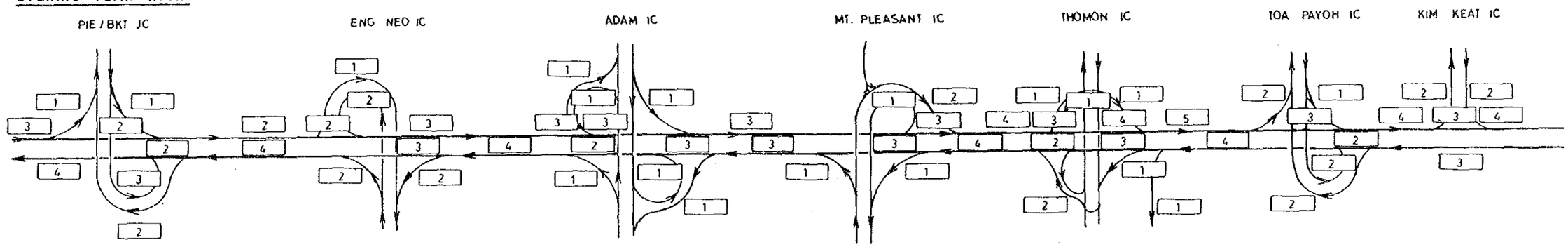


Fig. 6.7 Necessary number of lanes in 2010

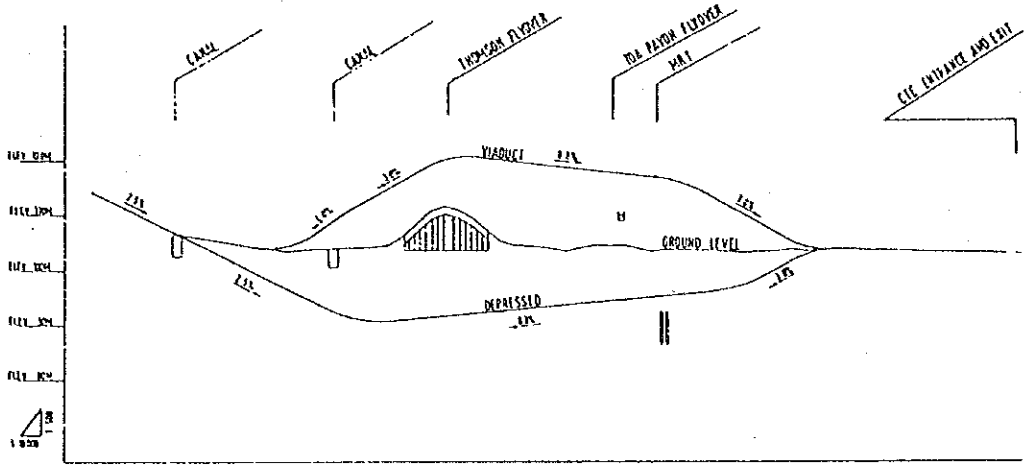


Fig. 6.8 Proposed profile of PIE

In order to find out the possibility of connecting the ground level road to an elevated or semi-underground road, a rough calculation of the necessary distance for extension is done. (see Fig.6.10.)

A rough calculation based on the above conditions shows that a minimum extended distance of 550m is required for overlapping to the main road. Besides, the connection with the ramp requires a minimum distance of 410m. The overlapping between main roads and interchanges requires a minimum approach-end spacing of 1,500m (550 x 2 + 400m (weaving distance)). This is impossible for stretches other than the stretch between PIE/BKE IC and PIE/Eng Neo IC. Besides, an on/off ramp requires a minimum distance of 1,220m (410 x 2 + 400m). For this targeted stretch, only East-bound of PIE/BKE IC -PIE/Eng Neo IC, PIE/Adam IC - PIE/Mt. Pleasant IC and West-bound of PIE/Eng Neo IC - PIE/BKE IC satisfy this condition.(see Fig. 6.11).

6.3.4 Viewpoint on Traffic Treatment

A summary of the types of viewpoints is given in Table 6.2.

From a traffic management standpoint, all these comparisons will form part of the target for schematic design and evaluation.

Table 6.2 Viewpoint for comparison

Alternative		Viewpoint	
I	1-a	Traffic management capacity of existing weaving, converging or diverging stretch.	between CTE and Thomson
	1-b		between Toa Payoh and Thomson
	1-c		combination of ON ramps
	1-d		shifting of ON ramps
II	1	Grade separation of passing traffic and access traffic.	between CTE and Thomson
III	2		between CTE and BKE

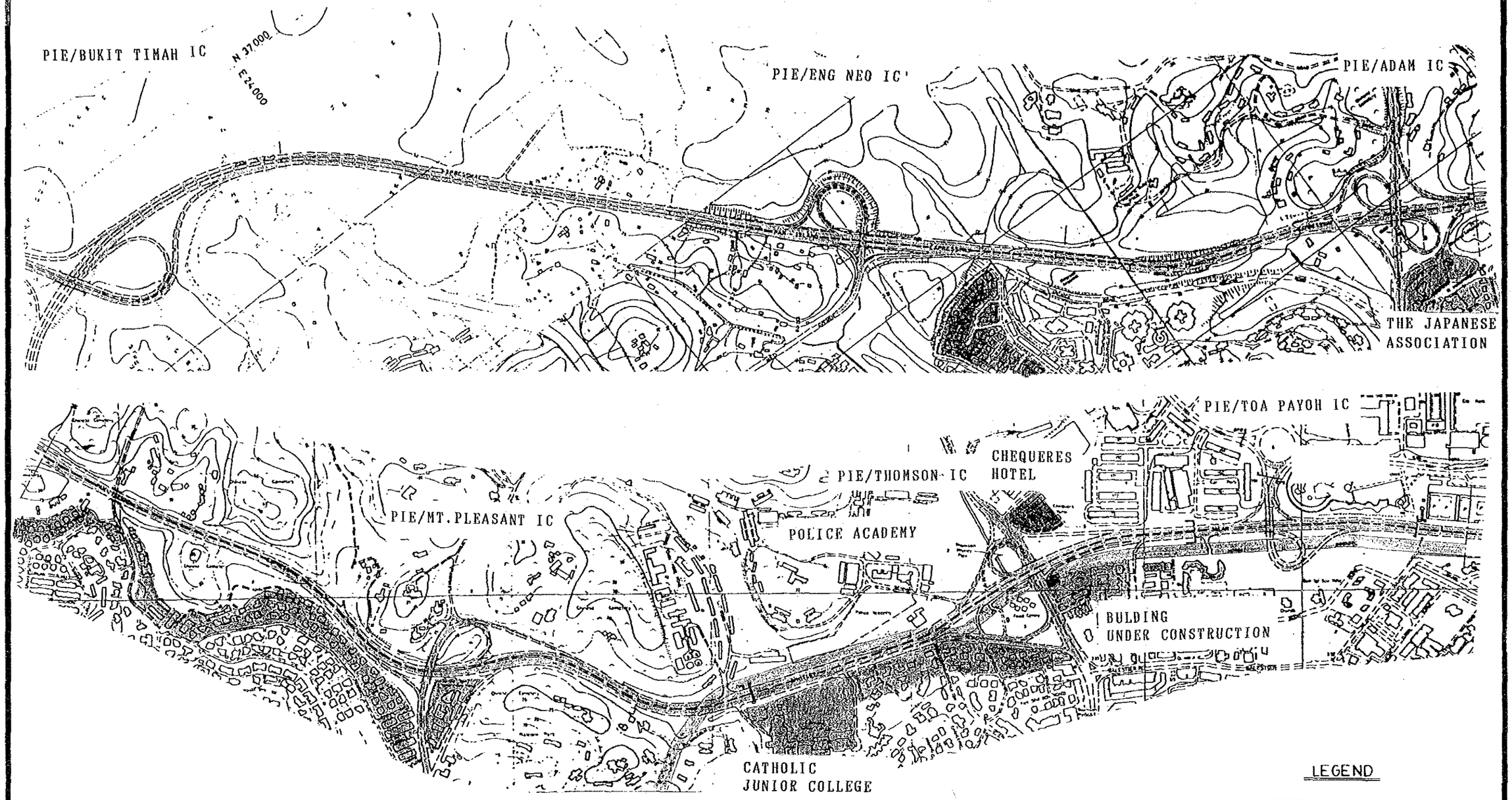


Fig. 6.9 Control point along PIE

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

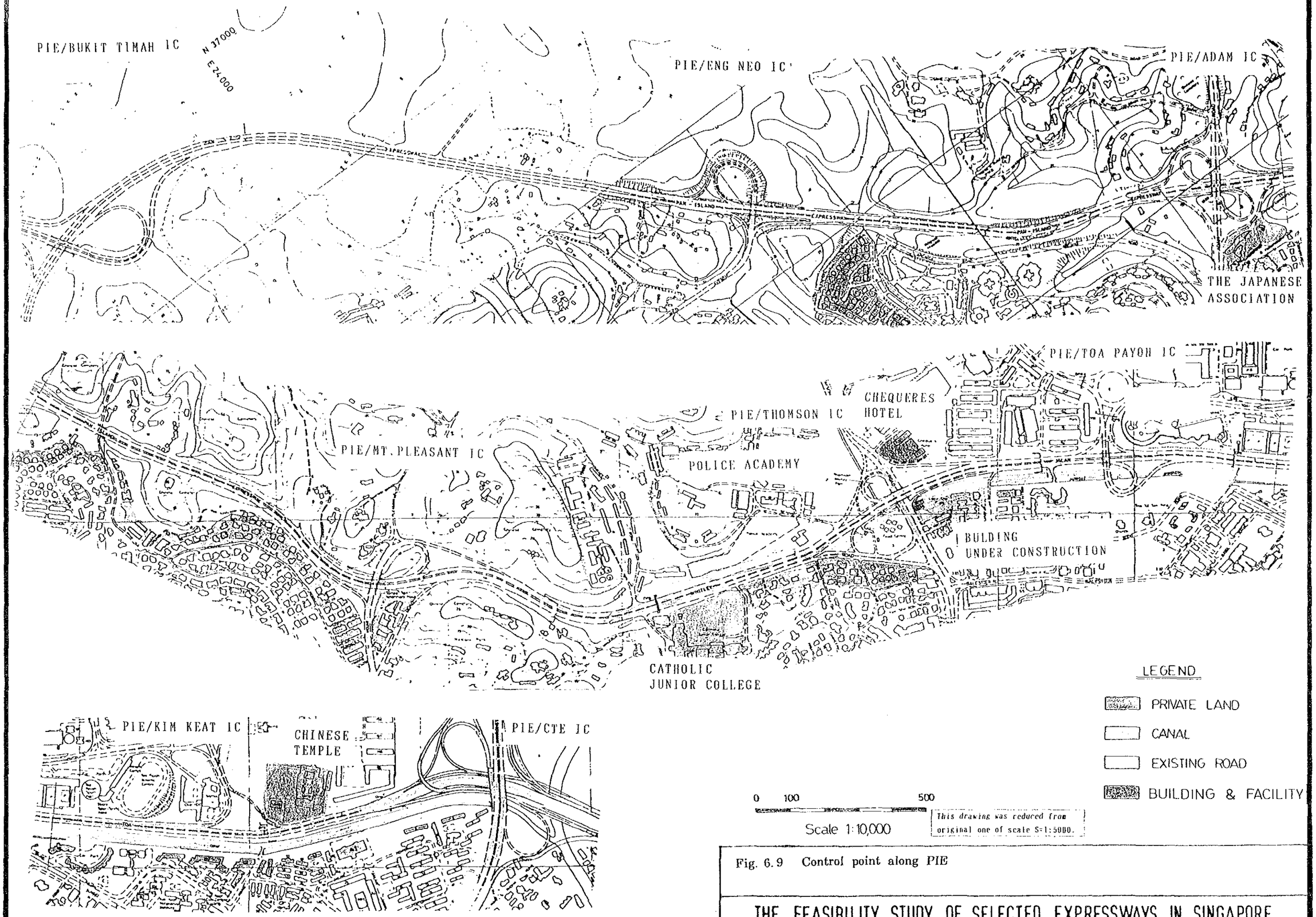


Fig. 6.9 Control point along PIE

THE FEASIBILITY STUDY OF SELECTED EXPRESSWAYS IN SINGAPORE

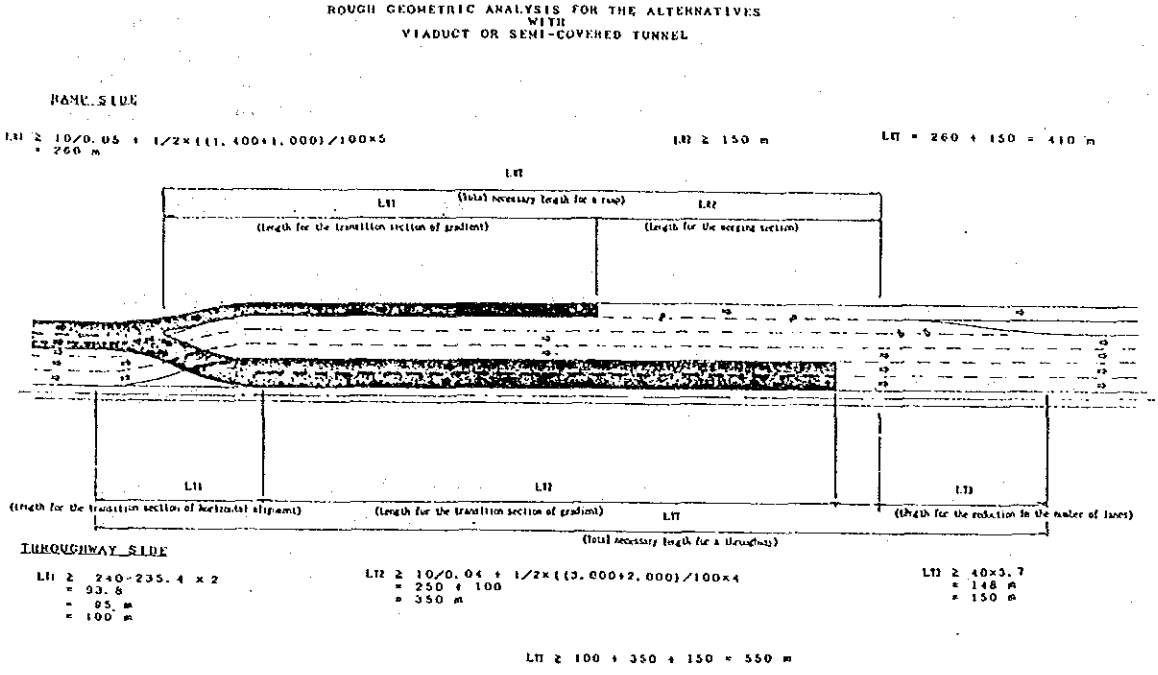


Fig. 6.10 Required distance for transition

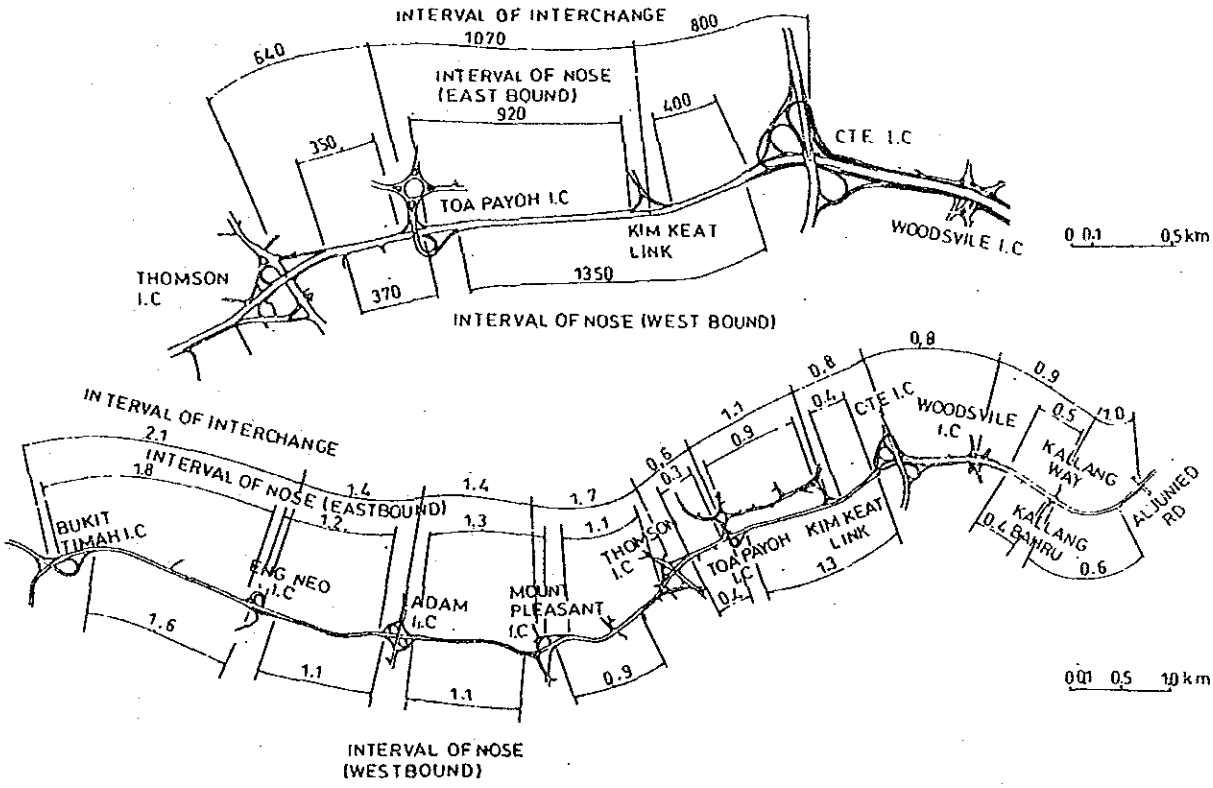


Fig. 6.11 Interval of interchanges on PIE

6.3.5 Viewpoint on Construction Technique

All the potential alternatives are applicable based on a structural viewpoint. However, there might still be some unfavorable points remaining behind, as all of them have not been accessed quantitatively based on economical efficiency and ease of implementation, technical comprehensiveness and impact on society.

In other words, the basis for quantitative assessment is as follow:

Economical efficiency	: appropriate construction fee.
Impact on Society	: effect on existing traffic and city life.
Ease of Implementation	: no special technique required, safe works can be completed in a short duration.
Technical Comprehensiv-ness	: Strength, durability, easy maintenance and management

Based on the ranking given by the above judgment, the feasibility of each proposal is commented. Table 6.3 and 6.4 show the comparative results of all the alternative plans from an implementation viewpoint. The result shows that Alternative I and IV were ranked top in terms of viability, followed by the II. Other alternatives are considered not competitive. (refer to Appendix 6.3)

Table 6.3 Selection of feasible alternatives

		Eng Neo FO		Adam FO		MT.Pleasnt FO		Thomson FO		Toa Payoh FO	
		T	C	T	C	T	C	T	C	T	C
I	Additional 4 lanes at only one side		○	○	○	○	○	○	○		△
II	Widening of 1 lane at both sides	○								○	△
III	Construction of new viaduct with 4 lanes in the center										
IV	Construction of new 2 lanes viaduct at both sider	○	○	○	○	○	○	○	○	○	○
V	Construction of new 4 lanes semi-covered depressed type in the center		×						×		
VI	Constructio of new 2 lanes semi-covered depressed type at each side	○	○	○	○	○	○	○	×	○	○

Note: ○; better than the other
△; having th same dondition
×; construction is very difficult

T; Traffic Management Aspect
C; Construction Aspect

Table 6.4 Alternative comparison on construction technique

	Economy	Construction Easiness	Social Effect	Operation Easiness	Score	Viable
I	Reasonable 4	Easy 4	Moderate 3	Easy 2	13	0
II	Moderate 3	Difficult 2	Fair 2	Easy 2	9	
III	Costly 1	Difficult 2	Considerable 1	Easy 2	6	-
IV	Moderate 3	Easy 3	Little 4	Easy 2	12	0
V	Costly 2	Very Diffi. 1	Considerable 1	Difficult 1	5	-
VI	Costly 2	Difficult 2	Fair 2	Difficult 1	7	-

6.3.6 Selected Alternatives

From the above result, it is identified that the semi-underground proposal which possesses serious defects is not feasible for the implementation at PIE/Thomson IC and is taken out from the schematic design and evaluation.

That is, the following alternative plans remain as alternatives for further comparison.

Improving existing infrastructure:

(1) Increase one lane each on both sides of the existing road : I-1-a
(2) Placement of divider for the above : I-1-b
(3) Rectifying the traffic flow by removing the Off Ramp at Toa Payoh and the On Ramp at Kim Keat in the direction towards Changi : I-1-c
(4) In addition, shifting the ON Ramp from Toa Payoh to Kim Keat in the direction toward Jurong : I-1-d

Viaduct

(5) Constructing viaduct from PIE/CTE to PIE/Mt. Pleasant. West of this region depends on improvement done to existing infrastructure : II-1
(6) Connecting the whole stretch from PIE/CTE to PIE/BKE by viaduct : II-2