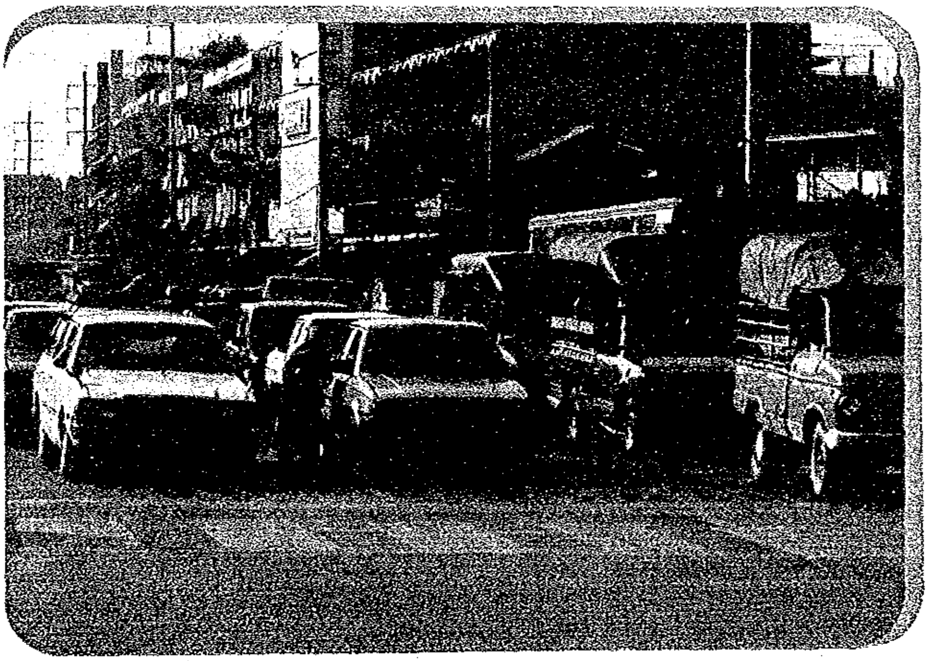
# PART II
# THE STUDY AREA, ITS ECONOMY AND TRAFFIC



# CHAPTER 2

# STUDY AREA CHARACTERISTICS AND PROSPECTS

## 2.1 The Study Area

### 2.1.1 Subject Area

Effects of the New Krungthep Bridge and Thonburi Road Extension will not be confined to the immediate vicinity. Traffic using the existing Krungthep Bridge comes from places all over the Bangkok Metropolitan Area and beyond it. The Thonburi Road Extension Section will become a major artery and its users will be similarly varied. It was decided therefore that the entire Bangkok Metropolitan Region be studied in terms of the effects of the two facilities with a particular attention to the vicinity. Fig. 2.1.1 shows Changwats and Amphoes in the Bangkok Metropolitan Region (BMR).

### 2.1.2 Climate and Natural Conditions

1) Climate

Thailand is located in the tropics between latitude 5°37'N. and 20°27'N., longitude 97°22'E. and 105°37'E.

The climate of Thailand is dominated by the northeast and southwest monsoons.

The northeast monsoon from China mainland or cold season normally affects Thailand from November to February, which is the season of relative little rainfall and lower humidity.

The southwest monsoon or rainy season, from May to September, brings a stream of warm moist air from the Indian Ocean, causing abundant rain and high humidity.

A short drought period of one to two weeks normally appear between June and July due to the influence of anticylonic circulation aloft.

The climate of the project area can be divided from the meteorological point of view into the following three seasons:

a. <u>Rainy season</u> or southwest monsoon period from May to mid October.

   The rainfall in the season is 1000 mm or about 80% of total, and average number of rainy days are about 13 days in May, 20 days in June, 16 days in July, 20 days in October. The humidity is in the range of 72% to 82% and the temperature is 28°C to 32°C.

b. <u>Cold season</u> or northeast monsoon period, from mid October to mid February, is the mildest in the year. The daily temperature during this period ranges from 24°C to 29°C. The number of rainy days per month is about 7 days in November, nil in December and January and 2 days in February.

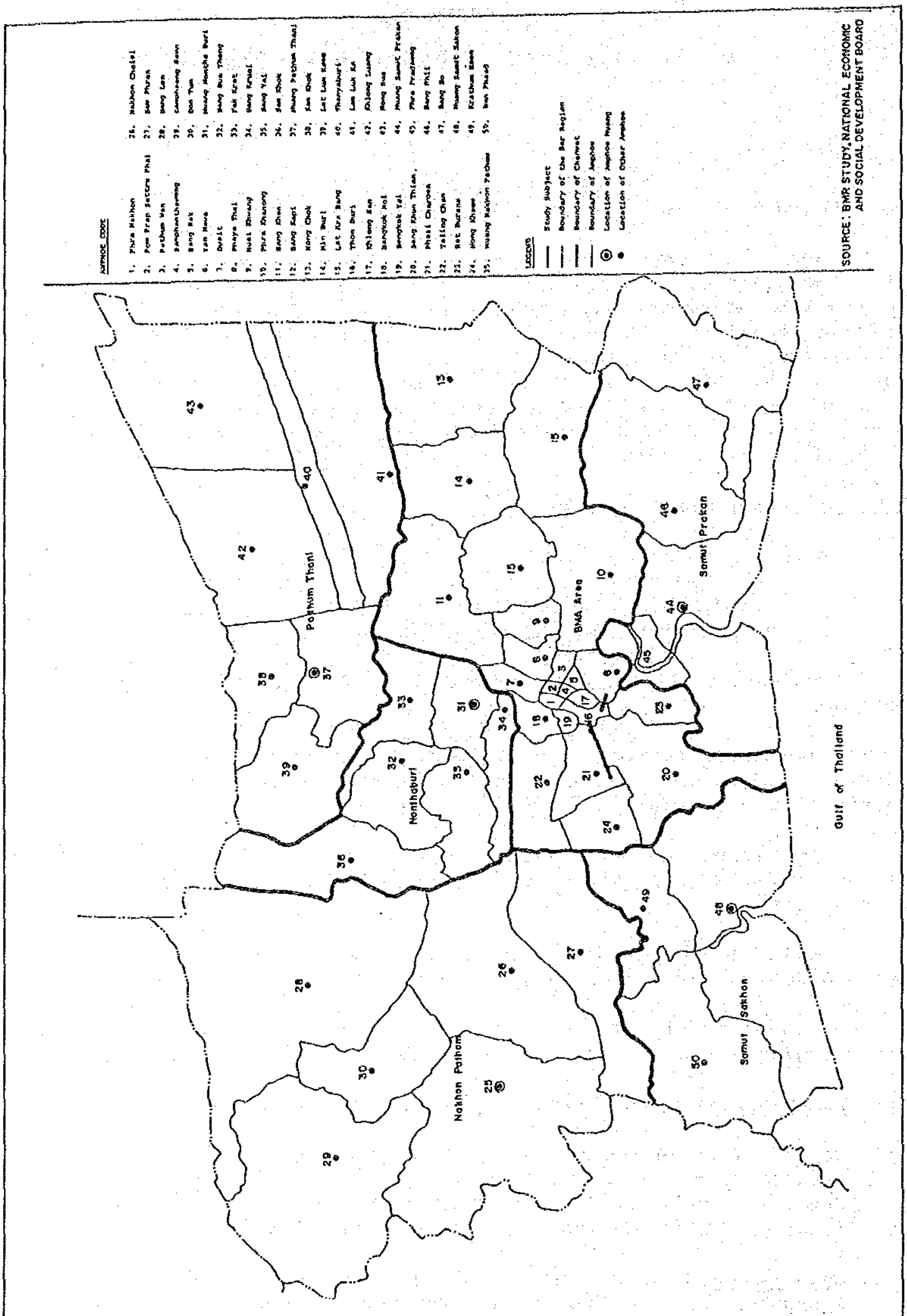



**Fig. 2.1.1 The Bangkok Metropolitan Region**

c. Hot season from mid February to mid May, is the transitional period from northeast to southwest monsoon. The warmest month is April and its temperature is 30°C to 32°C with about 7 rainy days in the month.

2) Natural Conditions

The project sites are situated in the capital of Thailand, Bangkok, which is located on the southern part of the Chao Phraya river delta about 40 km upstream of the river mouth. The city lies on a very low lying plain where the ground surface elevation is about 0 - 1.5 m above mean sea level.

Flooding in Bangkok, a frequest phenomenon, is caused by heavy rainfall and resulting overspill of the Chao Phraya river. The overspilling is mainly due to the combined effects of the river discharge from the north and high tide from the south, which usually occurs in the period of October to November.

Other special phenomenon in Bangkok is land subsidence caused by extraction of groundwater to cope with the need for industrial and residential development. In certain parts of the city the groundwater level in the eastside of the Chao Phraya river has been dropping at a persisting rate of 2 - 3 m per year during the past decade.

According to a preliminary study on flood protection/drainage project in eastern suburban Bangkok by JICA in 1984, the subsidence rate between 1980 and 1981 was more than 10 cm per year in the most serious zone. Based on their estimates, it is forcast that about 85 sq. km will be below MSL in 1990 and 150 sq. km in 2000. No study has been conducted concerning the subsidence problem in Thonburi district yet.

### 2.1.3 Economic Position

The BMR's dominant position in the national economy is apparent in Table 2.1.1. In 1983, 44% of total Gross Domestic Product (GDP) was produced in BMR. If limited to non-agricultural sectors, the figure is 55%. This dominance has been intensifying. In 1970 the BMR's share in GDP was 34%. More than half of the growth in GDP between 1970 and 1983 was produced by BMR.

Despite the Government's stated objective of decentralization, economic activities have continued to concentrate in Bangkok and come to such a level of importance to the national economy that the deterioration of its urban efficiency would seriously damage the overall performance of the national economy. As the future economic growth of Thailand will have to rely increasingly on non-agricultural sectors, it is vital to avoid the deterioration of urban efficiency from such urban problems as traffic congestion. The two projects covered by this study should be viewed in this context.

For the above reason the National Economic and Social Development Board (NESDB) commissioned the Bangkok Metropolitan Region Development Study (BMR Study) to explore the means of achieving an efficient use of resources for BMR. Its results have been utilized in this study where applicable.

Table 2.1.1 Gross Domestic and Regional Product, 1970 and 1983

1972 Prices: Million Baht

| | 1970 | | | | 1983 | | | |
|---|---|---|---|---|---|---|---|---|
| | Thailand | % | BMR | % | Thailand | % | BMR | % |
| Agriculture | 48,332 | 32.2 | 3,517 | 6.9 | 80,940 | 23.6 | 4,881 | 3.3 |
| Mining | 2,555 | 1.7 | 77 | 0.1 | 4,367 | 1.3 | 135 | 0.1 |
| Manufacture | 23,320 | 15.5 | 14,456 | 28.4 | 71,948 | 21.0 | 54,550 | 36.5 |
| Construction | 8,705 | 5.8 | 4,080 | 8.0 | 15,843 | 4.6 | 8,550 | 5.7 |
| Utilities | 1,638 | 1.1 | 362 | 0.7 | 7,393 | 2.1 | 1,499 | 1.0 |
| Transport | 9,195 | 6.1 | 5,590 | 11.0 | 23,608 | 6.9 | 12,548 | 8.4 |
| Trade | 26,524 | 17.7 | 6,665 | 13.1 | 55,591 | 16.2 | 21,058 | 14.1 |
| Banking | 5,800 | 3.9 | 4,049 | 7.9 | 24,330 | 7.1 | 17,716 | 11.8 |
| Dwellings | 3,000 | 2.0 | 1,448 | 2.8 | 5,152 | 1.5 | 2,987 | 2.0 |
| Public Admin. | 6,476 | 4.3 | 4,891 | 9.6 | 14,399 | 4.2 | 4,561 | 3.6 |
| Services | 14,541 | 9.7 | 5,838 | 11.5 | 39,306 | 11.5 | 20,083 | 13.5 |
| GNP/GRP | 150,092 | 100.0 | 50,973 | 100.0 | 342,878 | 100.0 | 149,576 | 100.0 |

Source: Gross Regional Product Accounts, NESDB

## 2.2 Growth of Bangkok Metropolitan Region

### 2.2.1 Urbanization Pattern

Bangkok, the capital city of Thailand, once a little "Ratanakosin Island" on the east bank of the Chao Phraya river and a few surrounding districts, has expanded enormously. Fig. 2.2.1 shows historical changes in its built-up areas. The past pattern of spatial development of Bangkok has been largely dictated by the construction of a few arterial highways, which have been built by the National Government primarily for the purposes of the national network. The population growth has been too fast for the municipal administration to secure sufficient financial resources for the construction of complementary distributor and access roads. The consequent lack of distributor and access roads has forced new developments close to highways and inaccessible large areas between highways have often been left undeveloped.

The polycentric spatial development pattern advocated during the Fourth (1977-81) and Fifth (1982-86) National Economic and Social Development Plans has not materialized. No urban centers challenging the existing core areas have emerged.

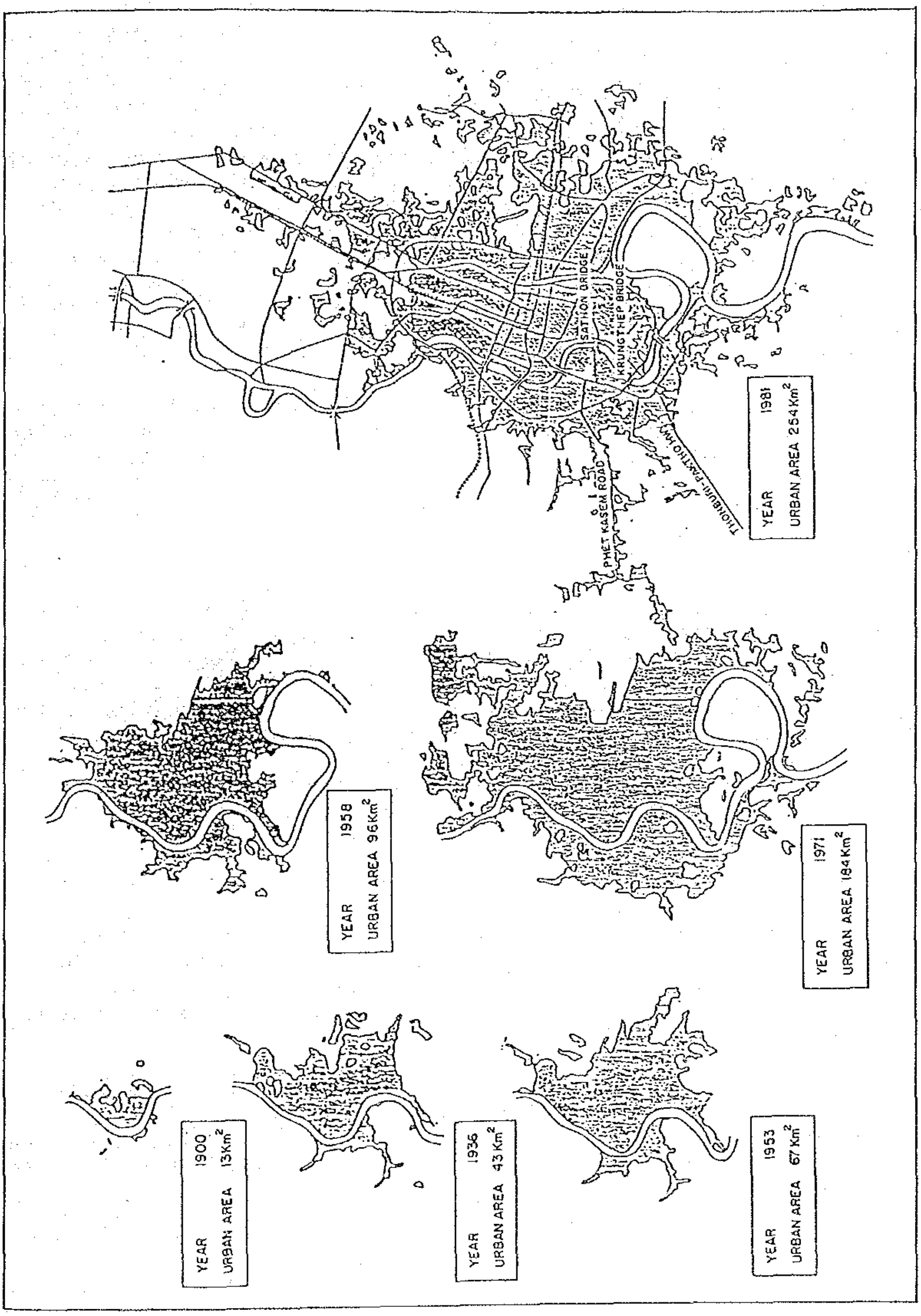



Fig. 2.2.1 Progress of Urbanization in Bangkok

In this regard a comment should be made concerning the definition of urban center. A remark is often heard in Bangkok that Bangkok has no central business district (CBD) as its center since amphoes of Phra Nakhon, Pom Prap Sattrupai, Patum Wan, Samphanthawong, and Bang Rak share CBD functions. This remark could have been valid against Bangkok of 20 years ago when urbanized area was much smaller. Today urbanized area is spilling into neighboring Changwats and more than twice as large as 20 years ago. The above six central Amphoes form the urban center of the much expanded Bangkok Metropolis. In older cities expansion took place at a much slower pace and may have had a small well defined CBD when they were small. As they grew to a size comparative to today's Bangkok, the area providing functions of urban center also grew to a size comparable to the area of the five Amphoes. Initial centers, however, are often still referred to as "the center". Actually their functional urban center is often much larger.

A salient feature of urban development of Bangkok is the fact that it has been very much asymmetrical. The reason for this can be attributed to the Chao Phraya river acting as physical as well as psychological barrier. The New Krungthep Bridge and Thonburi Road Extension would help correcting this asymmetrical pattern.

### 2.2.2 Population

The population of the Bangkok Metropolitan Region has been rapidly increasing as shown in Table 2.2.1. Its population, which was 4.7 million and 13.1% of the national total in 1970, is expected to reach 8.2 million and 15.5% of the national total in 1986. The rate of growth, however, has been declining in recent years reflecting the similar trend for the nation. For the Bangkok Metropolitan Area the rate of growth has declined from the average of 4.3% per annum in the 1970s to 2.9% in the 1980s. Some of the surrounding Changwats, however, have not shown a similar decline in the population growth rates as they have accommodated extra-population spilling over from BMA.

An examination of population density within the Region confirms the concentric pattern of Bangkok as shown in Fig. 2.2.2. It can be seen that population densities of Amphoes on the west bank are lower than those on the east bank with the exception of Thonburi, which has a history of its own. The average of road travel times from the Amphoe center to Phra Nakhon and to Bang Rak in 1985 is taken as the distance measure in the above analysis.

As an urban area is approaching its saturation point in terms of population density, its population growth rate becomes lower. This phenomenon is taking place in Bangkok as shown in Fig. 2.2.3. The growing area in Bangkok is a ring around the urban center and its location is gradually moving outward.

Table 2.2.1 Total Population of BMR by Province, 1970–86

| | 1970 '000 | 1980 '000 | 1986 '000 | Increase, % p.a. 1980-80 | Increase, % p.a. 1980-86 |
|---|---|---|---|---|---|
| Bangkok | 3,185 | 4,852 | 5,773 | 4.3 | 2.9 |
| Nakhon Pathom | 434 | 545 | 614 | 2.3 | 2.0 |
| Nonthaburi | 278 | 383 | 473 | 3.3 | 3.6 |
| Pathum Thani | 242 | 332 | 406 | 3.2 | 3.4 |
| Samut Prakarn | 341 | 503 | 625 | 4.0 | 3.7 |
| Samut Sakorn | 208 | 256 | 294 | 2.1 | 2.3 |
| Total BMR | 4,687 | 6,871 | 8,185 | 3.9 | 3.0 |
| Whole Kingdom | 35,633 | 46,718 | 52,654 | 2.7 | 2.0 |
| BMR/Whole Kingdom % | 13.2 | 14.7 | 15.5 | | |

Totals do not add because of rounding.

Source: 1970, 1980 Census adjusted for under-renumerations; BMR Study projections for BMR, 1986; Working Group on Population Project for Kingdom 1986.

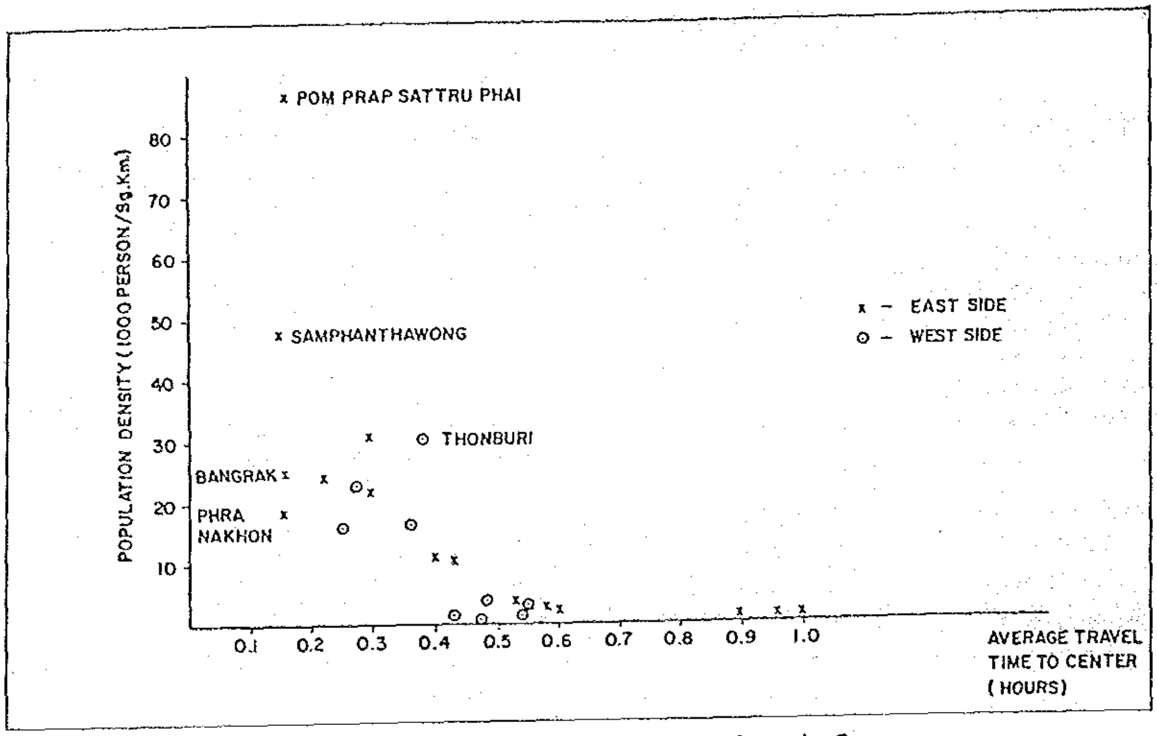



Fig. 2.2.2 Population Density and Distance from the Center

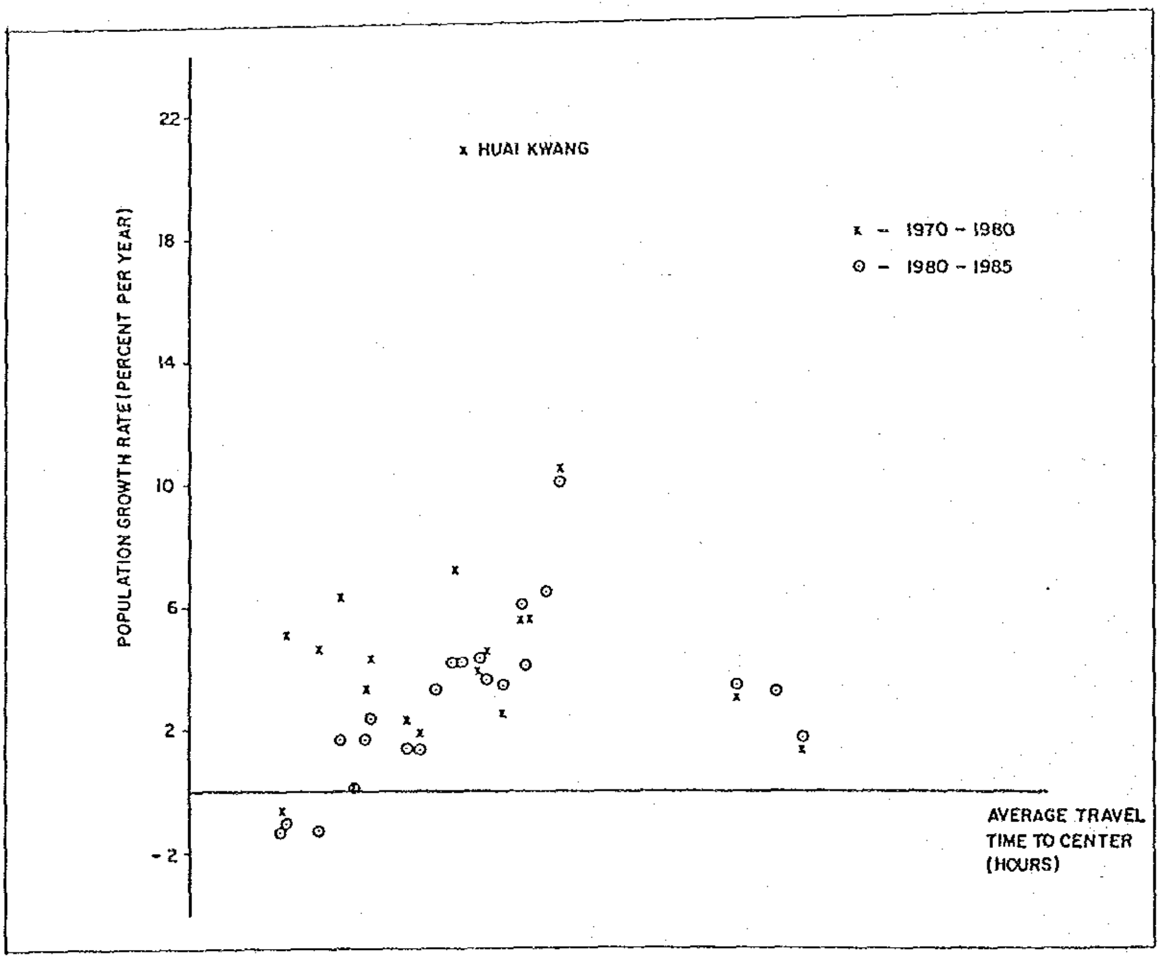



Fig. 2.2.3 Population Growth Rate and Distance from the Center

### 2.2.3 Employment

Employment in the BMR has been growing faster than the growth in population as shown in Table 2.2.2. During the 1970s, the average growth rate was 5.7% per annum for BMA and 5.2% for BMR as opposed to the population growth rates of 4.3% for BMA and 3.9% for BMR. This indicates a substancial increase in labor participation rate. This was accomplished under the condition of a heavy influx of immigrants from outside of BMR. Such growing job opportunities have attracted immigrants, and largely satisfied their expectations.

Within BMR the distribution of employment basically follows the population distribution pattern as shown in Table 2.2.3. BMA occupies about 70% of the regional total both for population and employment (Table 2.2.1). Pathum Thani has the largest employment relative to population. Manufacturing sector employment are 43% and 49% of the total in Pathum Thani and in Samut Prakan, indicating these Changwats are heavily industrialized.

Spatial pattern of employment is also concentric pattern. Fig. 2.2.4 illustrates how the employment density varies by ease of access to the urban center.

### 2.2.4 Land Use

The urbanized area as measured in terms of built-up area has grown at a rate of 3.3% per annum during the period of 1971-1981. The average population growth rate of BMA in the period of 1970-1980 was 4.3% per annum. This seeming intensification, however, is misleading. Population in central Amphoes has been declining in recent years while population of suburban Amphoes has been rapidly increasing. The net effect is an urban sprawl as clearly seen in Fig. 2.2.1.

Land use statistics exist for BMA and some other Changwats in the BMR for certain years. Internal inconsistency among these data was found to be so large that the idea of using land use statistics had to be abandoned. Several qualitative observations, however, may warrant presentation.

Land use in Bangkok has been and is basically determined by market forces in the absence of effective land use control. The market is quite complex. Land value, access to employment, access to service, environment, access to customers, access to school, access to transport, population pressure, prestige, and so on all come into play. Several mutually reinforcing factors seemed to have pushed the urban sprawl in Bangkok in the past decades. They are:

- population explosion at typically more than 4% per annum.
- motorization growing at typically more than 7% per annum
- expansion of public transport by governmental and private operators with the total fleet increasing at more than 10% per annum
- construction of radial arterial highways and their extension
- rising per capita income and declining household size

Table 2.2.2 Change in Employment, 1970–1980

% Change per Annum

| Place of Resident | Agriculture, Mining | Manufacture | Other Sectors | Total |
|---|---|---|---|---|
| BMA | -0.9 | 7.2 | 6.0 | 5.7 |
| Nonthaburi | -0.7 | 8.4 | 7.6 | 4.2 |
| Pathum Thani | 1.3 | 12.6 | 7.6 | 4.5 |
| Samut Prakarn | -1.7 | 10.5 | 6.8 | 5.4 |
| Samut Sakhon | 0.6 | 8.2 | 5.0 | 3.0 |
| Nakhon Pathom | 1.8 | 10.5 | 6.3 | 3.5 |
| Total, BMR | 0.4 | 8.0 | 6.2 | 5.2 |

Source: Census 1970, 1980/BMR Study

Table 2.2.3 Employment by Sector and Province, 1984

| Place of Work | Agriculture, Mining | | Manufacture | | Other Sectors | | Total | |
|---|---|---|---|---|---|---|---|---|
| | '000 | % Province | '000 | % Province | '000 | % Province | '000 | % Province |
| BMA | 132 | 5.4 | 610 | 25.0 | 1,697 | 69.6 | 2,439 | 100.0 |
| Nonthaburi | 60 | 41.4 | 13 | 8.7 | 73 | 49.9 | 146 | 100.0 |
| Pathum Thani | 74 | 28.3 | 113 | 43.2 | 75 | 28.5 | 262 | 100.0 |
| Samut Prakan | 46 | 17.0 | 131 | 48.8 | 92 | 34.2 | 269 | 100.0 |
| Samut Sakhon | 60 | 64.9 | 12 | 10.1 | 30 | 25.0 | 102 | 100.0 |
| Nakorn Pathom | 149 | 62.6 | 30 | 12.7 | 59 | 24.7 | 238 | 100.0 |
| Total, BMR | 521 | 15.1 | 909 | 26.3 | 2,026 | 58.3 | 3,456 | 100.0 |

Source: Labor Fore Survey, NSO/BMR Study

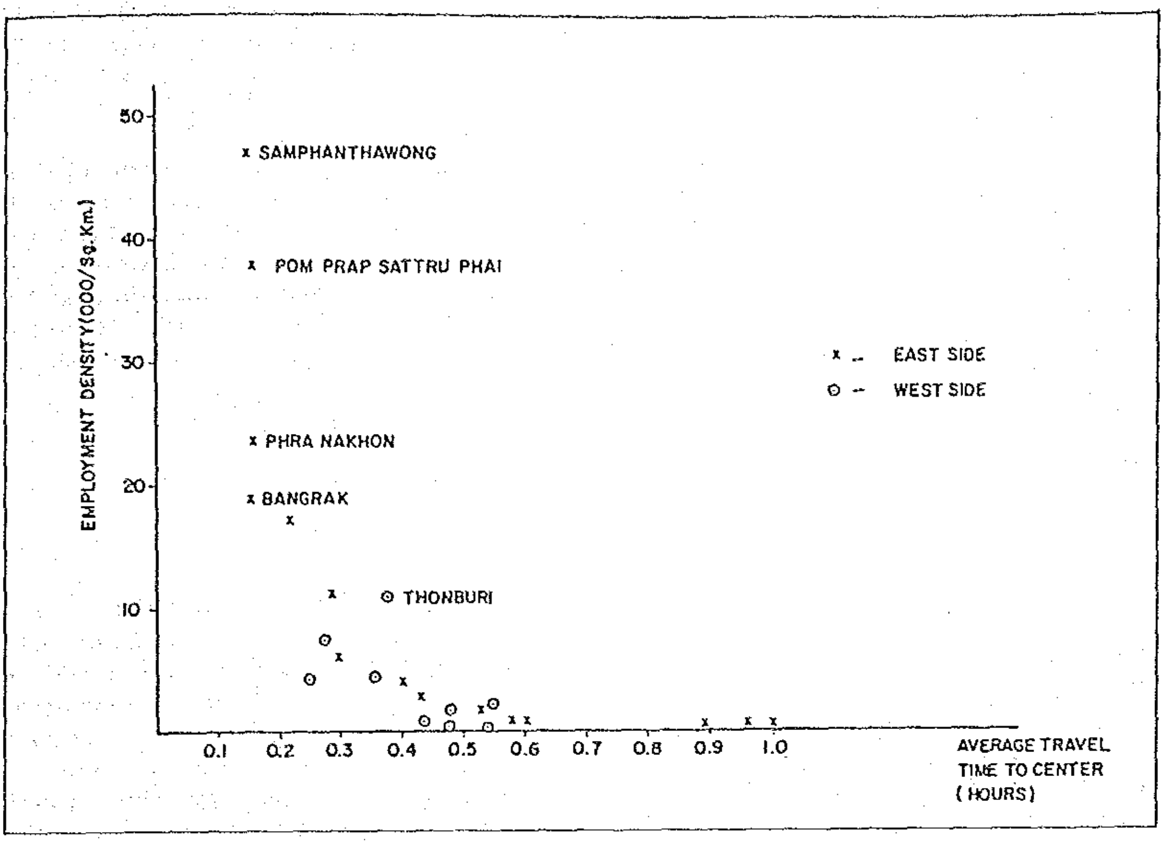



**Fig. 2.2.4 Employment Density and Distance to the Center**

The above phenomena took place at the same time in an area with abundant surrounding open space and without a history of significant urban rail transport. The present urban pattern of Bangkok can be seen as the equilibrium of such market forces.

Generally land use in Bangkok can be characterized by wide-spread mixed use. Some specialization, however, has been emerging. The land use plan of the Bangkok Metropolitan General Plan incorporates existing land use. Of particular importance to this study is the location of industries. Fig. 2.2.5 shows locations of factory concentration. Importance of the Krungthep Bridge to industry is clear as its location is the closest to the industrial concentration along the lower Chao Phraya river.

## 2.3 Future Development Prospects

### 2.3.1 Economic Growth Prospects

The Government's positive policies aiming at rapid economic growth including encouragement of foreign investment were helped by favorable external conditions for achieving the GDP growth rate averaging 7% in the 1970s. However, the second oil shock of 1979 and the subsequent recession in the world economy brought the slow down of Thai export market expansion and the fall in the prices of primary commodities for which the Thai economy is heavily dependent. Consequently the growth rate of Thai economy in the 1980s has been reduced to around 5%. The momentum of the expansionary economy shaped in two decades of rapid economic growth could not be readily redirected in the face of the unfavorable external conditions. Thailand started to borrow heavily from external sources. External debt, which was only US$ 4 billion at the end of the 1970s, reached US$ 12 billion at the end of 1985. The ratio of foreign debt service to the export receipt has exceeded 20%. This ringed an alarm bell throughout the Government and a tight control was imposed on foreign borrowings. It seems that policies aiming at economic stability has gained priority over those aiming at economic growth within the Government.

The Sixth National Economic and Social Development Plan (1986-1991) which is under finalization process lists 2 targets, 4 strategies and 10 programs. The first priority strategy is:

> To continue to proceed with the development and adjustment of economic and social framework of important policies carried over from the Fifth Plan. At the same time, to seek for new opportunities that will lead to economic progress and a wider distribution of benefits to the general population. However, prime consideration must always be given to economic limitations and the maintenance of the country's fiscal and monetary stability.

And the first priority program is:

> Economic and financial stabilization program.

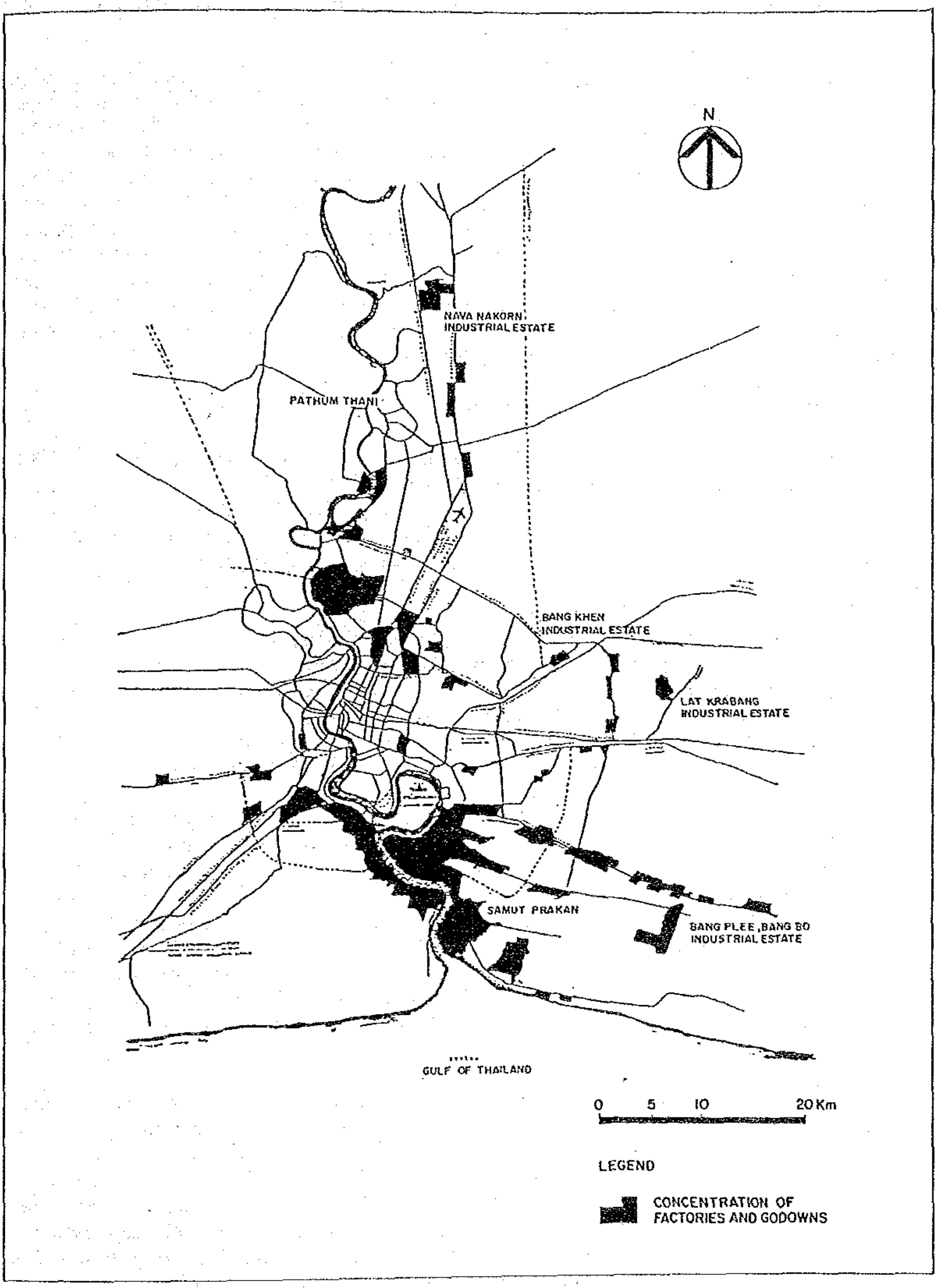



Fig. 2.2.5 Trend of Industrial Location (BKK)

Representing such cautious approach, the target GDP growth rate for the Sixth Plan is set at 5% per annum.

The National Economic and Social Development Board made economic projections by means of macro-economic modelling taking into account the Sixth Plan directions and various domestic and world economic prospects. Table 2.3.1 shows their results. Thailand's GDP is expected to grow at 4.6% per annum during 1986-1991 and at 4.3% per annum thereafter. An attempt was made to estimate the economic growth of BMR by means of allocating the estimated nation-wide GDP taking into account past trends of BMR. Table 2.3.2 summarizes the projections. Table 2.3.3 reveals the underlying assumption. The share of BMR to the whole kingdom in terms of GDP will continue to increase, exceeding 50% by 2001, whereas within BMR the BMA's share will fall as the urban activities will increasingly be borne by surrounding Changwats.

### 2.3.2 Population and Employment Projections

The Working Group on Population Projections comprising NESDB, NSO and the Institute of Population Studies, Chulalongkorn University formulated three scenarios for the future population growth in the BMR as a part of the BMR Study. Various factors were examined in formulating the three (high, medium, and low) scenarios such as:

- increasing life expectancy
- decline in fertility rate for natural growth, and
- diminishing supply of unused cultivable land
- continued increase in agricultural labor productivity
- limitations of rural industrial growth
- disappearance of Middle East market for Thai labor
- growth of upcountry urban centers for immigrants to BMR.

The BMR Study adopted the medium projections as the most likely net effect of the above factors. Table 2.3.4 shows the projections by Changwat. Although projected growth rates represent a declining trend in the recent past, absolute amounts of population increase are awsome. BMR is expected to have additional 3.4 million of inhabitants in the coming 15 years and the BMA alone is expected to see its population increased by 2.1 million in the same period. The total population of 11.5 million of BMR in 2001 would be almost 18% of the national total and that of 7.9 million of BMA in 2001 would be 12% of the national total.

Detailed projections were made by the above study for each Tambon. These projections are the basis for the population projections for each traffic zone in this study as described in the next chapter.

The Chulalongkorn University Social Research Institute completed the Draft Final Report on Projections of Economic Activities and Employment in BMR in December 1985 fr the BMR Study. Estimates of GDP are shown in the preceding section. Estimates of employment were determined by means of labor productivity by sector taking into account probable future changes in productivity, which were assumed based on the past trends. Table 2.3.5 shows a summary of regional employment projections for BMR. Employment projections thus obtained are sensitive to assumptions on productivity changes. Nevertheless, the estimated employment growth

Table 2.3.1 GDP Forecasts 1986–2001

| | Billion baht 1982 prices | | | 1972 prices: Billion<br>% growth per annum | |
|---|---|---|---|---|---|
| | 1986 | 1991 | 2001 | 1986-91 | 1991-2001 |
| Agriculture | 88.4 | 100.9 | 129.8 | 2.7 | 2.6 |
| Manufacture | 82.1 | 109.4 | 188.8 | 5.9 | 5.6 |
| Services | 45.3 | 59.4 | 97.3 | 5.6 | 5.1 |
| Other sectors | 179.1 | 224.8 | 337.5 | 4.7 | 4.1 |
| Total GDP | 394.9 | 494.5 | 753.4 | 4.6 | 4.3 |

Source: NESDB

Table 2.3.2 Projections of Gross Regional Products, 1986–2001

| | Million baht, 1972 prices | | | % growth per annum | |
|---|---|---|---|---|---|
| | 1986 | 1991 | 2001 | 1986-91 | 1991-2001 |
| BMR | | | | | |
| Agriculture | 5,580.9 | 6,061.6 | 7,087.1 | 1.67 | 1.57 |
| Manufacture | 61,517.7 | 80,236.8 | 133,158.6 | 5.46 | 5.20 |
| Services | 25,008.0 | 36,061.9 | 72,964.6 | 7.60 | 7.30 |
| Other sectors | 82,984.8 | 106,580.7 | 166,220.0 | 5.13 | 4.54 |
| Total | 175,091.4 | 228,941.0 | 379,430.3 | 5.51 | 5.18 |
| BMA | | | | | |
| Agriculture | 723.2 | 782.9 | 899.7 | 1.60 | 1.40 |
| Manufacture | 40,352.1 | 48,694.1 | 68,564.9 | 3.83 | 3.48 |
| Services | 22,661.0 | 32,532.8 | 65,203.3 | 7.50 | 7.20 |
| Other sectors | 68,268.0 | 85,745.6 | 123,821.3 | 4.70 | 3.74 |
| Total | 132,004.3 | 167,755.4 | 258,489.2 | 4.91 | 4.42 |
| Non-BMA | | | | | |
| Agriculture | 4,857.8 | 5,278.7 | 6,187.4 | 1.68 | 1.60 |
| Manufacture | 21,165.5 | 31,542.7 | 64,593.7 | 8.31 | 7.43 |
| Services | 2,347.0 | 3,529.1 | 7,761.3 | 8.50 | 8.20 |
| Other sectors | 14,716.9 | 20,835.1 | 42,398.7 | 7.20 | 7.36 |
| Total | 43,087.2 | 61,185.6 | 120,941.1 | 7.27 | 7.05 |

Source: Working Paper on Employment and Economic Activity

Table 2.3.3 Change in GDP Shares of BMR and BMA

| | Percent Share | | |
|---|---|---|---|
| | 1986 | 1991 | 2001 |
| BMR to Kingdom | 44.3 | 46.3 | 50.4 |
| BMA to BMR | 75.4 | 73.3 | 68.1 |

Source: Tables 2.5 and 2.6

Table 2.3.4 Population Growth by Changwat, 1980–2001

| | Total population '000 | | | Population growth, | % per annum |
|---|---|---|---|---|---|
| | 1986 | 1991 | 2001 | 1986-91 | 1986-2001 |
| BMA | 5,773 | 6,477 | 7,850 | 2.3 | 2.1 |
| Nakhon Pathom | 614 | 672 | 796 | 1.8 | 1.7 |
| Nontha Buri | 473 | 556 | 782 | 3.3 | 3.4 |
| Pathum Thani | 406 | 478 | 681 | 3.3 | 3.5 |
| Samut Prakan | 625 | 739 | 1,002 | 3.4 | 3.2 |
| Samut Sakhon | 294 | 331 | 430 | 2.4 | 2.6 |
| Total BMR | 8,185 | 9,253 | 11,541 | 2.5 | 2.3 |
| Thailand(1) | 52,654 | 57,196 | 65,138 | 1.7 | 1.4 |
| BMR/Thailand | 15.5% | 16.2% | 17.7% | | |

Note: (1) Data interpolated from the "medium" projections for 1985, 1955 and 2000 of the Working Group on Population Projections (comprising NESDB, NSO and the Institute of Population Studies, Chulalongkorn University).

Table 2.3.5 Forecasts of Region Employment, 1986–2001

| | Employment, '000 | | | % change per annum | |
|---|---|---|---|---|---|
| | 1986 | 1991 | 2001 | 1986-91 | 1991-2001 |
| BMR | | | | | |
| Agriculture | 557.1 | 528.5 | 434.3 | -1.05 | -1.94 |
| Manufacture | 1,014.8 | 1,228.5 | 1,698.5 | 3.90 | 3.29 |
| Other sectors | 2,186.1 | 2,502.8 | 3,184.5 | 2.74 | 2.44 |
| Total | 3,758.0 | 4,259.9 | 5,317.3 | 2.54 | 2.24 |
| BMA | | | | | |
| Agriculture | 139.5 | 135.4 | 126.2 | -0.60 | -0.70 |
| Manufacture | 709.1 | 855.7 | 1,204.8 | 3.83 | 3.48 |
| Other sectors | 1,827.6 | 2,084.0 | 2,616.0 | 2.66 | 2.30 |
| Total | 2,676.2 | 3,075.1 | 4,947.0 | 2.82 | 2.53 |
| Non-BMA | | | | | |
| Agriculture | 417.6 | 393.1 | 338.0 | -1.20 | -1.50 |
| Manufacture | 305.7 | 372.8 | 493.7 | 4.05 | 2.85 |
| Other sectors | 358.5 | 418.9 | 568.4 | 3.16 | 3.10 |
| Total | 1,081.8 | 1,184.8 | 1,400.1 | 1.84 | 1.68 |

Source: Working Paper on Employment and Economic Activity rates of 2.5 - 2.2% for BMR and 2.8 - 2.5% for BMA are alarming as the labor force is expected to grow at a much higher rate in the coming 15 years. Unemployment and underemployment problems will become acute. Considering the present very high labor participation rate (61.3% of the population aged 11 and over in BMA), however, a likely outcome would be a fall in the labor participation rate, particularly for women.

The aforementioned Report contains employment projections by Amphoe, on which zonal employment projections in this study were based.

### 2.3.3 Spatial Development Policies

As far as the spatial development policy is concerned, the Fourth (1977-1981) and Fifth (1982-1986) National Economic and Social Development Plans' major emphasis was on decentralization, i.e. economic growth outside the Bangkok Metropolitan Area. A number of provincial cities were identified as growth poles, which were intended to be developed to counter the attraction of BMA. As a result the development of Bangkok has been most noticable in the spread of urban activities into the surrounding Changwats as mentioned earlier.

A land use plan for Bangkok called the Structure Plan was prepared by NESDB for the Fifth Plan. It called for the development outside BMA, an urban pattern with multiple centers, often referred to as polycentric pattern. The intention was again to restrain the growth of BMA. The plan envisaged an urban land use pattern consisting of the Inner Area, the Green Belt Area, and the Outer Area. The Inner Area was the area already urbanized at the time. The sprawling of economic activities was intended to be contained by the surrounding Green Belt Are. The Outer Area contained a number of vicinity cities and towns, which were hoped to grow by absorbing activities not locatable in the Green Belt Area. However, subsequent development did not conform with the plan.

The Department of Town and Country Planning (DTCP) revised the Structure Plan in 1983-84.

Basically in line with the revised Structure Plan, DTCP prepared comprehensive urban development plans for BMA and selected major urban areas of the surrounding Changwats. Such plans, called Comprehensive Plan or General Plan, will have legal effect once final approval is given by the cabinet. Before the final approval, many steps are required including repeated public hearings. It is expected that a considerable amount of modifications will be applied to the draft plan such as shown in Fig. 2.3.1. The current stage of each of the General Plans is shown in Fig. 2.3.2. It is unlikely that the General Plan of BMA will be given the final approval by th end of 1986.

After reviewing what actually emerged against stated past policies, the Government planners seemed to have changed their stance concerning spatial development policy during the preparation process of the Sixth Plan. Decentralization is no longer the key word, but efficiency is. Improving the operational efficiency of Bangkok is desirable as its large and growing contribution to the national economy necessitates such investments to keep the national economy moving. Within BMR it is more important to develop an integrated system than simply promoting vicinity towns. The Direction of the Sixth National Economic and Social


Fig. 2.3.1 Bangkok Metropolitan Area General Plan

| Procedure & Activity | BMA | Samut Prakarn | Nonthaburi | Pathum Thani | Prachatipat | Nakhon Pathom | Om yai | Samut Sakhon |
|---|---|---|---|---|---|---|---|---|
| 1. Royal Decree: establishment of planning area | | | | | | | | |
| 2. Formation of (Local) Planning Advisory Board (10-15 members) | | | | | | | | |
| 3. Rules on serveying and Planning activities upon approval by the (national) Board of Town Planning | | | | | | | | |
| 4. First public hearing (planning area) and local Planning Advisory Board meeting | | | | | | | | |
| 5. GTP formulation | | | | | * | | * | |
| 6. *BMR's General Town Plan Coordinating Committee | * | * | * | | | | | |
| 7. Second public hearing (draft plan & prescription concerning the use of property) and local Planning Advisory Board | * | * | * | | | * | | |
| 8. Submission of draft plan to Board of Town Planning | | | | | | | | |
| 9. Upon Approval by the Board of Town Planning, the plan and prescription concerning use of property must be made available for public inspection for 90 days | | | | * | | | | |
| 10. After modifications, as requested by the public and approved by the board of Town Planning, together with draft of ministerial regulations will be submitted to Ministry of Interior | | | | * | | * | | * |
| 11. Submission of Plan and Ministerial Regulations to the Cabinet and Office of Jurisdical Council for legal consideration | | | still in process | | | | | * |
| 12. Ministerial Regulations, valid for five years, and enforcement of plan | | | | | | | | |

* An ad hoc committee set up by the Ministry of Interior in order to closely Coordinate as well as to comment the proposed plan more effectively.

Note : Between 6 and 7 the GTP will be submitted to the Inter-Agency meeting (24 and more) most of which are implementing agencies. This stage is a non-legal procedure, its intention is to coordinate with these agencies particularly to clarify if they are

**Fig. 2.3.2 Legal Procedure for the Preparation of BMR General Town Plans and Their Current Status Feb. 1987**

Development Plan, October 1985, states under the Urban and Specific Zones Development Program:

- Accelerate the improvement and expansion of the network for consumer goods and services in the Bangkok Metropolis and its suburbs in order to become 'an integrated system'. This must coincide with the city plan and the increased orderly use of land in the future. This is especially true with the sewage system and flood prevention system which must be made permanent.

- Develop the transportation and traffic control systems in the Bangkok area together with the development of the city infrastructure to become a more complete and flexible system.

The BMR Study in principle follows the above guidelines and recommended spatial development strategies. Its long term strategies which have direct bearig on this study are:

- Government investments, through infrastructure, will lead development to areas which are most suitable for development.

- Development controls will be implemented to help shape a more economic form of BMR; these shall cover regulations on land use, and other measures to anticipate, or defer growth and development. For instance, development of areas liable to flooding will be deferred by withholding infrastructure until such problem has been resolved; areas for priority development will be identified to allow development to occur in areas needing more immediate attention.

- Investment in the northeast, east and southeastern sectors will be contained and phased to discourage continued ribbon development and to ensure long term service provision and environmental protection of the flood retardation and retention areas.

- Development in the north-west and western sectors where there is a projected or potential high demand based on existing and proposed levels of accessibility will be encouraged by providing urban services, especially water supply and development roads in the medium to long term.

- The appropriateness of corridor expansion to the west to improve long-term efficiency of the spatial pattern of BMR will be explored.

Fig. 2.3.3 shows principal guidelines for spatial development as proposed by the BMR Study.

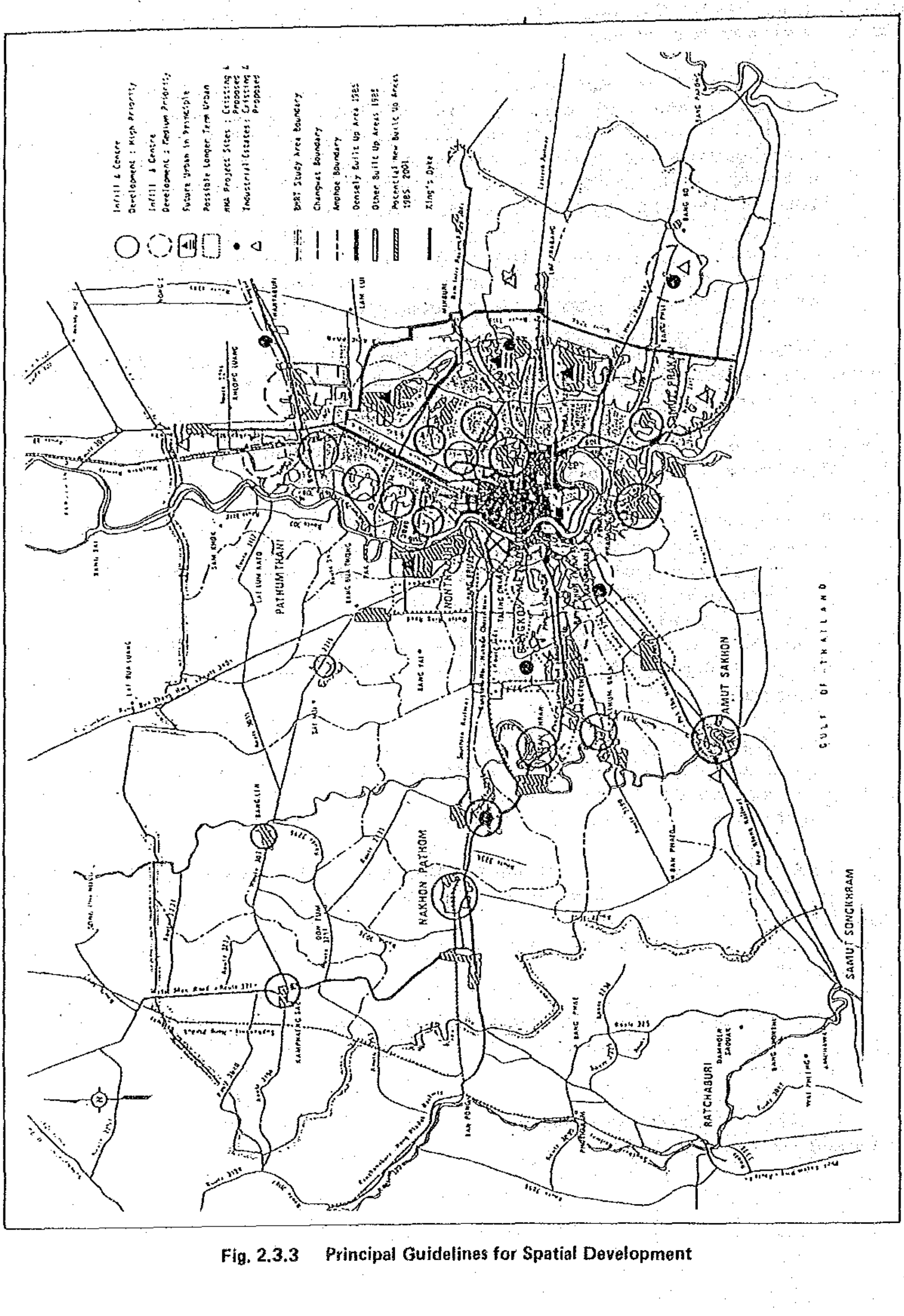



**Fig. 2.3.3 Principal Guidelines for Spatial Development**

### 2.3.4 Transportation Development Plans

Since the Bangkok Transportation Study (BTS) carried out in the early 1970s, various governmental agencies have engaged in the planning, design, and construction of individual projects basically in line with the BTS recommendations. Two of the major recommendations, however, did not materialize. The polycentric urban development and the restriction on private car ownership were not taken place. The private vehicle ownership has kept growthing at a rapid pace in the absence of effective restrictions. The most conspicuous outcome of the study was the creation of the Expressway and Rapid Transit Authority of Thailand and the implementation of the First Stage Expressway System, the last leg of which is under construction.

In 1985 the Short Term Urban Transport Review Study (STTR Study) was carried out for NESDB. The Study produced an inventory of all existing transportation projects by various agencies to the extent possible, added some of their own recommended projects, and prioritized them in light of their assessment of the current and future situations, and worked out a five-year investment program under the normal funding and additional investment program under an extra funding tied to the proposed central area road pricing system. Major recommended projects of the STTR Study as adopted in the BMR Study are:

- central area road pricing (toll) system will a toll of Baht 30 per car per entry.
- road and bridge projects,
- truck terminals,
- bus ways, and
- traffic management projects.

Fig. 2.3.4 shows locations of recommended STTR projects for roads and bridges.

The subject area of the STTR Study was roughly the area inside the Outer Ring Road. In order to cover the remainder within BMR, the Bangkok Metropolitan Region Transport Study was commissioned and completed in March 1986. Fig. 2.3.5 shows its recommended projects. The results of this study together with those of STTR were integrated in the BMR Study.

The role of the BMR Study is advisory whereas the General Plan will have legal effect. As a comparison of Fig. 2.3.1 and Fig. 2.3.4 shows, currently these two plans do not exactly coincide as agencies involved are still in the process of mutual consultantion. In early 1986 a high level committee was established by a cabinet decision with a specific objective of formulating an integrated transportation plan for BMR. The Committee on Policy and Plan for Transportation in BMA and Vicinity comprises 24 members including 4 ministers with the Director of OCMRT as its secretary. In late 1986 an even higher level committee chaired by a deputy prime minister was formed as a decision-making organ for the development of BMR. A coordinated and coherent transportation development plan is expected to emerge from these committees some time in the near future.

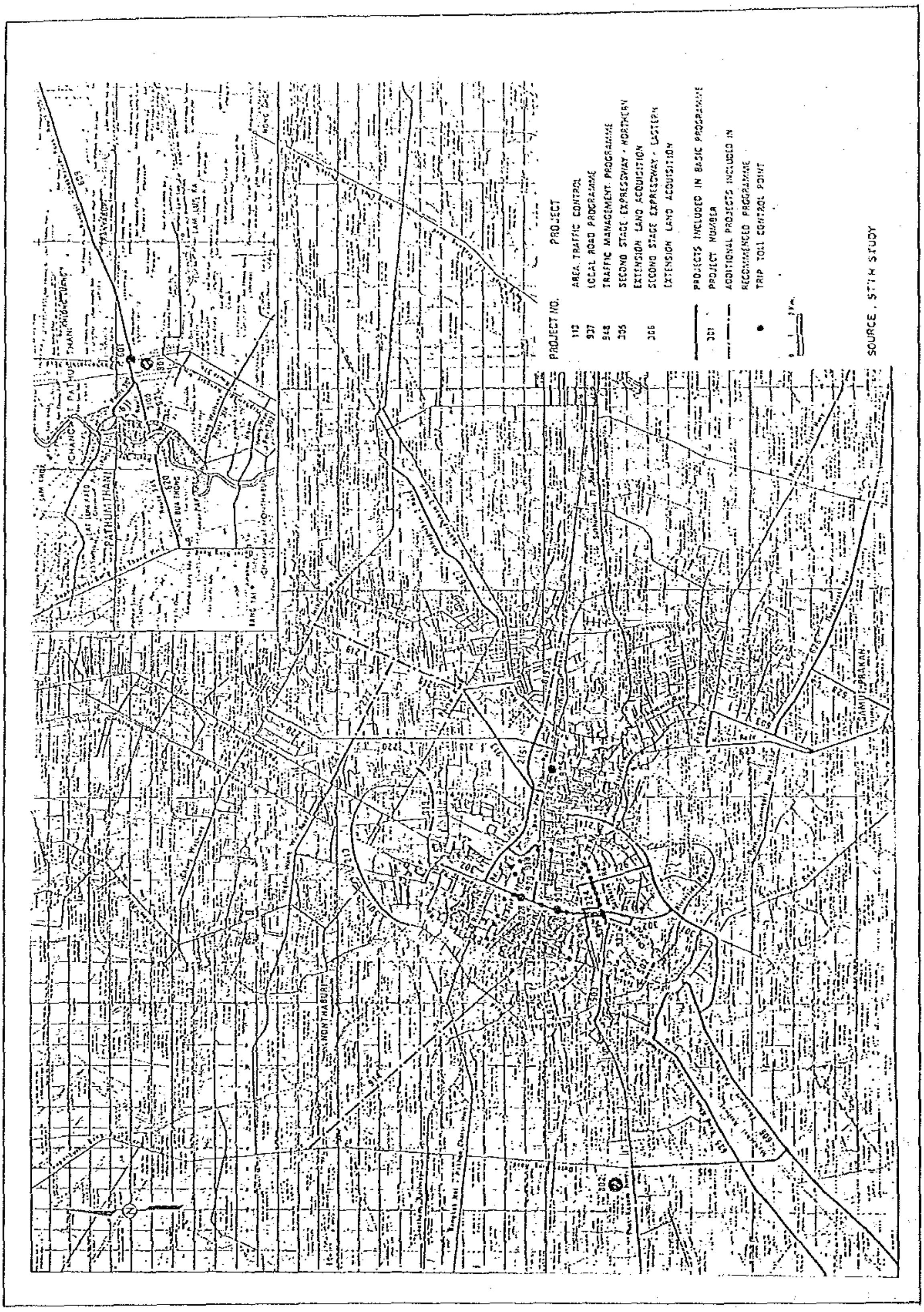


Fig. 2.3.4 Recommended Programme Roads, Highways and Bridges

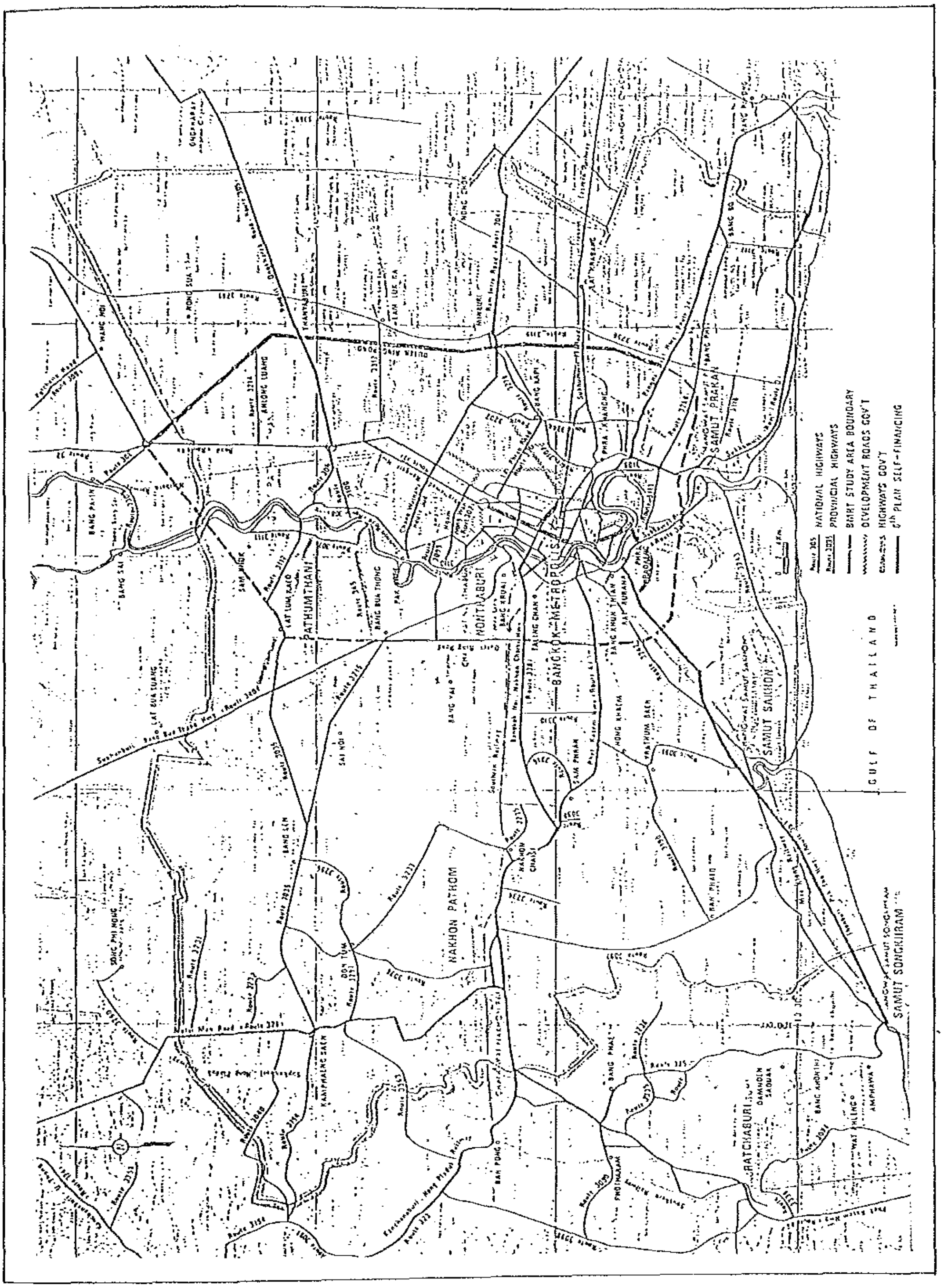



**Fig. 2.3.5 Highway Investment Program (1987–91)**

# CHAPTER 3

# EXISTING TRAFFIC DEMAND

## 3.1 Available Data

Several studies have been conducted concerning traffic in the Bangkok Metropolitan Region in recent years. Therefore, in the Study, various existing data were utilized to the extent possible wherever applicable.

Following data were available for the estimation of present traffic origins and destinations (O&D).

1) Results of traffic surveys by the Study Team

Detailed information on traffic demand especially concerning the study area.

2) The Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok (hereinafter referred to as BMA Traffic Study)

The BMA Traffic Study had the task of estimating present traffic O&D. Number of traffic zones was 86 for BMR. In the BMA Traffic Study, traffic O&D for the area within the Middle Ring Road, which consists of 58 zones, were the primary concern.

Vehicles were categorized into the following 6 types.

- Passenger car
- Pick-up, Light truck
- Heavy truck
- Taxi, Samlor
- Minibus
- Heavy bus

3) The Metropolitan Bangkok Short Term Urban Transport Review (STTR)

STTR also estimated present traffic O&D concerning BMR. Traffic zones for STTR were totaling 99 zones and a higher accuracy was assumed for areas outside the Middle Ring Road because of dense zoning compared to the BMA Traffic Study.

Vehicles were categorized into the following 6 types.

- Passenger car
- Taxi & Samlor
- Motorcycle
- Trucks
- Minibus
- BMTA bus

4) The Second Stage Expressway System in Bangkok Study (SES)

SES estimated present traffic O&D by modifying the O&D tables established by the original Bangkok Transport Study (BTS) of 1975. STTR used the same basis but the modification work was done more recently than SES. Therefore, SES data were used only for reference purposes in the Study.

A large number of traffic counts have been taken by various studies and agencies, among which those by the Office of Committee for Management of Road Traffic (OCRT) were the most comprehensive in coverage. Previous traffic counts were assembled to the extent possible.

## 3.2 Traffic Surveys

### 3.2.1 Survey Methods

The main objective of the traffic surveys in this study was to establish present traffic volumes and traffic movements on the road network particularly in the vicinity of the Krungthep bridge and the proposed Thonburi Road Extension to supplement available data.

1) Traffic Volume and Turning Movement Counts

The locations of survey stations for traffic volume counts and turning movement counts are shown in Fig. 3.2.1. These surveys were carried out for the period of 16 hours (6:00 - 22:00) on normal working days.

For these surveys, traffic volumes were counted for the 8 vehicle types as shown below. A sample survey sheet is attached in Appendix 3.2.1.

a) Passenger Car
b) Pickup
c) 6-wheel truck
d) 10-wheel truck and trailer
e) Taxi, Samlor, Silor
f) Minibus
g) Heavy Bus (BMTA, Others)
h) Motorcycle

2) Roadside OD Survey

Roadside OD surveys were carried out at 4 selected intersections, shown in Fig. 3.2.2, in order to obtain information mainly about origins and destinations of vehicles passing at these intersections. All of these survey stations were set up at signalized intersections in order to avoid disturbance to traffic flows due to interviews as well as to secure the safety of interviewers.

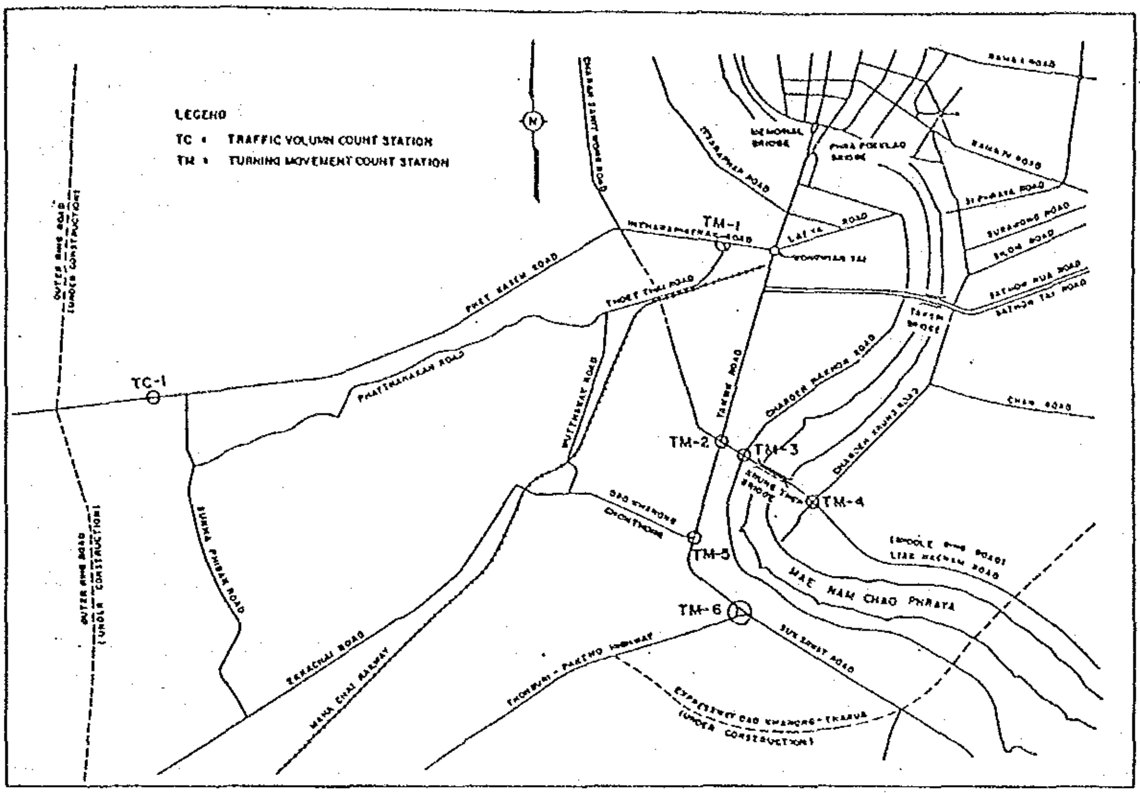



Fig. 3.2.1 Location of Survey Stations for Traffic Volume Counts and Turning Movement Counts

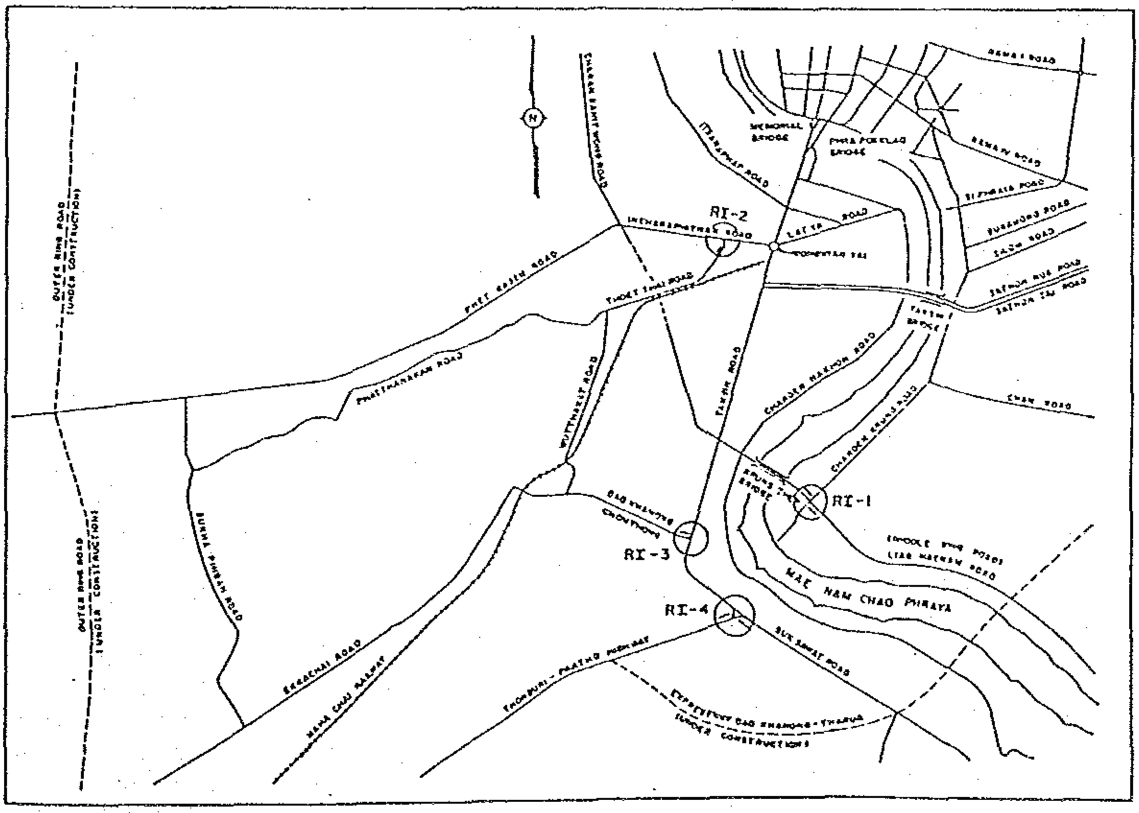



Fig. 3.2.2 Location of Roadside OD Survey Stations

Interviews to drivers were possible only during the red phase period in every cycle time of traffic signals, which ranged between 2 and 3 minutes on an average. Therefore, it was inevitable to limit the number of questions to drivers to a minimum. A questionnaire was designed and shown in Appendix 3.2.1. The contents of a questionnaire are as follows.

- Vehicle type
- Origin and destination
- Trip purpose
- Number of passengers
- Type and volume of cargo
- Route of trip

Interviews were carried out by survey teams consisting of supervisors and interviewers posted at each intersection while policemen were also present in order to stop vehicles on free left turning lanes.

The roadside OD surveys were carried out for a period of 12 hours (7:00 - 19:00) on weekdays and vehicle drivers of about 5 percent of the total traffic passing the intersections were asked questions according to the questionnaire explained above. In order to secure the necessary sample size and typical vehicle type composition at each survey station, the hourly sample size was determined by type of vehicle in advance, based on the results of previous traffic volume counts on nearby roads.

The total number of samples obtained through the roadside OD surveys at survey stations was about 5,000, while sampling rates at each survey station was ranged from 5.1% to 6.8% (see Table 3.2.1).

3) Home Interview Survey

As mentioned before, a comprehensive OD survey was carried out within the area surrounded by the Middle Ring Road during the course of the BMA Traffic Study, which included home interview survey in every zone inside this area. Since the Study Team was able to obtain OD Tables prepared as a result of this comprehensive OD survey, several zones in the study area, excluding zones inside the Middle Ring Road, were selected for the home interview survey. The selected zones for the home interview survey are indicated in Fig. 3.2.3.

At the early stage, it was intended to carry out the sampling from registration cards in LDPD (Licences Division of Police Department) and in DLT (Department of Land Transport). However, after consultation with relevant agencies as well as the study team carrying out the BMA Traffic Study, it was found that this sampling procedure required much time and was not suitable for this study, since the area for the home interview survey was limited.

Instead, the Study Team employed a procedure which allocated a target sample number in the survey area according to the number of registered vehicles, prior to the actual home interview survey. Interviewers were dispatched to the survey area for finding vehicle operations and making interviews until a sufficient number of samples could be collected in each zone.

Table 3.2.1 Sample Size at Each Roadside OD Survey Station

| Station No. | Road Name | Traffic Volume in 12 hours | Sample Size | Sampling Rate |
|---|---|---|---|---|
| RI - 1 | Riab Mae Nam Rd. | 32,621 | 1,668 | 5.1% |
| RI - 2 | Thoed Thai Rd. | 11,105 | 741 | 6.7% |
| RI - 3 | Dao Khanong Rd. | 9,260 | 638 | 6.8% |
| RI - 4 | Suksawat Rd.<br>Thonburi - Paktoh Rd. | 34,533 | 1,784 | 5.2% |

Table 3.2.2 Sample Size of Home Interview Survey

| No. of Registered Vehicle | No. of Allocated Samples | No. of Collected Samples | No. of Effective Samples | Sample Rate |
|---|---|---|---|---|
| 28,000 | 3,000 | 3,017 | 2,192 | 7.8% |

The number of registered vehicles, allocated sample numbers, the total number of collected samples and the number of effective samples (excluding vehicles which did not make any trip or only made trips inside each zone) in the survey area are summarized in Table 3.2.2.

The following are the major items included in the questionnaire for the home interview survey.

a) General information
   - From of ownership
   - Occupation
   - Type of vehicle
   - Period of ownership
   - Frequency of vehicle use per week

b) Information about each trip
   - Origin and destination
   - Departure and arrival time
   - Trip purpose
   - Parking place
   - Number of passengers
   - Type and volume of commodity carried

Besides these questions, effects of the completion of the Dao Kanong - Port Expressway through the Wat Sai Bridge were asked to vehicle operators in certain zones. In addition, some questions about the truck fleet were also asked to operators of trucks.

The details of the questionnaire utilized for the home interview survey are presented in Appendix 3.2.1.

4) Vehicle Speed Survey

A vehicle speed survey was carried out on 4 routes, including several check points, as shown in Fig. 3.2.4. On each route, passing time at each check point was recorded and 12 round trips were made, including the morning and the evening peak hours.

An example of the survey sheet for the vehicle speed survey is presented in Appendix 3.2.1.

### 3.2.2 Traffic Types and Volumes

1) Traffic Volumes on Major Roads

Fig. 3.2.5 illustrates the average daily traffic volume (ADT) on major roads in the central Bangkok area, based on the results of traffic survey carried out by the BMA Traffic Study.

From this Figure, heavy traffic volumes can be observed on the Viphawadi Rangsit Highway (128,000 vehicles/day) and Phaholyothin Road (79,000) in the northern corridor, Petburi Road (67,0000) and Sukumvit Road (66,000) in the eastern corridor, Taksin Road (79,000) in the southern corridor, and Petkasem Road (47,000) and Nakhon Chaisri Highway (48,000) in the western corridor. In the central part of Bangkok, the Rama IV Road (83,000), Rama I Road (85,000), Phayathai Road (78,000)),

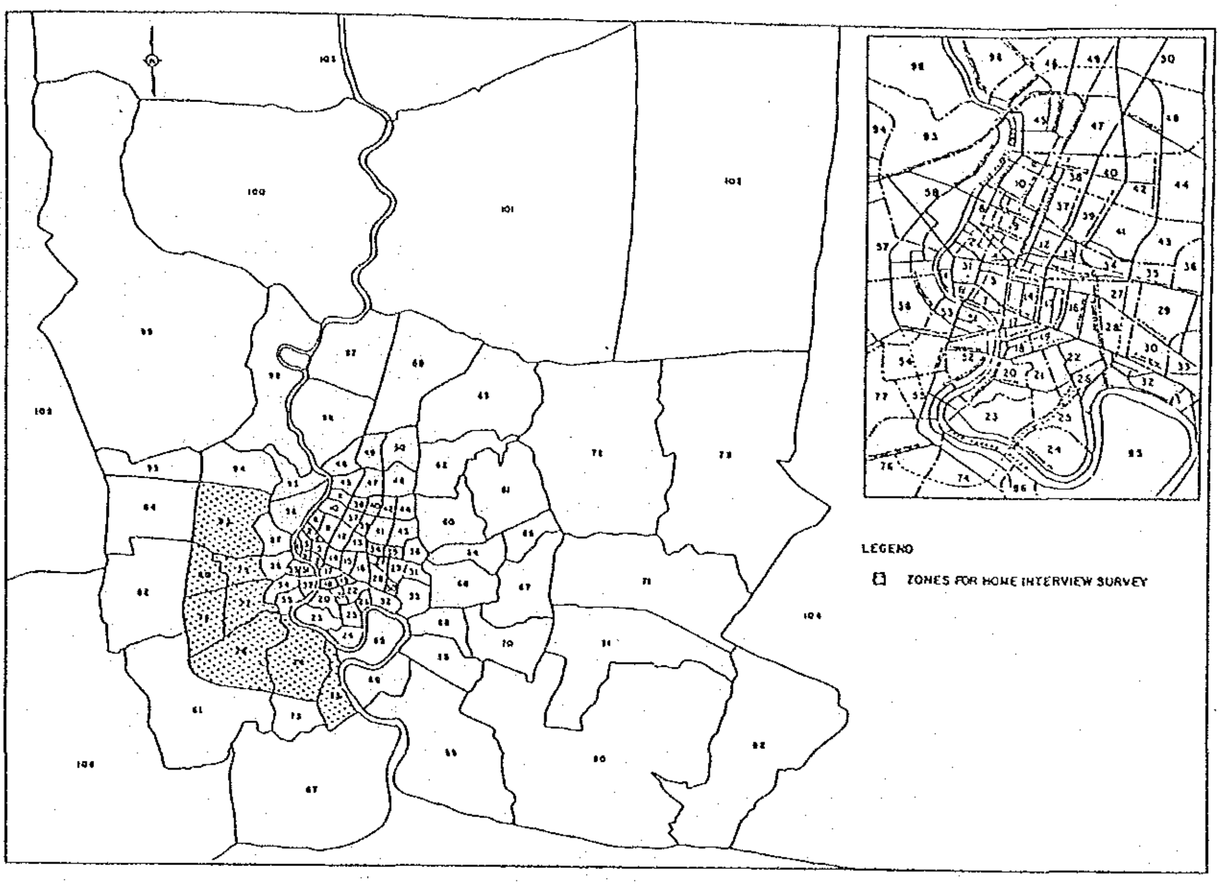



Fig. 3.2.3 Selected Zones for Home Interview Survey

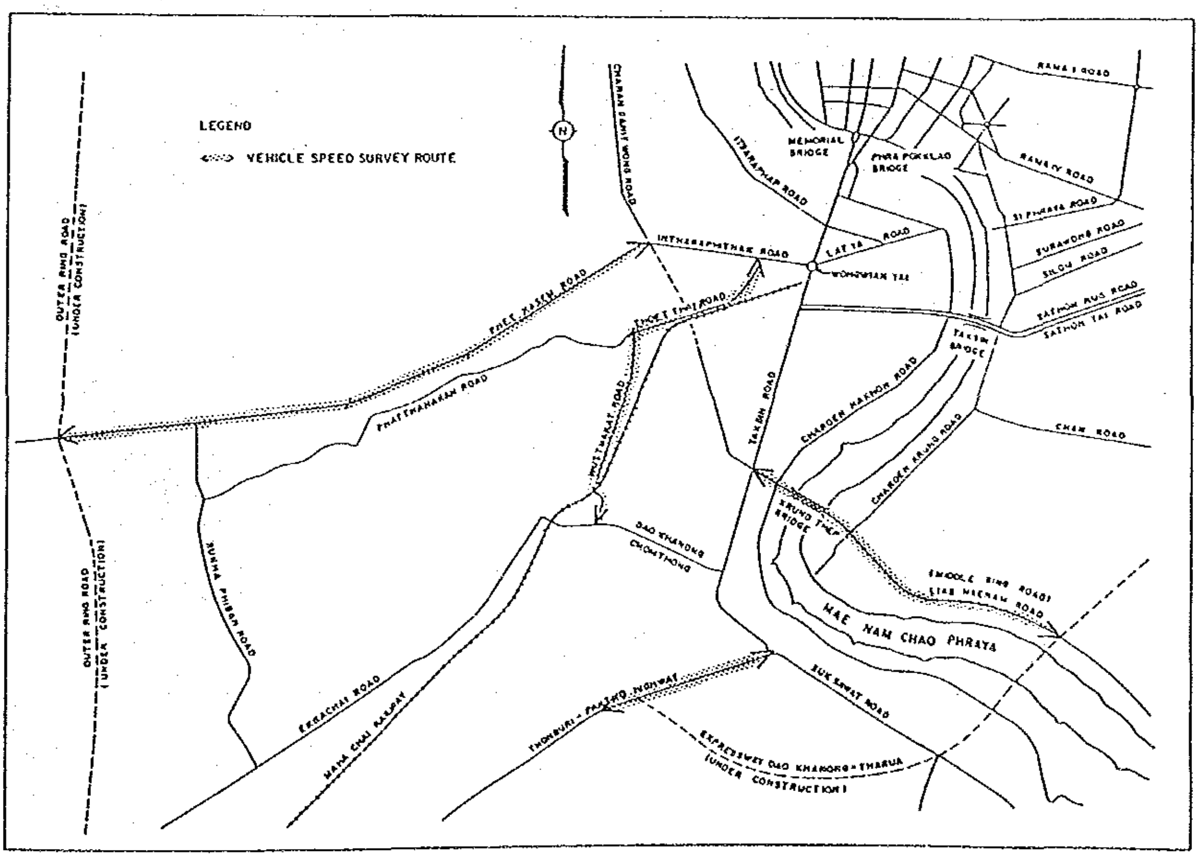



Fig. 3.2.4 Vehicle Speed Survey Locations

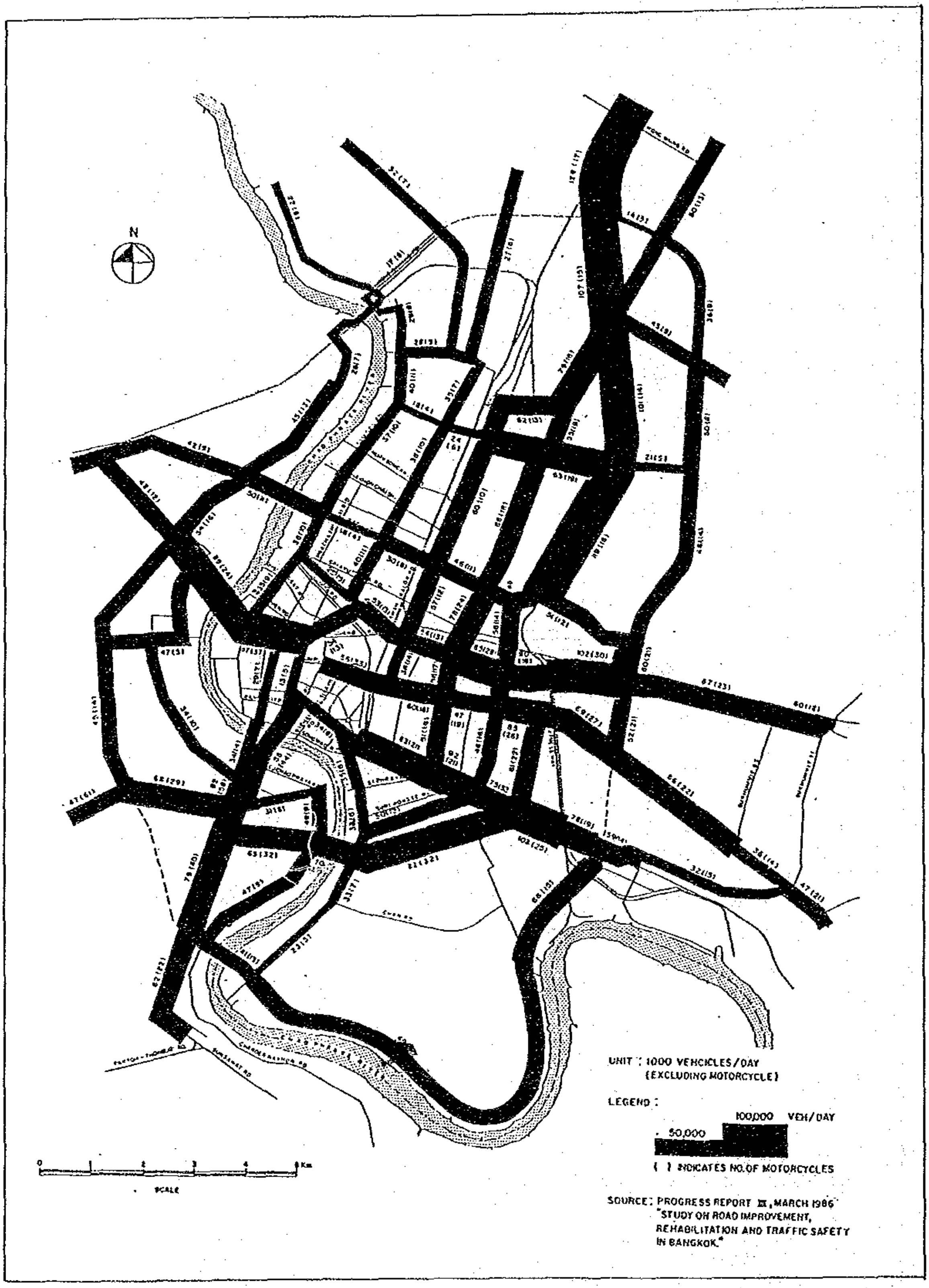



Fig. 3.2.5 Average Daily Traffic Volume on Major Roads in Bangkok

Ratchadamnoen Klang Road (117,000) and Sathorn Nua and Tai Road (82,000) carry heavy traffic volumes.

Fig. 3.2.6 illustrates ADTs on major roads in the study area, mainly based on the results of the traffic surveys carried out by the Study Team. At this time, it should be noted that even though the traffic surveys were conducted during the school holiday season, the total traffic volumes as well as the hourly fluctuation of traffic volume (see Appendix 3.2.2) obtained were almost same or even larger than the previous survey results in the normal season, even though the compositio percentage of passenger cars and pickups was lower in the school holiday season. Therefore, it can be considered that there was not much difference in traffic volume, between the normal season and the school holiday season at least in the study area. Hence, no modification was made for the actual survey results.

In the study area, the Taksin Road (80,000), Sathon Nua and Thai Road (66,000) and Intharapitak Road (74,000) are three major roads with heavy traffic volumes, followed by Petkasem Road (54,000), Suksaeat Road (49,000) and Thonburi-Paktoh Highway (48,000). In contrast, the Thoed Thai Road (35,000) and Dao Kanong Road (30,000) proved carrying much less traffic volumes due to their lower capacity.

As for bridges across the Chao Phraya River, ADT (excluding motorcycle) on the Memorial Bridge and Phra Pokklao Bridge (92,000) is the heaviest, followed by the Prapinkhlao Bridge (89,000), Taksin Bridge (70,000), Klung Thon Bridge (50,000) and the Krungthep Bridge. Past trends of traffic volumes (including motorcycle) on these bridges are shown in Fig. 3.2.7 and Appendix 3.2.2. Traffic volume on the Krungthep Bridge has gradually been increasing since 1982, while traffic volumes on the Taksin Bridge and Prapinkhlao Bridge decreased since 1984.

2) Hourly Fluctuation of Traffic Volume

Hourly fluctuations of traffic volume on major roads in the study area are presented in Fig. 3.2.8 and Appendix 3.2.2.

In the study area, hourly fluctuation patterns seem to fall into several types. On the Charoen Nakhon Road, the peak hours can particularly be observed in the morning and evening commuting hours, whereas peak hours can be observed not in the commuting hours roads such as the Petkasem Road (10:00 - 11:00) and Taksin Road (11:00 - 13:00). Particular peak cannot be found on the Suksawat Road and Charoen Krung Road.

On the Krungthep Bridge, there were two peak hours in the commuting hours, i.e. 7:00 - 8:00 and 16:00 - 18:00. However, there was not so much difference between peak hour and off-peak hour volumes during daytime. In addition, traffic volume towards Yannawa (Bangkok Side) was longer than in the other direction during the whole survey period of 8 a.m. to 9 p.m.

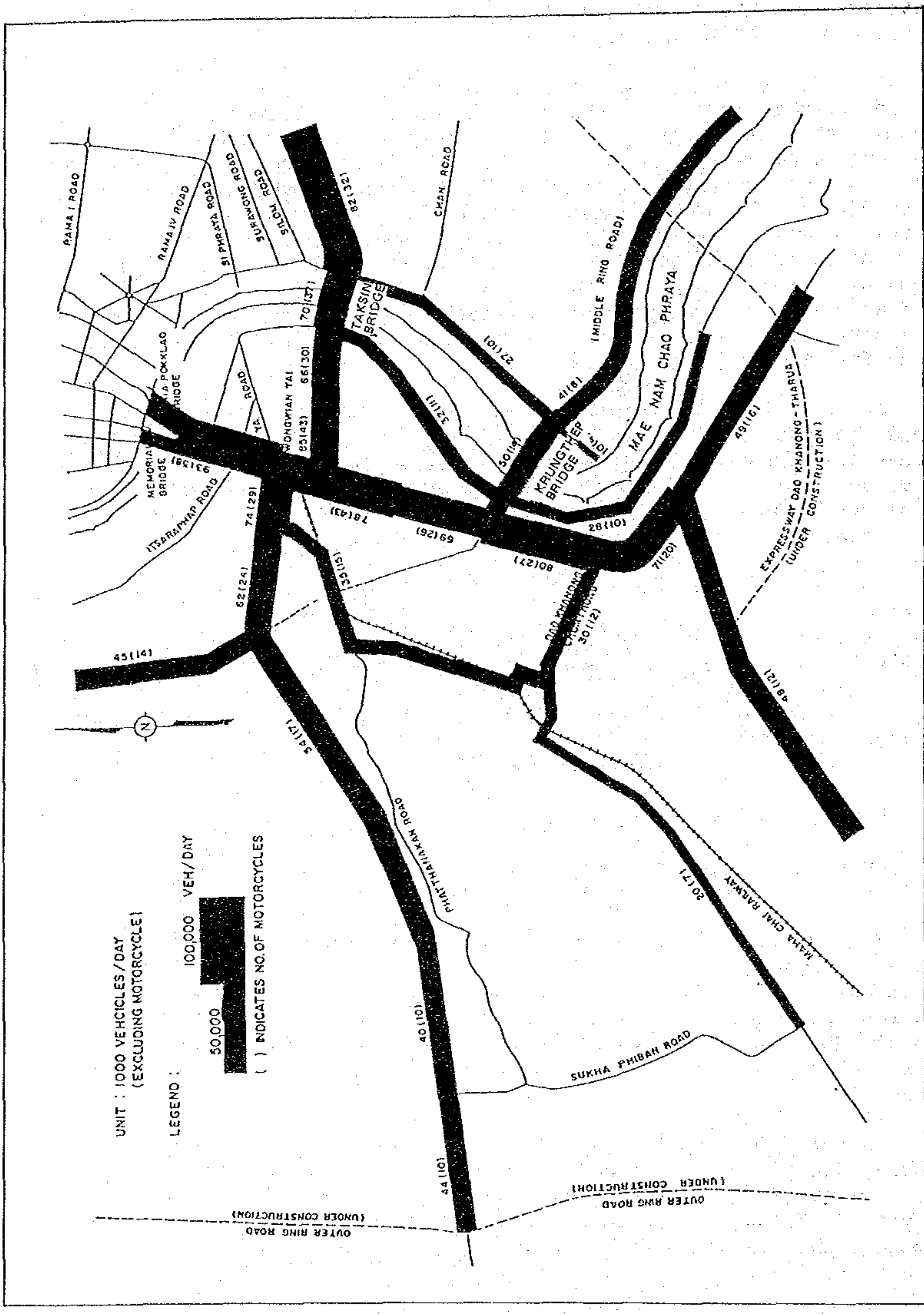



Fig. 3.2.6 Average Daily Traffic Volume in the Study Area

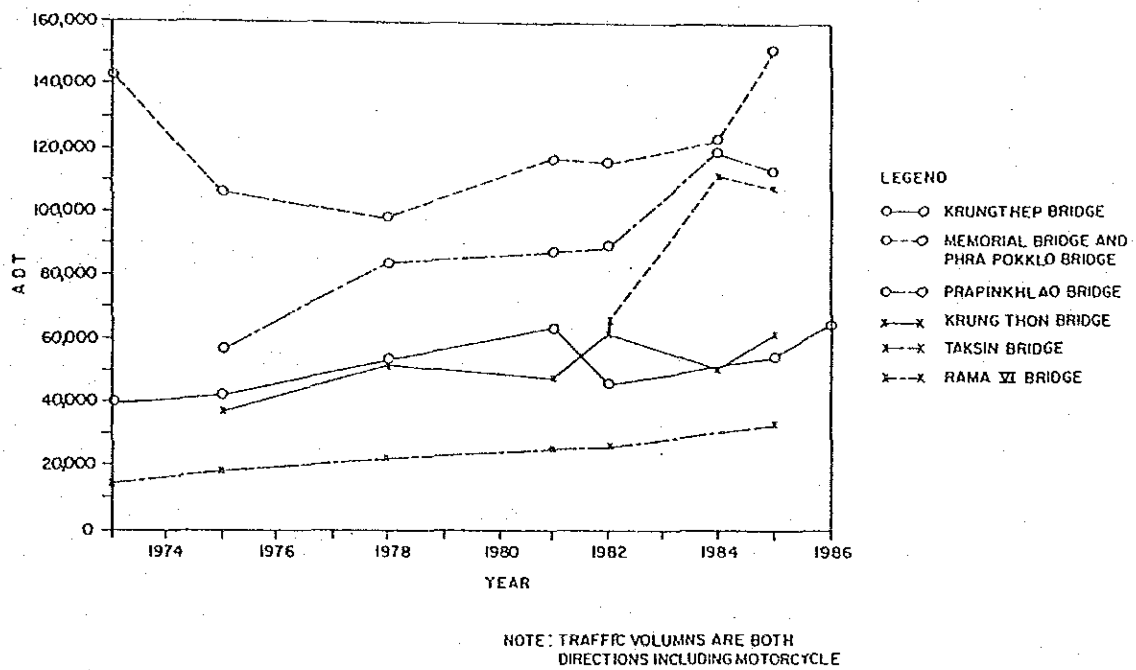
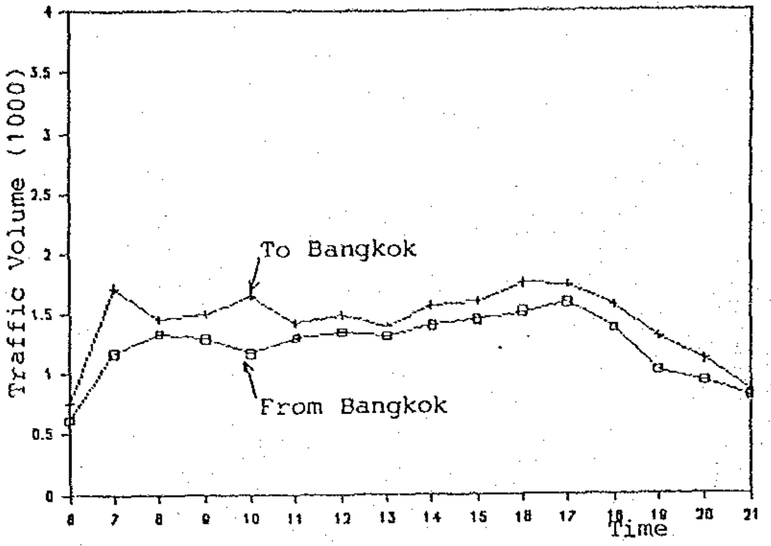



**Fig. 3.2.7 Trend of Traffic Volume on Bridge over Chao Phraya River**




Krungthep Bridge

**Fig. 3.2.8 Hourly Fluctuation of Traffic Volume**

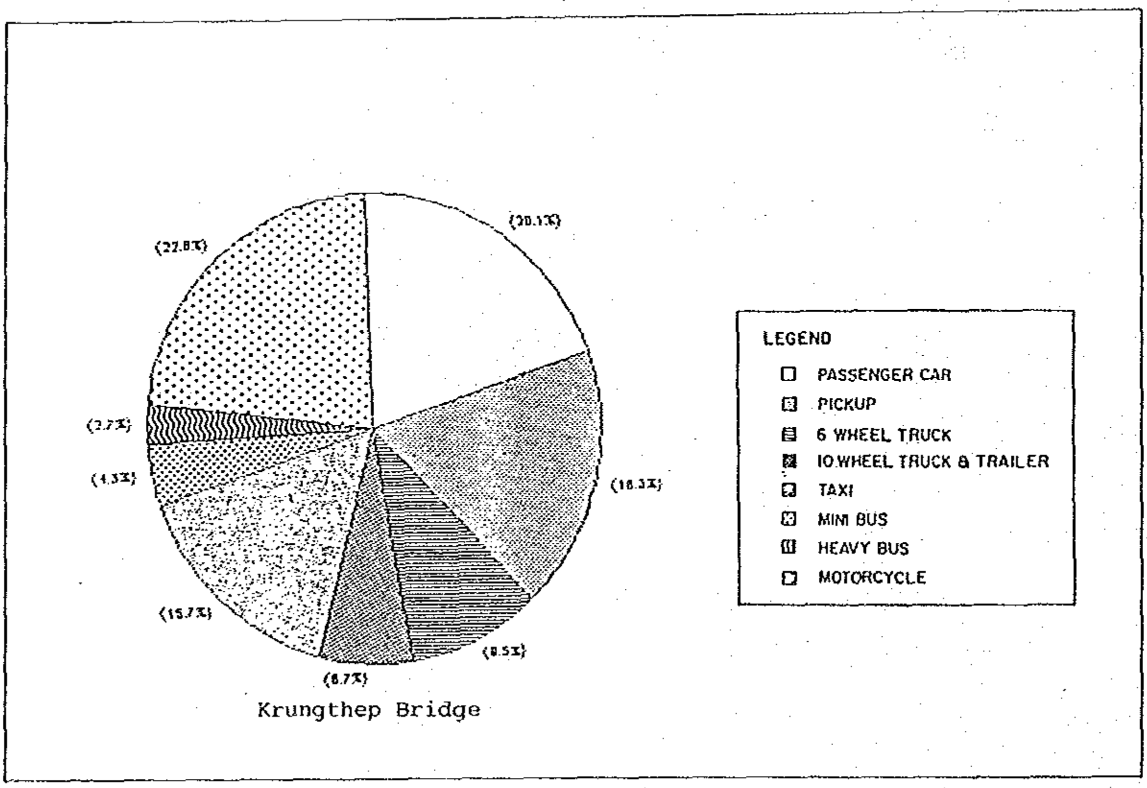



**Fig. 3.2.9 Vehicle Composition**

3) Vehicle Composition

Fig. 3.2.9 illustrates the vehicle composition on the Krungthep Bridge, while that of major roads in the study area are presented in Appendix 3.2.3.

From these figures, roads in the vicinity can be classified into 2 categories in terms of vehicle composition. The first type of roads carry a limited number of trucks (6-wheel and 10-wheel truck, and trailer) and composition percentage of trucks was less than 10%. This is mainly due to the restriction on truck routes into certain sections in the BMA area. Roads under this category are Intharapitak Road, northern part of Taksin Road and Charoen Nakhon Road, Charoen Krung Road, Dao Kanong Road and Thoed Thai Road.

On these roads, composition rate of passenger cars and taxis was about 20%, while motorcycles varied from 25% to 30%, except Thoed Thai Road, on which composition percentages of taxis and motorcycles were as high as 25% and 31%, respectively.

On the other types of road, composition percentage of trucks was high: more than 15%. These roads function as primary distributors as well as corridors for the physical distribution in the area. Road under this category are Riab Mae Nam Road including the section of Krungthep Bridge, Suksawat Road, Thonburi Paktho Highway and the western part of Petkasem Road. On these roads, composition percentage of taxis and motorcycles were much lower than those of the first type of roads.

The composition percentage of heavy vehicles, including 6-wheel and 10-wheel trucks, trailers, minibuses (6 wheels) and heavy buses, was 23% on the Krungthep Bridge while that of light vehicles was 54%.

4) Turning Movements of Vehicles at Major Intersections

Turning movements of all vehicles except motorcycles, at intersections related to the New Krungthep Bridge Project, i.e. Taksin/ Riab Mae Nam Intersection, Charoen Nakhon/Riab Mae Nam Intersection and Charoen Krung/Riab Mae Nam Intersection, are illustrated in Fig. 3.2.10. Turning movements of trucks at these intersections and movements of all vehicles except motorcycles at other major intersections in the area, are shown in Appendix 3.2.4.

At Taksin/Riab Mae Nam Intersection, 65% of the inflow traffic from Riab Mae Nam Road made left turning, while 73% of trucks made left turning.

At Chaeron Nakhon/Riab Mae Nam Intersection, 41% of the inflow traffic from both sides of Riab Mae Nam Road made turning here, while 59% of them were throught traffic. On the other hand, only 30% of trucks from Riab Mae Nam Road made turning at this intersection.

At Charoen Krung/Riab Mae Nam Intersection, 69% of the inflow traffic from both sides of Riab mae Nam Road were through traffic, while 87% of trucks on this road were through traffic at this intersection.

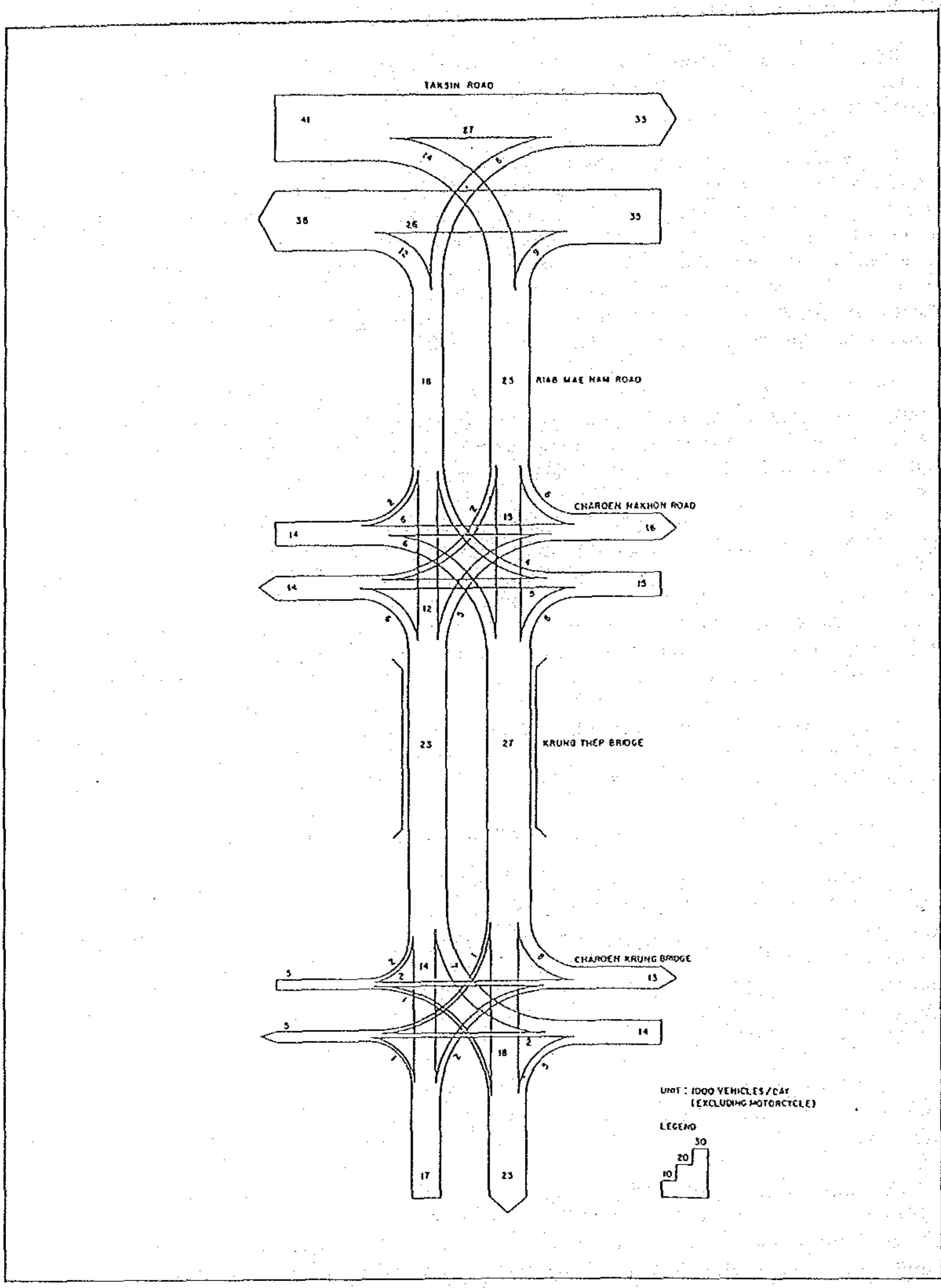



Fig. 3.2.10 Turning Movements of Traffic at Intersections Related to the Krungthep Bridge

### 3.2.3 Traffic Characteristics

Results of the roadside OD surveys and the home interview surveys carried out in this study gave a number of supplementary information concerning the characteristics of traffic in the vicinity of the Krungthep Bridge and Thonburi Road Extension.

One third of laden pickups and trucks carried consumer goods whereas agricultural commodities which are predominant cargo outside Bangkok were carried by less than one fouth of vehicles. About 40% of loaded vehicles were fully loaded whereas 30% were half loaded. Among traffic using the existing Krungthep bridge only 39% were that going in straight between Taksin Road and Riab Mae Nam Road without turning into or from Charoen Krung Road. Shop owners came out as the top vehicle owners with 39% of all vehicles.

Among truck operators interviewed 40% indicated they would not use the Port-Dao Kanong section of the expressway which is under construction, while another 20% indicated they would not use it if the fare would be increased from the present 20 Baht to 40 Baht. The remaining 40% indicated they would use it even when the toll is increased to 40 Baht.

Details of the results of roadside and home interview surveys are presented in Appendix 3.2.5.

## 3.3 Traffic Zones and Zonal Characteristics

### 3.3.1 Determination of Traffic Zones

Traffic zones for the study were established largely based on the zones defined in the STTR and the BMA Traffic Study.

For the traffic analysis, zones within the Middle Ring Road were established corresponding to the BMA Traffic Study and outer zones of the said road were basically taken from STTR. Furthermore, zones along the Thonburi Road Extension Section were subdivided taking following points into consideration.

- Road network
- Tambon boundary
- Canal
- Railway line
- Land use (distribution of residences)

Results of zoning work are summarized in the following table and shown in Fig. 3.3.1.

Table 3.3.1 Traffic Zones

| Area | | Number of Zones |
|---|---|---|
| BMA | Inside the Middle Ring Road | 58 |
| BMA | Outside the Middle Ring Road | 26 |
| Sub-total | | 84 |
| Samute Prakarn | | 8 |
| Nonthaburi | | 7 |
| Pathum Thani | | 3 |
| Other | | 4 |
| Total | | 106 |

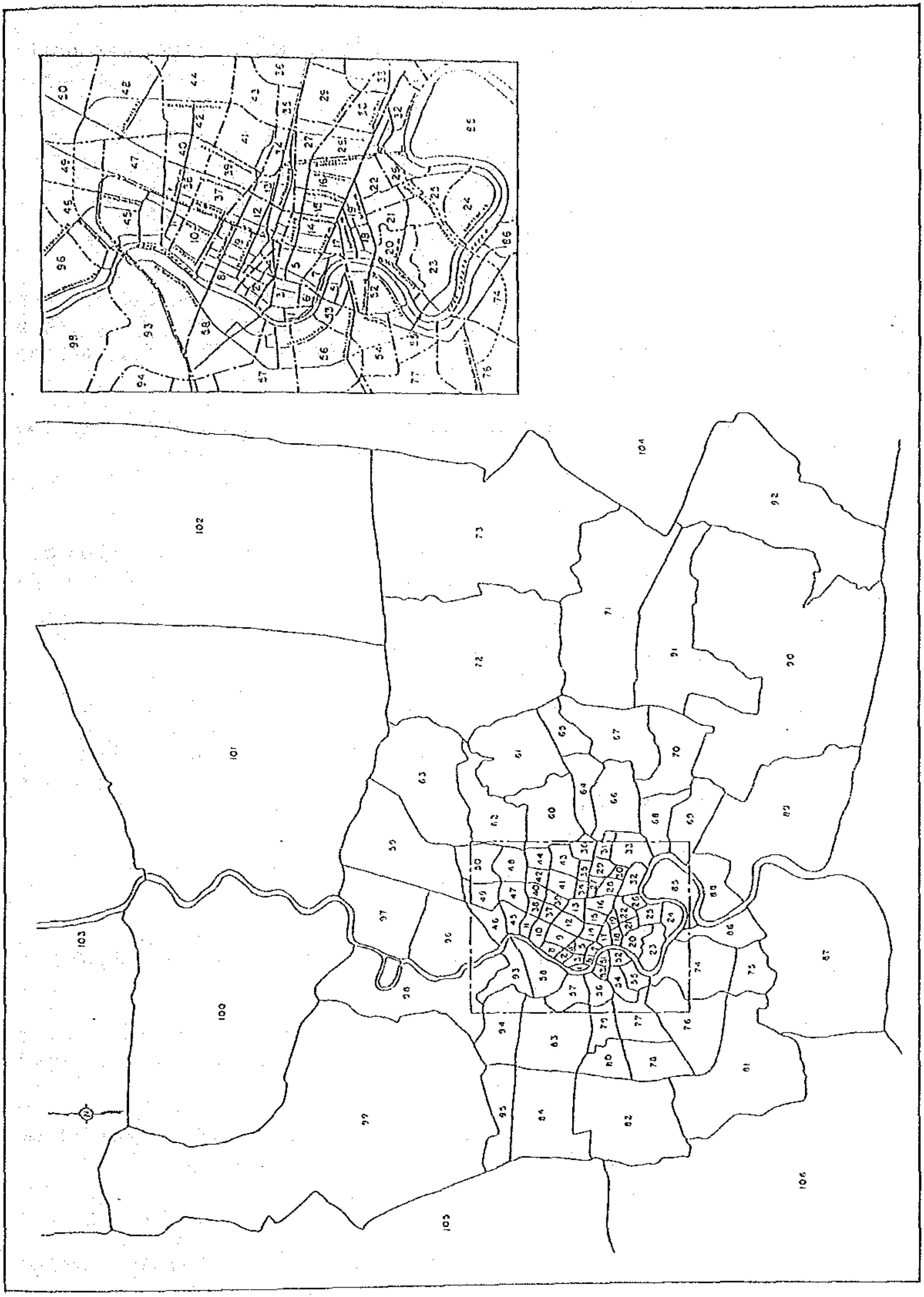


Fig. 3.3.1 Traffic Zones

### 3.3.2 Socio-economic Indicators of Traffic Zones

To explain the traffic demand by zone, following socio-economic indicators were employed.

- Population
- Employment
- Car ownership
- Number of students

1) Population

Population by zone was estimated based on the data presented in "BMR Study, Population Working Paper, Draft Final Report, NESDB December 1985". From the said report, population by tambon for BMR and by amphoe for the changwats within surrounding changwats are available.

Population by zone was allocated adjusting the above data by tambon or amphoe boundaries. Results are shown in Appendix 3.3.1.

2) Employment

Figures by zone were determined based on "Projection of Economic Activities and Employment in BMR, Chulalongkorn University/NESDB December 1985".

Results are shown in Appendix 3.3.2.

3) Car Ownership

Car ownership by zone was estimated based on the methodology explained in "Income and Vehicle ownership, STTR Internal Working Paper No. 7, May 1985" and updated by the Study Team.

Results are shown in Appendix 3.3.3.

4) Number of Students

It was observed that in Bangkok taking children to their schools is an important factor of additional vehicular trips.

Present number of students by zone was estimated allocating number of students by school as shown in Appendix 3.3.4. Data were collected from agencies concerned as shown in Table 3.3.2.

For Changwats, future numbers were estimated applying population growth rate by zone and controlled by the total of Changwat.

- Higher Education

Future number of students was estimated applying the growth rate of population of appropriate age class by BMA and Changwat.

Growth rates of population by area and age class are shown in Table 3.3.3 and 3.3.4.

Table 3.3.2 Agencies Concerned with Education

| Level | | Agency Concerned |
|---|---|---|
| • Kindergarden | ----------- | Ministry of Education |
| | ----- | Bangkok Metropolitan Administration |
| • Primary School | ----------- | Department of General Education (MOE) |
| | ----- | Bangkok Metropolitan Administration |
| • Secondary School | ----------- | Ministry of Education |
| • Colledge | ----------- | Vocational Education Department (MOE) |
| • Governmental University (some faculty) | ----- | |
| • Governmental University | ----- | Office of University Affairs |
| • Private University | ----- | |

Future number of students by zone was estimated based on the population growth rates and control totals quoted from "Population Working Paper" Draft Final Report, NESDB December 1985.

Details are explained below.

- Kindergarten, Primary and Secondary School.

For BMA, future number of students was estimated applying population growth rate by area, which was categorized by BMA Study, and controled by BMA totals estimated based on the growth rates by age class. Population growth rates are shown in Table 3.3.3.

Table 3.3.3 Population Growth Rate by Area

| Area | 1986-1991 | 1981-1996 | 1996-2001 |
|---|---|---|---|
| Saturated Urban Area | 1.83 | 1.74 | 1.66 |
| Slow Growing Urban Area | 3.30 | 3.42 | 3.50 |
| Fast Growing Urban Area | 3.34 | 3.52 | 3.70 |
| Transitional Area | 3.38 | 3.12 | 3.07 |
| Rural Area | 2.38 | 2.57 | 2.75 |

Source : BMA Study

Zone 77, 78 : Average figures of Fast Growing Urban Area and Transitional Area were applied.

For Changwats, future numbers were estimated applying polulation growth rate by zone by zone and controled by the total of Changwat.

- Higher Education

Future number of students were estimated applying the growth rate of population of appropriate age class by BMA and Changwat.

Growth rates of population by age class are shown in Table 3.3.4.

Table 3.3.4 Population Growth Rate by Age

| Area | School | 1986-1991 | 1991-1996 | 1996-2001 |
|---|---|---|---|---|
| BMA | Kindergarten | 0.9 | -1.4 | -0.4 |
| | Primary School | 3.5 | -0.5 | -1.4 |
| | Secondary School | 1.5 | 3.5 | 6.8 |
| | High Education | -1.0 | 0.7 | 2.8 |
| Samut Prakan | Kindergarten | 1.9 | 0.9 | 0.9 |
| | Primary School | 2.8 | 1.5 | 0.4 |
| | Secondary School | 2.1 | 2.8 | 2.2 |
| | High Education | 1.6 | 1.9 | 2.9 |
| Nonthaburi | Kindergarten | 1.3 | 0.9 | 2.3 |
| | Primary School | 2.6 | 0.8 | 1.5 |
| | Secondary School | 1.5 | 3.1 | 1.9 |
| | High Education | 1.3 | 0.0 | 5.0 |
| Pathumthani | Kindergarten | 1.5 | 1.6 | 1.9 |
| | Primary School | 1.8 | 1.9 | 1.7 |
| | Secondary School | 1.5 | 2.6 | 2.9 |
| | High Education | 2.6 | 2.3 | 3.3 |

## 3.4 Existing Road Network and Characteristics

### 3.4.1 Existing Road Network

A considerable amount of effort was directed to establishing a complete representation of the existing road network in the Greater Bangkok Area. Primary souces of information were as follows:

- 1:20,000 maps of 1984 version produced by the Royal Survey Department
- 1:27,000 map published by Prannok Pittaya Co. in 1985
- Road inventory map prepared by the JICA BMA Traffic Study Team
- Schematic network diagram prepared by the JICA BMA Traffic Study Team
- Schematic network diagram by JICA SES Study Team
- Schematic network diagram prepared by STTR study team

All the above were carefully examined against actual situation. Field inspections were made when there were some doubts. Errors were corrected and some roads missing in the previous schematic diagrams were added. The result was a schematic diagram of the existing road network in Bangkok, which the Study Team believes to be the most accurate of its kind of date. The original measures about 1.5 m by 2.0 m. Fig. 3.4.1 shows a reduced version of the schematic diagram. The total number of links including dummy links such as connectors to zonal centroids is 1,411 and the total number of nodes 531.

### 3.4.2 Link Performance Characteristics

The overall performance of an urban road network depends on the performance of each individual roadway and intersection. It is essential to assess the performance of individual road link or intersection under specified traffic load. A link performance model for Bangkok was established for the purpose of primarily focusing on delays at intersections instead of conventional link average speed-traffic volume model since under the current conditions in Bangkok intersection delays are by far the dominant factor.

For expressways imaginary time delays equivalent to toll charges to users were developed so that they can be modelled in a similar manner as ordinary roads. This was done considering the fact that the objective of this study is to evaluate a bridge and a road, not an expressway.

The following subsections explain characteristics of the road network assumed in this study in some detail.

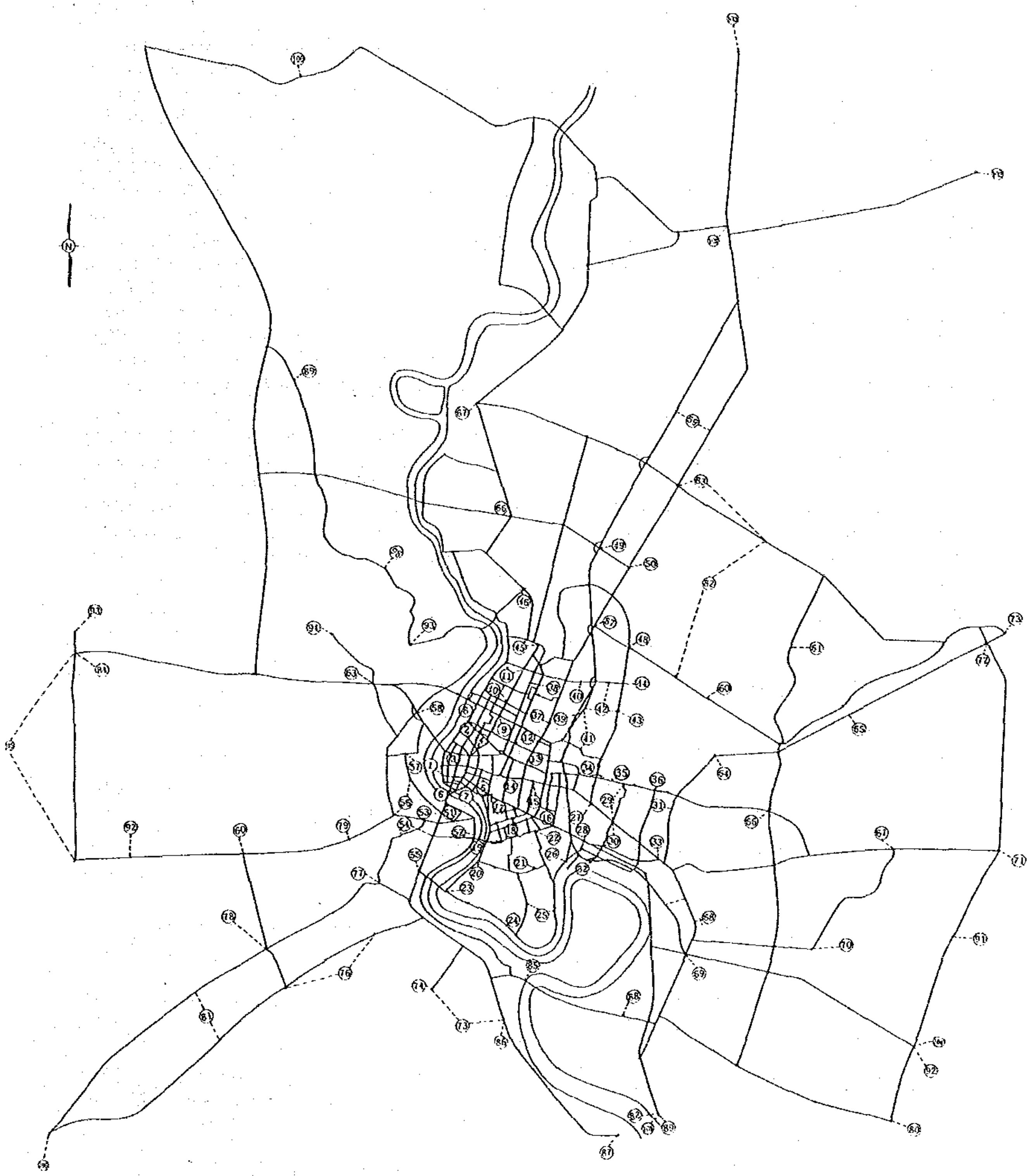


Fig. 3.4.1 Base Network in Base Year

1) Intersection Delay

In urban street network, the total travel time from one point to the other comprises the sum of running time on streets and delay at intersections. The running speed on roadway is not much affected by traffic volume up to areas close to the capacity, which is typically 2000-2500 vehicles/hour/lane. Data in Japan indicate 9 km/hour reduction for every 1000 vehicles/hour under the stable condition. Capacity of a signalized intersection is only as high as the portion of the approach capacity available to the approach by the green signal. Due to queueing, the average delay at intersection increases dramatically as traffic volume nears its capacity. If the approach lane capacity of an intersection is 2000 vehicles/hour and 50% of signal cycle time is allocated to the approach, the average delay would be theoretically infinite at the approach traffic volume of 1000 vehicles/hour. This volume level is only half of the roadway capacity and the increase in travel time due to running speed reduction is negligible in comparison.

Several intersection delay models have been developed, among which Webster's formula proved to give sufficiently accurate results. However, such models are complex and not suitable for the purposes of network assignment which requires iterative travel time calculations for each link. In this study, therefore, the following models were adopted on the grounds that they give volume-delay relationships sufficiently close to the reality.

$$T_a = T_{01} + T_{02} + \frac{kv/C}{(1 - v/CQ)}$$

where

$T_a$ = adjusted travel time on link in minute

$T_{01}$ = original travel time on link (under normal free flow conditions)

$T_{02}$ = average intersection delay under no queueing

$v$ = the volume on the link in pcu/hour

$C$ = the capacity of the intersection approach in pcu/hour

$Q$ = coefficient for curve fitting

$k$ = constant (0.1 minute)

The original travel time $T_{01}$, for each link was calculated by means of the free flow speed on each link which was estimated considering physical and environmental characteristics of each type of roads.

The average delay under no queueing, can be expressed as follows:

$$\bar{d} = \frac{1}{2} yr^2 \quad (=T_{02})$$

where y is the cycle time in minutes and r is the ratio of red time including start-up delay to the cycle time.

The capacity of an intersection with respect to one of its approach can be expressed as follows:

$$C = \sum_{i} l_i * (1-r_i)$$

where $l_i$ is the saturation flow of $i_{th}$ approach lane, and $r_i$ is the red time ratio of the $i_{th}$ lane.

OCMRT estimated the saturation flow of intersection approach at 2200 pcu/hour for straight traffic and 10% less for left and right turning traffic based on their extensive traffic volume surveys in Bangkok. These figures were adopted without modification.

Evaluation of intersection delay is difficult in Bangkok as the manual operation of signals by Police is the norm rather than exception. During peak-hours virtually all signals are operated manually and even during off-peak hours most of them are under manual control. Not only the cycle time but also phasing may not be kept stable as the police officer in charge attempts to absorb random traffic fluctuations at his best.

A survey of traffic signal phasing and timing was carried out for selected intersections throughout the Study area. Resulting average cycle time and average red time ratio obtained for the sampled intersections are shown in Appendix 3.4.1.

It was found in general that larger intersections tend to have longer cycle time, that, as expected, intersections of oneway roads have shorter cycle time, and that red time ratio depends on whether the flow with which the subject approach intersect is higher, same or lower than the flow on it.

Based on the results of this survey, the speed and delay survey done by this Study on the west bank, OCMRT's surveys and the BMA Traffic Study's surveys, typical intersection cycle time and red time ratio were developed for types of roads classified by the number and type of approach lanes, whether the other approach intersect with the approach in question carried higher, same or lower level of traffic flow, and whether the approach was on an oneway road or not.

Saturation flows for each type of approach as classified above were calculated by means of the basic saturation flow rate of 2200 pcu/hour and assumed lane utilization rate by turning movements. The average saturation flow per lane was calculated and the total approach capacity was calculated as follows:

$$C = \bar{l} * N * (1-\bar{r})$$

where $\bar{l}$ is the average saturation flow per lane,

$\underline{N}$ is the number of approach lanes, and

$\bar{r}$ is the average red time ratio for the entire approach lanes

For intersection types with additional right turn lane(s) the number of right turning lane(s) was counted as 0.5 lane per lane considering the fact that the queue length is ordinarily longer than the length of additional right turning lane in Bangkok.

The average intersection delay under no queueing was claculated from the above determined cycle time and red time ratio by means of the aforementioned formula.

2) Link Delay:

For expressways and roads in outlying areas the following delay function was used to reflect the higher importance of roadway performance.

$$Ta = To^{*}(0.9 + \frac{0.1}{1 - v/LQ})$$

where the symbols are as before, except that L is the link capacity.

Link capacity figures generally used in Japan were adopted for this study considering the similarities in traffic characteristics between Bangkok and Japanese cities.

In all 48 intersection types and 6 link types were identified and associated capacity and delay characteristics were calculated. Table 3.4.1 summarizes the resulting link performance model parameters for each type of intersections and links.

In the range close to the capacity, neither Webster's equation nor approximated equations shown in 1) and 2) above would apply. For intersection delays the maximum was set at the value corresponding to the 98% capacity traffic. This implies roughly a maximum average delay of 5 cycle times. For link delays a similar limit was assumed.

### 3.4.3 Expressway Characteristics

Three different components of the expressway system were identified, the throughway, the off-ramp and the on-ramp.

The throughway section between consecutive two ramps was treated as a road section with no intersection delay. Only the link delay due to traffic interference was considered. Capacity and initial speed are shown in Table 3.4.1.

The off-ramp was treated as a short link with an intersection at the end. In Bangkok all off-ramps except for the Bangna and Din Daeng exit ramps intersect with ordinary roads, most of them with traffic signals. Appropriate intersection delay types were selected for each of the off-ramps.

On-ramp requires special attention. Its capacity is determined by the number of toll booths and the speed of service. Toll itself must be considered. Taking advantage of the fact that a flat toll is charged throughout the system, the effect of toll is modelled in this study as

Table 3.4.1 Road Types and Characteristics

| No. | Category | Location | No. of One way Lanes Link | No. of One way Lanes Appr. | Saturation Cap./lane Link | Saturation Cap./lane Appr. | Free Flow Spd. | Intersect with Major or Minor Flow | Link Capacity | Cycle Time | Red Ratio | Appr. Cap. | Base Delay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ordinary Two way | Urban | 1 | 1 | 1000 | 2090 | 45 | Major | 1000 | 2.7 | 80 | 418 | 0.86 |
| | | | | | | (L 20, C 60, R 20) | | Same | | 1.7 | 50 | 1045 | 0.21 |
| | | | | | | | | Minor | | 1.7 | 40 | 1236 | 0.14 |
| 2 | | | 1 | 2 | 1000 | 2068 | 45 | Major | 2000 | 2.9 | 79 | 869 | 0.90 |
| | | | | | | (L 20, C 80, R 100) | | Same | | 2.4 | 53 | 1944 | 0.34 |
| | | | | | | | | Minor | | 1.9 | 38 | 2564 | 0.14 |
| 3 | | | 2 | 2 | 1300 | 2156 | 50 | Major | 2600 | 3.0 | 78 | 949 | 0.91 |
| | | | | | | (L 20, C 160, R 20) | | Same | | 2.6 | 56 | 1897 | 0.41 |
| | | | | | | | | Minor | | 2.1 | 36 | 2760 | 0.14 |
| 4 | | | 2 | 3 | 1300 | 2090 | 50 | Major | 2600 | 3.2 | 77 | 1202 | 0.95 |
| | | | | | | (L 50, C 150, R 100) | | Same | | 2.7 | 58 | 2194 | 0.45 |
| | | | | | | | | Minor | | 2.3 | 34 | 3448 | 0.13 |
| 5 | | | 3 | 3 | 1600 | 2127 | 55 | Major | 4800 | 3.3 | 76 | 1531 | 0.95 |
| | | | | | | (L 50, C 200, R 50) | | Same | | 2.9 | 61 | 2489 | 0.54 |
| | | | | | | | | Minor | | 2.5 | 32 | 4339 | 0.13 |
| 6 | | | 3 | 4 | 1600 | 2090 | 55 | Major | 4800 | 3.5 | 75 | 1829 | 0.98 |
| | | | | | | (L 100, C 200, R 100) | | Same | | 3.1 | 64 | 2624 | 0.63 |
| | | | | | | | | Minor | | 2.7 | 32 | 4974 | 0.14 |
| 7 | | | 4 | 4 | 1600 | 2118 | 55 | Major | 6400 | 3.8 | 74 | 2203 | 1.04 |
| | | | | | | (L 100, C 250, R 50) | | Same | | 3.4 | 65 | 2965 | 0.72 |
| | | | | | | | | Minor | | 3.0 | 40 | 5083 | 0.24 |

Note: Capital letters and figures in parentheses indicate assumed percentages of lane utilization by direction.

Table 3.4.1 Road Types and Characteristics (Continued)

| No. | Category | Location | No. of One way Lanes Link | Appr. | Saturation Cap./lane Link | Appr. | Free Flow Spd. | Intersect with Major or Minor Flow | Link Capacity | Cycle Time | Red Ratio | Appr. Cap. | Base Delay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | | | 4 | 5 | 1600 | 2112 | 55 | Major | - | 4.0 | 73 | 2566 | 1.07 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 300 | | Same | | 3.7 | 66 | 3231 | 0.81 |
| | | | | | | R 100 | | Minor | | 3.3 | 46 | 5132 | 0.35 |
| 9 | | | 5 | 5 | 1600 | 2134 | 55 | Major | - | 4.3 | 72 | 2988 | 1.11 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 350 | | Same | | 4.0 | 67 | 3521 | 0.90 |
| | | | | | | R 50 | | Minor | | 3.7 | 51 | 5228 | 0.50 |
| 10 | | | 5 | 6 | 1600 | 2090 | 55 | Major | - | 4.5 | 71 | 3334 | 1.13 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 300 | | Same | | 4.3 | 68 | 3679 | 0.99 |
| | | | | | | R 200 | | Minor | | 4.0 | 54 | 5768 | 0.58 |
| 11 | | | 6 | 6 | 1600 | 2090 | 55 | Major | - | 4.8 | 71 | 3635 | 1.21 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 300 | | Same | | 4.6 | 69 | 3939 | 1.10 |
| | | | | | | R 200 | | Minor | | 4.3 | 55 | 5719 | 0.65 |
| 12 | Oneway urban | | 3 | 3 | 1600 | 2090 | 55 | Major | | 2.8 | 57 | 2696 | 0.45 |
| | | | | | | L 50 | | | | | | | |
| | | | | | | C 150 | | Same | | 2.5 | 48 | 3260 | 0.29 |
| | | | | | | R 100 | | Minor | | 2.1 | 45 | 3449 | 0.21 |
| 13 | | | 4 | 4 | 1600 | 2090 | 55 | Major | - | 2.8 | 57 | 3595 | 0.45 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 200 | | Same | | 2.5 | 48 | 4347 | 0.29 |
| | | | | | | R 100 | | Minor | | 2.1 | 45 | 4598 | 0.21 |
| 14 | | | 5 | 5 | 1600 | 2068 | 55 | Major | - | 2.8 | 57 | 4446 | 0.45 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 200 | | Same | | 2.5 | 48 | 5377 | 0.29 |
| | | | | | | R 200 | | Minor | | 2.1 | 45 | 5687 | 0.21 |
| 15 | | | 6 | 6 | 1600 | 2090 | 55 | Major | - | 2.8 | 57 | 5392 | 0.45 |
| | | | | | | L 100 | | | | | | | |
| | | | | | | C 300 | | Same | | 2.5 | 48 | 6521 | 0.29 |
| | | | | | | R 200 | | Minor | | 2.0 | 45 | 6897 | 0.20 |

Table 3.4.1 Road Types and Characteristics (Continued)

| No. | Category | Location | No. of One way Lanes Link | No. of One way Lanes Appr. | Saturation Cap./lane Link | Saturation Cap./lane Appr. | Free Flow Spd. | Intersect with Major or Minor Flow | Link Capacity | Cycle Time | Red Ratio | Appr. Cap. | Base Delay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | | | 7 | 7 | 1600 | 2074 | 55 | Major | – | 2.8 | 57 | 6243 | 0.45 |
| | | | | | | L 200 | | | | | | | |
| | | | | | | C 300 | | Same | | 2.5 | 48 | 7549 | 0.29 |
| | | | | | | R 200 | | Minor | | 2.0 | 47 | 7695 | 0.24 |
| 17 | | | 8 | 8 | 1600 | 2090 | 55 | Major | – | 2.8 | 57 | 7189 | 0.45 |
| | | | | | | L 200 | | | | | | | |
| | | | | | | C 400 | | Same | | 2.5 | 48 | 8694 | 0.29 |
| | | | | | | R 200 | | Minor | | 1.9 | 47 | 8862 | 0.27 |
| 18 | Ordinary | Sub-urban | 1 | – | 1600 | | 50 | | 1600 | – | – | – | – |
| 19 | | | 2 | – | 1800 | | 60 | | 3600 | – | – | – | – |
| 20 | | | 3 | – | 1800 | | 65 | | 5400 | – | – | – | – |
| 21 | Express-way | Ramp | 1 | – | 1800 | | 50 | | 1800 | – | – | – | – |

Highway Types and Characteristics

| No. | Category | Location | No. of One way Lanes Link | No. of One way Lanes Appr. | Saturation Cap./lane Link | Saturation Cap./lane Appr. | Free Flow Spd. | Intersect with Major or Minor Flow | Link Capacity | Cycle Time | Red Ratio | Appr. Cap. | Base Delay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | | Thruway | 2 | – | 2200 | | 90 | | 4400 | – | – | – | – |
| 23 | | " | 3 | – | 2200 | | 90 | | 6600 | – | – | – | – |
| 24 | Ferry boat | | – | – | – | – | 5 | | $\alpha$ | – | – | – | – |

an equivalent extra time delay to users at the entry point of the expressway system.

If the arrival rate of users is completely even, then the absolute capacity of on-ramp can be expressed as follows:

$$C = 3600/ST * N \text{ (vehicles/hour)}$$

where ST is the average service time, and N is the number of booths. Due to the randomness of arrival and service, actual capacity is less because of queueing. As the number of booths get larger, the effect of queueing gets smaller. The following formula was used in this study assuming the average service time of 8 seconds per vehicle.

$$C = 441*N - 77 \text{ (vehicles/hour)}$$

The above formula was derived as the average of the absolute maximum of 450 vehicles/hour and the relationship between C and N for the average queue length of 1 vehicle; C = 431*N - 153.

Two approaches were attempted to estimate the value of time for the expressway users, the income approach and the utilization rate approach.

The income approach assumes that the perceived value of time savings by the expressway is equal to the value of time which could be spent for other purposes. Based on hourly wages, percentage of work trips, vehicle occupancy, type of passengers per hour values for each vehicle type were calculated. More explanation of time values based on income is shown in Section 4.6. Table 3.4.2 shows resulting value of time and time in minutes equivalent to expressway toll fares. The resulting equivalent time figures, however, seemed too large to be used as the basis for selecting O&D pairs which are likely to use the expressway system.

Table 3.4.2 Income Approach Value of Time

| Vehicle Type | 1986 Value of Time (Baht/Hour) | Fare (Baht) | Equivalent Time (min.) |
|---|---|---|---|
| Car | 18.9 | 10 | 31.7 |
| Taxis | 35.5 | 10 | 16.9 |
| Pickups | 34.3 | 10 | 17.5 |
| Trucks | 25.6 | 20 | 46.9 |
| Buses | 259.0 | 20 | 4.6 |

The logic of the utilization rate approach is as follows. It is assumed that if the perceived value of time savings by the expressway is larger than the fare, then the user selects the expressway. Because the perceived value varies depending upon the user, the utilization rate, p, can be expressed as follows:

$$P (V > F) = p,$$

where the left term indicates the probability of the perceived value V is larger than the fare, F. The total perceived value, V is the product of unit time value, v, and the time saving, d, i.e. V-vd. The unit time value, v, is a probability variable.

If X is defined as; X = F/d, then the above equation can be rewritten as; $P(v > X) = p$.

The average unit time value, v, then is equal to the average value of X, $\bar{X}$.

The utilization rate, p, has been estimated by the BMA Traffic Study and the Detailed Design of Second Stage Expressway Project in the following form:

$$p = \frac{K}{1 + A\,x^{\alpha}}$$

where K, A and α are parameters.

Estimated parameters are shown in Table 3.4.3.

Table 3.4.3 Expressway Utilization Rate Estimates

| | BMA Traffic Study | | | Second Stage Expressway Project | | |
|---|---|---|---|---|---|---|
| | K | A | | K | A | |
| Cars | 1.0 | 0.244 | 1.365 | 1.0 | 0.255 | 1.931 |
| Pickups | 0.9 | 0.100 | 1.469 | 1.0 | 0.120 | 3.156 |
| Trucks | 0.8 | 0.019 | 2.210 | 1.0 | 0.559 | 2.325 |

It should be noted that in the case of the BMA Traffic Study, p is not defined to be above p = 0.9 or p = 0.8 for pickups and trucks respectively. The above formulae proved to reproduce sufficiently accurate traffic volumes on expressway links by means of network assignment models.

The aforementioned function form of p can be rewritten as:

$$x = \frac{1}{A}\left(\frac{k}{p} - 1\right)^{\frac{1}{\;}}$$

Because of the fact that the goodness of fit of the above equation in the low range of p was very poor in both studies, the lowest m x 100% were not included in the average calculation.

Average time values were calculated by applying the above formula to parameters shown before. Table 3.4.4 summarizes the results with m = 0.1. The average of the two cases was used in this study as the first estimates.

Table 3.4.4 Value of Time and Equivalent Time of Fare

| Vehicle Type | From BMA Study Parameters (Baht/min) | From SES Study Parameters (Baht/min) | Average (Baht/min) | Equivalent Time (min) |
|---|---|---|---|---|
| Cars | 2.724 | 1.106 | 1.915 | 5.22 |
| Pickups | 3.309 | 0.566 | 1.938 | 5.16 |
| Trucks | 1.958 | 0.546 | 1.252 | 16.0 |

For taxis the same value as for cars was used and for buses the same as trucks.

In order that motorcycles are not assigned on the expressway, an arbitrarily large time of 500 min. was used for them.

## 3.5 Establishment of Existing O&D Tables

### 3.5.1 Derivation of Basic Origin and Destination Matrices

O&D tables were made available from three different sources. O&D tables developed by the BMA Traffic Study are applicable to trips having at least one end within the Middle Ring Road and excluding motorcycles but based on the most recent and extensive field surveys. O&D tables developed by the STTR Study include those for motorcycles but basically based on obsolete O&D information. O&D tables obtained as a result of this study's field surveys are only applicable to trips having one end in the selected zones in the west bank. All the above three were integrated to produce the best estimates.

1) Vehicle Type

In this Study all vehicles were categorized into 7 vehicle types. They are shown below with respective abreviations.

| | | |
|---|---|---|
| Passenger Car | : | PC |
| Taxi | : | TX |
| Light Bus | : | LB |
| Heavy Bus | : | HB |
| Light Truck/Pickup | : | LT |
| Heavy Truck | : | HT |
| Motorcycle | : | MC |

2) Adjustment of Vehicle Type

LT and HT are categorized by STTR as Goods Vehicle. Therefore STTR O&D table for goods vehicles was divided using the percentage of LT which was estimated based on the LT and HT O&D tables by the BMA Study classified by locations of trip end. The LT percentages are shown below.

Table 3.5.1 Percentage of LT to Total Goods Vehicles

| Destination / Origin | Inside the Middle Ring Road | Outside the Middle Ring Road |
|---|---|---|
| Inside the Middle Ring Road | 90.0 | 75.6 |
| Outside the Middle Ring Road | 75.6 | 57.7 |

Note: Calculated based on BMA O&D Tables.

3) Zonal Adjustments

The O&D tables of six vehicle types, except motorcycle, were adjusted to reconcile the differences in zone system sof BMA Study and STTR as follows.

a. Trips having both ends located within the Middle Ring Road.

O&D volumes were directly taken from O&D tables by BMA Study

b. Trips having no end located within the Middle Ring Road.

O&D volumes were taken from O&D tables by STTR.

c. Trips having no end located within the Middle Ring Road requiring subdivision

O&D tables by STTR were divided based on the generation/attraction volumes of O&D tables by BMA Study with controlled totals taken from O&D volumes of BMA Study for the corresponding area.

d. Related O&D volumes of zones 74, 76, 77, 78, 79 and 80.

Estimates based on the survey results by the Study Team were taken directly.

O&D table for MC was estimated as follows.

a. Trips having both ends located within the Middle Ring Road.

O&D values by STTR were applied. In case zones do not match, O&D volumes were divided using the proportions of PC O&D volumes by BMA Study.

b. Trips having no end located within the Middle Ring Road.

Same adjustments as for other vehicle types were applied.

c. Trips having one end located within the Middle Ring Road.

O&D volumes were subdivided based on the zonal generation/attraction of the PC O&D table by BMA Study.

d. Related O&D volumes of zones 74, 76, 77, 70

Estimates based on the survey results by the Study Team were applied.

e. Estimated O&D volumes of zones 78, 79.

O&D volumes of zone 77 were adjusted in proportion to zonal population.

### 3.5.2 Estimation of Base Year Hourly O&D Tables

It was decided in this Study that examination of traffic should be done not only on daily basis but also on hourly basis, at least for peak hour and off-peak hour because of the highly non-linear nature of transport costs. Difference in transport costs for different infrastructure schemes which give different transport service levels would be underestimated if traffic is examined on daily basis alone. The problem could be alleviated somewhat by applying the incremental assignment method and calculating the transport costs at every increment and summing up at the end.

A direct development of hourly O&D tables would have to be based on insufficient number of samples. The hourly distribution of trips by trip purpose could give a good guidance in developing such tables. Such data, however, are not available. Hourly O&D tables developed by this study as explained below, therefore, contain a margin of error. The question is the balance between the drawbacks of daily traffic assignment and the margin of error in the hourly O&D tables. It was decided in this study that the level of congestion in Bangkok calls for the hourly assignment.

The development of hourly O&D tables was carried out in the following manner. (See Fig. 3.5.1.)

1) Morning Peak

a. Area-wide traffic peak hour ratios were calculated for each vehicle type from a large number of traffic counts for a typical morning peak hour.

b. Daily O&D tables for each vehicle type were multiplied by the respective peak hour ratios to give preliminary peak hour O&D tables. (See Table 3.5.2)

c. For passenger car traffic in the peak hour, zonal generation and zonal attraction were assumed to be proportionate to zonal car ownership and zonal employment respectively. The passenger car O&D table obtained by b. above was modified by the Fratar method with the zonal generation and attraction as explained above.

d. For taxi O&D table, a process similar to c. above was applied except that population was used instead of car ownership.

e. For peak hour motorcycle O&D table a process similar to c. above was applied except that motorcycle ownership was used instead of car ownership. Motorcycle ownership by zone is shown in Appendix 3.5.1.

f. All tables thus far developed were then subjected to the automatic O&D matrix adjustment program to ensure that the model reproduces the actual traffic counts.

2) Evening Peak

g. Evening peak hour traffic ratios were calculated from hourly traffic counts for each vehicle type and the total O&D volumes for the evening peak hour were obtained by multiplying the ratios to daily totals respectively. (See Table 3.5.2)

h. Preliminary evening peak hour O&D tables were obtained by reversing the morning peak O&D tables obtained in 1) f. above.

i. Tables obtained in h. above were subjected to the automatic O&D matrix adjustment program using evening peak traffic volumes for control purpose.

3) Off-Peak

j. Off-peak hour O&D tables were obtained as follows: (See Table 3.5.2)

$$OTi = (ATi - MTi \times MH - ETi \times EH)/OHi$$

where

| | | |
|---|---|---|
| OTi | : | Off-peak hour O&D table |
| ATi | : | Daily O&D table |
| MTi | : | Morning peak O&D tables |
| ETi | : | Evening peak O&D tables |
| MH | : | Duration of morning peak (2 hours) |
| EH | : | Duration of evening peak (3 hours) |
| OHi | : | Off-peak hours traffic ratio equivalent hours<br>OHi = (1-MRi x MH - ERi x EH)/ORi |
| MRi | : | Morning peak hour traffic ratio |
| ERi | : | Evening peak hour traffic ratio |
| ORi | : | Off-peak hour traffic ratio |
| i | : | Vehicle Type |

k. Tables obtained in j above were subjected to the automatic O&D matrix adjustment program using off-peak traffic volumes for control purpose.

Figure 3.5.1 illustrates the above procedures.

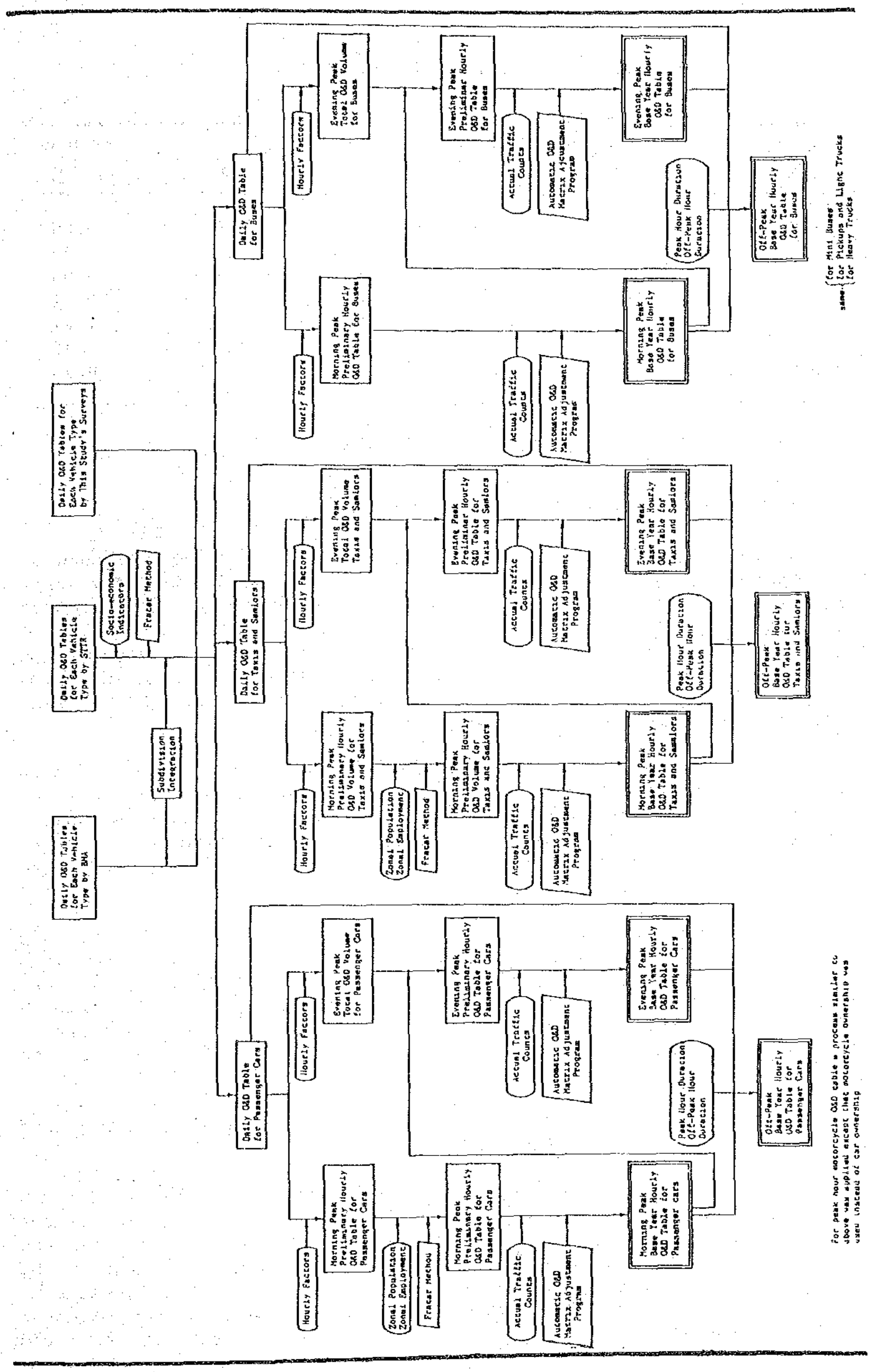



**Fig. 3.5.1 Estimation of Base Year Hourly O&D Tables**

Table 3.5.2 Peak, Off-peak Hour Traffic Ratios

(%)

| Vehicle Type | Morning Peak | Evening Peak | Off Peak | Off Peak Hours | Evening / Morning |
|---|---|---|---|---|---|
| PC | 7.1 | 6.1 | 4.3 | 15.7 | 0.86 |
| TX | 4.3 | 4.2 | 4.4 | 17.9 | 0.98 |
| LB | 6.5 | 5.5 | 4.2 | 16.8 | 0.85 |
| HB | 6.4 | 5.8 | 4.6 | 15.2 | 0.91 |
| LT | 3.7 | 4.5 | 5.7 | 13.9 | 1.22 |
| HT | 1.1 | 1.3 | 6.9 | 13.6 | 1.18 |
| MC | 7.4 | 5.8 | 5.0 | 13.6 | 0.78 |

Source: Weighted average of various traffic counts.

### 3.5.3 Estimation of the Most Likely Existing O&D Tables

Original O&D data are normally collected by field surveys such as home interviews and roadside interviews, which are necessarily on a sampling basis. Because of the large number of O&D pairs the sampling rate for each O&D pair is often low, resulting in a large margin of sampling error. Efforts have been made in many countries to improve the reliability of O&D table, e.g. Iida (1978) and Inoue (1977) in Japan, Nguyen (1977) and LeBalanc (1982) in USA, Holm et al (1976) and Willumsen (1980) in U.K.

One method is to estimate O&D table from link traffic counts, which are normally reliable. The method provides the most likely O&D table by means of solving a minimization problem. The method starts from a given O&D table and modifies it until its assignment on the network reproduces the given traffic counts. This method was used in this study to ensure the reliability of O&D tables.

Recent hourly traffic counts data were obtained from the BMA Traffic Study and the Study Team's surveys at 109 oneway count locations spreading throughout the network. Locations of these oneway counts are shown in Fig. 3.5.2. The program compared assigned traffic volumes with actual counts and interatively adjusted O&D table until the difference was within a prespecified range. This was done by vehicle type for each of the three time periods.

Appendix 3.5.1 is a Table showing how close the resulting assigned traffic volumes are to actual counts.

In Appendix 3.5.3 are Figures illustrating the patterns of trip length distribution of O&D matrix before and after the adjustment process. Except for short (20 minutes range) trips, two patterns are generally similar. This difference in short trips may indicate the usual problem of under-reporting in interview surveys. The significant difference in patterns for trucks may indicate how poor the original matrix was against the actual due to the low sampling rate in the field surveys.

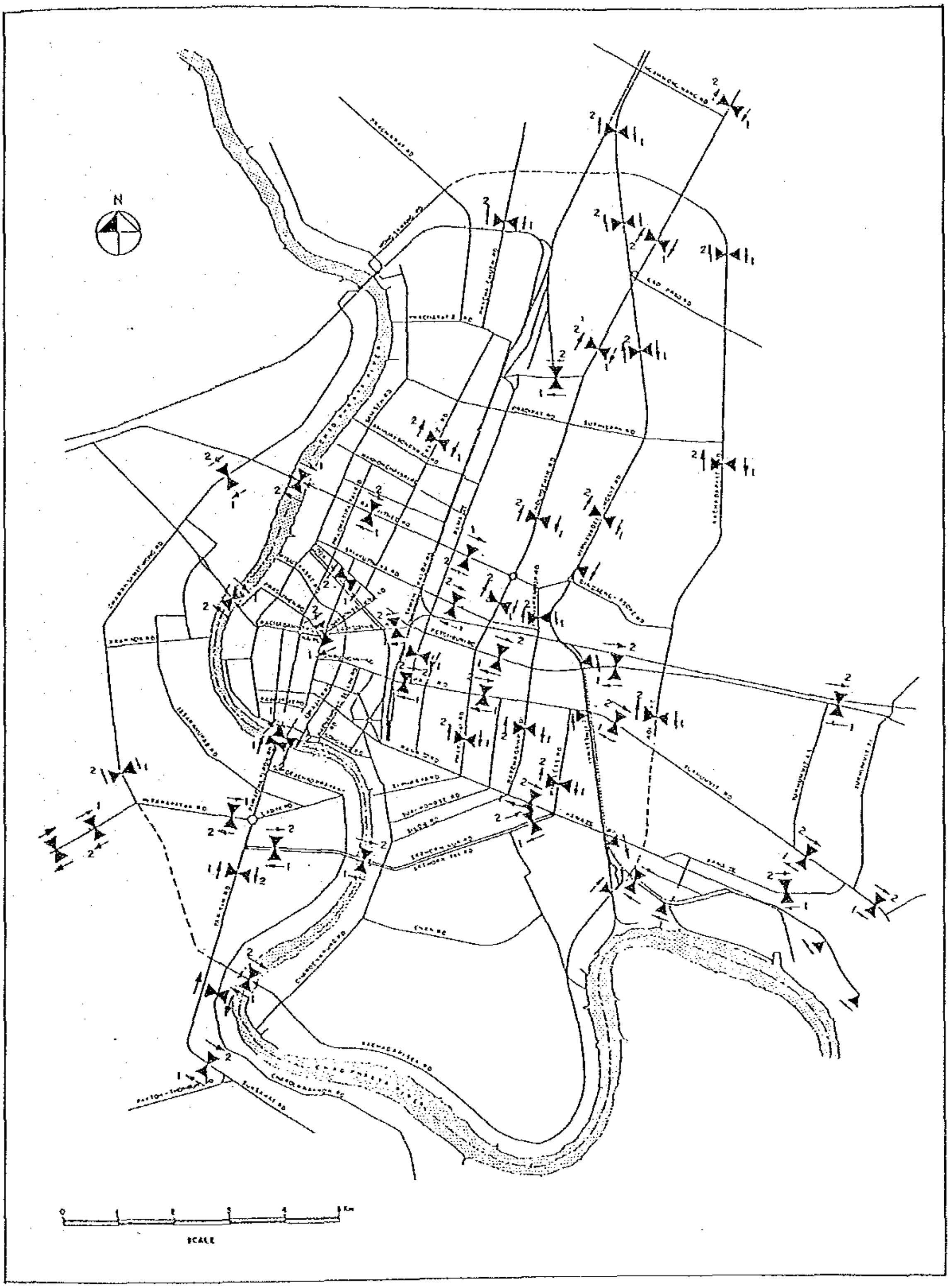


Fig. 3.5.2 Locations of Volume Control Points

### 3.5.4 Base Year O&D Tables

Resulting base year hourly O&D Tables (Appendix 3.5.5) by type of vehicle which were compressed to 27 zones for presentation purposes are shown in Appendix 3.5.4 and total numbers of trips by vehicle type are summarized in Table 3.5.3 together with daily figures.

Total numbers of trips were 168 x $10^3$, 155 x $10^3$ and 137 x $10^3$ in the morning peak, evening peak and off-peak hours respectively. Variance among hourly volumes during the day was low.

The percentage of passenger cars in traffic during off-peak hours was 10% less than during peak hours and this is compensated by the increase in the shares of taxis and trucks during off-peak hours.

Fig. 3.5.3 and 3.3.4 illustrates major vehicle movements for selected vehicles and time periods.

The traffic pattern of passenger cars in the morning period given in Fig. 3.5.3 shows a marked concentration into the central area. It is interesting to note that northward movements along the northern corridor are also strong. This confirms an observation that the growth of employment opportunities, particularly industrial, in the northern parts of Bangkok including Nonthaburi and Pathumthani has reached a level that the northward and the southward traffic in the morning are balanced. Passenger cars move generally in the reverse direction in the evening peak period but with less intensity than in the morning. During off-peak hours passenger car movements are still centered in the central area but for both directions.

Fig. 3.5.4 shows movements of each type of vehicles on daily basis. The long distance nature of heavy trucks and the short distance nature of motorcycles are clearly shown. Taxi movements are similar to motorcycles. Light buses seem to go everywhere but heavy bus movements, which are longer than light buses, are more centered except the heavy movements on the west bank.

Table 3.5.4 Total Number of Trips by Vehicle Type in Base Year

(Vehicles)

| Type of Vehicle | Passenger Car Equivalent Factor | Morning Peak Hour | | Evening Peak Hour | | Off Peak Hour | | Daily | |
|---|---|---|---|---|---|---|---|---|---|
| Passenger Car | 1.000 | 91,391 | (44.7) | 78,187 | (43.0) | 50,797 | (37.2) | 1,123,467 | (35.5) |
| Taxi, Samlor | 0.930 | 30,401 | (14.9) | 29,537 | (16.3) | 31,833 | (20.2) | 688,825 | (21.8) |
| Light Bus | 1.500 | 4,214 | (2.1) | 3,777 | (2.1) | 2,693 | (1.7) | 60,789 | (1.9) |
| Heavy Bus | 2.100 | 5,803 | (2.8) | 5,290 | (2.9) | 4,141 | (2.6) | 84,618 | (2.7) |
| Light Truck | 1.000 | 17,409 | (8.5) | 21,279 | (11.7) | 24,897 | (15.8) | 427,316 | (13.5) |
| Heavy Truck | 2.500 | 1,190 | (0.6) | 1,554 | (0.9) | 4,710 | (3.0) | 69,910 | (2.2) |
| Motorcycle | 0.175 | 54,246 | (26.5) | 42,005 | (23.1) | 38,800 | (24.6) | 707,943 | (22.4) |
| Total Vehicles | – | 204,654 | (100) | 181,629 | (100) | 157,871 | (100) | 3,162,868 | (100) |
| Passemger Car Equivalent | – | 168,229 | | 155,107 | | 136,969 | | 2,758,937 | |

Note
( ) : Traffic composition in percent

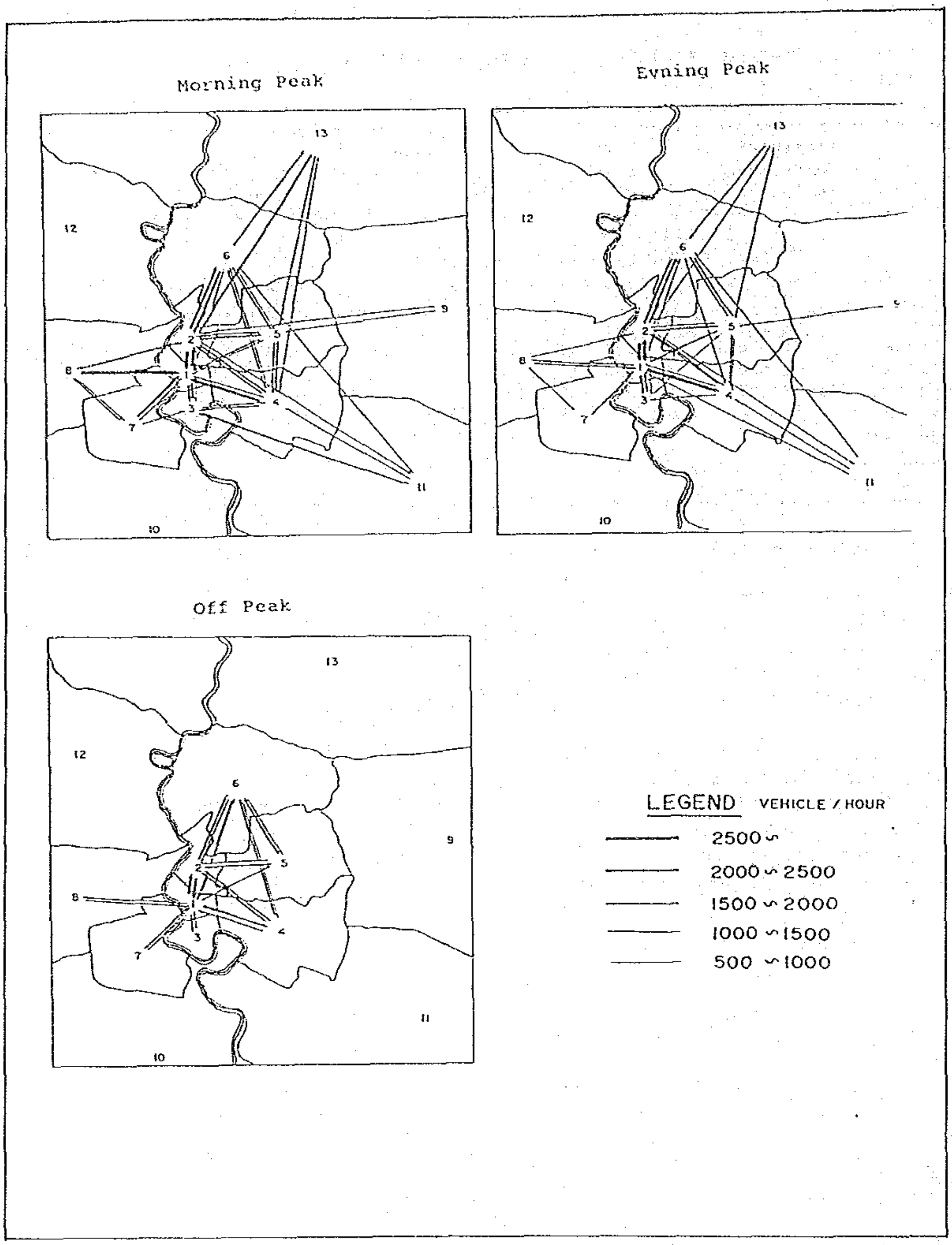



**Fig. 3.5.3 Passenger Car Movements by Period**

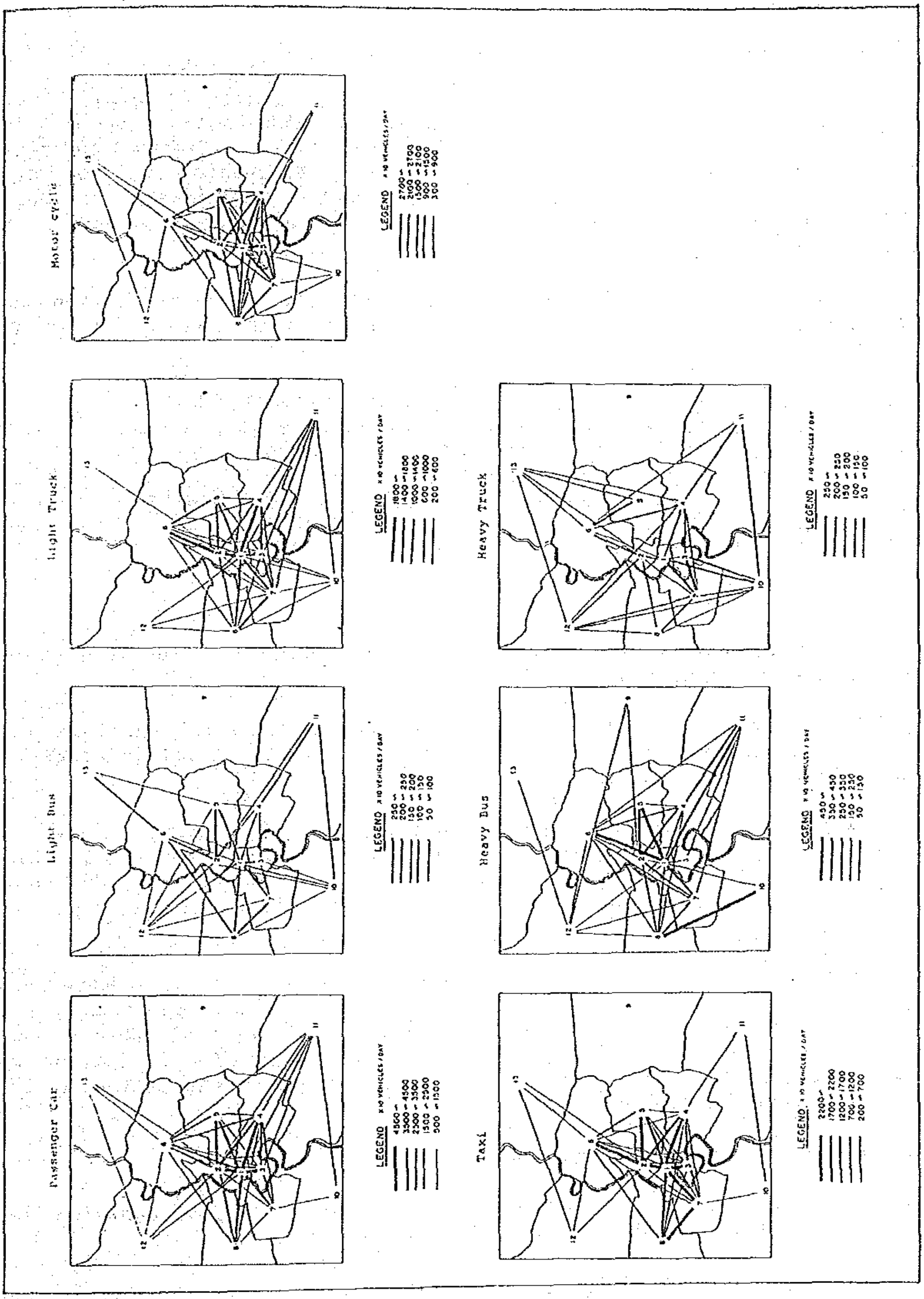



**Fig. 3.5.4 Daily Vehicular Movements by Type**

## 3.6 Trip Demand Characteristics

### 3.6.1 Generation and Attraction

Base year zonal trip generation and attraction totals were calculated as the sums of rows and columns of O&D tables respectively for each vehicle type. This was done for three different periods: morning peak, evening peak and off-peak hours. Regression analyses were carried out with zonal generation or attraction as dependent variable and zonal indicators of population, employment, car ownership, number of students as independent variables.

A series of generation/attraction models were built as the results of the regression analyses. The general form of the regression is as follows.

$$Y_i : a_{1i} \cdot X_{1i} + a_{2i} \cdot X_{2i} + a_{3i} \cdot X_{3i} + a_{4i} \cdot X_{4i} + c_i$$

where
- Y : Generation or Attraction
- X : Explanatory variables
- a,c : Model's parameters
- i : Type of vehicle
- 1 : Population
- 2 : Employment
- 3 : Car ownership
- 4 : Number of students

Best-fit regression equations were selected and resulting co-efficients are tabulated in Table 3.6.1.

Number of students in each zone was also applied to vehicle types other than passenger cars as an indicator of activity level in general, not only limited to school trips.

Repression for morning peak generally showed a high degree of correlation and for off-peak low. Especially passenger cars and taxis in the morning and evening peak show high correlation, i.e. trucks show very low correlation varying from .210 to .332 regardless of peak or off-peak period.

Amounts of generation and attraction calculated by these equations did not coincide with the original generation or attraction amounts due to particularities of each zone. Ratios of original amount and calculated amount for each zone were calculated as the factor indicating particularities of each zone and they were applied in the estimation of future generations and attractions.

### 3.6.2 Relationship with Travel Impedance

In order to establish future O&D tables, possibility of applying the gravity model was examined. The model equation was:

$$Xij = K \cdot \frac{Gi \cdot Aj}{Tij}$$

## Table 3.6.1 Parameters of Generation/Attraction Model

Morning Peak

| Vehicle Type | G/A | Population | Employment | Car Ownership | No. of Stucent | Constant | Corrilation Coefficient |
|---|---|---|---|---|---|---|---|
| Passenger Car | G | - | - | 149.4 | - | 223.3 | 82.3 |
| | A | - | 23.17 | - | - | 219.4 | 69.4 |
| Taxi | G | 2.112 | - | 17.45 | - | 70.1 | 70.9 |
| | A | - | 6.794 | 7.798 | - | 69.4 | 68.3 |
| Light Bus | G | 0.057 | - | - | 2.052 | 10.2 | 45.8 |
| | A | 0.145 | - | - | 1.686 | 8.7 | 41.8 |
| Heavy Bus | G | - | 0.391 | - | 3.791 | 3.1 | 58.3 |
| | A | - | 0.064 | - | 2.757 | 18.5 | 41.9 |
| Light Truck | G | - | 0.782 | - | 5.437 | 78.5 | 44.5 |
| | A | - | 1.115 | - | 4.093 | 84.7 | 37.3 |
| Heavy Truck | G | - | 0.085 | - | 0.573 | 0.6 | 33.2 |
| | A | - | 0.143 | - | 0.268 | 3.8 | 22.7 |
| Motorcycle | G | 2.045 | - | 39.37 | - | 211.9 | 55.9 |
| | A | - | 13.767 | - | - | 138.0 | 64.2 |

Evening Peak

| Vehicle Type | G/A | Population | Employment | Car Ownership | No. of Stucent | Constant | Corrilation Coefficient |
|---|---|---|---|---|---|---|---|
| Passenger Car | G | - | 19.88 | - | - | 191.0 | 73.0 |
| | A | - | - | 126.6 | - | 195.8 | 80.5 |
| Taxi | G | - | 7.098 | 4.649 | - | 66.3 | 71.2 |
| | A | 1.928 | - | 12.42 | - | 96.1 | 63.3 |
| Light Bus | G | 0.112 | - | - | 1.739 | 5.9 | 46.2 |
| | A | 0.088 | - | - | 1.547 | 10.1 | 43.4 |
| Heavy Bus | G | - | 0.308 | - | 3.564 | -2.9 | 59.6 |
| | A | - | 0.085 | - | 2.697 | 13.0 | 45.8 |
| Light Truck | G | - | 1.715 | - | 4.986 | 93.5 | 39.0 |
| | A | - | 1.330 | - | 6.418 | 87.2 | 44.9 |
| Heavy Truck | G | - | 0.053 | - | 0.459 | 5.3 | 20.9 |
| | A | - | 0.181 | - | 0.412 | 3.3 | 21.0 |
| Motorcycle | G | - | 10.85 | - | - | 101.5 | 68.3 |
| | A | 1.259 | - | 29.05 | - | 193.4 | 48.1 |

Off-Peak

| Vehicle Type | G/A | Population | Employment | Car Ownership | No. of Stucent | Constant | Corrilation Coefficient |
|---|---|---|---|---|---|---|---|
| Passenger Car | G | - | 0.743 | 21.444 | 9.049 | 265.9 | 30.4 |
| | A | - | 0.408 | 20.795 | 9.861 | 267.8 | 31.2 |
| Taxi | G | - | 2.071 | 26.03 | - | 138.4 | 32.8 |
| | A | - | 1.766 | 26.47 | - | 144.7 | 32.9 |
| Light Bus | G | 0.153 | - | - | 1.227 | 1.0 | 43.1 |
| | A | 0.066 | - | - | 1.292 | 5.0 | 40.5 |
| Heavy Bus | G | - | 0.294 | - | 2.764 | -2.7 | 56.2 |
| | A | - | 0.066 | - | 2.259 | 9.4 | 47.6 |
| Light Truck | G | - | 1.685 | - | 6.009 | 116.6 | 41.5 |
| | A | - | 1.782 | - | 5.427 | 121.6 | 40.0 |
| Heavy Truck | G | - | 0.326 | - | 0.853 | 20.2 | 32.5 |
| | A | - | 0.331 | - | 0.733 | 22.8 | 24.5 |
| Motorcycle | G | - | - | 33.51 | - | 232.4 | 28.6 |
| | A | - | - | 31.93 | - | 239.0 | 27.7 |

Note: G Generation
A Accraction
- Ignore

where $X_{ij}$ : Trips from zone i to zone j.
$G_i$ : Total trip generation of zone i
$A_j$ : Total trip attraction of zone j
$T_{ij}$ : Time distance from zone i to zone j
K, : Parameters

In this model time distance was assumed to be the inter-zonal impedance. Relationship between $X_{ij}/(G_i.A_j)$ and $T_{ij}$ was examined by regression analysis between log values of above two variables. These values were plotted and are shown in Appendix 3.6.1.

Plotted points of the two variables show a faint tendency that the number of trips of shorter distances is larger than the one of longer distances. However, as shown in those log value plottings, no significant relationship was found sufficient to determine the parameters of a gravity model. Analyses were done for the morning peak, evening peak and off-peak periods by vehicle type, but results were similar. It was decided, therefore, that the Fratar method using the present pattern with differentiated zonal growth be applied for the estimation of future
O&D tables.

# CHAPTER 4

# TRAFFIC FORECASTS AND BENEFITS

## 4.1 Total Vehicular Traffic Demand

If quality of travel in the future will remain at least at the same level as the present, the amount of trips in the future will depend largely on: a. population growth, b. per capita income growth, and c. income elasticity of demand for transport. In reality, the total demand level will be affected by the level of service or the quality of travel. In the extreme case, no growth can take place where the traffic volume reaches the absolute capacity. In this section the total amount of vehicular trips in the future under no constraints by the supply of transport services is discussed.

Table 4.1.1 and Table 4.1.2 show population and gross Changwat (province) product projections made for the NESDB's BMR Study. Table 4.1.3 shows population and per capita income growth rates for the area covered by this study's internal zones, i.e. BMA, Samut Prakarn, Nonthaburi, and Pathum Thani.

Historical records of traffic counts are hard to come by despite the large number of past counts. Screenline traffic counts were taken at the same locations with an interval of four years, once in 1982 for the feasibility study of the second stage expressway system and again in 1986 for the detailed design of the second stage expressway system. Table 4.1.4 compares the results. Because of the difference in vehicle classification particularly for pickups, figures for pickups were split into the categories of buses and trucks. High growth rates for motorcycles and trucks reflect high sales figures of motorcycles and pickups, which can be considered temporary phenomena. During the period of 1982 to 1986, growth rates of population and per capita income were 3.0% and 2.4% respectively. Income elasticities of traffic for this period can be calculated as 1.5 for cars, 5.2 for motorcycles, 0.6 for buses, and 5.6 for trucks, of which majority are pickups.

People do not make more trips forever as he earns more. The rate of increase in trip making decreases as one's income becomes higher. In other words income elasticity of demand for transport generally decreases at higher income. There is also a tendency of shift from public transport to private transport, from motorcycles to pickups or cars. It is expected that the growth of motorcycle traffic would become sharply lower due to the market saturation in the 1990s. The growth of bus use would decline to the level of population growth. Per capital income elasticities for the future periods were assumed as shown in Table 4.1.5. Elasticity of transport demand with regard to population was assumed to be unity. Applying these elasticities to population and per capita income growth rates, vehicular trip demand growth rates were calculated and the results are shown in Table 4.1.6. Growth rates of truck traffic were determined taking into account the future growth in gross regional products and changes in economic structure. Truck traffic growth was assumed to grow at 2% per annum, much lower than the growth rate of gross regional product, since much of the future economic

Table 4.1.1 Population Projections

| Changwat | 1980 | 1986 | 1991 | 2001 | 2911 | Growth Rate % p.a. 1980-86 | 1986-91 | 1991-01 | 2001-11 |
|---|---|---|---|---|---|---|---|---|---|
| Bangkok | 4852 | 5774 | 6477 | 7850 | 8930 | 2.9 | 2.3 | 1.9 | 1.3 |
| Samut Prakarn | 503 | 625 | 739 | 1002 | 1310 | 3.7 | 3.4 | 3.1 | 2.7[2] |
| Nonthaburi | 383 | 473 | 556 | 782 | 1070 | 3.6 | 3.3 | 3.5 | 3.2 |
| Nakhon Pathom | 545 | 614 | 672 | 796 | 920 | 2.0 | 1.8 | 1.7 | 1.4 |
| Pathum Thani | 332 | 406 | 478 | 681 | 940 | 3.4 | 3.3 | 3.6 | 3.3 |
| Samut Sakorn | 256 | 294 | 331 | 430 | 560 | 2.3 | 2.4 | 2.7 | 2.6 |
| BMR | 6871 | 8185 | 9253 | 11541 | 13730 | 3.0 | 2.5 | 2.2 | 1.8 |
| Thailand | 46718 | 52654 | 57196 | 65138 | 71240 | 2.0 | 1.7 | 1.3 | 0.9 |
| BMR % | 14/7 | 15.5 | 16.2 | 17.7 | 19.3 | - | - | - | - |

Source: "BMR Study Population Working Paper" NESDB Dec. 1985
Stury Team's forecast for 2011

Table 4.1.2 Gross Changwat Product 1976–2011

| | GCP 1972 Prices Baht bill | | | | | | Growth Rate % p.a. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Changwat | 1976 | 1982 | 1986 | 1991 | 2001 | 2011 | 1976 -82 | 1982 -86 | 1986 -91 | 1991 -01 | 2001 -11 |
| Bangkok | 68.0 | 104.4 | 130.2 | 164.5 | 269.1 | 414 | 7.4 | 5.5 | 4.7 | 4.9 | 4.4 |
| Samut Prakarn | - | - | 22.5 | 31.7 | 59.8 | 105 | - | - | 7.1 | 6.6 | 5.8 |
| Nonthaburi | - | - | 2.7 | 3.5 | 5.8 | 9 | - | - | 5.3 | 5.2 | 4.6 |
| Nakhon Pathom | - | - | 5.8 | 7.5 | 12.4 | 19 | - | - | 5.3 | 5.2 | 4.6 |
| Pathum Thani | - | - | 10.3 | 16.4 | 41.0 | 84 | - | - | 9.7 | 9.6 | 7.5 |
| Samut Sakorn | - | - | 3.7 | 5.1 | 9.4 | 16 | - | 0 | 6.6 | 6.3 | 5.5 |
| Total BMR | - | 137.9 | 175.2 | 228.7 | 397.5 | 647 | - | 6.2 | 5.3 | 5.5 | 5.0 |
| Rest of Kingdom | - | 186.1 | 219.7 | 264.0 | 374.7 | 529 | - | 4.2 | 3.7 | 3.6 | 3.5 |
| Thailand | 221.2 | 324.0 | 394.9 | 492.7 | 772.2 | 1176 | 6.6 | 5.1 | 4.5 | 4.6 | 4.3 |
| BMR % | - | 42.6 | 44.4 | 46.4 | 51.5 | 55 | - | - | - | - | - |

Sources: "BMR Economic Activities Projection" Chulalongkorn University/ NESDB Dec. 1985.

Study Team's forecasts for 2011

Table 4.1.3 Study Area Population and per Capita Income Growth Rates

(percent p.a.)

| | 1980-86 | 1986-91 | 1991-01 | 2001-11 |
|---|---|---|---|---|
| Population | 3.0 | 2.5 | 2.2 | 1.6 |
| Per Capita Income | 2.4 | 2.6 | 3.0 | 3.0 |

Source: Tables 4.1.1 and 4.1.2

Table 4.1.4 Screenline Traffic Growth 1982-1986

| 1982 1/ | | | | | 1986 2/ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type | North | East | River | Total | Type | North | East | River | Total | Total Growth Rate |
| Car | 199002 | 98799 | 209203 | 507004 | Car & Taxi | 246154 | 171029 | 240097 | 657280 | 6.7 |
| Motor-cycle | 44513 | 32289 | 102944 | 179846 | Motor-cycle | 89911 | 61693 | 167723 | 319327 | 15.4 |
| Bus | 29056 | 21528 | 27286 | 77870 | Bus & 16% P/U | 29148 | 30071 | 3330 | 92549 | 4.4 |
| Truck | 39502 | 30502 | 52648 | 122652 | Truck & 84% P/U | 73359 | 72839 | 79976 | 226174 | 16.5 |

Source: 1/ Feasibility Study of Second Stage Expressway System in Bangkok
2/ Detailed Design of Second Stage Expressway System in Bangkok

Table 4.1.5 Per Capita Income Elasticity

| Vehicle Type | 1985-1991 | 1991-2001 | 2001-2011 |
|---|---|---|---|
| Motorcycles | 1.7 | 0.5 | 0.1 |
| Cars | 1.0 | 0.9 | 1.1 |
| Taxis | 1.1 | 0.7 | 1.1 |
| Pickups | 1.5 | 1.0 | 1.1 |
| Buses | 0.4 | 0.2 | 0.0 |

Source: Study Team's assumptions

Table 4.1.6 Vehicular Traffic Demand Growth Rates

| Vehicle Type | 1985-91 | 1991-01 | 2001-11 |
|---|---|---|---|
| Motorcycles | 6.9 | 3.7 | 1.9 |
| Cars | 5.1 | 4.9 | 4.9 |
| Taxis | 5.4 | 4.3 | 4.9 |
| Pickups | 6.4 | 5.2 | 4.9 |
| Buses | 3.5 | 2.8 | 4.9 |
| Trucks | 2.0 | 2.0 | 2.0 |

Source: Study Team's estimates

growth is expected to occur in industrial sector and no-cargo-carrying service sector, and cargo of agricultural sector is expected to grow at a rate well lower than the growth of the total economy.

The foregoing discussions should apply to those trips having both ends within the internal zones. For trips having at least one end outside of the internal zones, growth in traffic demand in external zones should be taken into account. After reviewing the growth prospects of traffic demand in external zones and the overwhelming weight of internal zones it was decided to apply the same traffic demand growth rates by vehicle type to traffic having one end in external zones as well.

The total number of trips of each of origin/destination matrices by vehicle type was expanded by using the overall growth rates shown above to determine control totals for each vehicle type for each of the target years.

## 4.2 Unconstrained Future O&D Tables

It was found in this study as explained in Section 3.6 that no relationship between trip demand and travel time could be observed in the present trip pattern in Bangkok. This will most likely not be the case in the future because as traffic congestion in the central area becomes severer and residential settlements farther from the center more people would change their trip pattern to closer destinations. It was not possible however to substantiate this in quantitative manner with the available data. More indepth research is needed to determine such future changes. The following briefly describes the estimation process.

### 4.2.1 Determination of Future Zonal Trip Gration and Attraction

For each of the target future years, zonal socio-economic indicators were estimated as shown in Appendix 3.3.1 to 3.3.4. Zonal trip generation and attraction for future years were estimated by applying the trip generation and attraction model equations and zonal adjustment factors developed in Section 3.6 for internal zones. They were then adjusted pro rata so that their total matched the area-wide totals estimated globally as described in Section 4.1. This process was carried out for each vehicle type and for each target year. For external zones generation and attraction for future years were estimated globally.

### 4.2.2 Determination of Future O&D Tables

The remarkable urban growth of the Bangkok Metropolitan Area has been described in Section 2.2. Growth centers of population and employment have been shifting outward, changing the settlement pattern. Under such circumstances it is not likely that the future trip distribution pattern would merely be an expansion of the existing pattern. However, in the absense of factual evidence to support such changes in pattern as mentioned before, future trip demand between zone i and zone j was estimated by modifying the existing demand between zone i and zone j in proportion to changes in trip generation in zone i and trip attraction in zone j.

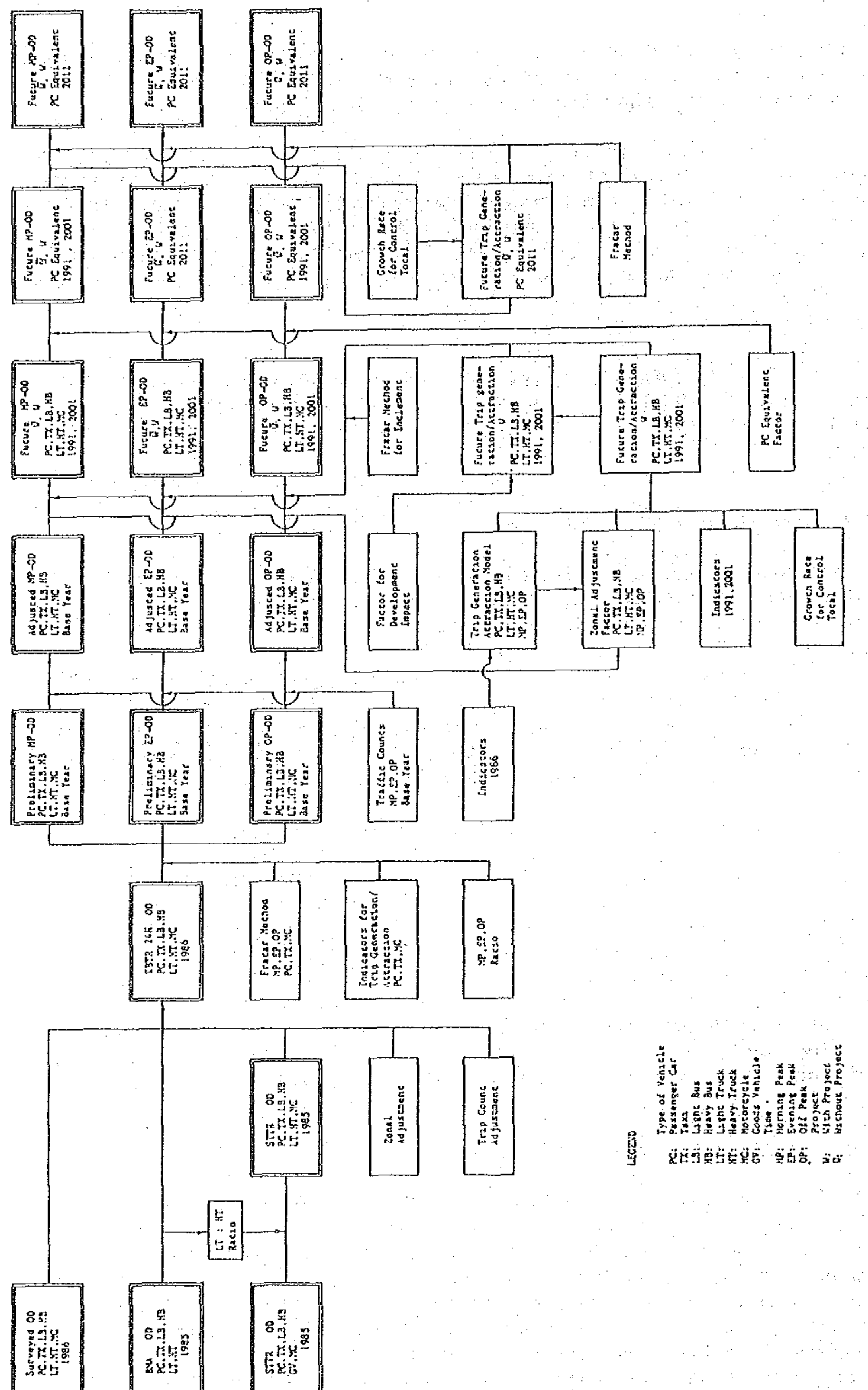



**Fig. 4.2.1 Establishment of Future O&D Tables**

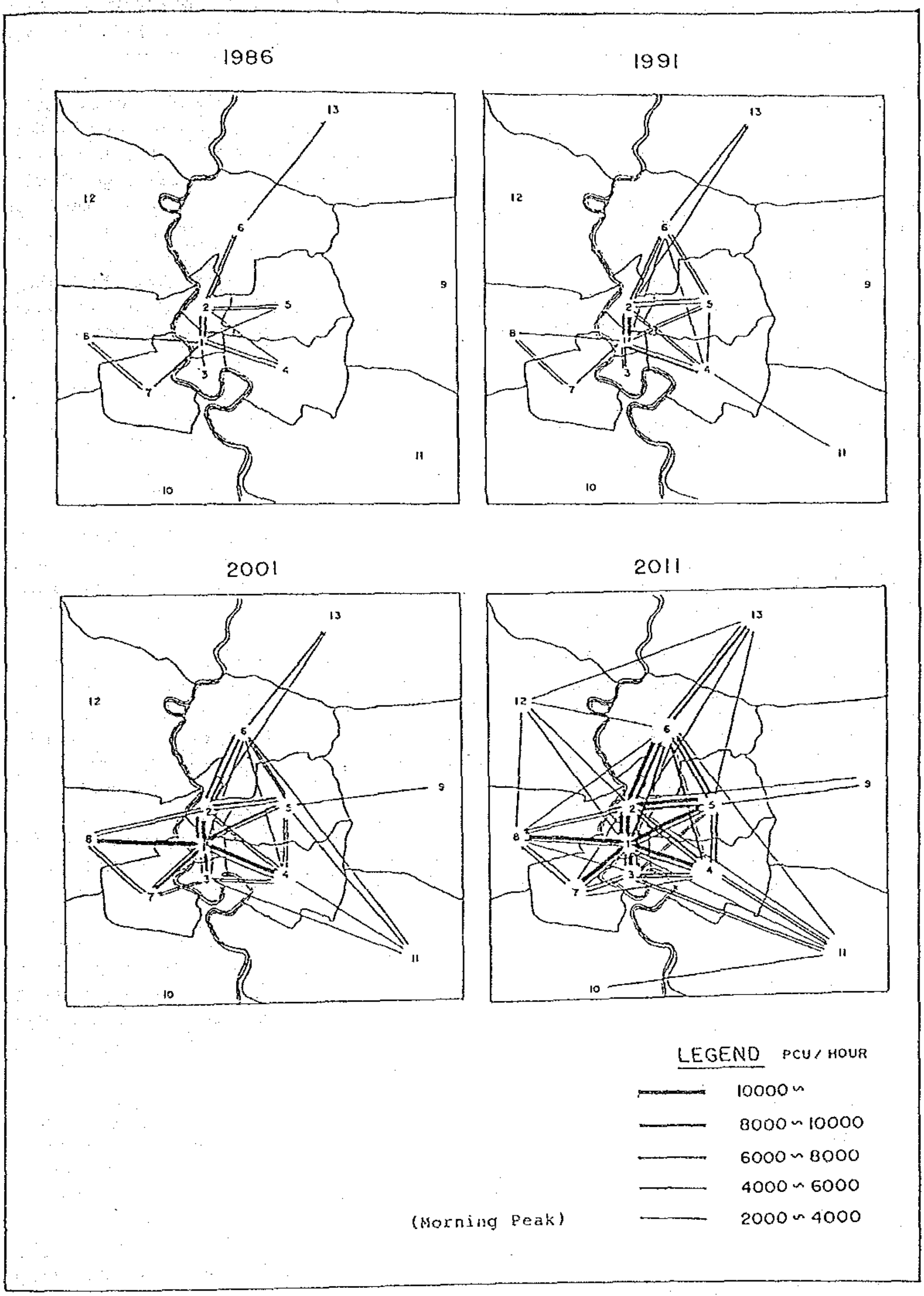



Fig. 4.2.2 Changes in Major Vehicular Movements (Morning Peak)

The above procedures were taken for the three time periods of day for each vehicle type and for each target year. Fig. 4.2.1 illustrates the whole process of determining unconstrained future O&D tables.

Fig. 4.2.2 illustrate changes in major vehicular movements over time by means of the amounts of vehicle movements between zones aggregated for presentation purposes. Existing patterns show a heavy concentration in the central area and no single zone in the outlying area produces significantly high flow for any particular O&D pair. As time goes in the future, some flows to or from outlying zones start to show themselves. Figures for future years show latent demand. Actual traffic will not be like them due to the capacity constraints, particularly in the central area. Present and hourly O&D Tables in unit of passenger car which were compressed into 27 zones from 106 zones are shown in Appendix 4.2.1.

## 4.3 Future Road Network

### 4.3.1 Base Target Year Networks

There are many plans for the improvement of the road network in Bangkok, some firm and others not so firm. For this study future configuration of the road network in Bangkok was assumed taking into account the latest information available.

For the target year of 1991, plans included in the BMA's next five year road development plan, which is under the last stage of preparation, were adopted as additions to the existing network. Those additions are basically the same as shown in STTR with a notable exception of North-South Road through Yannawa. Charoen Sanitwong - Issaraphab Road is not included in the current BMA plan but was added to the 1991 target year network after consultation with BMA officials. The Second Expressway System was assumed to be completed by then up to the Ministry of Finance to the north, to Rajadapisek Road to the east, and including a middle feeder linking with the Pathumwan commercial area.

For the target year of 2001 the road network proposed in the General Plan of Bangkok prepared by the Department of Town and Country Planning was taken except for the southern link of the Outer Ring Road which must include a costly tunnel or a very high bridge and the Third Stage Expressway. The Second Stage Expressway was assumed to be extended to Nonthaburi to the north and Raemkhamheng to the east.

For the target year of 2011 the same network as for 2001 was used for evaluation purposes. It was considered sufficient for the purposes of this study since plans for the year 2011 are uncertain at this moment and the effects of difference in network configuration in terms of present value would be minimal in any case.

Fig. 4.3.1 and Fig. 4.3.2 illustrate future additions to the base network assumed in this study.

Fig. 4.3.1 Base Network for 1991

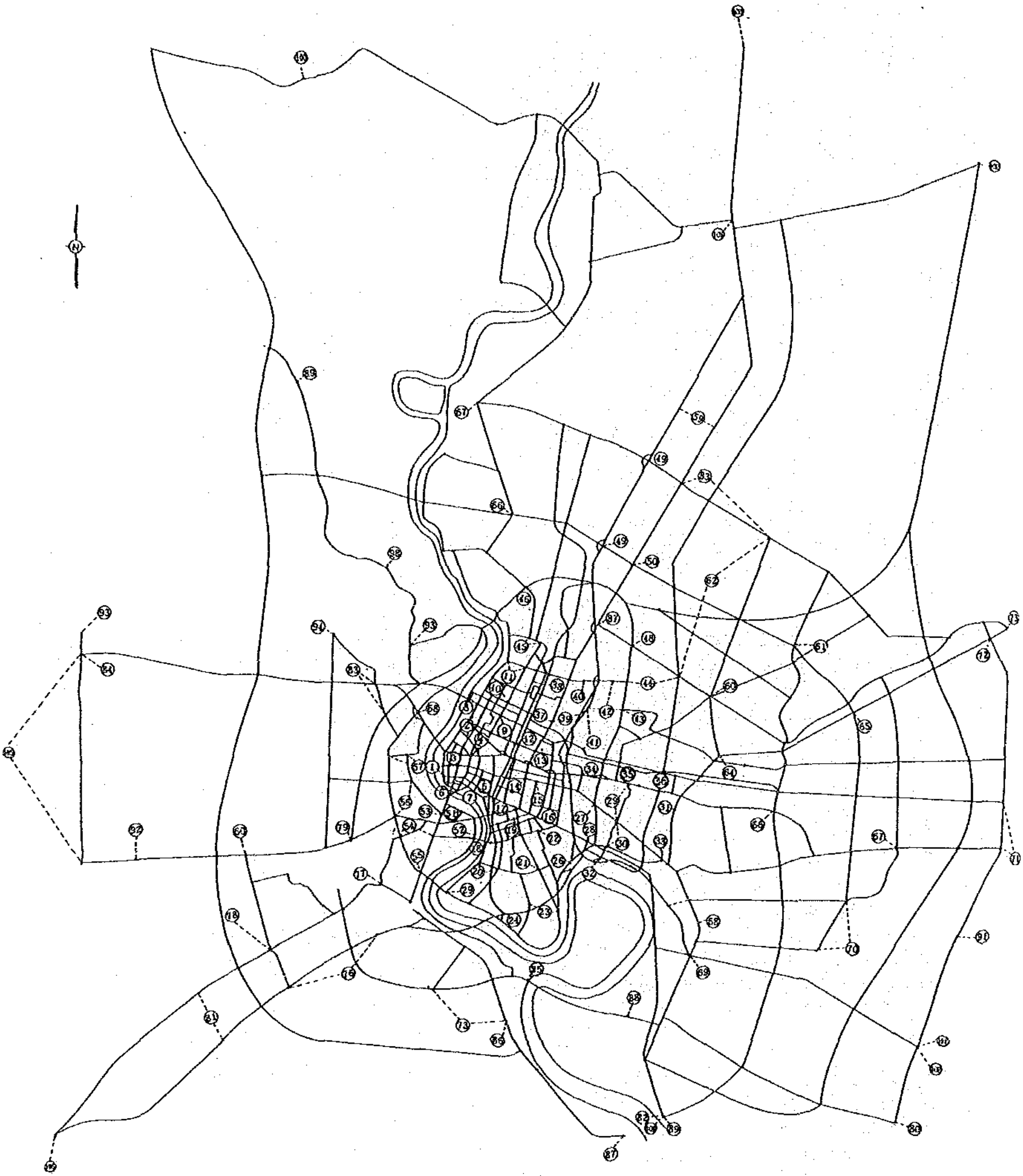


Fig. 4.3.2 Base Network for 2001 and 2011

## 4.4 Effect of New Road

The proposed Thonburi Road Extension will greatly enhance the accessibility of the area served by it, where there is no existing road. In such a case it is very likely that new development would be induced to be located in the immediate vicinity of the new road. The question is to what extent such new development would be induced.

An excellent precedent can be found in the case of the opening of the Bangkok Noi - Nakorn Chaisri Highway. This four lane divided highway was partially opened in December 1981 and completely in May 1984. Its alignment lies largely on where no road previously existed and its position relative to the central area of Bangkok is similar to the Thonburi Road Extension. (See Fig. 4.4.1) A significant amount of new development, particularly new houses, sprung up along its route and vicinity since its opening. After its origin in Khet (district) Bangkok Noi, the highway goes through Khet Taling Chan. Fig. 4.4.2 shows the relative position of the highway against Tambon (subdistrict) boundaries, other roads, and man-made and natural waterways (Khlong) which act as barriers to land transportation. It can be observed that out of 8 Tambons only three are directly accessible to the highway without crossing Khlongs.

In order to make comparison of changes in each Tambon an attempt was made to collect as many Tambon data as possible.

Building permits issued in each year were classified by Tambon from the original records in the Khet office. No conclusive trend could be found probably due to the high degree of market fluctuation. Data population by Tambon were also collected from the Khet office and the results were revealing.

Fig. 4.4.3 shows population of each Tambon in April of every year since 1978. Population of Tambon Taling Chan and Tambon Chim Phli, which have direct access to the new highway, show a sudden jump after the opening, whereas the increases in the remaining Tambons have been modest. Fig. 4.4.4 shows the above changes in population in terms of index with the population in 1978 as 1.0. The uppermost line shows the changes in the combined population of Tambon Taling Chan and Tambon Chim Phli, and the lowermost line shows the changes in the combined population of the remaining six Tambons.

Tambon Taling Chan and Tambon Chim Phli had been growing faster than the rest even before the new highway. Year to year growth rate of the former group had been 2.571 times that of the latter group between the year 1978 and 1983 on an average. If this relationship would have continued after 1983 without the new highway, population of Tambon Taling Chan and Tambon Chim Phli would have growth following the dotted line in Fig. 4.4.4. The difference between the actual changes shown by the uppermost line and the dotted line could be attributable to the effect of the new highway. The ratio of growth indices for the actual and the estimated without-case was 1.121 for 1984 and 1.087 for 1985. The average for the two years was 1.104.

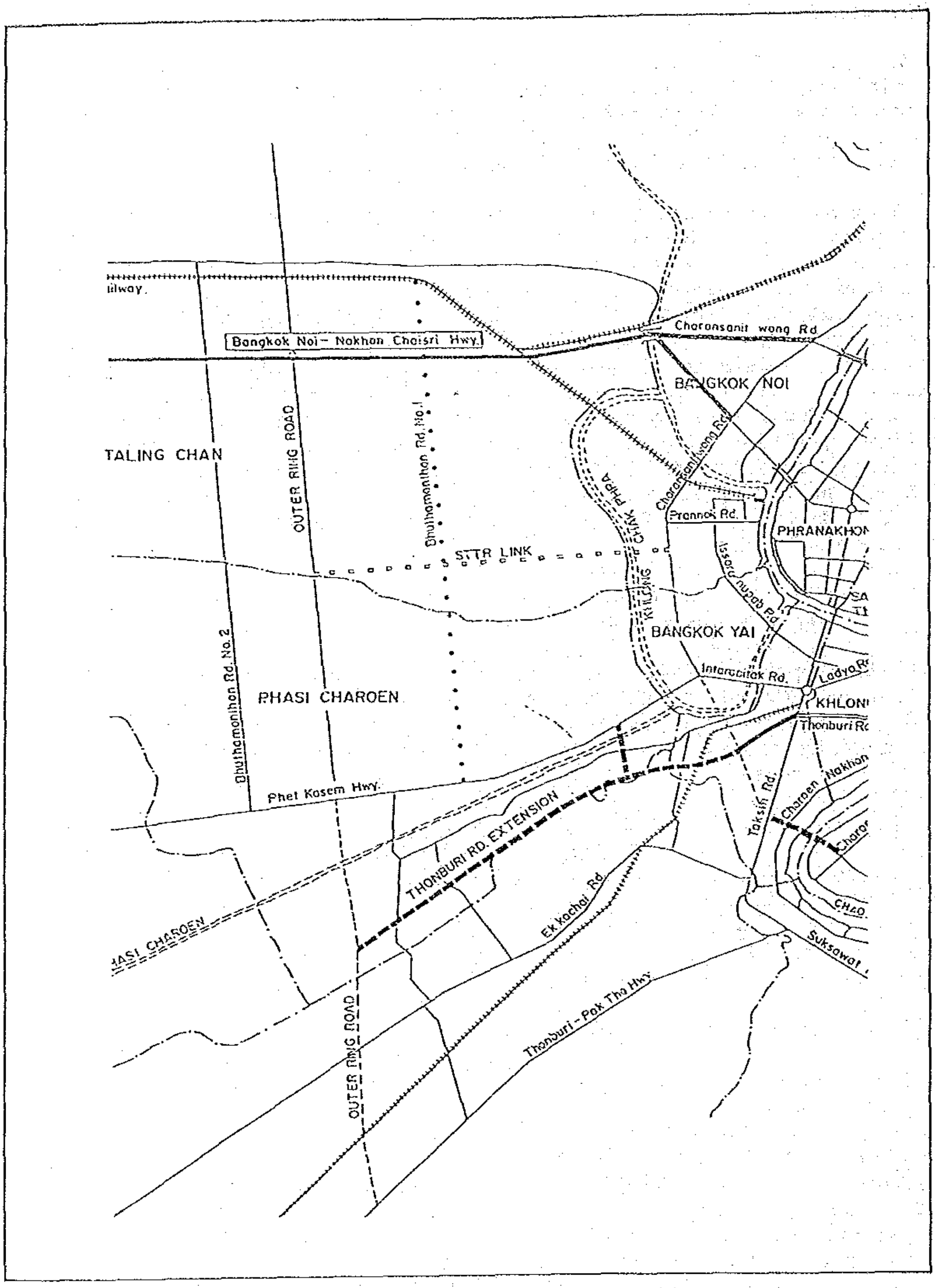



Fig. 4.4.1 Location of Bangkok Noi-Nakhon Chaisri Highway

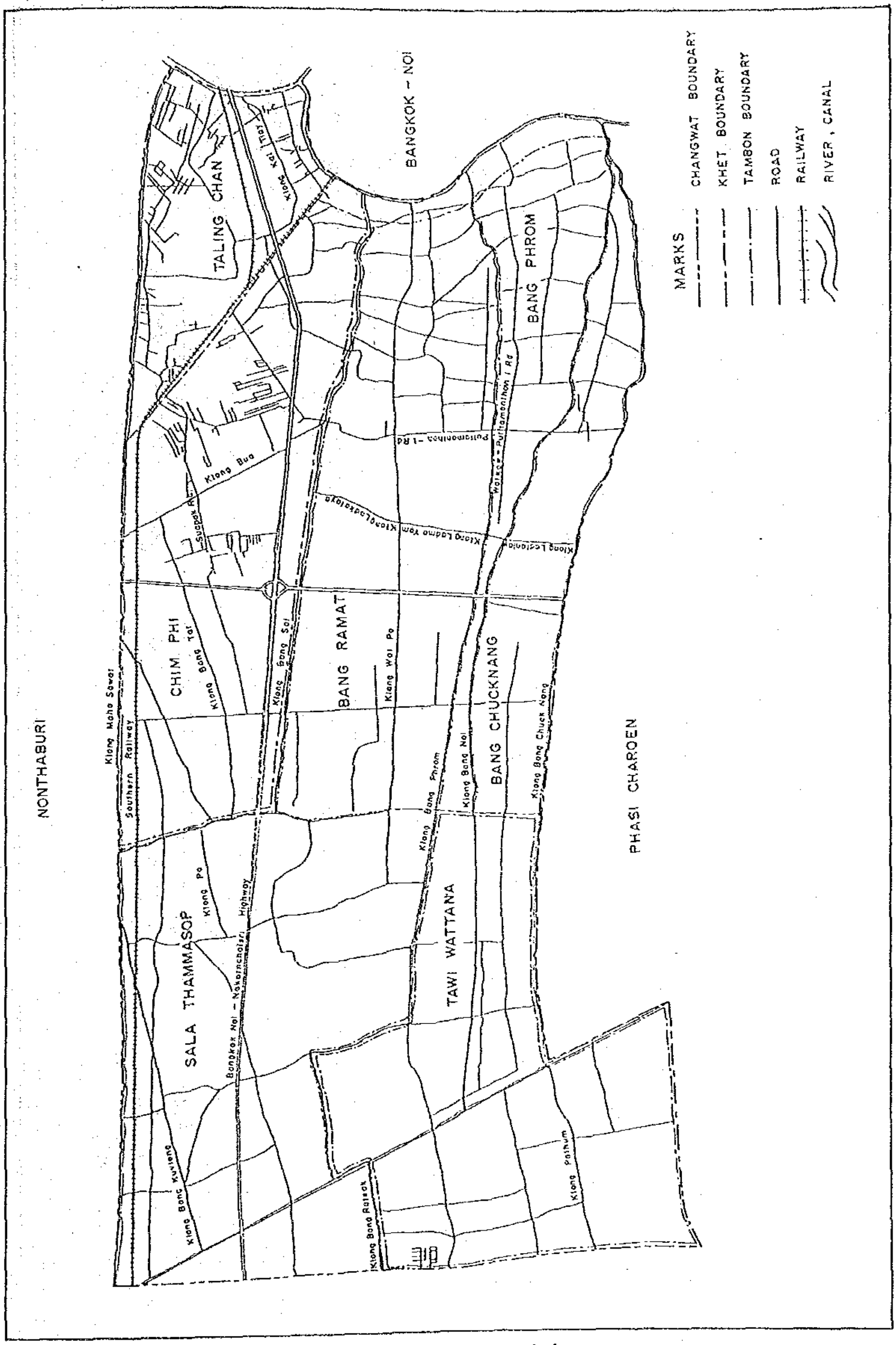



**Fig. 4.4.2 Tambon Boundaries**

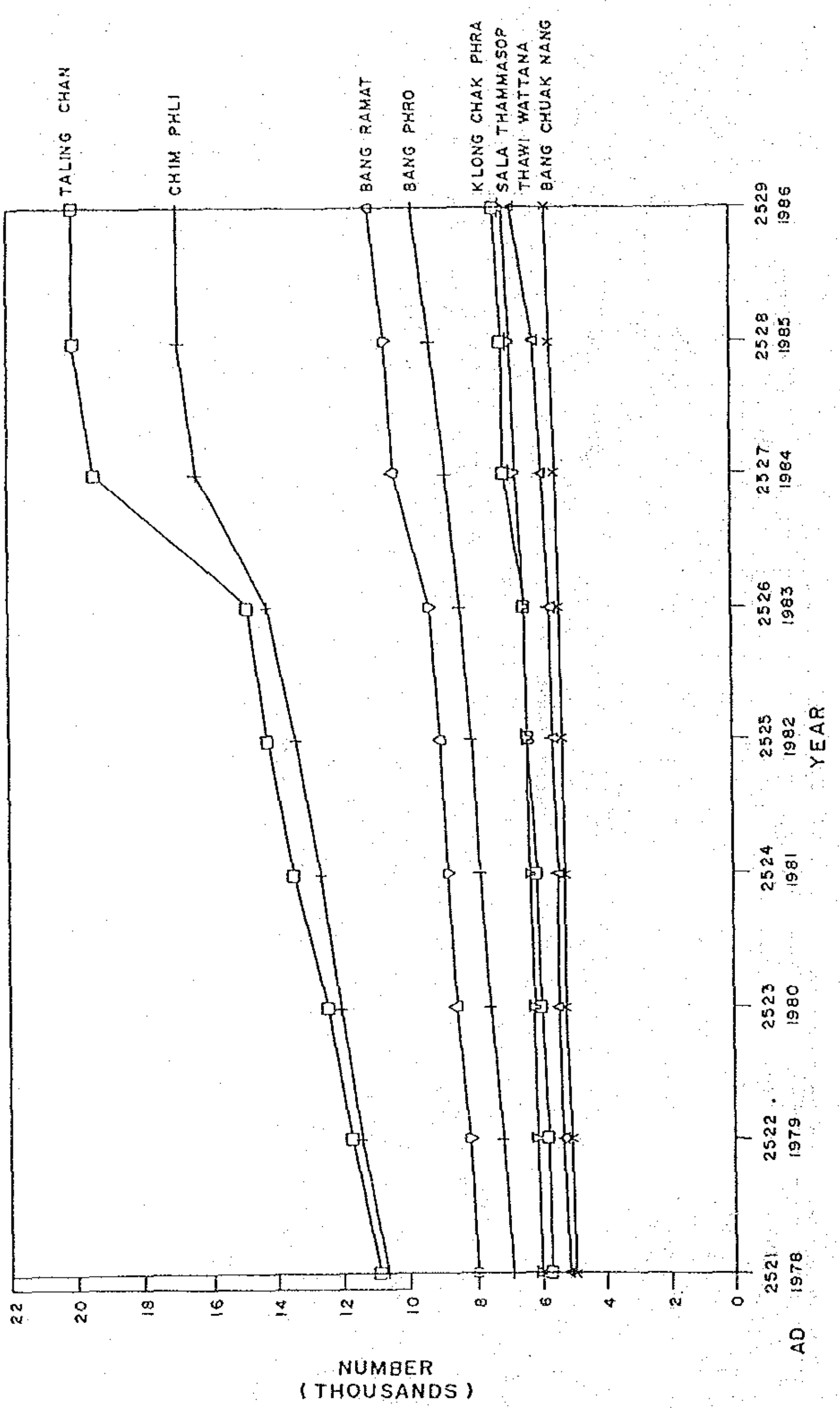



Fig. 4.4.3 Population by Tambon: Khet Taling Chan

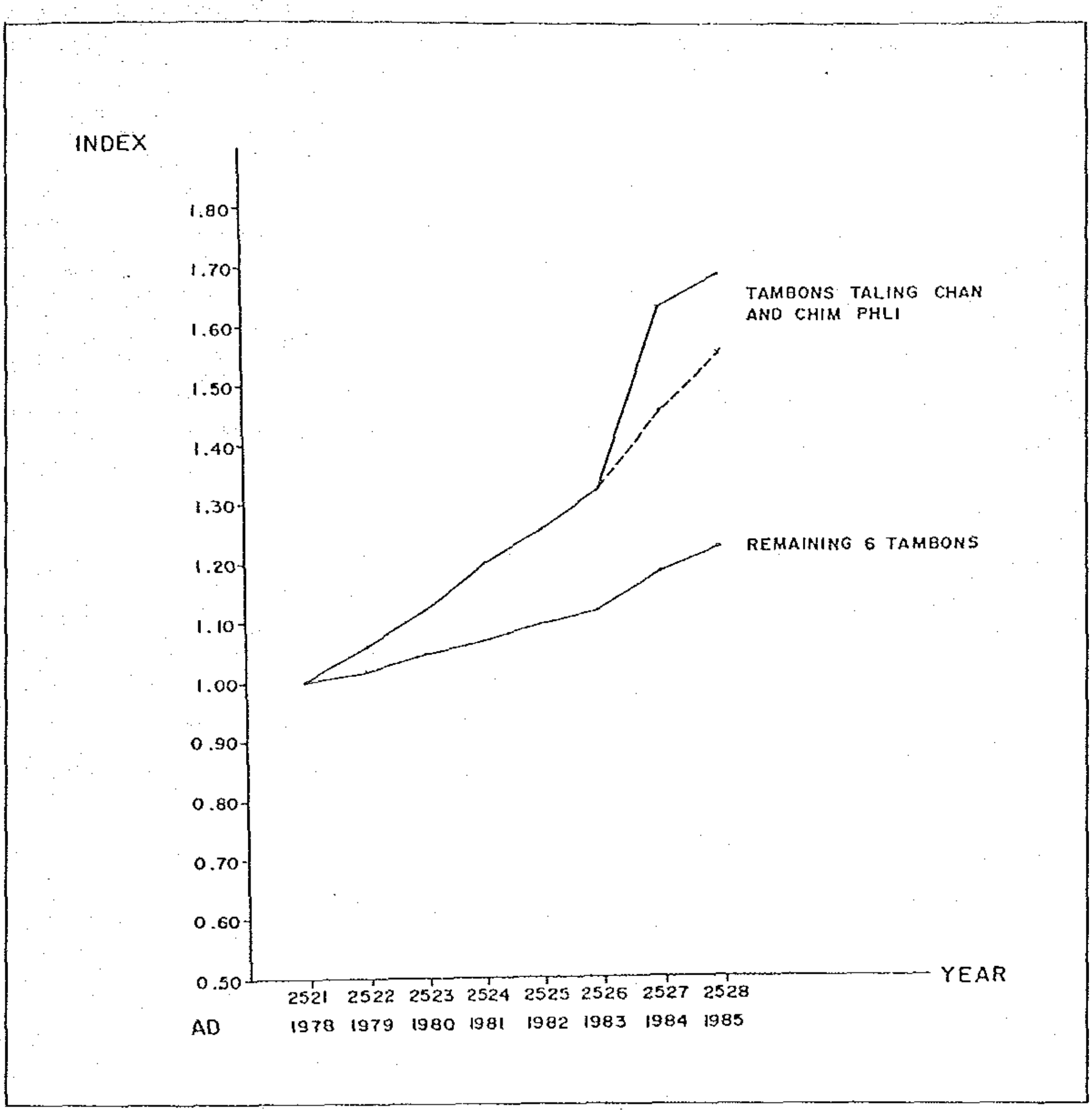



**Fig. 4.4.4 Population Changes in Khet Taling Chan**

It was determined that the proposed new Thonburi Road Extension would induce 10% more population in the immediate vicinity, namely zones 78 and 79, on top of population estimated without such a road.

O&D tables which were prepared taking development effect into consideration, are shown in Appendix 4.2.2 and total numbers of trips are summarized in Tables 4.4.1 through 4.4.3.

Table 4.4.1 Total Number of Trips by Vehicle Type in 1991

(Vehicle)

| Type of Vehicle | Passenger Car Equivalent Factor | Morning Peak Hour | Evening Peak Hour | Off Peak Hour | Daily |
|---|---|---|---|---|---|
| Passenger Car | 1.000 | 123,576(7.5) | 105,728(6.4) | 68,632(4.2) | 1,641,858 |
| Taxi | 0.930 | 41,225(4.2) | 39,946(4.1) | 43,154(4.4) | 974,745 |
| Light Bus | 1.500 | 5,213(6.5) | 4,669(5.8) | 3,320(4.1) | 80,209 |
| Heavy Bus | 2.100 | 7,186(6.4) | 6,538(5.8) | 5,130(4.6) | 111,962 |
| Light Truck | 1.000 | 25,328(3.9) | 30,907(4.8) | 36,182(5.6) | 646,307 |
| Heavy Truck | 2.500 | 1,314(1.7) | 1,707(2.2) | 5,212(6.6) | 78,632 |
| Motorcycle | 0.175 | 81,489(7.1) | 63,016(5.5) | 58,293(5.1) | 1,145,081 |
| Passenger Car Equivalent | - | 228,004(5.8) | 210,133(5.3) | 184,395(4.7) | 3,947,081 |

Note ( ): Hourly percentage

Table 4.4.2 Total Number of Trips by Vehicle Type in 2001

(Vehicle)

| Type of Vehicle | Passenger Car Equivalent Factor | Morning Peak Hour | Evening Peak Hour | Off Peak Hour | Daily |
|---|---|---|---|---|---|
| Passenger Car | 1.000 | 202,043(7.5) | 172,721(6.4) | 112,177(4.2) | 2,683,428 |
| Taxi | 0.930 | 61,759(4.2) | 59,715(4.2) | 64,523(4.1) | 1,457,621 |
| Light Bus | 1.500 | 6,891(6.5) | 6,168(5.8) | 4,399(4.1) | 106,189 |
| Heavy Bus | 2.100 | 9,457(6.4) | 8,623(5.8) | 6,768(4.6) | 147,657 |
| Light Truck | 1.000 | 41,460(3.9) | 50,706(4.8) | 59,349(5.6) | 1,059,989 |
| Heavy Truck | 2.500 | 1,563(1.7) | 2,034(2.2) | 6,231(6.6) | 93,970 |
| Motorcycle | 0.175 | 155,081(7.1) | 88,951(5.5) | 82,298(5.1) | 1,616,268 |
| Passenger Car Equivalent | - | 355,350(5.8) | 327,129(5.4) | 282,721(4.6) | 6,086,140 |

Note ( ): Hourly percentage

Table 4.4.3 Total Number of Trips in Passenger Car Equivalent

(Vehicle)

| Year | Morning Peak Hour | Evening Peak Hour | Off Peak Hour | Daily |
|---|---|---|---|---|
| Base Year | 168,229(6.1) | 155,107(5.6) | 136,969(5.0) | 2,758,939 |
| 1991 | 228,004(5.8) | 210,133(5.3) | 184,395(4.7) | 3,947,081 |
| 2001 | 355,350(5.8) | 327,129(5.4) | 282,721(4.6) | 6,086,140 |
| 2011 | 550,873(5.8) | 507,032(5.3) | 438,191(4.6) | 9,502,441 |

Note ( ): Hourly percentage

## 4.5 Traffic Forecasts

### 4.5.1 Capacity Constraints on Trip Demand in Saturated Network

Future O&D tables developed as described in section 4.2 and modified for cases with the project as described in Section 4.4 were then assigned onto the future networks to obtain future traffic volumes on road links and bridges. For the purpose of the evaluation a simplification was made in that all O&D tables of various vehicle types were converted in terms of passenger car unit (PCU) and then combined into a single O&D table of all vehicles expressed in PCU for each of the target years.

The conventional method of traffic assignment, the last stage of traffic forecasting process, has been to assign the entire amount of trip volumes from origins to destinations onto likely routes while "balancing" the routes in some ways. When the assigned traffic volume on a link reaches its capacity, the travel speed on it is set at the minimum level. However, additional traffic is normally allowed to be assigned on it beyond its capacity as long as the link is selected as a part of a likely route. When the number of links with the problem of absolute capacity is limited and the network as a whole has sufficient excess capacity against the total demand, such procedure may not affect overall picture. However, in Bangkok where the absolute capacity of the road network, particularly in the central area, is in question, such procedure may produce a serious distortion from the reality. No additional traffic can actually go through a link at its capacity. In this study an innovative approach was taken in that excess demand volumes in the unconstrained origin and destination table were taken out of further assignment. The amount of demand volumes which cannot be accommodated by the network was determined O&D pair by O&D pair for future years.

### 4.5.2 Assignment Procedure with Trip Demand Cut-off

The assignment process was done in the following manner.

First the entire O&D matrix was assigned on the subject network on the basis of all or nothing through the minimum paths. The volume/capacity ratios were calculated for each link and the link with the highest ratio was selected and all volumes were divided by the ratio so that traffic on all links did not exceed the capacity. All links with assigned volumes exceeding 98% of their respective capacity were identified and taken out of the network for further assignments. Shortest paths were then redetermined for the loaded network by means of a revised link travel times calculated against assigned traffic volumes. The remainder of the O&D matrix which was taken out after the first iteration was then assigned onto the network piece meal, 2% of the original amount at a time. In every iteration link travel times were recalculated, at-capacity links taken out, shortest paths redetermined, and assignments done through updated shortest paths.

Actual cut-off point for capacity links used in this study was a little more complex than the above in order to best approximate the travel time increases in the neighbourhood of capacity. Fig. 4.5.1 and Fig. 4.5.2 illustrate this.

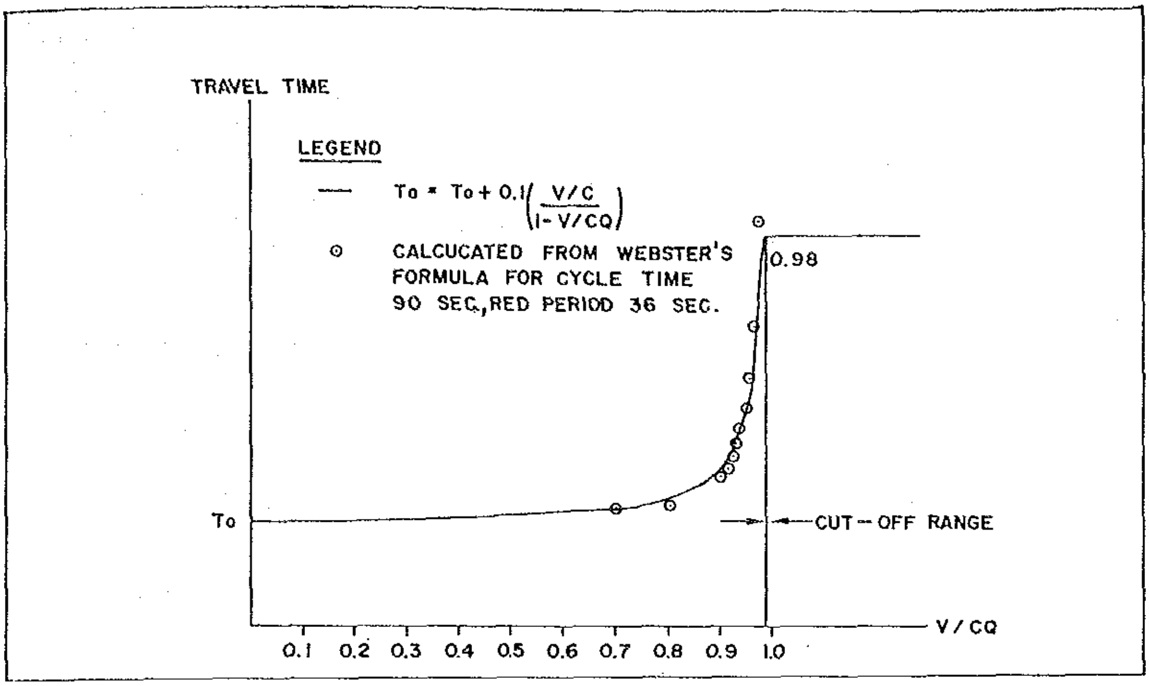



Fig. 4.5.1 Volume Capacity Ratio and Intersection Delay Increase

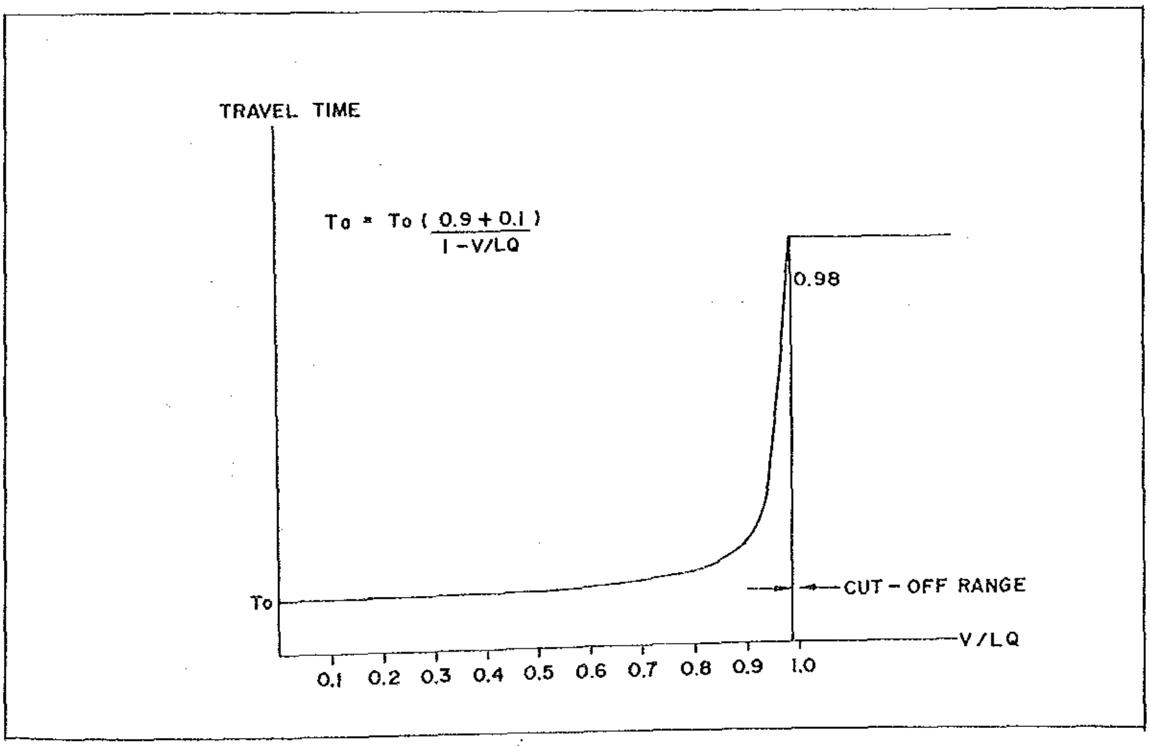



Fig. 4.5.2 Volume Capacity Ratio and Link Delay Increase

After a certain number of iterations two occasions may take place. One is that no path can be found to connect an origin to a destination since all possible paths contain at least one link at capacity. Another is that the latest path found for an O&D pair is unrealistically long. Both occasions indicate a situation in which no additional volume can be assigned for that particular O&D pair. The amount of the yet unassigned O&D volume of the O&D pair is recorded and this particular O&D pair is eliminated from further assignment procedures. The process goes on to the next O&D pair, and so on until entire amount of all O&D pairs is either fully assigned or partially eliminated. The end results are an assigned network with assigned traffic volumes always at or below the actual physical capacity of each link, and a matrix showing amounts of O&D volumes that cannot be assigned.

The length of detour drivers would make to avoid congestion varies depending on the distance. For a short trip one may take a circuitous route several times longer than the absolute shortest path distance, but for a long distance trip one would stop making the trip altogether if the detour is, say, more than 50% longer. Fig. 4.5.3 illustrates the relationship between the absolute shortest route distance and the allowable detour distance increase assumed in this study.

The above method is realistic in that it only constraints trip volumes where there are actual constraints but does not restrict trips that can be made through routes with excess capacity and reasonable length. In Bangkok's case in which future traffic demand to and from the central area is in excess of the combined road capacity, resulting traffic forecasts show that traffic growth would be limited in the central area but be high in the outlying areas.

### 4.5.3 Amount of Suppressed Demand

Table 4.5.1 through 4.5.2 show percentages of unconstrained traffic demand which would be suppressed due to the shortage of capacity by aggregated zones. Thee tables show that almost 100% of traffic demand could be realized in 1991, but 86% to 96% in 2001 and 64% to 77% in 2011 of it would be suppressed. Aggregated zones 1 to 3 would be completely full in 2011. Traffic demand to or from these zones would be suppressed by up to 60%. These figures are for the case with the recommended new Krungthep bridge and Thonburi Road Extension.

Various cases of traffic assignments were carried out since many alternative schemes were examined for the bridge and the new road. Resulting forecast traffic volumes are presented in relevant sections in Part III and Part IV of this report.

Table 4.5.1 Suppressed Traffic Demand by Case

| YEAR | CASE | PERIOD | OD Total (pcu/hr) | Rest OD | % Assign. |
|---|---|---|---|---|---|
| 1991 | Without New Krungthep br. proj. | Morning Peak | 228,004 | 3,551 | 98.44 |
| | Without Thonburi rd. | Off-peak | 184,395 | 185 | 99.90 |
| | With High New Krungthep br. | Morning Peak | 228,004 | 3,486 | 98.47 |
| | Without Thonburi rd. | Off-peak | 184,395 | 143 | 99.92 |
| | With High New Krungthep br. | Morning Peak | 227,990 | 2,244 | 99.02 |
| | With Thonburi rd. (short) | Off-peak | 184,398 | 24 | 99.99 |
| | With High New Krungthep br. | Morning Peak | 227,990 | 2,265 | 99.01 |
| | With Thonburi rd. (long) | Off-peak | 184,398 | 24 | 99.99 |
| 2001 | Without New Krungthep br. proj. | Morning Peak | 355,350 | 50,426 | 85.81 |
| | Without Thonburi rd. | Off-peak | 282,721 | 15,125 | 94.65 |
| | With High New Krungthep br. | Morning Peak | 355,350 | 50,319 | 85.84 |
| | Without Thonburi rd. | Off-peak | 282,721 | 14,871 | 94.74 |
| | With High New Krungthep br. | Morning Peak | 355,363 | 46,848 | 86.82 |
| | With Thonburi rd. (short) | Off-peak | 282,692 | 12,940 | 95.42 |
| | With High New Krungthep br. | Morning Peak | 355,363 | 46,316 | 86.97 |
| | With Thonburi rd. (long) | Off-peak | 282,692 | 12,936 | 95.42 |
| | With High New Krungthep br. | Morning Peak | 355,363 | 45,087 | 87.31 |
| | With Thonburi rd to RAMA IV br. | Off-peak | 282,692 | 11,884 | 95.80 |
| 2011 | Without New Krungthep br. proj. | Morning Peak | 550,873 | 196,002 | 64.42 |
| | Without Thonburi rd. | Off-peak | 438,191 | 109,613 | 74.99 |
| | With High New Krungthep br. | Morning Peak | 550,873 | 194,758 | 64.65 |
| | Without Thonburi rd. | Off-peak | 438,191 | 108,890 | 75.15 |
| | With High New Krungthep br. | Morning Peak | 550,905 | 188,325 | 65.58 |
| | With Thonburi rd. (long) | Off-peak | 438,126 | 104,754 | 76.09 |
| | With High New Krungthep br. | Morning Peak | 550,905 | 185,872 | 66.26 |
| | With Thonburi rd. to RAMA VI br. | Off-peak | 438,126 | 101,024 | 76.094 |

## Table 4.5.2 Percentage of Suppressed Traffic Demand by Aggregated Zones

With Thonburi Road Extension and New Krungthep Bridge: Morning Peak Hour in 1991

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 95 | 100 | 100 | 100 | 100 |
| 2 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 95 | 100 | 100 | 100 | 100 |
| 3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 91 | 93 | 100 | 100 | 100 |
| 4 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 |
| 5 | 100 | 100 | 95 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 92 | 93 | 100 | 100 | 100 |
| 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 0 |
| 7 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 92 | 91 | 100 | 100 | 100 |
| 8 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 97 | 97 | 96 | 100 | 100 | 100 | 100 |
| 9 | 90 | 93 | 96 | 94 | 94 | 93 | 96 | 84 | 93 | 97 | 94 | 91 | 57 | 90 | 82 | 95 | 89 | 93 | 91 | 94 | 96 | 95 | 94 | 94 | 93 | 92 | 91 |
| 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 74 | 85 | 100 | 100 | 0 |
| 11 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 100 | 0 | 100 | 100 | 100 | 88 | 91 | 100 | 100 | 100 |
| 12 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 92 | 94 | 100 | 100 | 100 |
| 13 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 | 0 | 100 | 100 | 0 | 0 | 100 | 96 | 100 | 0 | 0 |
| 14 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 15 | 97 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 16 | 94 | 92 | 97 | 100 | 100 | 100 | 100 | 96 | 97 | 100 | 98 | 100 | 0 | 100 | 99 | 100 | 90 | 93 | 100 | 100 | 91 | 97 | 0 | 86 | 100 | 100 | 100 |
| 17 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 | 100 | 100 | 100 | 100 |
| 18 | 97 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 |
| 19 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 20 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 |
| 21 | 100 | 98 | 100 | 100 | 100 | 97 | 98 | 98 | 100 | 100 | 100 | 0 | 83 | 100 | 95 | 95 | 100 | 100 | 100 | 100 | 95 | 99 | 100 | 100 | 0 | 0 | 100 |
| 22 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 0 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 23 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 24 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 |
| 25 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 | 100 | 0 | 100 | 100 |
| 26 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 |
| 27 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 |

With Thonburi Road Extension and New Krungthep Bridge: Morning Peak Hour in 2001

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 93 | 87 | 98 | 92 | 79 | 100 | 87 | 100 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 86 | 98 | 100 | 65 | 67 | 100 | 100 | 100 |
| 2 | 70 | 90 | 88 | 92 | 79 | 98 | 86 | 82 | 88 | 99 | 98 | 97 | 99 | 90 | 92 | 87 | 96 | 94 | 84 | 96 | 96 | 97 | 74 | 86 | 99 | 94 | 100 |
| 3 | 66 | 90 | 87 | 86 | 77 | 92 | 90 | 88 | 83 | 98 | 92 | 80 | 95 | 94 | 92 | 94 | 98 | 100 | 88 | 77 | 86 | 95 | 64 | 79 | 98 | 93 | 85 |
| 4 | 68 | 95 | 94 | 94 | 77 | 100 | 92 | 100 | 95 | 100 | 100 | 78 | 100 | 100 | 99 | 100 | 100 | 100 | 100 | 84 | 100 | 99 | 0 | 67 | 99 | 100 | 100 |
| 5 | 67 | 90 | 74 | 87 | 97 | 100 | 98 | 92 | 86 | 100 | 100 | 100 | 100 | 94 | 92 | 89 | 96 | 100 | 100 | 100 | 88 | 98 | 64 | 64 | 100 | 93 | 100 |
| 6 | 65 | 77 | 80 | 79 | 81 | 98 | 91 | 79 | 75 | 97 | 95 | 91 | 100 | 80 | 79 | 82 | 86 | 86 | 81 | 91 | 81 | 81 | 0 | 50 | 92 | 78 | 0 |
| 7 | 66 | 86 | 81 | 80 | 81 | 99 | 87 | 77 | 83 | 100 | 95 | 100 | 100 | 82 | 81 | 83 | 100 | 83 | 100 | 100 | 87 | 84 | 72 | 64 | 100 | 83 | 100 |
| 8 | 68 | 83 | 94 | 90 | 77 | 100 | 89 | 100 | 95 | 100 | 100 | 80 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 80 | 100 | 87 | 78 | 77 | 100 | 100 | 100 |
| 9 | 58 | 65 | 70 | 82 | 66 | 68 | 68 | 67 | 90 | 68 | 68 | 61 | 70 | 100 | 100 | 100 | 100 | 100 | 100 | 80 | 98 | 73 | 68 | 78 | 80 | 100 | 100 |
| 10 | 65 | 90 | 82 | 80 | 79 | 100 | 99 | 81 | 100 | 100 | 100 | 100 | 100 | 92 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 55 | 60 | 100 | 100 | 0 |
| 11 | 64 | 80 | 77 | 76 | 84 | 100 | 95 | 76 | 78 | 100 | 95 | 97 | 100 | 86 | 82 | 79 | 86 | 80 | 0 | 90 | 86 | 83 | 66 | 64 | 100 | 100 | 100 |
| 12 | 67 | 79 | 81 | 85 | 83 | 100 | 95 | 83 | 79 | 100 | 100 | 100 | 100 | 86 | 86 | 86 | 91 | 86 | 87 | 100 | 78 | 86 | 64 | 68 | 100 | 92 | 87 |
| 13 | 60 | 62 | 88 | 100 | 79 | 100 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 83 | 100 | 0 | 0 | 0 | 75 | 100 | 0 | 0 | 100 | 69 | 100 | 0 | 0 |
| 14 | 68 | 86 | 100 | 89 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 81 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 79 | 100 | 100 | 100 | 91 | 100 | 100 | 100 |
| 15 | 68 | 92 | 99 | 89 | 77 | 100 | 98 | 100 | 100 | 100 | 100 | 81 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 80 | 100 | 100 | 96 | 80 | 100 | 100 | 100 |
| 16 | 63 | 72 | 97 | 92 | 76 | 100 | 100 | 98 | 98 | 100 | 91 | 81 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 87 | 87 | 95 | 0 | 92 | 100 | 100 | 100 |
| 17 | 68 | 90 | 100 | 87 | 81 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 78 | 100 | 0 | 0 | 100 | 100 | 100 | 100 |
| 18 | 67 | 75 | 92 | 98 | 74 | 100 | 88 | 100 | 100 | 100 | 100 | 83 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 81 | 100 | 0 | 98 | 95 | 100 | 100 | 100 |
| 19 | 68 | 96 | 100 | 82 | 86 | 100 | 100 | 100 | 100 | 100 | 0 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 81 | 100 | 100 | 89 | 100 | 100 | 100 | 100 |
| 20 | 68 | 83 | 80 | 85 | 85 | 100 | 98 | 87 | 85 | 100 | 100 | 100 | 100 | 86 | 86 | 87 | 90 | 100 | 87 | 100 | 95 | 92 | 88 | 93 | 100 | 0 | 86 |
| 21 | 64 | 69 | 74 | 67 | 68 | 68 | 83 | 58 | 96 | 100 | 89 | 0 | 100 | 100 | 97 | 94 | 100 | 100 | 91 | 100 | 96 | 100 | 90 | 88 | 0 | 0 | 100 |
| 22 | 65 | 93 | 82 | 71 | 77 | 100 | 97 | 79 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 0 | 0 | 100 | 100 | 97 | 100 | 92 | 88 | 100 | 100 | 100 |
| 23 | 68 | 97 | 93 | 80 | 83 | 100 | 100 | 98 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 0 | 100 | 100 | 100 | 100 | 100 | 85 | 75 | 100 | 100 | 100 |
| 24 | 68 | 94 | 85 | 82 | 85 | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 |
| 25 | 68 | 95 | 88 | 0 | 82 | 100 | 100 | 86 | 85 | 100 | 100 | 100 | 100 | 92 | 100 | 86 | 83 | 0 | 86 | 100 | 0 | 100 | 93 | 89 | 0 | 100 | 86 |
| 26 | 68 | 75 | 89 | 87 | 75 | 74 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 82 | 97 | 100 | 99 | 97 | 100 | 0 | 0 |
| 27 | 59 | 100 | 100 | 82 | 86 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 0 | 100 | 81 | 100 | 100 | 96 | 100 | 100 | 0 | 0 |

With Thonburi Road Extension and New Krungthep Bridge: Morning Peak Hour in 2011

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 85 | 73 | 83 | 75 | 52 | 79 | 67 | 97 | 85 | 100 | 80 | 75 | 79 | 100 | 99 | 100 | 100 | 100 | 100 | 56 | 76 | 86 | 43 | 43 | 86 | 100 | 100 |
| 2 | 46 | 73 | 67 | 65 | 52 | 75 | 62 | 56 | 68 | 98 | 79 | 74 | 82 | 64 | 69 | 60 | 79 | 80 | 61 | 66 | 77 | 81 | 45 | 59 | 54 | 78 | 82 |
| 3 | 44 | 59 | 67 | 68 | 49 | 67 | 64 | 65 | 55 | 70 | 64 | 53 | 64 | 82 | 71 | 83 | 90 | 85 | 67 | 49 | 64 | 60 | 42 | 50 | 69 | 78 | 63 |
| 4 | 45 | 63 | 58 | 82 | 49 | 68 | 64 | 85 | 68 | 73 | 70 | 49 | 59 | 94 | 92 | 96 | 91 | 98 | 84 | 54 | 93 | 71 | 0 | 40 | 72 | 100 | 100 |
| 5 | 45 | 64 | 50 | 65 | 92 | 100 | 85 | 74 | 59 | 100 | 100 | 94 | 100 | 76 | 78 | 75 | 79 | 71 | 80 | 83 | 69 | 80 | 42 | 41 | 94 | 77 | 70 |
| 6 | 44 | 46 | 48 | 48 | 59 | 93 | 76 | 48 | 47 | 92 | 87 | 79 | 100 | 47 | 47 | 47 | 58 | 46 | 50 | 64 | 48 | 51 | 0 | 33 | 84 | 49 | 0 |
| 7 | 44 | 60 | 50 | 50 | 55 | 88 | 58 | 48 | 51 | 100 | 80 | 90 | 89 | 53 | 49 | 48 | 50 | 51 | 50 | 82 | 56 | 56 | 48 | 42 | 94 | 52 | 83 |
| 8 | 46 | 54 | 61 | 73 | 49 | 73 | 69 | 93 | 76 | 72 | 74 | 53 | 73 | 100 | 98 | 97 | 100 | 100 | 100 | 53 | 90 | 57 | 52 | 54 | 74 | 100 | 100 |
| 9 | 36 | 42 | 46 | 55 | 41 | 44 | 44 | 63 | 68 | 64 | 44 | 38 | 46 | 69 | 66 | 88 | 74 | 99 | 66 | 52 | 77 | 47 | 44 | 52 | 51 | 100 | 91 |
| 10 | 43 | 66 | 52 | 52 | 52 | 84 | 81 | 49 | 76 | 100 | 100 | 100 | 100 | 60 | 68 | 68 | 79 | 81 | 62 | 65 | 72 | 80 | 34 | 38 | 94 | 79 | 0 |
| 11 | 43 | 49 | 45 | 47 | 55 | 66 | 59 | 48 | 44 | 98 | 67 | 64 | 96 | 57 | 54 | 47 | 58 | 49 | 0 | 54 | 50 | 53 | 46 | 42 | 89 | 77 | 50 |
| 12 | 45 | 50 | 52 | 57 | 59 | 100 | 92 | 53 | 50 | 100 | 98 | 95 | 100 | 58 | 58 | 58 | 57 | 58 | 60 | 90 | 50 | 63 | 42 | 45 | 94 | 64 | 58 |
| 13 | 47 | 49 | 48 | 67 | 53 | 100 | 97 | 67 | 77 | 100 | 100 | 100 | 100 | 63 | 67 | 0 | 0 | 0 | 60 | 97 | 0 | 0 | 0 | 45 | 89 | 0 | 0 |
| 14 | 46 | 57 | 56 | 72 | 60 | 74 | 74 | 94 | 100 | 86 | 74 | 53 | 74 | 100 | 100 | 100 | 100 | 100 | 100 | 51 | 100 | 88 | 67 | 63 | 74 | 100 | 100 |
| 15 | 46 | 64 | 61 | 71 | 49 | 73 | 72 | 90 | 100 | 83 | 74 | 53 | 67 | 100 | 100 | 100 | 100 | 100 | 100 | 52 | 100 | 100 | 64 | 57 | 75 | 100 | 100 |
| 16 | 42 | 47 | 63 | 72 | 47 | 67 | 67 | 69 | 90 | 76 | 63 | 53 | 0 | 100 | 84 | 100 | 67 | 100 | 100 | 60 | 60 | 76 | 0 | 63 | 75 | 100 | 100 |
| 17 | 46 | 66 | 64 | 67 | 54 | 74 | 67 | 90 | 98 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 58 | 88 | 0 | 0 | 100 | 74 | 100 | 100 |
| 18 | 45 | 53 | 64 | 94 | 48 | 67 | 70 | 85 | 100 | 100 | 81 | 54 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 53 | 100 | 0 | 84 | 64 | 67 | 100 | 100 |
| 19 | 47 | 65 | 66 | 55 | 63 | 67 | 76 | 89 | 84 | 100 | 0 | 62 | 71 | 100 | 100 | 100 | 100 | 100 | 100 | 54 | 87 | 79 | 59 | 67 | 76 | 100 | 100 |
| 20 | 46 | 56 | 53 | 56 | 62 | 100 | 95 | 55 | 58 | 100 | 97 | 100 | 100 | 58 | 58 | 58 | 50 | 67 | 59 | 95 | 65 | 78 | 61 | 61 | 93 | 0 | 58 |
| 21 | 38 | 42 | 43 | 38 | 40 | 39 | 53 | 36 | 39 | 65 | 54 | 0 | 70 | 50 | 38 | 38 | 56 | 65 | 70 | 67 | 65 | 77 | 61 | 60 | 0 | 0 | 70 |
| 22 | 43 | 80 | 55 | 56 | 45 | 79 | 75 | 49 | 91 | 88 | 85 | 82 | 0 | 77 | 66 | 72 | 0 | 0 | 96 | 72 | 73 | 88 | 68 | 60 | 93 | 100 | 100 |
| 23 | 46 | 79 | 63 | 54 | 54 | 71 | 76 | 72 | 74 | 64 | 81 | 69 | 66 | 100 | 100 | 0 | 0 | 83 | 64 | 73 | 88 | 83 | 68 | 60 | 94 | 88 | 100 |
| 24 | 46 | 66 | 61 | 54 | 57 | 66 | 65 | 66 | 83 | 66 | 66 | 67 | 66 | 67 | 92 | 100 | 100 | 100 | 69 | 71 | 94 | 80 | 79 | 0 | 94 | 100 | 100 |
| 25 | 46 | 60 | 57 | 0 | 56 | 100 | 65 | 59 | 57 | 100 | 100 | 100 | 100 | 61 | 67 | 60 | 58 | 0 | 58 | 100 | 0 | 67 | 75 | 59 | 0 | 82 | 58 |
| 26 | 46 | 53 | 60 | 65 | 47 | 52 | 67 | 86 | 100 | 100 | 100 | 100 | 89 | 100 | 100 | 100 | 100 | 100 | 100 | 53 | 65 | 100 | 86 | 64 | 83 | 0 | 0 |
| 27 | 41 | 62 | 69 | 55 | 58 | 71 | 80 | 89 | 100 | 0 | 67 | 67 | 0 | 100 | 100 | 100 | 100 | 0 | 100 | 53 | 100 | 100 | 64 | 67 | 67 | 0 | 0 |

Note : "0" = No Trip Demand

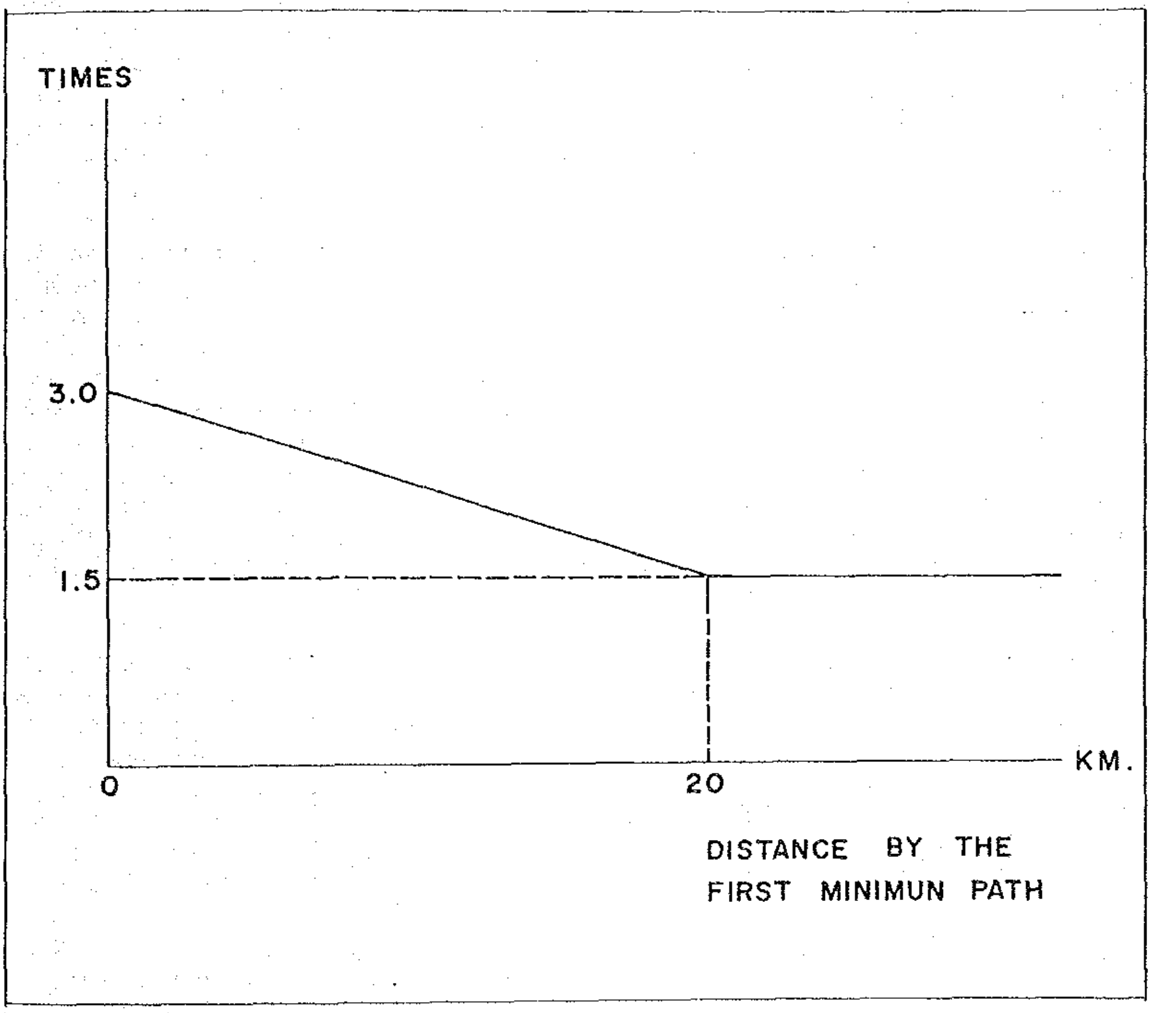



Fig. 4.5.3 Maximum Allowable Detour