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THE KINGDOM OF THAILAND

BANGKOK METROPOLITAN ADMINISTRATION

STUDY ON ROAD IMPROVEMENT, REHABILITATION AND TRAFFIC SAFETY IN BANGKOK

FINAL REPORT

VOLUME I INTRODUCTION TRAFFIC SURVEY

MARCH 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF ABBREVIATIONS

BMA	Bangkok Metropolitan Administration
CPD	City Planning Division, BMA
CMD	Construction and Maintenance Division, BMA
DD	Design Division, BMA
PPD	Policy and Planning Division, BMA
PPSd	Public Works Planning Sub-division, BMA
DPW	Department of Public Works, BMA
DDS	Department of Drainage and Sewerage, BMA
TED	Traffic Engineering Division, BMA
MOI	Ministry of Interior
OARD	Office of Accelerated Rural Development, MOI
OCMRT	Office of the Committee for the Management Road Traffic, MOI
OPP	Office of Policy and Planning, MOI
PWD	Public Works Department, MOI
TCPD	Town and Country Planning Department, MOI
TPD	Traffic Police Division, MOI
LDPD	License Division of Police Department, MOI
MOC	Ministry of Communications
DOH	Department of Highways, MOC
DLT	Department of Land Transport, MOC
ETA	Expressway and Rapid Transit Authority of Thailand
NESDB	National Economic and Social Development Board
SRT	State Railway of Thailand
MEA	Metropolitan Electricity Authority
AIT	Asia Institute of Technology
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
BS	British Standards
CAB	Cable Box
CBD	Central Business District
HCM	Highway Capacity Manual
MCI	Maintenance Control Index
MSL	Mean Sea Level
MTS	Mass Transit System
NECO	National Executive Council Order
PCU	Passenger Car Unit
PSI	Present Serviceablility Index
RAL	Richtlinien für die Anlage von Landstraßen
SSES	Second Stage Expressway System
STTR	Short Term Urban Transport Review

INTRODUCTION

1. INTRODUCTION

The Final Report of the Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok presents all the findings of this study which is composed of eight (8) volumes as the following:

- Summary
- Vol. I Introduction & Traffic Survey
- Vol. II Road Improvement
- Vol. III Pavement Rehabilitation
- Vol. IV Traffic Safety
- Vol. V Road Inventory, Review on Road Organization of BMA & Other Studies
- Vol. VI Technical Guideline
- Vol. VII Drawings

1.1 Background

The Bangkok Metropolitan Area covers an area of some 1,600 km^2 and has a population of approximately 6 million, about 12% of the total population of the country. With regard to GNP, the Metropolitan Area accounts for some 40% of the nation's total production. As is obvious from these figures, the Bangkok Metropolitan Area is the center of Thailand's social and economic activities with the cultural and educational facilities concentrated in the region.

As the basic transport facilities to support these activities, there are railways, waterways and roads. The roles of the railways and waterways have become less important since the greater part of passenger and freight traffic is carried by roads. For this reason, in the Metropolitan Area, some one million vehicles are concentrated out of the nation's total of about 2.5 million (including motorcycles).

Meanwhile, the road facilities are being gradually improved through the efforts by the people concerned, but they are not sufficient for the rapidly increasing traffic volume. In almost the whole Metropolitan Area, traffic congestion and accidents are occurring with increasing frequency. To cope with the growing traffic problems, it is necessary to promote large-scale road projects based on a long-term perspective. However, since these projects require a vast amount of investment and long periods of time, it is required, in parallel with large-scale projects, to make full use of the existing road system to ensure smooth and safe traffic.

Since a large portion of road network in Bangkok has developed somewhat to substandard, the traffic congestions in the area are expected, to a certain degree, to ameliorate when relatively moderate improvement works are executed on the existing roads. Therefore, the Bangkok Metropolitan Administration (BMA) responsible for the management of the majority of the road system in Bangkok is contemplating to embark on various road projects based on properly prepared plans in road improvement, pavement rehabilitation and traffic safety measures on the major roads under its jurisdiction. These plans, however, are able to be worked out with support of sound means such as road rating system, road data collection and their analyses, and technical standards as well as administrative experiences, whereas BMA has relatively less experiences in these expertises.

In the light of the above fact, BMA has decided to employ the engineering and administrative experiences on urban roads in Japan who has been exerting itself for the solution of the similar road traffic problems as faced in Bangkok. The Government of Thailand, therefore, requested the Government of Japan for technical assistance to conduct a "Study on Road Improvement, Pavement Rehabilitation and Traffic Safety in Bangkok" (hereinafter referred to as the Study).

The Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programs of the Government of Japan, has engaged the International Engineering Consultants Association (IECA) of Japan for consulting services to the Study.

1.2 Objectives

The objectives of the Study are as follows;

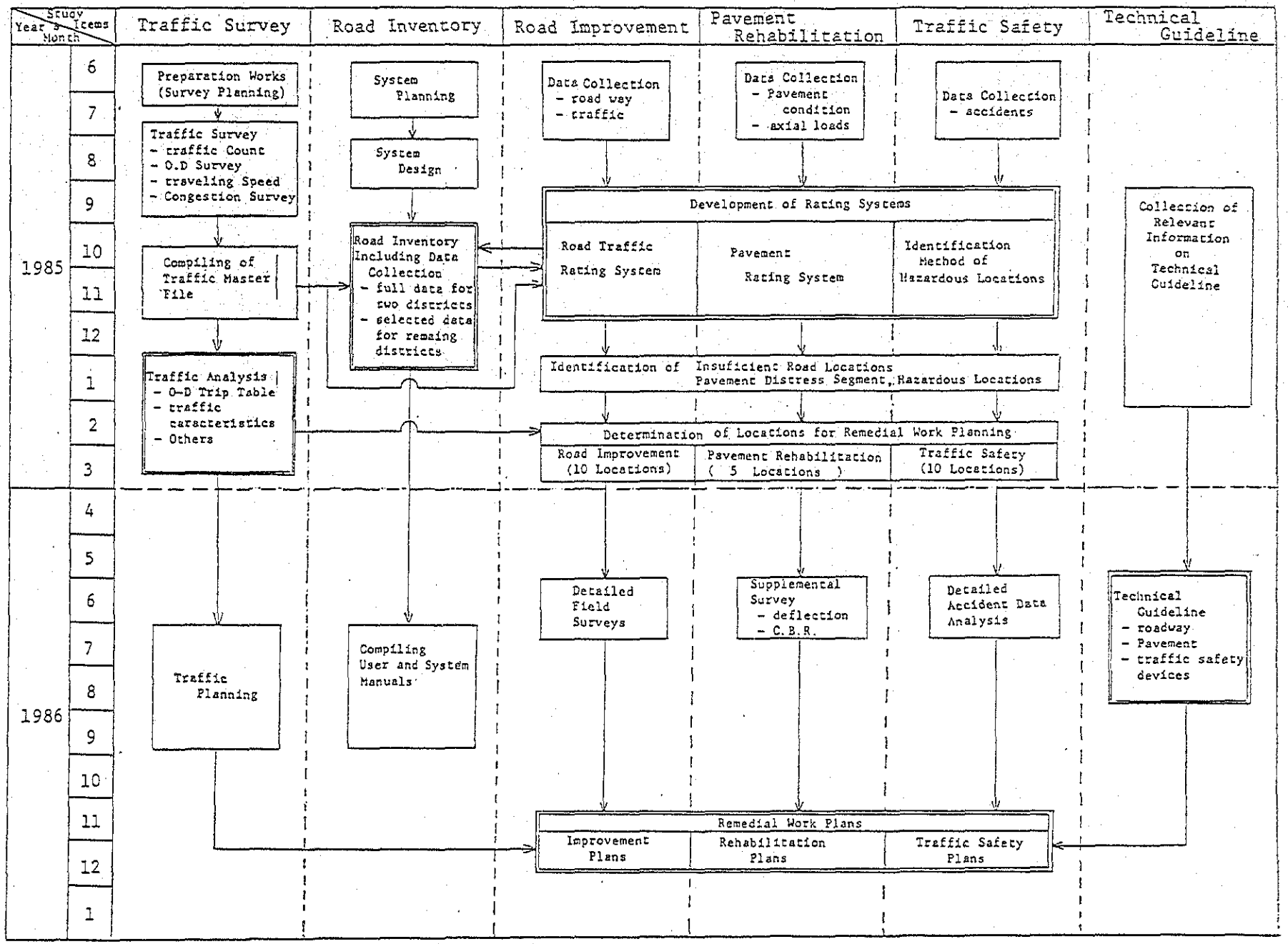
(1) to assist BMA in preparation of
   i) road improvement plans,
   ii) pavement rehabilitation plans, and
   iii) traffic safety plans, and

(2) to perform technology transfer to the BMA counterparts in the course of the implementation of the Study.

1.3 Scope of Study

In order to achieve the objectives, the activities under the Study are classified into the following seven (7) categories;

Figure 1.3.1 General Study Flow



(1) Traffic Survey;
- traffic counts, O-D survey, intersection traffic volume survey
- O-D trip table
- traffic analysis

(2) Road inventory;
- development of road data base system
- pilot road inventory for two districts

(3) Road improvement;
- development of a road traffic rating method to identifytraffic bottlenecks
- preparation of road improvement plans for eleven (11) locations

(4) Pavement rehabilitation;
- development of a pavement rating method to identify pavement failures
- preparation of pavement rehabilitation plans for five (5) locations

(5) Traffic safety;
- development of an identification method of hazardous road locations
- preparation of traffic safety remedial work plans for ten (10) locations

(6) Technical Guideline
- preparation of technical guidelines for planning of road improvement, pavement rehabilitation and traffic safety.

(7) Review on BMA road organization

The study flow for study items (exclusive of item 7) is schematically shown in Figure 1.3.1. Although the study flow is presented in simplified streamlines for explanatory purpose, it should be noted that there is a close interaction among the study works. Detailed study approaches, methodologies, analyses and findings are discussed aspresented in each study item.

1.4 Study Roads

The roads to be covered under the Study are major roads located within the area encircled by the middle ring road totaling approximately 350km, and certain extensions of some of them stretching out across the middle ring road (see Figure 1.4.1).

1.5 Schedule

The Study started in June, 1985 was planned to be completed within 22 months from the starting date (i.e. March 1987). The study schedule by study

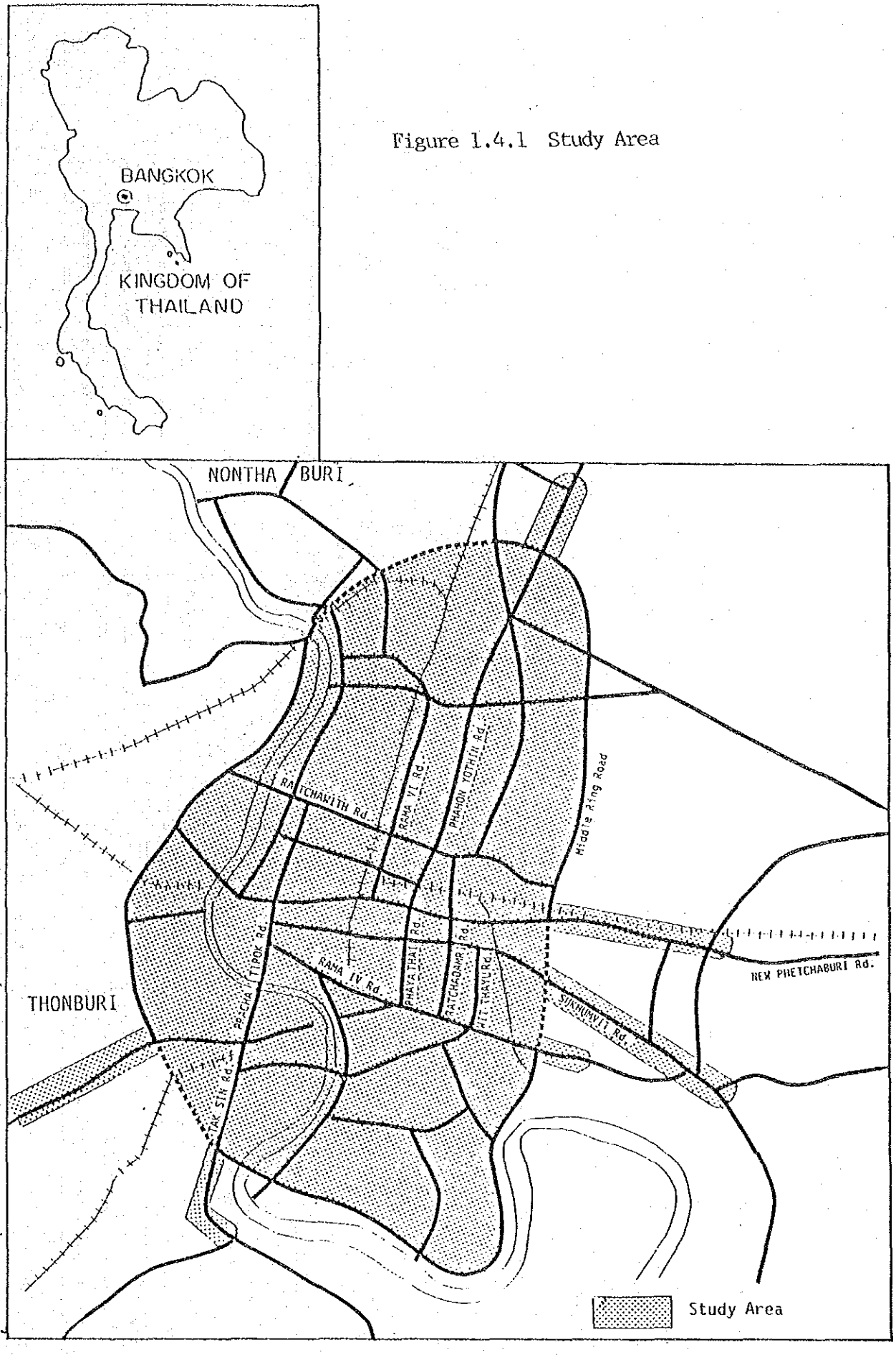
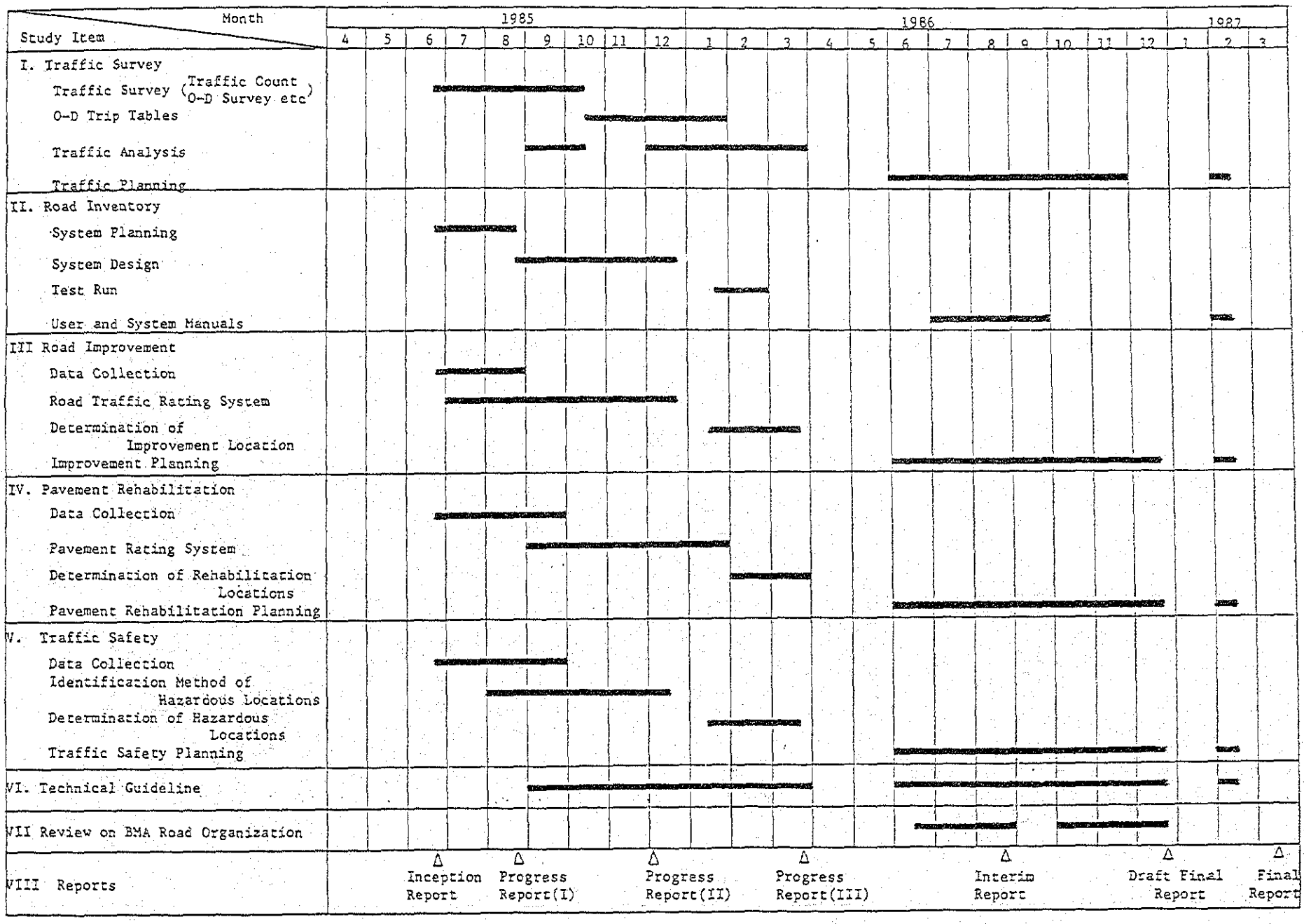


Figure 1.4.1 Study Area

Figure 1.5.1 Study Schedule



items is shown in Figure 1.5.1. Respective reports during the study period were submitted to BMA in the following sequence.

(1) Inception Report (30 copies) : June 1985,
(2) Progress Report(I) (30 copies) : August 1985,
(3) Progress Report(II) (30 copies) : December 1985,
(4) Progress Report(III) (30 copies) : March, 1986,
(5) Interim Report (30 copies) : August, 1986,
(6) Draft Final Report (30 copies) : December, 1986,
(7) Final Report (50 copies) : March, 1987.

1.6 Organization

The parties directly concerned with the implementation of the Study are BMA, the counterpart team on the part of BMA, JICA, the Advisory Committee organized by JICA, and the study team (hereinafter referred to as the Team) set up by IECA. The schematic organization chart for the Study is shown in Figure 1.6.1.

The Study were carried out by the Team under the supervision of the Advisory Committee. The Team also performed its consulting services in collaboration with the BMA counterparts.

Figure 1.5.1 Study Schedule

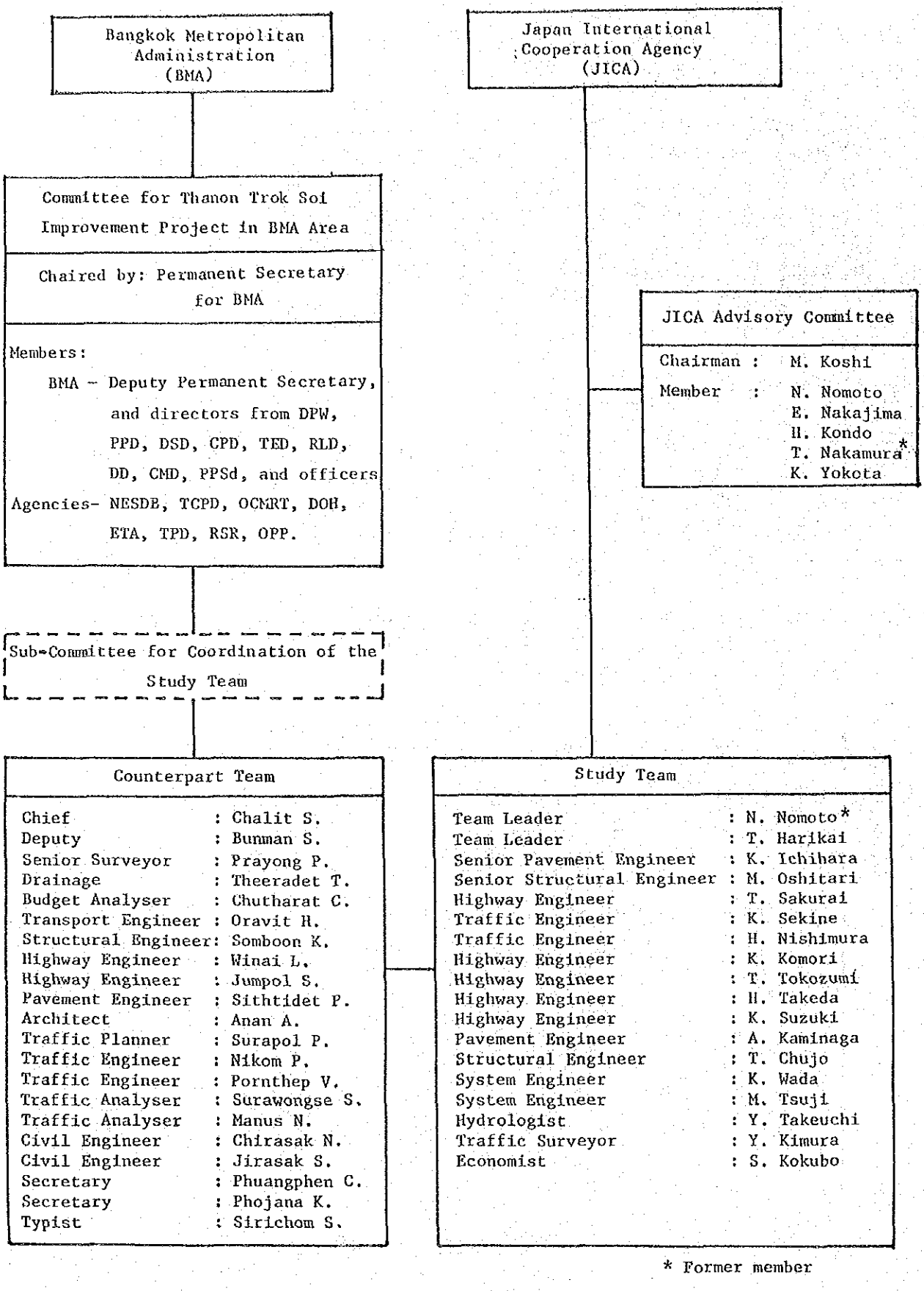


Figure 1.6.1 Organization Chart of the Study

TRAFFIC SURVEY

2. TRAFFIC SURVEY

2.1 Introduction

As traffic data and information are prerequisit to accomplish the objectives of the study which include, among others, planning of road improvement, pavement rehabilitation and traffic safety, and development of a road traffic rating method, several types of traffic surveys were carried out as a part of this study. They are traffic volume, motor vehicle O-D, travel speed and traffic congestion surveys.

This chapter presents firstly the methods of the above traffic surveys and data processing, followed by the results of their data analyses which feature characteristics on road network, urban traffic, traffic movement and traffic flow. The characteristic of road network stands for the configuration and road density of the road. The urban traffic characteristics are derived mainly from the analysis of the O-D data and its analysis comprises trip generation, distribution, its length and purpose, while traffic movement characteristics are based on traffic volume and travel speed.

A traffic assignment was also attempted on the major roads by using the O-D data based on the motor vehicle O-D survey in order to grasp traffic flow on the road network, which were incorporated to road classification.

2.2 Traffic Survey

2.2.1 Introduction

The main aim of the traffic survey in the study is to obtain relevant traffic data to the extent of ensuring requirements for achieving the objectives of the study which include;

- development of a road traffic rating method to identify road locations where there are traffic bottlenecks, traffic hazards or pavement distresses, and
- preparation of road improvement plans, traffic safety plans and pavement rehabilitation plans for selected road locations where remedial works are in need.

The results of the traffic survey also are to be incorporated into the road inventory.

The following five (5) different types of survey were planned and carried out in cooperation with concerned authorities including police agencies.

a) Traffic volume survey (ordinary count and cordon line count)
b) Intersection traffic volume survey
c) Motor vehicle O-D survey
d) Travel speed survey
e) Traffic congestion survey

The detailed plans for above surveys were worked out through discussions with the BMA counterparts and other concerned authorities at the central government level. Summarized in Table 2.2.1 is the outline of the survey plans. The details of survey plans are presented in the following sections.

2.2.2 Traffic Survey

(1) Traffic volume survey

1) Ordinary count stations

There are traffic volume counting data exclusive of motorcycle conducted by OCMRT in 1985 at approximately 220 stations which cover almost all the study roads. OCMRT survey which was carried out without classification of vehicle type was made for a period of 12 hours between 7:00 a.m and 7:00 p.m.

Table 2.2.1 Summary of Traffic Survey

Survey Items			No. of Counting Stn.	Survey Period	Remarks
Traffic Volume Survey	Ordinary Traffic Volume Count		50	14 Hours	
	Intersection Traffic Volume Survey		46	Peak Hours (7:00am-9:00am) (4:00pm-6:00pm)	The Survey was carried out both a.m and p.m peak only for the important intersections
Motor Vehicle O-D Survey	Home Interview		Sampling 6.1% Rate	-	No. of registered vehicles in the study area (1984, excluding motorcycle and fixed route bus) 492,000 Veh.
	Roadside Interview	Roadside Interview	Station 27 Sampling Rate 5-13%	14 Hours (7:00am-9:00pm)	No. of samples approximately 60,000 Veh.
		Cordon Line Count	28	Ditto	The survey was carried out 24 hours as to Vibhavadi-Rangsit Hwy, Sukhumvit Rd. and Tak Sin Rd.
Traffic Congestion Survey (Queue Length of Waiting Cars)			Approxi- 46 mately	Peak Hours (7:00am-9:00am) (4:00am-6:00am)	
Travel Speed Survey			23 Major Routes	Ditto	6 times measured for both am. and pm. peak hours.

In this study, 50 counting stations were selected in a manner to update and supplement the OCMRT data. About 40 stations were the same as those of OCMRT in order to update their data as well as to obtain additional information on vehicle types, while the remaining 10 stations were additions mainly for supplement. Appendix 2.2.1 shows the location of ordinary traffic volume counting stations. As seen, the counting stations are well distributed in the study area and located mainly on arterial roads and one-way traffic roads.

2) Classification of vehicles

Vehicles were classified into eight types as shown below, taking into account the study objectives after discussions with BMA and OCMRT.

a) Passenger Car
b) Pick-up, Light Truck
c) Heavy Truck
d) Taxi, Samlor
e) Mini Bus
f) Bus (BMTA, Others)
g) Motorcycle
h) Others

This vehicle classification has been applied to the other types of traffic survey in the study with the exception of intersection traffic volume survey.

3) Counting

The ordinary traffic volume counting was commenced on July 23, and completed on Aug.8,1985. The counting was made manually for a period of 14 hours from 7:00 a.m to 9:00 p.m on weekdays in spite of widely practiced 12-hour count in view of the fact that heavy trucks (4 and 6 wheels) are banned to enter into the CBD of Bangkok at daytime between 7 a.m - 9 a.m and 4 p.m - 6 p.m. under the current traffic law to ease traffic congestions. The expanded counting period enabled the study to obtain traffic data of heavy trucks on the study roads.

4) Cordon line counting

As the traffic volume countings on the cordon line in the study area were designed and undertaken together with "Roadside Interview" of motor vehicle O-D survey at the same places, the details of cordon line count are described in the section of the roadside interview survey.

(2) Intersection traffic volume survey

1) Objectives of survey

In order to analyze traffic flows at major intersections, intersection traffic volume survey was conducted at selected intersections together with other surveys, inclusive of travel speed.

2) Survey intersection

Forty six (46) major intersections were selected, out of about 400 intersections in the study area. These intersections scatter more or less uniformly over the study area. Particular attention was also paid to one-way traffic roads and their crossing roads. The locations of the intersection traffic volume survey are plotted in Appendix 2.2.2.

3) Classification of vehicle type

As main objectives of the intersection traffic volume survey are to obtain necessary data for calculation of the traffic capacity and rational design of intersections, vehicles were classified into only three types as shown below.

a) Motorcycle
b) Small sized vehicle (Passenger car,Taxi and Light truck)
c) Large sized vehicle (Heavy truck and Bus)

4) Survey method

The intersection traffic volume survey was commenced on Aug. 14, and completed on Aug. 21, 1985. This survey was carried out manually at intersections during peak hours of traffic between 7:00 a.m and 9:00 a.m and 4:00 p.m and 6:00 p.m. The survey counted the volumes of inflow traffic and their directional movement, i.e., left-turn, right-turn and straight.

(3) Motor vehicle O-Dsurvey

Motor vehicle O-D survey (herein after referred to as O-D survey) in the study consists of "Home Interview" and "Roadside Interview". The home interview was made with the selected vehicle owners whose dwelling places are located within the study area. Thus, the movements of internal trips in the study area can be identified from this interview. The roadside interview is to obtain the movements of vehicles which are owned by those whose residences are outside the study area but make trips into the study area crossing a cordon line.

The cordon line count carried out at the same time with the roadside interview is to provide information necessary for expansion of the results of the roadside interview conducted on a sampling basis. The roadside interview and the cordon line count were carried out at 28 stations on the fringe of the study area, of which 10 stations were located at on-ramps of the ETA expressway.

The home interview with about 31,000 samples was conducted during August to September 1985. The roadside interview with vehicles stopped at rate of about 8 percent of the vehicles passing the stations was made between August 14 and August 22, 1985.

1) Home interview

The home interview was made in the following sequence of work items. The flow chart of these work items is shown in Figure 2.2.1.

- zoning
- sampling
- design of questionnaire and notification letter
- interview
  * preparation of survey manual
  * explanation and education to interviewers
  * pre-survey
  * home / office interviews

* collection and inspection

- data processing

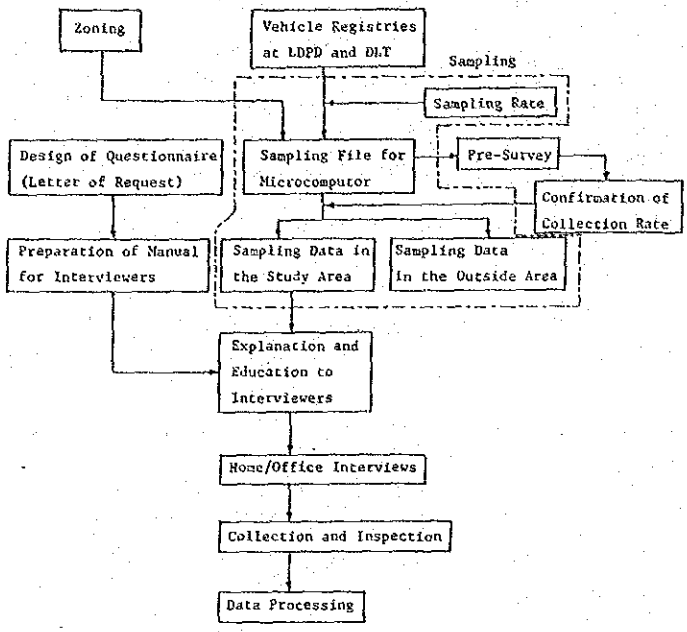


Figure 2.2.1 Survey Flow of Home Interview

a) Zoning

The zoning of survey area which identifies the locations of origin and destination of vehicular trips, is governed by various factors such as density of road network, geographical distribution of registered vehicles, survey area size and purpose of the O-D survey.

The study area was divided into smaller zones totaling 58, referring to the zoning in the Feasibility Study on the Second Stage Expressway System (SSES) and the Short Term Urban Transport Review (STTR),while the whole outside area was divided into wider zones of 28. Zones inside the study area were set to be relatively small to obtain more detailed information of trip characteristics in the study area. The zones and zone numbers are shown in Appendix 2.2.3 and 2.2.4, while Appendix 2.2.5 indicates zone conversion between this zoning system, and SSES's and STTR's zoning systems.

b) Sampling of vehicles

A sampling rate in the O-D survey can be statistically determined by total number of vehicles, number of zones and confidence limit.

The total number of registered vehicles excluding motorcycle is approximately 700,000 in Bangkok in 1984 of which approximately 640,000 are registered in LDPD[1/] and 60,000 are in DLT[2/] (See Appendices 2.2.6 and 2.2.7).

The number of registered vehicles in the study area was estimated to be 490,000 on the assumption that it is in proportion to the number of samples selected from the registration cards.

In order to determine a sampling rate, the sampling error should be maintained within an acceptable range. The sampling rate for a certain confidence limit can be calculated by statistical method when number of zones and total number of registered vehicles are given. To secure confidence limit of 90%, the sampling rate should be 6% with variable range of OD trips being approximately 20% which are generally accepted for motor vehicle O-D surveys. The minimum sample size, thus, shall be approximately 30,000 for all types of vehicles.

Table 2.2.2 Summary of Sample Size (Home Interview : 1984)

Type of Vehicle	No. of Registered Vehicles			No. of Effective Samples	Remarks (Source)
	Inside of Study Area	Outside of Study Area	Total (Bangkok)		
1) Passenger Car	309,909	114,978	424,887	17,819 (5.7%)	LDPD
2) Pick-up, Light Truck	151,003	38,488	189,491	10,009 (6.6%)	"
3) Heavy Truck	28,869	13,233	42,102	2,000 (6.9%)	DLT
4) Taxi, Samlor	18,407	3,229	21,636	1,016 (5.5%)	LDPD
5) Mini Bus	2,444	1,084	3,528	175 (7.2%)	DLT
6) Bus	1,651	404	2,255	152 (8.2%)	"
7) Sub-Total	491,522	164,404	655,926	31,171 (6.1%)	
8) Fix-Route Bus	11,922	-	11,922	11,922 (100%)	DLT
9) Total	524,405	171,416	695,821		

Note : No. of passenger cars includes that of other vehicle types

1/ LDPD: The Licences Division of Police Department(LDPD) of MOI has full responsibility for registration of motorcycles, taxis, passenger cars and light buses with capacity of 6 passengers or less, and light trucks with maximum laden weight of 1.6 tons or less.

2/ DLT: The Department of Land Transport(DLT) of MOC has full responsibility for light buses with capacity of more than 7 passengers, heavy buses, and trucks with maximum laden weight more than 1.6 tons.

c) Interview

The home interview was conducted by type of vehicle. It was made by visiting either homes or offices (companies). As for fixed route bus, i.e., BMTA bus and long distance buses, the corresponding data on frequency of bus services and routes were collected from BMTA and other relevant bus authorities.

The home interview was commenced on September 2 and was completed on September 30, 1985. The total number of the collected samples was 31,000 or 6.1% excluding fixed route buses in study area (see Table 2.2.2). As for the fixed route buses, O-D trip data were provided by the bus authorities.

A manual for the interviewers was prepared in Thai language and three kinds of questionnaires were designed by type of vehicle. They are attached in Appendices 2.2.8 and 2.2.9, respectively. As information for home interview surveys to be made in the future, interviewer's experiences gained in this home interview are also summarized in Appendix 2.2.10.

2) Roadside interview

The roadside interview was carried out at the cordon line counting stations to obtain O-D data of vehicles which are registered outside the study area but travel into the study area. This survey also was used to reconcile the home interview.

On average, 8 percent of the vehicles passing the stations were stopped and their drivers were interviewed their origin and destination and other required information.

The roadside interview was conducted for 14 hours (7:00 a.m to 9:00 p.m) on weekdays between August 14 and August 22, 1985.

a) Interview station

The roadside interview was carried out at 17 stations where the radial arterials intersect with the cordon line, and ten (10) stations at on-ramps of the ETA expressway. All the 17 stations except the one on Vipavadee Rangsit Highway were set up in the places where traffic signals existed, in order to avoid disturbance of traffic flows due to interview.

The locations and road conditions of roadside interview stations are

presented in Figure 2.2.2 and Table 2.2.3, respectively.

b) Sample size

The sampling rates for the roadside interview ranged from 5 and 13%. These sampling rates were determined taking into account the traffic and road conditions. The total number of interviewed vehicles was approximately 60,000.

Although the sampling rates may be a little smaller as compared to those in other similair surveys, the actual number of interviewed vehicles as many as 60,000 was considered to be sufficient for the purpose of the study.

c) Design of questionnaire

On roads with heavy traffic, interviews to drivers or passengers are possible only for a red-light phase of traffic signal which ranges between 1 and 2 minutes on average in the study area. Thus, it is indispensable to limit the number and kind of questions to drivers to an absolutely necessary minimum.

The contents of questionnaire for the roadside interview were limited to information of trips only. The information regarding ownership like driver's occupation, as being the case with the home interview, was excluded. As the information to be obtained from interviewees is common for all types of vehicle, only one uniform questionnaire was prepared. Appendix 2.2.11 shows a sheet of questionnaire for roadside interview.

d) Cordon line count

The cordon line count of traffic volume at locations where arterial roads intersect with a cordon line encircling the study area, has twofold objectives. One is to supplement the ordinary traffic volume count. The other is to obtain expansion factors to be applied to the results of the roadside interview conducted on a sampling basis.

The cordon line count must be made at same time with the roadside interview because of the above discussions. The counts was carried out at the 28 stations which, except one, coincided with roadside interview stations. Cordon line count was carried out by vehicular type from August 14 to August 22, 1985.

The traffic volume counts at the cordon line were made for 14 hours (7:00

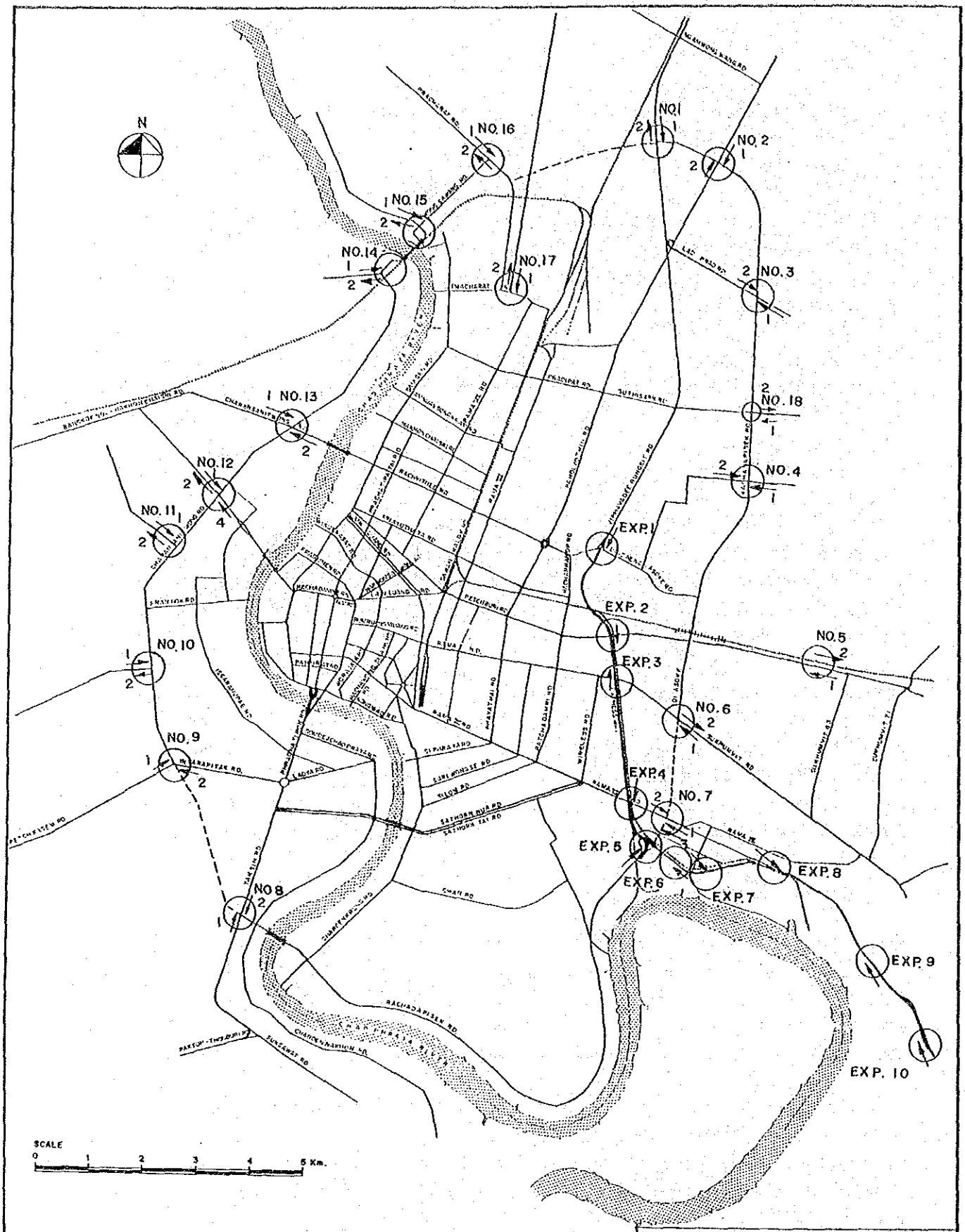


Figure 2.2.2 Roadside Interview Survey Stations (Cordon Line Count)

Table 2.2.3 Road Conditions of Roadside Interview

Sta. No.	Road Name	Traffic Vol. in 14 hours	Sampling Rate (%)	Sample Size	Surveying Duration (hour)		No. of Interviewers	Surveying Date
					Interview	Traffic Count		
1	Wipawadee – Rangsit Hwy.	102,106	5.9	6,016	14	24	48	Aug, 22
2	Phahol Yothin Rd.	43,942	6.6	2,879	14	14	19	Aug, 20
3	Ladphao Rd.	35,153	11.2	3,942	14	14	23	Aug, 20
4	Pracharat Bamphen Rd.	20,949	7.6	1,600	14	14	7	Aug, 20
5	New Petchaburi Rd.	52,941	9.1	4,800	14	14	28	Aug, 20
6	Sukhumvit Rd.	52,436	6.2	3,256	14	24	25	Aug, 22
7	Rama IV Rd.	69,680	6.7	4,666	14	14	29	Aug, 22
8	Tak Sin Rd.	49,691	9.9	4,929	14	24	29	Aug, 14
9	Petchakasem Rd.	51,505	11.0	5,674	14	14	27	Aug, 14
10	Panitchakarn Thonburi Rd.	10,073	9.2	931	14	14	4	Aug, 14
11	Bang Khun Non – Taling Chan Rd.	13,579	12.7	1,722	14	14	9	Aug, 14
12	Pra Pin Klao Rd.	39,705	6.0	2,368	14	14	15	Aug, 15
13	Rachawithi Rd.	35,595	4.8	1,724	14	14	10	Aug, 15
14	Rama VI – Bang Kruae Rd.	5,295	12.6	669	14	14	4	Aug, 15
15	Pibul Songkram Rd.	12,710	13.0	1,653	14	14	9	Aug, 15
16	Krungthep – Nontha – buri Rd.	25,244	8.0	2,012	14	14	11	Aug, 15
17	Prachachuen Rd.	21,561	11.1	2,392	14	14	10	Aug, 15
18	Sutthisan Winitchai Rd.	18,289	–	–	–	14	–	Aug, 20
Sub-total				51,233			307	
Exp – 1	Dindaeng	24,201	10.0	2,416	14	14	11	Aug, 21
Exp – 2	New Phatchaburi	8,834	10.6	932	14	14	4	Aug, 21
Exp – 3	Sukhumvit	8,602	7.9	682	14	14	4	Aug, 21
Exp – 4	Rama IV	9,988	7.9	791	14	14	4	Aug, 21
Exp – 5	Riverside	16,248	7.5	1,212	14	14	6	Aug, 21
Exp – 6	Kasemrat 1	4,122	7.0	289	14	14	2	Aug, 21
Exp – 7	Kasemrat 2	2,676	11.9	318	14	14	1	Aug, 21
Exp – 8	At Narong	3,612	10.8	327	14	14	2	Aug, 21
Exp – 9	Sukhumvit 62	7,301	6.8	496	14	14	3	Aug, 21
Exp – 10	Bangna	18,558	11.3	2,092	14	14	9	Aug, 21
Sub-total				9,555			46	
TOTAL				60,788			353	

am - 9:00 pm) except three counting stations, where the counts were carried out for 24 hours. These three stations were station No.1 (Vipavadee - Rangsit Highway), No. 6 (Sukumvit Rd.) and No. 8 (Tak Sin Rd.). The 24-hour countings were made in order to get expansion factor for the roadside interview results, and to estimate daily traffic volumes from the 14-hour count (see Table 2.2.3).

(4) Travel speed survey

The travel speed survey was carried out along 23 major routes during morning and evening peak hours. Appendix 2.2.12 illustrates the routes where travel speeds were measured. Since the results of this survey were expected to be used for developing the road traffic rating method, the survey routes covered the major roads in the study area.

The survey was planned to be carried out during peak hours to see the conditions of traffic jams at their most severe time. Since travel speed fluctuates according to traffic conditions, travel speed during peak hours was measured 6 times for both morning and evening peak hours on each route in both directions, to obtain a statistically representative travel speed. Travel time and distance were measured between the two adjacent intersections using a watch and odometer of the car. Time was measured to the accuracy of seconds and distance was measured to the accuracy of 0.01 km. Travel speed survey was completed on September 30, 1985.

(5) Traffic congestion survey

Traffic congestions in terms of queue length of vehicles build up at intersections were measured at 46 intersections which were likely to be potential bottlenecks of traffic. The records were taken every 15 minutes for a period of 2 hours. This survey was carried out between August 14 and August 21, 1985. The locations of the surveyed intersections are shown in Appendix 2.2.13.

2.2.3 Data Processing of O-D Survey

The O-D survey in the study consists of "Home Interview" and "Roadside Interview". The survey results were compiled and stored in magnetic tapes for a mainframe computer. O-D tables were composed by using the O-D survey data. The data processing was done in many steps from data filing to screen line check as shown below.

- data filing
- inspection of filed data
- determination of expansion factor
- division of sample data into each trip
- adjustment of internal and external trip
- compilation of O-D Master File
- screen line check

Important steps are explained in the following sections.

(1) Determination of expansion factor

Since the O-D survey was conducted on sampling basis, the survey results had to be expanded to obtain the total number of motor vehicle trips. Expansion factor of the home interview was estimated from the number of the home interviewed vehicles (31,000) and registered vehicles (561,000) in the year 1985 (this figure was available only after completion of the home interview), while that of the roadside interview was estimated from the traffic volume counted on the cordon line and sample data.

The expansion factors of the home interview were estimated for each type of vehicle and by zone block which is defined as a aggregated zone combining several adjacent zones (see Appendices 2.4.4 and 2.4.5). As for the roadside interview, the expansion factors were estimated for each station on the cordon line, for each direction (inbound and outbound), by time and by type of vehicle.

(2) Adjustment of internal and external trip

The movements of internal trips of the vehicles registered in the study area were surveyed by the home interview. The roadside interview was to cobtain the movements of vehicles registered outside the study area which trip into the study area crossing the cordon line. Therefore, trips of vehicles registered in the study area crossing the cordon line could possibly be doubly counted in both surveys.

Among the trips crossing the cordon line, those obtained from the roadside interview were given priority and the external trips derived from the home interview were discarded. Data from home interviews were used only for the trips which have both origin and destination within the study area. This is summarized in Table 2.2.4.

Table 2.2.4 Summary of O-D Table

Traffic Survey	Type of Vehicle	Trip	Survey period	Estimated Period	Expansion Factor
Home Interview	1) Passenger Car, Others 2) Pick-up, Light Truck 3) Heavy Truck 4) Taxi, Samlor 5) Mini Bus (excluding BMTA) 6) Bus (ex. BMTA & L.D Bus)	Internal Zone Trip	24-hours	Daily, Hourly	1) Type of Vehicle 2) Zone Block
Home Interview (Bus Authority)	7) BMTA's Mini Bus 8) BMTA's Bus 9) Long Distance Bus	Internal and External Zone Trips	24-hours	Daily	Making O-D table from bus diagram directly
Roadside Interview	1) Passenger Car, Others 2) Pick-up, Light Truck 3) Heavy Truck 4) Taxi, Samlor 5) Mini Bus (excluding BMTA) 6) Bus (excluding BMTA's & Long Distance Bus)	External Zone Trip	14-hours	Daily = 14-hours $\times \frac{\text{24-hours Count}}{\text{14-hours Count}}$ hourly	1) Station 2) Direction 3) Time 4) Type of Vehicle

In order to obtain the internal trips made by the owners' vehicles which are registered outside the study area, approximately 130 samples were collected in a supplement home interview. The number of internal trips estimated from those sample data was approximately 50,000 trips.

(3) O-D master file

Composition of an O-D master file is the final step. Format of the O-D master file in this study includes all the information from the questionnaire form. The form is shown in Appendix 2.2.14. It was filed in floppy disks and a magnetic tape, and is called "O-D Master File".

(4) Screen line check

In order to confirm the accuracy of the O-D survey, the expanded O-D trips supposed to cross the screen lines were compared to the traffic volumes counted on the lines. This process is called 'screen line check'. Three screen lines were established as shown in Appendix 2.2.15. The comparison is shown in Table 2.2.5. As seen in the table, the results are satisfactory with the comparison ratios ranging between 0.86 and 1.09.

Table 2.2.5 Screen Line Check between Observed and O-D Trips in 1985

(Unit : Vehicle Trips)

Screen No.	Designation	Passenger Car	Pick-up and Heavy Truck	Taxi and Samlor	Mini Bus and Bus	Total
1 (On the Chao Phraya River)	(A) Observed (on Road)	176,000	83,000	100,000	21,000	380,000
	(B) O-D trips	191,000	92,000	103,000	29,000	415,000
	(B)/(A)	1.09	1.11	1.03	1.38	1.09
2 (Eastern Screen)	(A) Observed (on Road)	436,000	157,000	181,000	58,000	832,000
	(B) O-D trips	343,000	157,000	159,000	59,000	718,000
	(B)/(A)	0.79	1.00	0.88	1.02	0.86
3 (East and West Screen)	(A) Observed (on Road)	390,000	141,000	161,000	44,000	736,000
	(B) O-D trips	333,000	152,000	153,000	53,000	691,000
	(B)/(A)	0.85	1.08	0.95	1.02	0.94

2.2.4 Data Processing of Traffic Master Files

The results of the traffic surveys (excluding the O-D survey) in the study were compiled and stored in computer floppy disks and a magnetic tape. These data are called "Traffic Master Files".

Traffic Master Files contain the data obtained by trafic volume, intersection traffic volume, travel speed and traffic congestion surveys. They are composed of the "Traffic Master File for Mid-Block Section" and "Traffic Master File for Intersection". Mid-block section means a road section between two adjacent intersections.

Traffic Master Files can be used for the analysis of the general characteristics of urban traffic, for development of a road traffic rating method, and for preparation of the road improvement plan.

(1) Traffic master file for mid-block section

The traffic master file for mid-block section contains the traffic volume data observed at 50 counting stations and the OCMRT's traffic volume data in 1984 updated by extrapolation or interpolation using traffic volumes observed in this study.

Some of road inventory data and traffic indices, such as road capacity and volume/capacity ratio, calculated from the survey results were also stored in this file.

(2) Traffic master file for intersection

The traffic master file for intersection contains the intersection traffic volume data at 46 intersections and the OCMRT's data in 1984 updated in the same manner as the traffic master file for mid-block section. The master file also includes road inventory data and queue length data at intersections. Traffic indices, such as saturation flow rate and saturation degree, were also stored in this file.

2.3 Road Network

2.3.1 Introduction

In this section, the road network in the study area was reviewed to see the road network characteristics such as road composition, configuration, density, and road indices by zone block.

2.3.2 Road Network

The road network in Bangkok is composed of several radial major roads, a circumferential road surrounding the central districts, and minor roads and 'sois' giving access to the major roads. Their total length in Bangkok is approximately 2,800 km (include PWD, DOH and ETA). Besides them the First Stage Expressway is, at present, under service with the length of 16.8 km in the north - south direction. The third section of the Expressway (Dao khanong - Port expressway) is under construction with a length of 10.3 km. The radial roads start at the CBD and stretch to the outer area. Middle Ring Rd. (having the planned diameter of about 8.5 km for east-west direction and 14 km for north - south) to serve the traffic as a circumferential road in the urbanized area has been mostly completed.

The study road network is shown in Appendix 2.3.1, where the numbers of lanes are expressed by the widths of line. The total length of the study road is approximately 372 km, of which approximately 330 km (89% of total length) is under the jurisdiction of BMA, 18 km (5%) is DOH roads, 13 km (4%) within the study area is administered by ETA and other belong to DPW. The road length ratios by lane are composed of the following. The 4-lane roads are predominant, compared with others.

2 - lane	: 20%
4 - lane	: 37%
6 - lane	: 26%
8 - lane or more	: 17%

2.3.3 Road Density

Several indices for road network data are presented in Table 2.3.1. These indices are the road density, the road areas per population and per vehicle trip by zone block as defined in Appendices 2.4.4 and 2.4.5.

According to this table, the average road density in the study area is approximately 3.98% or 1.66 km/km^2. The high density zone blocks are block No. 1 (Phra Nakhorn), No. 3 (Phaya Thai) and No. 4 (Pathum Wan & Bang Rak). To contrary, the road areas per vehicle trip in these zone block which are located in CBD show relatively small values implicitly indicating traffic congestions.

Table 2.3.1 Road Network Data

Zone Block No.	Road Length (Km)	Road Area (ha)	$\frac{\text{Road Length (Km)}}{\text{Zone Area (Km}^2\text{)}}$	$\frac{\text{Road Area}}{\text{Zone Area}} \times 100$	$\frac{\text{Road Area (M}^2\text{)}}{\text{Population}}$	$\frac{\text{Road Area (M}^2\text{)}}{\text{No. of Trips*}}$
1	55,750	100.81	6.27	12.46	2.91	1.86
2	55,137	122.10	2.61	5.77	2.27	3.97
3	43,203	143.95	2.70	8.99	2.67	3.29
4	54,302	114.24	3.91	8.22	3.93	1.65
5	39,179	85.61	1.06	2.32	2.15	2.84
6	18,803	30.99	0.82	1.36	1.11	0.61
7	16,042	44.22	0.67	1.86	1.93	2.33
8	19,410	89.54	0.59	2.72	5.09	3.67
9	41,811	73.25	2.00	3.51	1.41	2.24
10	21,904	63.17	0.94	2.71	1.50	2.80
Total	365,541	877.86	1.66	3.98	2.27	2.29

Note : Data source of zone area and population in 1984 are STTR.
*... Trip Generation and Attraction

2.4 Urban Traffic Characteristics

2.4.1 Introduction

This section summarizes the characteristics of urban traffic in Bangkok which are consisted of information on trip generation, trip distribution, trip purpose and trip length in the study area. They were obtained by analyzing data of the O-D survey.

This information to indicate the characteristics of urban traffic in Bangkok is the latest because of the fact that the O-D survey has not been carried out for about 10 years. The information can be used to analyze present traffic conditions, and to derive estimates of future traffic conditions.

2.4.2 Registered Motor Vehicles

In order to grasp the basic situation of current traffic in the study area and Bangkok, population and registered vehicles are summarized in Table 2.4.1. As seen in this table, the number of registered vehicles excluding motorcycle is approximately 700,000 in Bangkok in 1984, of which approximately 530,000 are registered in the study area and 170,000 are outside the study area.

Vehicle ownership is approximately 136 veh. per 1,000 persons for all vehicle types in the study area and 124 in Bangkok as a whole.

The vehicle ownerships of several cities in South East Asian countries are shown in appendix 2.4.1. Although the data in this table are not latest, the vehicle ownerships in Bangkok, Kuala Lumpur, and Singapore are almost at the same level of between 130 and 140 veh./1000 persons in 1979, while the vehicle ownership in Tokyo is approximately 400 veh./1,000 persons in 1984.

2.4.3 Vehicle Trip Generation

(1) Vehicle trip generation

The vehicle trip generation/attraction of urban travel reflects the activities of vehicle traffic. It also depends on the socio-economic characteristics of the urban area and travel attitudes of urban residents.

The vehicle trip generation/attraction by type of vehicle are summarized in Table 2.4.2. Total trip generation in the study area in the year 1985 is approximately 1.9 million veh/day (except motorcycle), of which about 45% are passenger car, 21% pick up and heavy truck, and 34% other types.

Comparison of the vehicle trip generation and attraction by zone block is shown in Figure 2.4.1 and Appendix 2.4.2. The vehicle trip generation and attraction in zone block No. 1 (Phra Nakhorn), No. 4 (Pathum Wan & Bang Rak) are higher than those of other blocks. These zone blocks are also high in their vehicle trip generation per capita or per registered vehicle. This indicates that these zone blocks are the cores of the activity of vehicle traffic.

Table 2.4.1 Population and Registered Vehicle in 1984

Items	Bangkok	Study Area
1) Area (Km^2)	1,569	221
2) Population (person)	5,625,455	3,866,363
3) Population Average Growth Rates (%/year)	3.0	-
4) Registered Vehicles (Veh.)	695,821	524,405
5) Registered Vehicle Average Growth Rates (%/Year)	12.2	-
6) Vehicle Ownership (Veh./1,000 persons)	123	137
7) Car Ownership (Veh./1,000 persons)	71	75

Note : 1) Population average growth rates indicate between 1981 and 1985.
2) Registered vehicles exclude motorcycles
3) Car ownership indicates a passenger car owner.
4) Registered vehicle average growth rates indicate between 1980 and 1984.

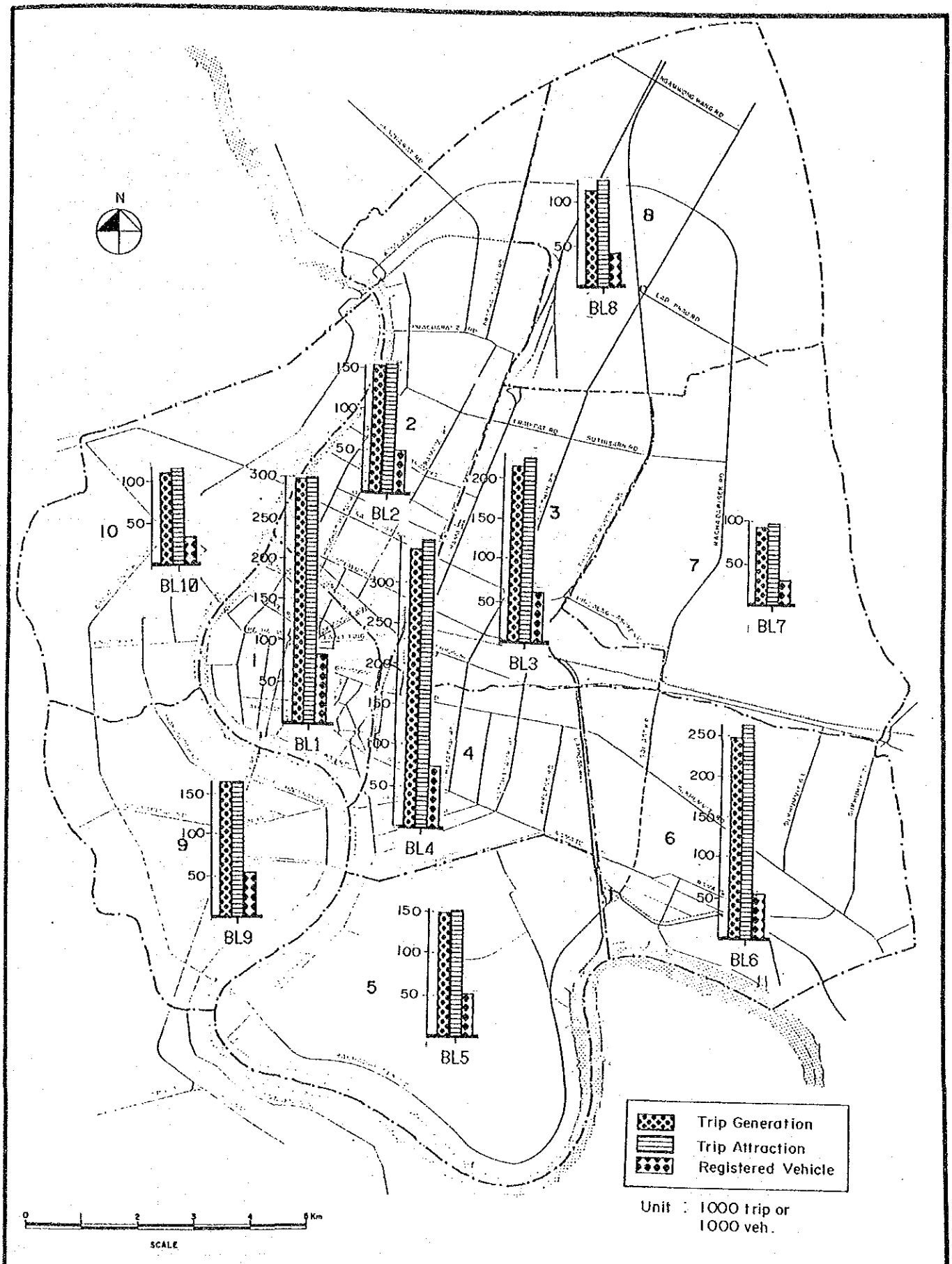


Figure 2.4.1 Trip Generation and Attraction

(2) Vehicle trip generation factors

The vehicle trip generation factors such as the average number of trips and rate of unoperated vehicle at time of survey to registered vehicle are the important information for estimations of future traffic demand and other traffic conditions.

Table 2.4.3 shows the relationships among the type of vehicle, average number of trips and rate of unoperated vehicle at time of survey. The average number of trips for all vehicle types is approximately 4.23, of which approximately 3.57 are passenger car, 2.86 for pick up, 2.82 for heavy truck and 35.01 for taxi. Percentage of the unoperated vehicle to registered vehicle is approximately 19.7% for all vehicle types.

Table 2.4.2 Vehicle Trip Generation and Attraction in 1985 (Study Area)

(Unit: Vehicle Trip/day)

Type of Vehicle	Trip Generation	Trip Attraction	Total
1. Passenger Car	850,800	888,300	1,739,600 (45.4%)
2. Pick-up & Heavy Truck	392,200	412,500	804,700 (21.0)
3. Taxi & Samlor	550,500	558,700	1,109,200 (29.0)
4. Mini Bus & Bus	87,300	88,600	175,900 (4.6)
5. Total	1,880,800	1,948,600	3,829,400 (100.0)

Table 2.4.3 Number of Trip and Rate of Unoperated Vehicle

Type of Vehicle	Average Number of Trips	Rate of unoperated vehicle (%)
Passenger Car	3.57 (2.87)**	19.6
Pick-up and Light Truck	2.86 (2.30)	19.5
Heavy Truck	2.82 (2.17)	24.1
Taxi, Samlor	35.01 (32.09)	8.3
Mini Bus*	2.92 (1.99)	31.8
Bus*	2.62 (2.00)	23.6
Total	4.23 (3.39)	19.7

Note : * Exclude BMTA bus
** Include unoperated vehicle

2.4.4 Vehicle Trip Distribution

(1) Vehicle trip distribution

Summary of O-D table in 1985 is shown in Appendix 2.4.3. Summarized figure of the O-D table is shown in Figure 2.4.2 in which vehicle trip movement is classified by three kind of trips, i.e., internal trips, external trips and external-external trips.

Total number of vehicle trip movement in the study area was approximately 2.2 million vehicle/day (except motorcycle). Among them, the internal trips approximately 1.7 million, the external trips 500,000, and the external-external trips 53,000.

Trip distribution of all types of vehicle is shown in Figure 2.4.3 by desire line charts. In this figure, the two-directional movement between each pair of zone blocks is drawn by a straight line whose width is proportional to the number of trips between zone blocks. The desire lines are flows of traffic as they would proceed by the shortest distance between zones of origin and destination.

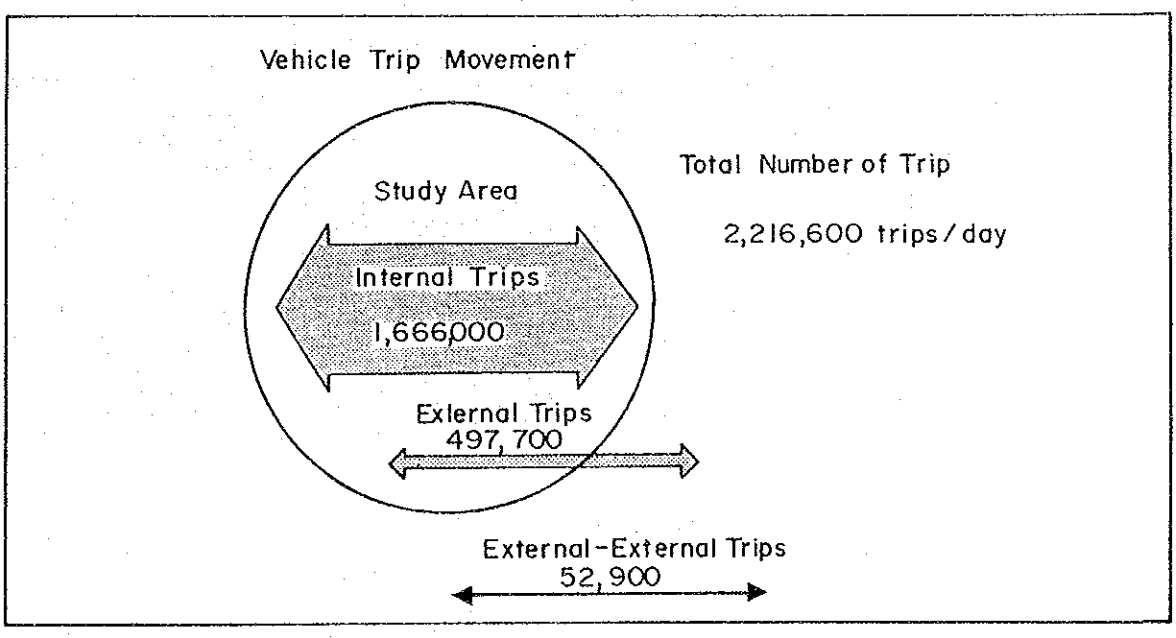


Figure 2.4.2 Vehicle Trip Movement

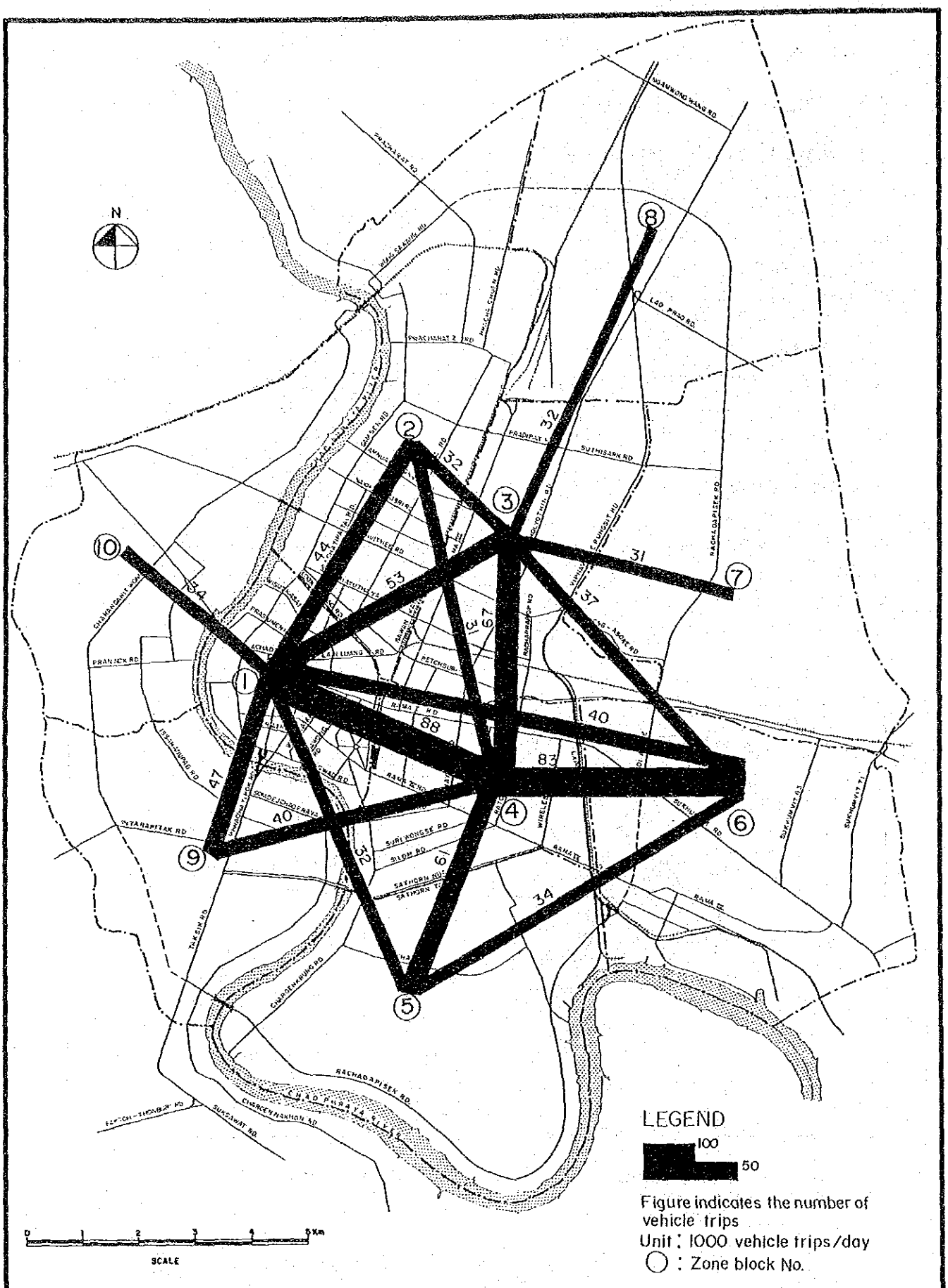


Figure 2.4.3 (1) Desire Lines of Internal Zone Trips

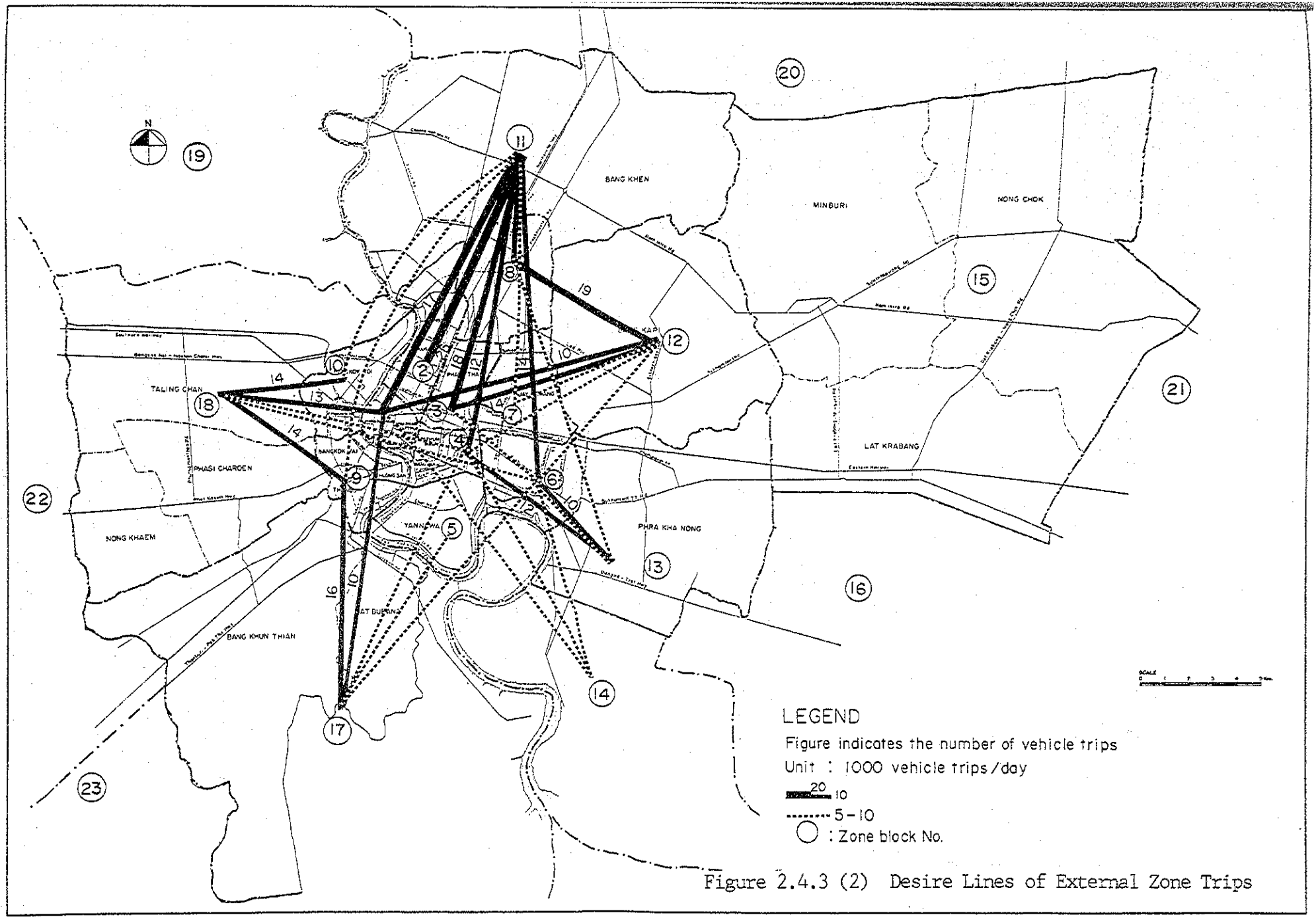


Figure 2.4.3 (2) Desire Lines of External Zone Trips

Strong desire lines are seen between zone block No.4 (Pathumwan & Bang Rak) and its surrounding zone blocks i.e., No.1 (Phra Nakhon), No.3 (Phaya Thai), No.5 (Yan Nawa) and No.6 (Pra Khanong). Zone block table and figure are shown in Appendices 2.4.4 and 2.4.5. Hence, it can be concluded that traffic flows are highly concentrated in the districts of Pathumwan & Bang Rak (zone block No.4) and Phra Nakhorn (zone block No.1).

(2) Travel and trip length distribution

1) Travel distances

Vehicle travel distances vary according to city size and reflect the relative locations among residencial areas, working places, shopping places and so on.

Travel distances which are total length of trips made by one vehicle in a day, are shown in Figure 2.4.4. The average travel distance of all vehicle types is approximately 35 km/day. The longest average travel distance by vehicle type is seen in taxi with approximately 235 km/day.

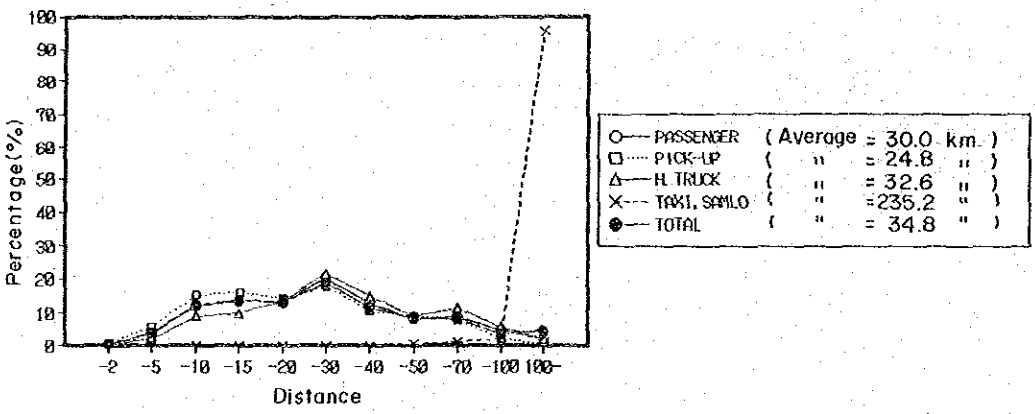


Figure 2.4.4 Travel Distance Distribution

2) Trip length

Histogram of trip lengths by vehicular type is shown in Figure 2.4.5. As for all vehicle types, the average trip length is approximately 9 km. As shown in the figure, heavy truck shows longer trip length while taxi and samlor indicate shorter trip length.

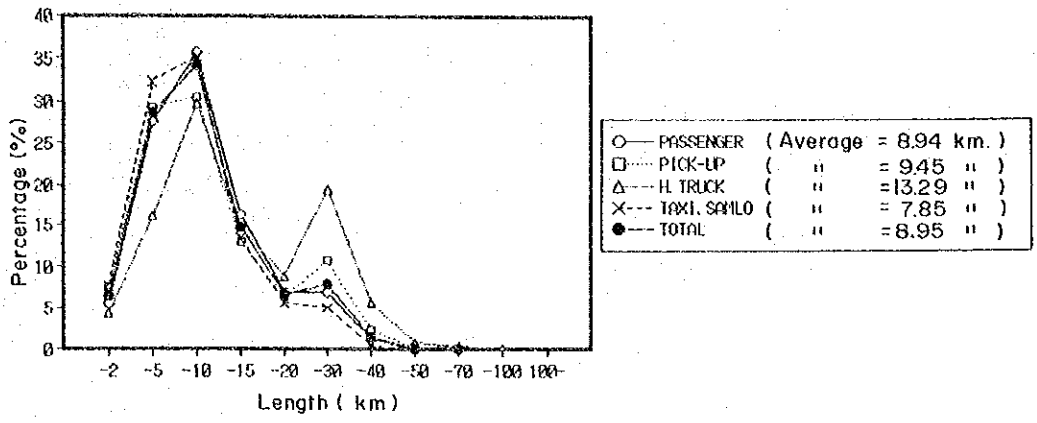


Figure 2.4.5 Trip Length Distribution

2.4.5 Trip Purposes

(1) Trip purposes

1) Trip purposes

All trips are made for some purposes, e.g., work, shopping, or visit friends. Trip purpose patterns, therefore, reflect the daily activities.

Figure 2.4.6 summarizes trip purposes of passenger car for a day. According to this figure, approximately 26.8% of total trips are "To work" and "To school", 16.5% "Business", 15.6% "Private" and the remaining 41.1% "Go home". Among "To work" purpose, "To work and school" purpose which takes children to shool first and then proceeds to the office is seen as a phenomenon specific to Bangkok. This trip pattern accounts for 16% of "To work" trips.

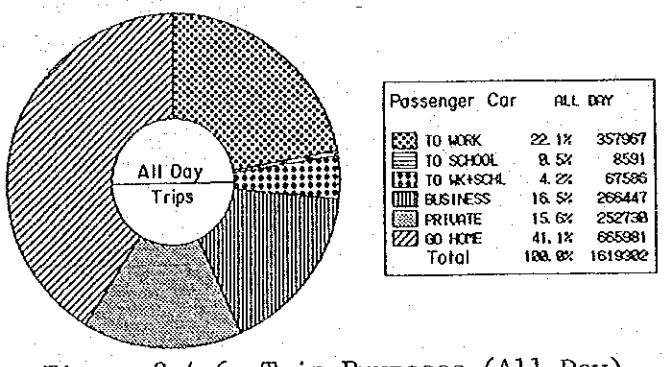
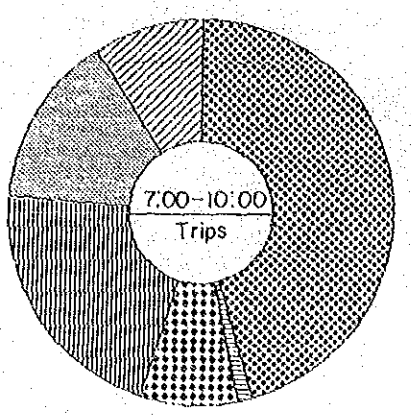
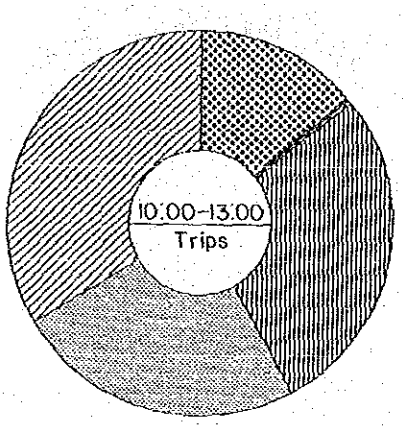


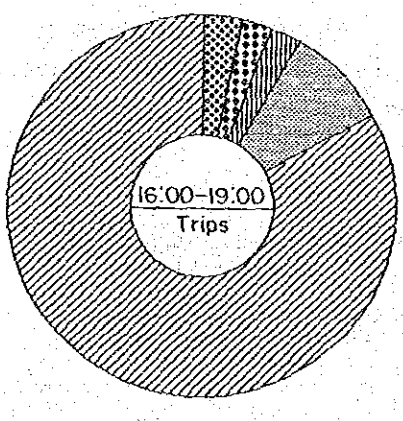
Figure 2.4.6 Trip Purposes (All Day)



Passenger Car	7:00-10:00	
TO WORK	45.5%	239864
TO SCHOOL	1.2%	6170
TO WK+SCHL	8.2%	43366
BUSINESS	21.4%	112942
PRIVATE	14.5%	76259
GO HOME	9.3%	49065
Total	100.0%	527666



Passenger Car	10:00-13:0	
TO WORK	13.6%	52572
TO SCHOOL	0.2%	751
TO WK+SCHL	0.4%	1487
BUSINESS	27.8%	107395
PRIVATE	24.4%	94225
GO HOME	33.7%	130283
Total	100.0%	386713



Passenger Car	16:00-19:0	
TO WORK	3.2%	9869
TO SCHOOL	0.1%	396
TO WK+SCHL	2.4%	7339
BUSINESS	2.6%	8080
PRIVATE	8.6%	26719
GO HOME	83.2%	259020
Total	100.0%	311423

Figure 2.4.7 Trip Purposes by Time Period

Comparison of trip purposes of passenger car according to three time zones of a day, i.e., the morning zone, the daytime and the evening, is shown in Figure 2.4.7. "To work" is predominant for the morning peak hour, "Business" and "Go home" become predominant in the daytime and then, "Go home" is major portion, exceeding 80%, in the evening peak hour.

2) Business trips

The central business district is the area of greatest travel intensity. Travel demand is high in this area, and usually business purpose trips are predominant. Business trips, therefore, are reviewed in this section.

Zonal distribution of business purpose trips are shown in Figure 2.4.8, in which vehicle trip generation and attraction are illustrated in histogram. The business trips in zone block No. 1 and No. 4 are higher than those of others, and are concentrated in these zone blocks.

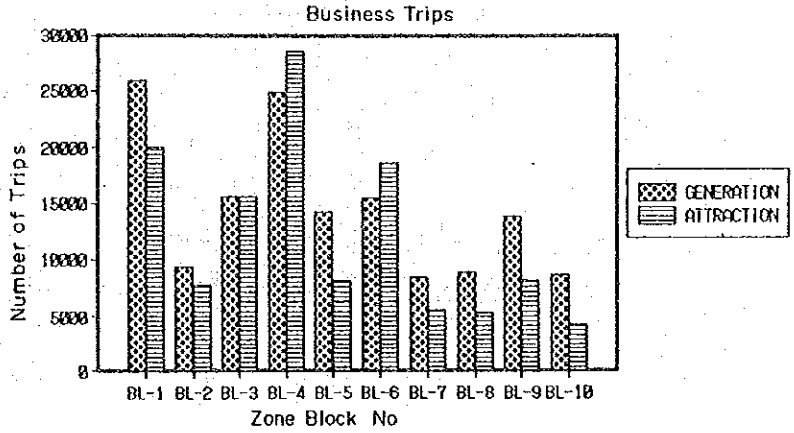


Figure 2.4.8 Zonal Distribution of Business Purpose Trips

Vehicle trip generation and attraction are plotted against the number of employments by zone block as shown in Figure 2.4.9. As seen in this figure, zone block No. 1 and No. 4 form an outstanding group which is characterized by heavy trip generation and high employments. From the features seen in Figures 2.4.8 and 2.4.9, it can be said that the central business district of Bangkok is located in zone block No. 1 and No. 4.

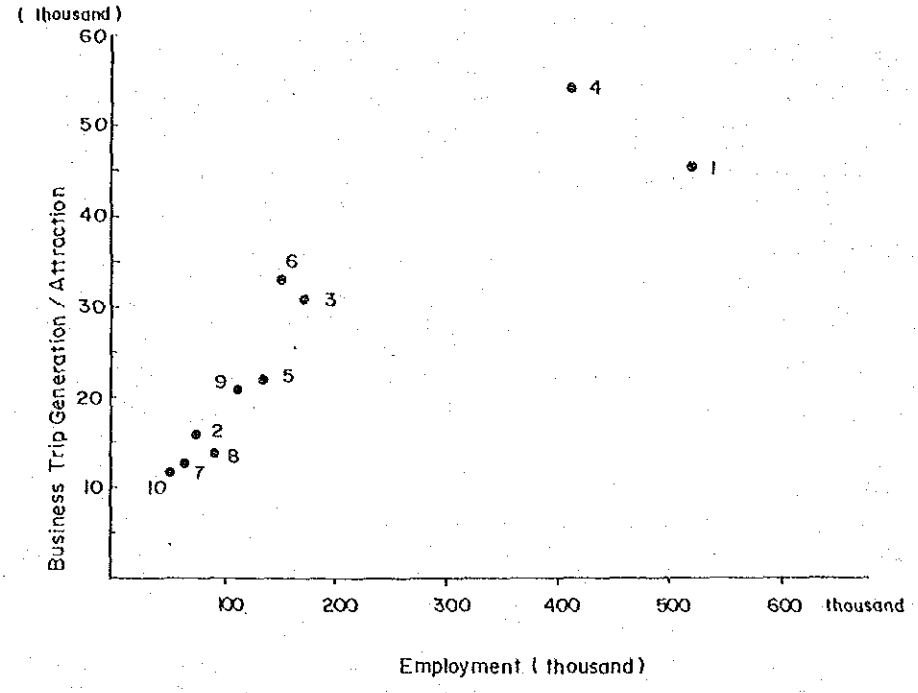


Figure 2.4.9 Relation between Business Trip and Employment

(2) Number of persons per car

The number of persons per passenger car according to trip purpose and those of taxi and samlor are shown in Figure 2.4.10. The number of persons per car ranges from 1.6 to 2.4 in passenger car, and is approximately 2.1 including driver in taxi and samlor.

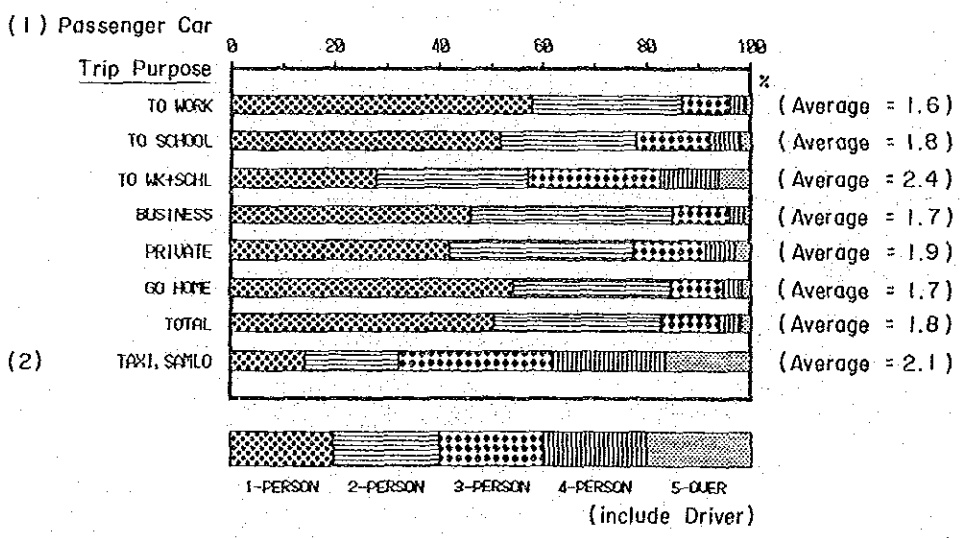


Figure 2.4.10 Number of Passengers per Car by Trip Purpose