seventh digit was used to indicate the number of survey stations on each particular boundary. In the existence of only one station, the seventh digit takes the zero value. For more than one station, the value of the seventh will be 1, 2, etc., according to the number of stations.

Numerically, the smaller of the two codes is written first, then the bigger. This pattern also indicates the direction of traffic flow on the road between the two Changwats. The direction from the smaller code to the bigger indicates the inbound traffic (I) or direction 1, while the opposite direction is the outbound traffic (O) or direction 2. For example, there is only one survey station between the two Changwats of Mae Hong Son (code 214) and Chiang Mai (code 203) which has a station code number of 2032140. Direction 1 (inbound I) is the direction from 203 to 214, i.e. from Chiang Mai to Mae Hong Son.

6.2 TRAFFIC SURVEYS AND RESULTS

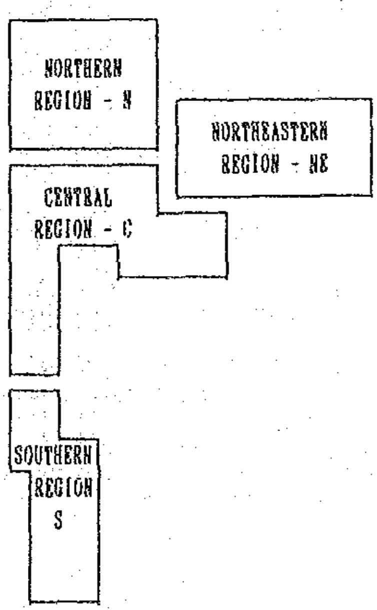
An attention has been paid in the planning process of the traffic surveys because of their complexity and costs. The executed traffic surveys in this study are;

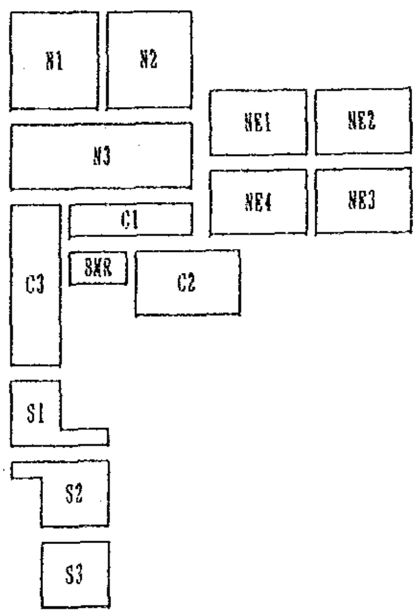
- Origin-Destination Roadside Interview
- Classified Traffic Counting
- Traffic Speed

The overall work program for the traffic surveys is divided into three main phases of mobilization, methodology and analysis of traffic survey results.

Table 6.1 DEFINITION OF REGIONS AND DIVISIONS

REGION	DIVISION	CHANGWAT
NORTHERN N	N1	MAE HONG SON-CHIANG MAI-LAMPHUN-LAMPANG
	N2	CHIANG RAI-PHAYAO-NAN-UTTARADIT-PHRAE
	N3	TAK-SUKHOTHAI-PHITSANULOK-PHETCHABUN-PHICHIT-KAMPHAENG PHET
NORTHEASTERN NE	NE1	LOEI-UDON THANI-MAHASARAKHAM-KHON KAEN
	NE2	NONG KHAI-NAKHON PHANOM-MUKDAHAN-SAKHON NAKHON-KALASIN
	NE3	ROI ET-YASOTHON-UBON RATCHATHANI-SI SA KET
	NE4	CHAIYAPHUM-NAKHON RATCHASIMA-BURIRAM-SURIN
CENTRAL C	C1	UTHAI THANI-NAKHON SAWAN-LOP BURI-SARABURI-SING BURI-CHAI NAT
	C2	NAKHON NAYOK-PRACHIN BURI-CHANTHA BURI-TRAT-RAYONG-CHON BURI-CHACHOENGSAO
	C3	KANCHANA BURI-SUPHAN BURI-ANG THONG-AYUTTHAYA-RATCHA BURI-SAMUT SONGKHRAM-PHETCHABURI-PRACHUAP KHIRI KHAN
	BMR	NAKHON PATHOM-NONTHABURI-PATHUM THANI-BANGKOK-SAMUT PRAKAN-SAMUT SAKHON
SOUTHERN S	S1	CHUMPHON-RANONG-SURATTHANI
	S2	PHUKET-PHANGNGA-TRANG-KRABI NAKHON SI THAMMARAT
	S3	SATUN-PHATTHALUNG-SONGKHLA-PATTANI-NARATHIWAT-YALA





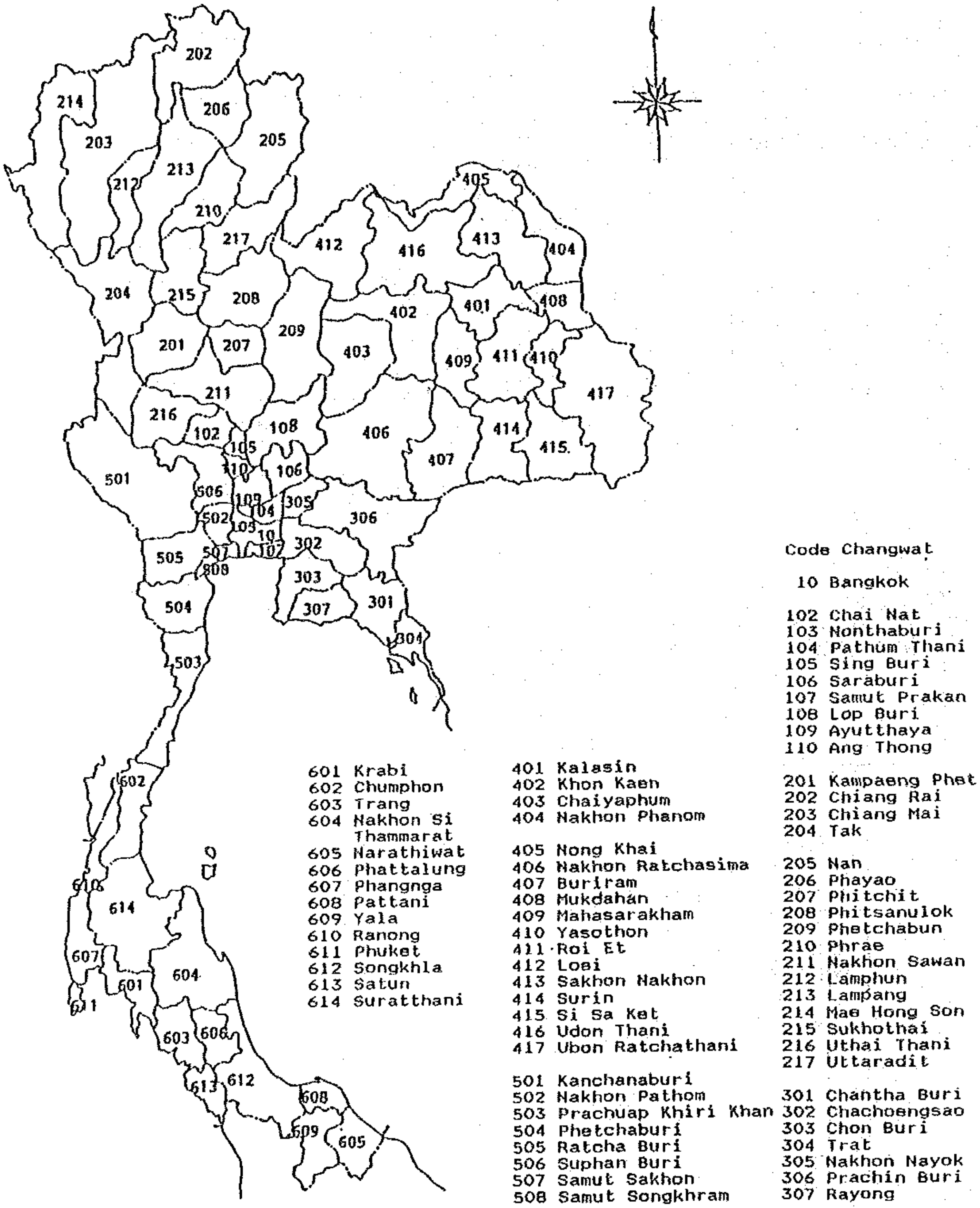


FIGURE 6.1 ZONING SYSTEM OF STUDY AREA

6.2.1 Mobilization

The majority of tasks of the mobilization phase are focused on the field operations planning to ensure the continuous flow of survey data. The key field operations planned in conjunction with other tasks of the study can be summarized as follows.

1) Program Coordination and Management

Because the nationwide traffic surveys involved extensive work in conjunction with specific data sampling requirements, a detailed schedule of activities was programmed for each field operation. Six survey parties were required to cover all the survey stations. An orientation program was undertaken for survey party leaders to explain the main points in the field works.

2) Survey Forms

Survey forms were developed for recording data obtained by surveyors in the field. Forms were designed in a simple pattern to be easily understood and with coding areas to ease the data processing procedure. Survey forms are shown in Appendix 6. 1.

3) Field Reconnaissance

The purpose of field reconnaissance task is to locate the exact and appropriate sites for the different traffic surveys on the national highway network.

Collected information through this task include:

- Station number
- Changwat jurisdiction
- Road width
- Number of lanes
- Location map
- Location photos
- Highway number
- Kilometer post
- Shoulder width
- Traffic volume (15 min.)
- Nearest police station
- Other remarks

6.2.2 Methodology

1) Origin-Destination Roadside Interview Survey

a. Purpose

The purposes of this survey are as follows:

i. To prepare the present OD tables
ii. To forecast the future OD tables
iii. To estimate the future traffic volumes on the motorway network

b. Zoning

Zoning is carried out on the administrative base in which each Changwat is considered as one zone. Zones with their coding numbers are clarified in Figure 6.1. Survey locations are located on the national highway network at the Changwat boundaries. There are 73 Changwats in the whole kingdom which will produce OD matrices with the size of 73 x 73.

c. Location of Survey Stations

A total number of 123 survey stations has been found to cover the requirements of establishing nationwide OD tables through reviewing and analyzing geographical and socio-conomic data. This number covers all Changwats and the national highway network. Only one station was located on a provincial highway in the Southern Region due to its special nature. The traffic survey stations are classified into three types according to their locations as follows, so they can be used as regional and divisional screen lines in the analysis procedure.

Region Stations	11
Division Stations	33
Changwat Stations	79
Total Number of Survey Stations	123

During the Road Development Study in the Central Region (JICA, 1989), ten stations were surveyed in the same procedure, in which the data of six stations are used in this study after adjustments. This makes the total number of stations to be surveyed is only 117 stations. Figure 6.2 clarifies the location of all survey stations while their detailed information are presented in Appendix 6.2.

d. Survey Items

The survey is carried out on the vehicles of the following nine types:

- Passenger car and taxi
- Light bus
- Medium bus
- Heavy bus
- Pick-up (passengers)
- Pick-up (commodity)
- 4-Wheel truck
- 6-Wheel truck
- 10-Wheel truck

In addition to the typical information of each survey station obtained during the reconnaissance stage, collected data during the survey include:

i. Vehicle data
   - Type
   - Capacity (tons or persons)

ii. Trip data
   - Origin (Changwat and Amphoe)
   - Destination (Changwat and Amphoe)
   - Purpose
   - Number of passengers
   - For trucks: Number of assistants
Commodity volume
Commodity type

e. Procedure

The survey is carried out in the two directions of traffic for twelve hours (06:00—18:00) on weekdays, including Saturdays, starting from March 21, 1990 for about six weeks. Sampling techniques were applied to get the target number of samples which was calculated for each survey station according to the ADT (1989) and using the following simplified formula which gives high sampling rates for low ADT and low rates for high ADT. The formula is diverted from the methodology of the Department of Transport in the United Kingdom and provides ± 5% accuracy rate.

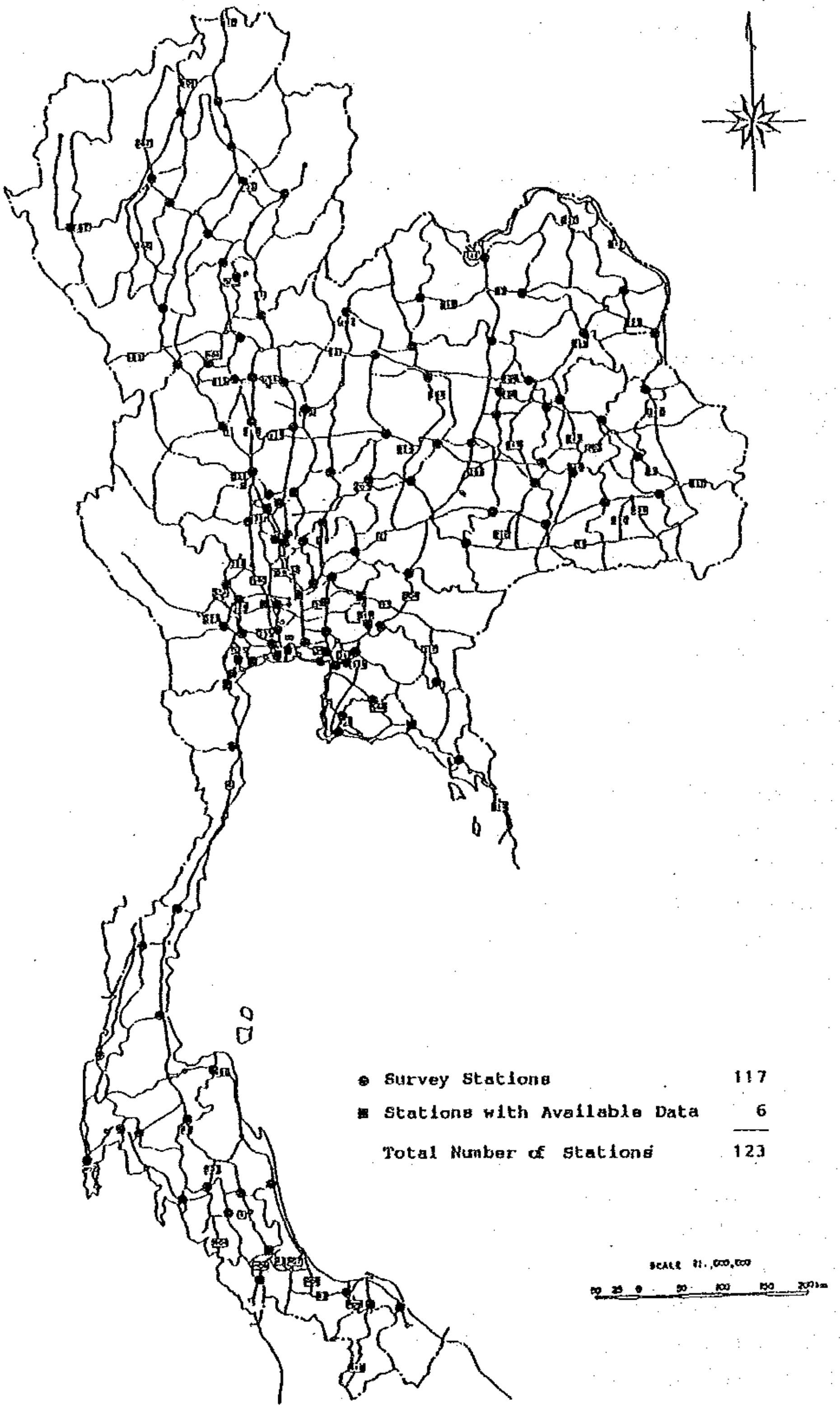


Figure 6.2 STATIONS OF OD AND CLASSIFIED COUNTING SURVEYS

Target Sample Size = ADT / (0.0003 ADT + 1)

The number of surveyors in each of the six parties varied for each station according to its target sample size.

2) Classified Traffic Counting Survey

a. Purpose

The purpose of this survey is to determine the distribution of vehicle categories in the traffic flow, so that expansion factors can be estimated to expand the OD data collected for twelve hours on sampling base.

b. Procedure

The survey is carried out at each station for twenty-four hours (06:00–06:00) at the same stations and on the same days of the OD survey. Manual counters are used to record the number of vehicles for each vehicle category separately. Categories of vehicles are as follows:

- Tricycle (with engine)
- Passenger car and taxi
- Medium bus
- Pickup truck
- 6–Wheel truck
- Other vehicles (with engine)
- Motorcycles
- Light bus
- Heavy bus
- 4-Wheel truck
- 10-Wheel truck

3) Traffic Speed Survey

a. Purpose

The purpose of this survey is to get basic data to estimate the travel time for each designated link in the national highway network.

b. Procedure

Survey locations are selected for this survey according to the different highway classifications and levels of service. The total selected number of sections is 35 sections which represent all the DOH classes for the national highway network.

Appendix 6.3 gives the detailed information of the selected survey stations.

The survey is carried out by one team for about three weeks during April 1990 using the floating car method, which consists of a minimum of three runs for each traffic direction. The collected data are as follows:

- Road and section identification
- Day, date, direction and weather
- Start and finish time
- Traffic volume for 15 minutes
  (before and after the survey for each direction)
- Time and speed for each run
- Average speed for each direction.

6.2.3 Results of Traffic Surveys

1) Check of Data Validity

It is essential to check the validity of data obtained through the traffic surveys and their expansion from sample survey data. All the data collected in the field were first manually checked and scrutinized for errors, omissions and ambiguous classifications during the coding procedure. Next, data were subject to systematical checks which were applied through the data processing stage to verify the accuracy of coding and the consistency of trip data.

The collected data for each survey station were graphically plotted on a zoning map to check the trip pattern and the interrelationship between the OD pairs and their survey stations. A special program was developed to examine this interrelationship on the division base and to review and exclude the odd data before the analysis procedure. Data of intra-zonal trips collected during the survey were excluded since they do not represent the inter-zonal movement which is the base of producing the present and future inter-zonal OD tables.

2) Classified Counting Survey

a. Rate of Heavy Vehicles

Number of heavy vehicles running on the roads is an important factor to be considered specially in the capacity analysis and pavement design and maintenance stages. The share of four types of heavy vehicles was sorted separately for all the survey stations. Sorted results of the five cases were composed together and plotted in one figure as shown in Figure 6.3. The minimum share of heavy vehicles on the national highway network was recorded as 10%, while the maximum share in few stations exceeds 60% of the total traffic volume.

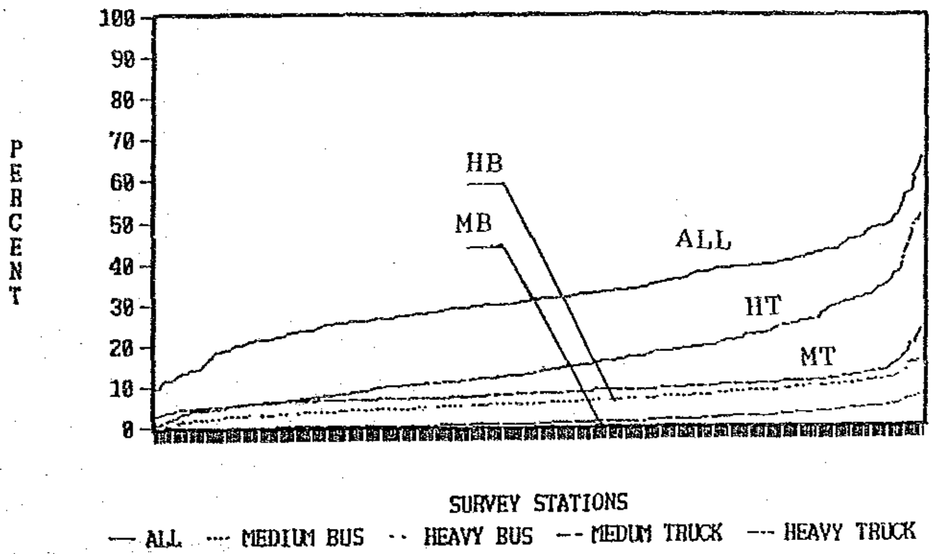


Figure 6.3 SORTED SHARE OF HEAVY VEHICLES BY CATEGORY

b. Nighttime Traffic

The counting survey continued for 24 hours (06:00—06:00) at each station while the OD survey was carried out for only 12 hours (06:00—18:00). The share of the nighttime traffic for all the survey stations is shown in sorted order in Figure 6.4.

In average the share of nighttime traffic is about 30% of the total traffic, which gives the OD survey high probability to collect more informative samples during the daytime surveys.

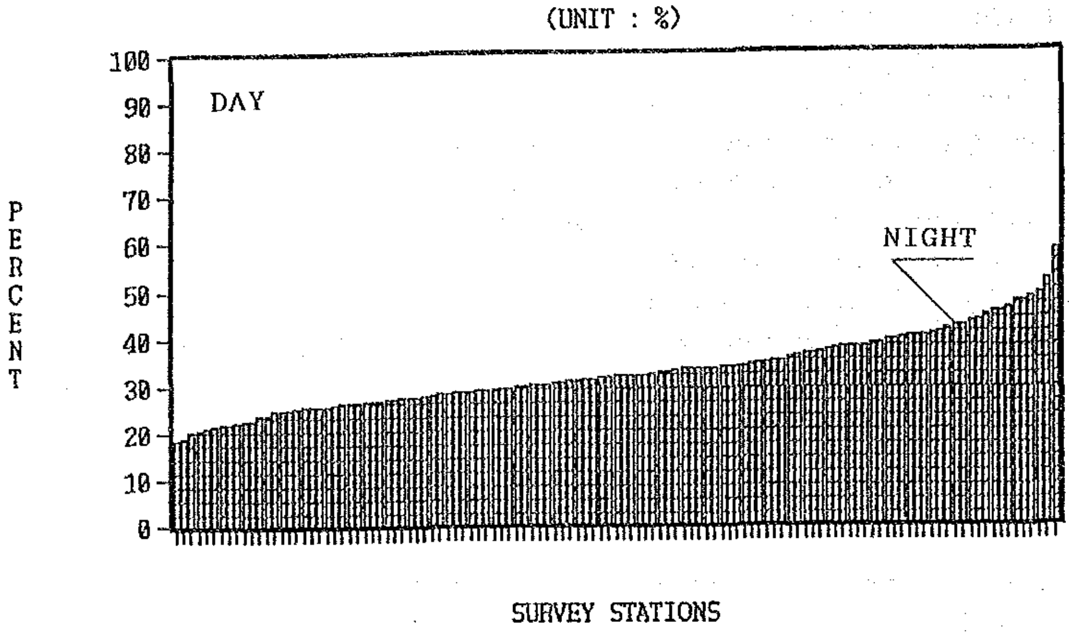


Figure 6.4 SHARE OF NIGHTTIME TRAFFIC

c. Expansion and Adjustment Factors

To expand the data collected on sampling base for the twelve-hour OD roadside interview survey, classified counting surveys were conducted for twenty-four hours at each survey station and on the same days. The relationship between the whole population of each vehicle category counted for 24 hours and the sample size for the same category gives its expansion factor on that highway. Expansion factors were determined using the following formula.

$$a_{ijk} = T_{ijk} / t_{ijk}$$

Where,

a_{ijk} = expansion factor of k category vehicles at station i in direction j

T_{ijk} = number of k category vehicles at station i in direction j

t_{ijk} = sample size of k category vehicles at station i in direction j

Tables of all expansion factors estimated per each vehicle category for both of the two directions of traffic at each survey station are presented in Appendix 6.4.

Directional split adjustment factors were applied on two of the surveyed highways (Routes No. 35 and No. 340) which were partially under rehabilitation work near to the survey location. Also, fluctuation factors are required so the bias in the collected data can be adjusted on the basis of the annual average daily traffic of each highway. To estimate such factors, the available traffic volume data of 1989 obtained through the newly installed continuous counting stations of DOH were used on regional base. Estimated values of the fluctuation multiplying factors for the different days of March and April are presented in Table 6.2.

Table 6.2 REGIONAL FLUCTUATION MULTIPLYING FACTORS

	SUN	MON	TUE	WED	THU	FRI	SAT
March:							
Central	0.879	1.011	1.047	1.061	1.037	0.965	0.890
Northeastern	1.035	1.063	1.053	1.050	1.045	0.988	0.940
Southern	1.039	1.059	0.977	1.008	1.031	0.975	0.958
Northern	0.985	1.044	1.025	1.040	1.037	0.976	0.929
April:							
Central	0.807	1.008	0.981	0.949	0.936	0.925	0.938
Northeastern	1.002	0.975	0.978	0.968	0.970	0.988	0.943
Southern	1.018	1.020	0.969	0.953	1.027	0.964	0.979
Northern	0.942	1.001	0.976	0.956	0.978	0.950	0.953

3) OD Roadside Interview

a. Number of samples

The actual number of effective samples by survey stations per vehicle category, which is the base of the OD tables, is presented in Appendix 6.5. The total number of effective samples is 203,528 vehicles, while the total number of the actually interviewed vehicles is 208,447 vehicles. The excluded samples represent a ratio of 2.36% of the collected data. The number of effective samples is still exceeding the target sample size of 193,820 vehicles which was estimated based on an accuracy rate of ± 5%. Appendix 6.6 presents the inter-Changwat traffic for each survey station after applying all expansions and adjustment factors. Because the field operations were carried out under different weather conditions such as rain or fog, the target sample size could not be achieved in some stations.

Figure 6.5 shows the actual and target samples in relation to the average daily traffic volumes at all survey stations.

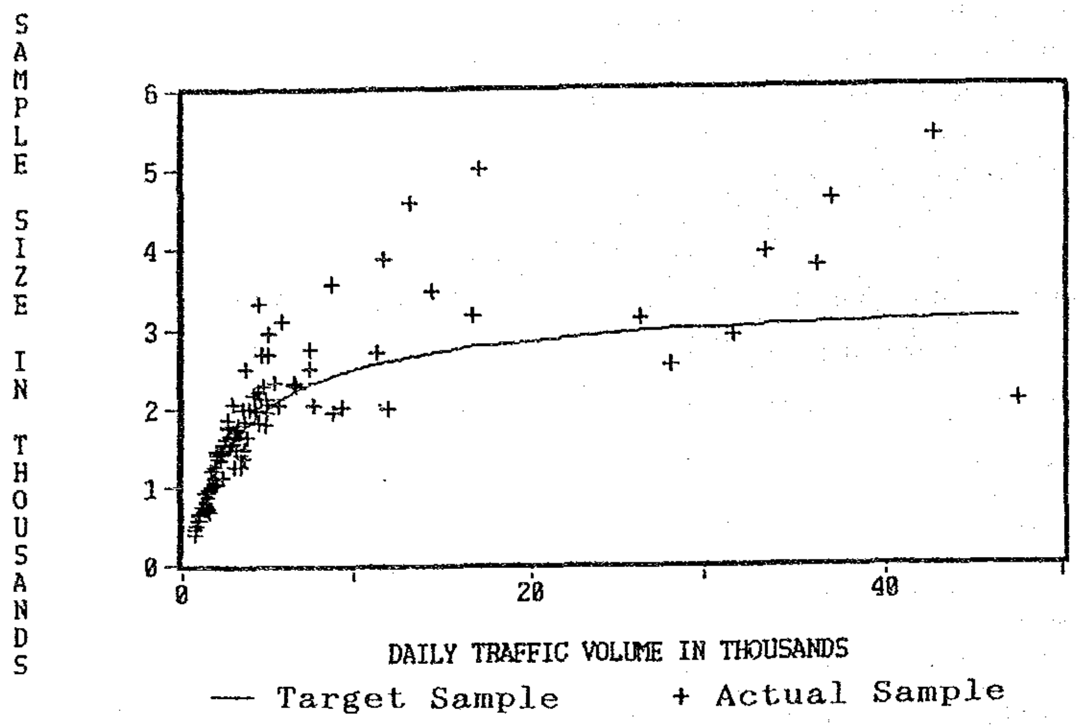


Figure 6.5 RELATIONSHIP BETWEEN ADT AND NUMBER OF SAMPLES

b. Truck movement characteristics

Four categories of trucks were interviewed during the OD survey. Data related to the movement characteristics of these four categories are presented in the following sections.

i. Capacity

The average actual capacity in tons for the four categories of all trucks interviewed during the OD survey is presented in Appendix 6.7 for the two traffic directions and their total for all survey stations. The average capacity values of trucks in the different regions are presented in Table 6.3.

Table 6.3 AVERAGE CAPACITY OF TRUCKS BY REGION (ton)

Location		Truck Type				
		PT	LT	MT	HT	TOTAL
Region:						
Northern:	N	1.0	3.4	5.6	14.3	7.0
Northeastern:	NE	1.0	3.2	5.3	13.7	4.4
Central:	C	1.1	3.4	6.2	14.2	9.4
Southern:	S	1.0	3.3	5.3	11.7	6.2
Whole Kingdom		1.1	3.3	5.8	13.8	7.3

ii. Payload

The interviewed trucks were not weighted during the traffic surveys, however, the payload was approximately estimated according to the proportional of the loaded volume to the total capacity in tons. Appendix 6.8 gives the estimated values of the average payload for each of the four categories of trucks. These values were estimated for the two directions of traffic after excluding empty trucks. Table 6.4 gives the estimated values of the payload in ton for each region and the whole country.

Table 6.4 AVERAGE ESTIMATED PAYLOAD OF TRUCKS BY REGION (ton)

Location		Truck Type				
		PT	LT	MT	HT	TOTAL
Region:						
Northern:	N	0.9	2.9	5.1	13.9	7.2
Northeastern:	NE	0.9	2.7	4.9	13.9	7.2
Central:	C	0.9	2.6	5.3	13.6	9.3
Southern:	S	0.8	2.4	4.5	11.2	6.6
Whole Kingdom		0.9	2.7	5.1	13.3	8.3

iii. Empty Vehicles

The percentage of empty commodity vehicles was calculated for interviewed vehicles at all survey stations. Appendix 6.9 gives the percentage for the four categories of commodity vehicles in both directions. Extreme values of 0.0% or 100% result due to the nonexisting or the few number of samples in some cases. Accumulating these results on regional base may give more accurate information on the movement of empty vehicles. Table 6.5 presents the ratio of empty vehicles in the four regions.

Table 6.5 EMPTY VEHICLE RATIO OF TRUCKS BY REGION (%)

Location		Truck Type				
		PT	LT	MT	HT	TOTAL
Region:						
Northern:	N	51.0	63.8	48.2	40.2	46.8
Northeastern:	NE	86.1	72.0	62.3	49.6	74.3
Central:	C	53.8	48.5	44.9	41.1	45.1
Southern:	S	55.6	47.7	45.6	32.8	44.2
Whole Kingdom		68.0	58.0	49.6	40.9	53.2

iv. Number of Assistants

Number of assistants in commodity vehicles is one of the factors used in the economical evaluation of vehicle operating cost. Appendix 6.10 gives the average number of assistants for the four categories of all the interviewed commodity vehicles. The average number of assistants per region is presented in Table 6.6.

Table 6.6 AVERAGE NUMBER OF ASSISTANTS BY REGION (person)

Location		Truck Type				
		PT	LT	MT	HT	TOTAL
Region:						
Northern:	N	0.3	0.7	0.6	0.5	0.4
Northeastern:	NE	0.0	0.1	0.2	0.2	0.1
Central:	C	0.3	0.6	0.6	0.4	0.4
Southern:	S	0.6	0.7	0.7	0.5	0.6
Whole Kingdom		0.2	0.5	0.5	0.4	0.3

v. Commodity Distribution and Flow

Commodities are divided into 23 different types according to the classification of the Land Transport Department (LTD) of Thailand. The estimated commodity flow for each type by survey station in tons per day is presented in Appendix 6.11. The regional flow of all types of commodities is presented in Table 6.7 which clarifies the regional activities and the regional interrelation through the flow direction of commodities.

Table 6.7 ESTIMATED COMMODITY FLOW BY REGION BOUNDARY (ton/day)

Region Boundary	Commodity Type: Rice	Sand & Gravel	Cement & Prod'ts	Steel	Construct'n Materials	Timber	Firewood	Petroleum Prod'ts
Northern to Northeastern	35	2025	1	2	4	29	3	86
Northeastern to Northern	36	63	1	0	18	2	1	7
Both Directions	72	2088	2	2	22	31	4	93
Northern to Central	849	939	301	165	229	393	264	1233
Central to Northern	190	1079	1579	328	483	87	1	2489
Both Directions	1039	2088	1880	493	712	480	265	3723
Northeastern to Central	1813	248	336	413	439	1702	143	1622
Central to Northeastern	283	687	2724	426	626	237	0	3027
Both Directions	2096	935	3060	839	1065	1939	143	4650
Central to Southern	307	119	193	139	370	239	29	335
Southern to Central	0	17	57	3	101	3534	460	270
Both Directions	307	136	250	142	471	3773	489	605

Region Boundary	Commodity Type: Minerals	Vegetable & Fruits	Cassava	Maze	Sugar	Bean	Jute & Prod'ts	Beverages
Northern to Northeastern	0	107	5	1	0	32	0	19
Northeastern to Northern	0	29	0	0	0	31	0	2
Both Directions	0	137	5	1	0	63	0	21
Northern to Central	5397	1059	939	62	402	390	2	217
Central to Northern	232	209	131	123	70	93	0	471
Both Directions	5628	1268	1070	185	472	483	2	688
Northeastern to Central	116	1103	7553	1134	170	392	179	247
Central to Northeastern	126	387	289	0	0	2	0	0
Both Directions	242	1490	7843	1134	170	394	179	247
Central to Southern	29	1231	0	2	60	86	0	22
Southern to Central	46	335	22	29	0	5	0	49
Both Directions	75	1566	22	31	60	91	0	71

Region Boundary	Commodity Type: Grocery	Animal	Fish	Fertilizer Animal-feed	Housh'd Appli-cances	Other Manu-fact'rs	All Others	Total
Northern to Northeastern	16	58	2	75	47	53	64	2661
Northeastern to Northern	9	70	13	8	10	15	133	447
Both Directions	25	128	15	83	57	68	198	3108
Northern to Central	623	154	156	311	180	335	2795	17391
Central to Northern	424	69	28	561	309	238	3445	12642
Both Directions	1047	223	184	873	489	573	6245	30033
Northeastern to Central	180	236	315	370	296	860	3640	23510
Central to Northeastern	25	152	178	436	231	218	3358	13414
Both Directions	205	388	493	806	527	1078	7004	36924
Central to Southern	171	103	93	1038	130	376	3270	8341
Southern to Central	126	100	2671	218	79	108	1890	10020
Both Directions	1976	204	2764	1256	209	484	5160	18362

c. Passenger-vehicle movement characteristics

Following sections present results related to the movement characteristics of the five categories of passenger vehicles.

i. Capacity

The average capacity for the five categories of passenger vehicles is presented in Appendix 6.12 for each survey station. Considering the regional boundaries, Table 6.8 gives the average capacity of passenger vehicles per type for the four regions.

Table 6.8 AVERAGE CAPACITY OF PASSENGER VEHICLES BY REGION (person)

Location		Vehicle Type					
		PC	LB	MB	HB	PP	TOTAL
Region:							
Northern:	N	5.1	18.2	40.9	58.6	12.8	15.4
Northeastern:	NE	5.5	14.0	26.8	61.8	11.9	20.6
Central:	C	5.2	13.4	24.4	55.7	11.1	17.2
Southern:	S	5.1	14.1	23.6	55.9	12.9	12.9
Whole Kingdom		5.2	14.7	29.6	57.0	11.9	16.6

ii. Occupancy

Occupancy data of passenger vehicles provide input to person-kilometers of travel and modal choice models which are normally used in comprehensive transportation studies. The average values of these data for each category of passenger vehicles, are presented in Appendix 6.13 for each survey station. Table 6.9 presents the regional characteristics of the total occupancy rates.

Table 6.9 AVERAGE OCCUPANCY OF PASSENGER VEHICLES BY REGION (person)

Location		Vehicle Type					
		PC	LB	MB	HB	PP	TOTAL
Region:							
Northern:	N	2.9	12.9	30.4	40.7	3.7	7.7
Northeastern:	NE	2.6	6.1	16.4	43.2	3.6	12.2
Central:	C	2.6	5.0	14.3	39.7	3.2	9.6
Southern:	S	3.6	7.2	14.7	45.5	3.7	7.2
Whole Kingdom		2.8	7.4	19.4	40.7	3.4	9.2

iii. Trip Purpose

Appendix 6.14 presents the average percentage for the trip purpose of passenger cars and pickups for passengers. Table 6.10 gives the average rates for the same two vehicle categories for trips recorded at the regional boundaries.

Table 6.10 TRIP PURPOSE OF PASSENGER VEHICLES BY REGION (%)

Region Boundary	Passenger Car				Pickup-Passenger			
	Work	Private	Tour	Other	Work	Private	Tour	Other
Northern to Northeastern	37.1	59.6	3.4	0.0	79.4	15.5	4.1	1.0
Northeastern to Northern	48.5	48.5	2.9	0.0	50.8	48.4	0.0	0.8
Both Directions	43.2	53.6	3.1	0.0	63.5	33.8	1.8	0.9
Northern to Central	50.4	39.2	10.2	0.1	56.2	37.7	5.8	0.3
Central to Northern	29.7	47.3	22.2	0.7	39.8	44.4	14.5	1.3
Both Directions	38.5	43.9	17.1	0.5	47.7	41.1	10.3	0.9
Northeastern to Central	42.4	46.5	10.9	0.2	49.7	42.6	7.5	0.1
Central to Northeastern	43.4	46.7	9.8	0.0	59.1	33.6	7.3	0.0
Both Directions	42.9	46.6	10.4	0.1	55.1	37.5	7.4	0.1
Central to Southern	35.8	41.9	18.9	3.4	40.1	48.1	4.6	7.2
Southern to Central	27.7	62.5	8.7	1.1	43.1	50.2	5.1	1.6
Both Directions	31.3	53.3	13.3	2.1	41.6	49.2	4.9	4.3

iv. High Generation and Attraction Amphoes

One main concept in studying the inter-Changwat trips is based on the assumption that all trips start and end at the Changwat centroids. However, more detailed information are required for the locational planning of the motorway network as well as the interchanges. During the traffic surveys, the origin and destination data were collected on the Amphoe level. These data were accumulated and sorted to produce information on the order of the high attraction and generation Amphoes in each Changwat. Almost in all Changwats, the highest trips belong to the Chang wat centers. Only eight Changwats have other Amphoes in the first place and their centers in the second place, which are: Bang Bua Thong in Nonthaburi, Phra Pradaeng in Samut Prakan, Ongkharak in Nakhon Nayok, Mae Sariang in Mae Hong Son, Chon Daen in Phetchabun, Ban Pong in Ratcha Buri, Hua Hin in Pra chuap Khiri Khan, and Hat Yai in Songkhla.

4) Traffic Speed Survey

To estimate the travel time on links of the road network and to determine the speed-flow relationship for assignment procedures, traffic speed surveys, with counts of the related hourly traffic volumes before and after the survey, were carried out on different 23 two-lane sections and 12 multi-lane sections on the national highway network.

a. Speed on Two-Lane Highways

On two-lane highways, where normal traffic flow in one direction influences flow in the other direction, overtaking slower vehicles requires the use of the opposing lane where sight distance and gaps in the opposing traffic stream permit. As volumes, or geometric restrictions, increase, the ability to overtake decreases, which will result in a delay due to the inability to pass. It can be said that the mobility function of these highways is reflected by the average travel speed.

The average hourly traffic volume before and after the survey was used with the average speed measurements to get the speed-flow relationship clarified in Figure 6.6. Assuming straight-line relationship, a regression line was developed to clarify the tendency in speed reduction against the increase in the hourly traffic volume. At low volumes, the speed measurements have an approximate average of 80 KPH, which decreases to just over 60 KPH at a higher volume of 1,400 VPH.

b. Speed on Multi-Lane Highways

The presence of vehicles other than passenger cars in the traffic stream of multi-lane highways affects flow in two ways: (a) such vehicles are mostly larger than passenger cars (heavy vehicles) and occupy more road space, and (b) the operating capabilities of such other vehicles (heavy vehicles and motorcycles) are generally inferior. Figure 6.7 shows the traffic speed observations in relation to the hourly traffic volume of 12 sections of multi-lane highways. No clear relationship was obtained during the field survey due to the limited number of survey locations. High speeds of about 90 KPH were measured at low volumes and some lower speeds of about 60 KPH at high volumes. However, at medium volumes speed data were largely scattered, which could be a result of other involved factors such as the existing of high rates of heavy vehicles or motorcycles in the traffic stream.

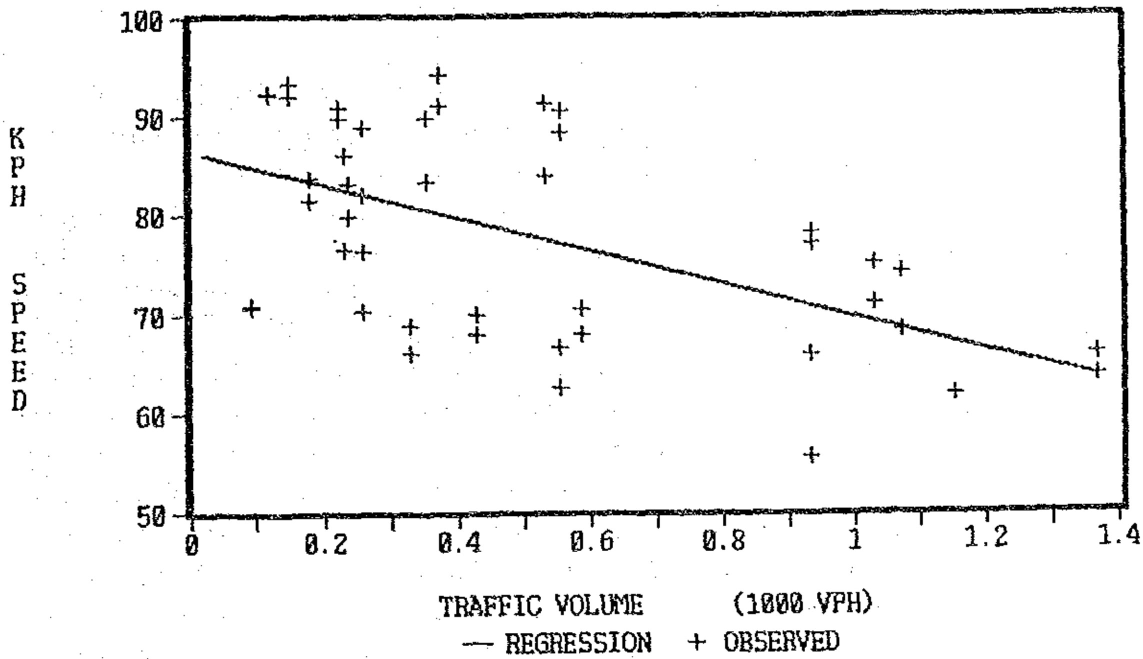


Figure 6.6 RELATIONSHIP BETWEEN SPEED AND TRAFFIC VOLUME ON TWO-LANE HIGHWAYS

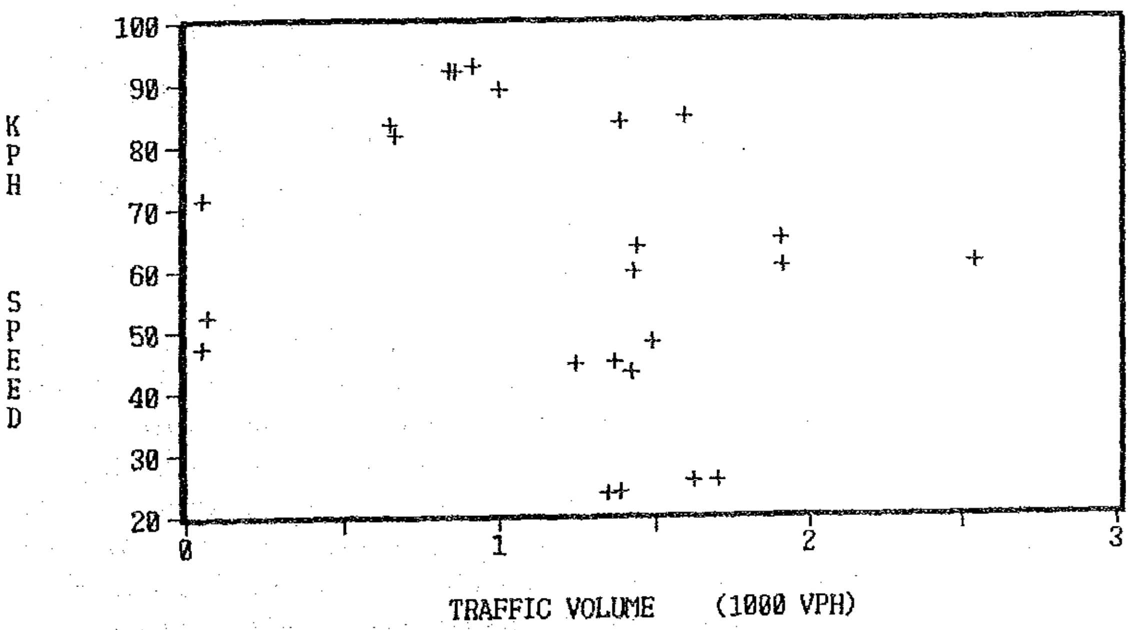


Figure 6.7 RELATIONSHIP BETWEEN SPEED AND TRAFFIC VOLUME ON MULTI-LANE HIGHWAYS

6.3 ESTABLISHMENT OF PRESENT AND FUTURE OD TABLES

6.3.1 Methodology of Present OD Tables

This section is concerned first with the establishment of the inter-Changwat trip matrices per vehicle category for the base year 1990 which form the foundation for the future forecasted OD tables. Starting from the expanded inter-zonal OD matrices, a screening procedure is established on two stages at the region and division boundaries to select data of inter-region and inter-division trips with no probability of being double counted. On the other hand, the unselected data, having some probability of being partially double counted on the region or division boundaries, are not excluded but applied to a feedback process. The objective of this process is first to adjust the OD pattern of trips by heavy buses from/to Bangkok due to their unique night trip pattern, then to adjust the OD pattern of other vehicle categories on the region and division screen lines. This technique is developed to allow reintroducing other unselected trip data with also no probability of being double counted into the trip matrices.

Next, and in order to synthesize the present OD trip tables, trips are assigned on the national highway network and the traffic volume pattern of the ADT data collected by DOH is used to supplement links of Changwat-pairs uncovered by the traffic surveys. Figure 6.8 presents the overall flow chart of the methodology applied to establish the present OD tables. Following is a more detailed explanation for the main steps in the methodology of preparing the present OD tables.

1) Expanded OD Matrices

The first step to produce a trip matrix in general is to form it directly from expanded observed trip records. The number of trips represented by each interview for each survey station is expanded on the basis of the estimated expansion factors. Daily and monthly fluctuation factors are applied as well as the directional split adjustment factors. The resulting number of trips for each vehicle type is accumulated with all other records sharing the same zones in the matrix cell defined by that origin and destination.

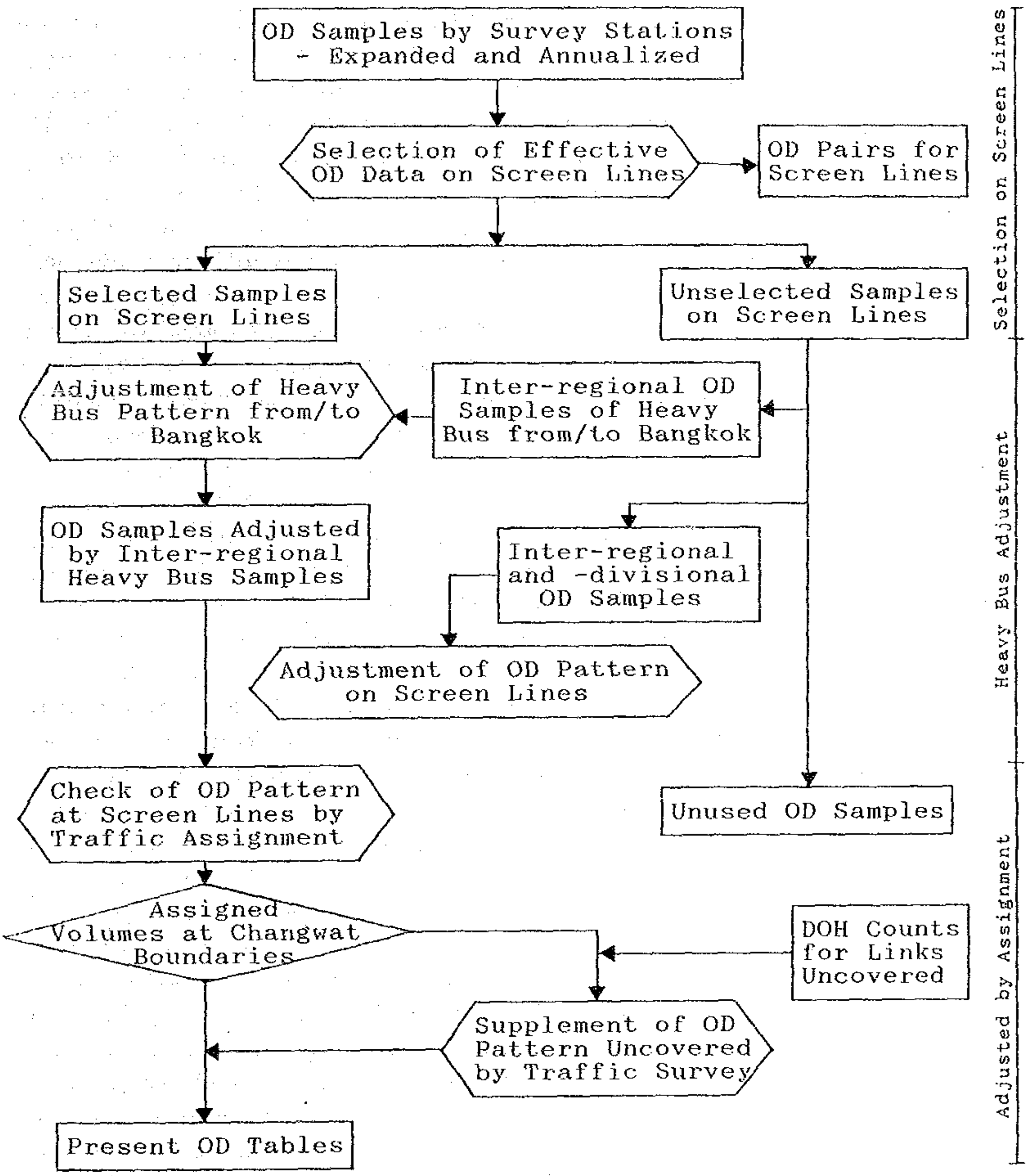


Figure 6.8 ESTABLISHMENT OF PRESENT OD TABLES

Trip matrices formed directly from expanded observations contain often a large proportional of cells with a zero value specially for individual vehicle categories. These zeros are considered not exactly true because a zero cell can not guarantee that there are actually no trips between the two zones during the survey period. Also, when using expanded data of surveys on sampling base to establish trip matrices, another error will be generated. Some cells of the observed data may have one observed vehicle in particular categories, so after expansion the new value will have the same OD pair of the original vehicle. This is not an accurate estimation and may cause some unbalance in the trip pattern.

In this study, and to minimize the data errors, adjustments are done separately on two stages, first to adjust the trip pattern of the heavy bus category, then to adjust the pattern of other vehicle categories. Next, trips are assigned on the national highway network and calibrated to produce synthetic trip matrices which match the existing conditions.

2) Screen Line Selection

One of the main points which has to be treated very carefully when producing trip matrices on the base of field data collected through an OD roadside interview survey is the double counting phenomena, in which some vehicles of long trips may be recorded twice at different survey stations. For limited and short-period OD surveys, there are some precautions which may be considered. In this study, however, such precautions are not of great effect since the OD survey is a comprehensive nationwide survey and involves large distances in conjunction with specific data sample requirements.

To solve this problem, a special screening technique on two stages is developed to select trip data with no probability of being double counted. In the first stage, data of inter-region trips are selected only from data of stations on region screen lines, i.e. stations on region screen lines are used to record OD movement between two Changwats in different regions. Then, in the second screening stage, data of intra-region inter-division trips are selected from data of stations on division screen lines. In other words, stations on division screen lines are used to record OD movement between two Changwats in different divisions but in the same region. Trip data between two Changwats in the same division are selected from data collected through the third type of survey stations which are located only on Changwat boundaries. Data selected through this technique have no probability of being double counted. On the other hand, the unselected data have some probability that they may contain a portion of double counted data. These data are re-called later and partially used in a feedback process to carry out the required adjustments.

3) Adjustment of OD Matrices

It was riquired to investigate and consider the effect of night trip pattern of heavy vehicles due to the night long trips traveled by fixed-route buses, and the restricted hours for the day operation of heavy trucks in Bangkok and some urban areas. Data of 24-hours OD surveys of buses and trucks collected by the Land Transport Department (LTD) at locations around BMA were analyzed separately for the movement of passengers and commodities in relation to their trip distances. Trip distances here are the distance between each Changwat and Bangkok Metropolitan. Results show that the two distributions of both day and night trips for commodity vehicles have nearly similar pattern which emphasizes high demand for short trips and lower demand for long trips either during day or night, as shown in Figure 6.9. For the trip pattern for passenger vehicles during the day time, short distance trips have higher demand while the demand for long distance trips is much lower. Night trips, however, have moderate demand for both short and long distances, as shown in Figure 6.10. Considering that the OD traffic survey was continued for only 12-hours between 06:00 am and 18:00 pm and by reviewing the time tables of long distance trips of heavy buses, which are mostly trips inbound to or outbound from Bangkok, many trips are found not to be recorded during the survey period. Accordingly, a special adjustment procedure is developed for the trip distribution of the heavy bus category while the heavy trucks are included in the adjustment procedure of other vehicle categories.

As the trip pattern of heavy buses is different than other vehicles due to long night trips from and to Bangkok, a special adjustment procedure is developed in which the number of inter-region trips by heavy buses between Bangkok and any other Changwat in both directions is systematically scanned in all locations recorded that particular OD pair. Considering the traffic volume of heavy bus category counted at screen lines, the maximum values of trips at any of that locations are found to give the optimum adjustment for the heavy bus trip matrix. The adjustment procedure can be expressed as follows.

$$T_{ij} \quad = \quad MAX\ (T^{1}_{ij},\ T^{2}_{ij},\ T^{3}_{ij},\ .....)$$

Where,

T_{ij}	:	No. of trips from zone *i* to zone *j*
T^{1}_{ij}	:	No. of trips from zone *i* to zone *j* recorded at survey station *1*
1,2,3,....	:	No. of survey stations (from *1* to *123*)

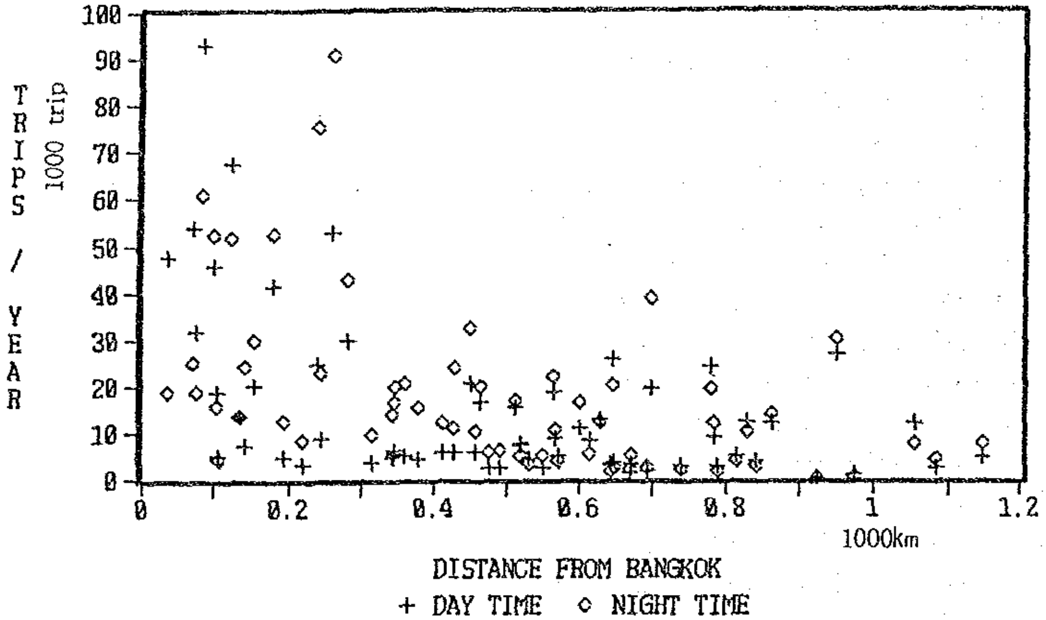


Figure 6.9 DAY AND NIGHT COMMODITY FLOW — 1988
(Source: Land Transport Department)

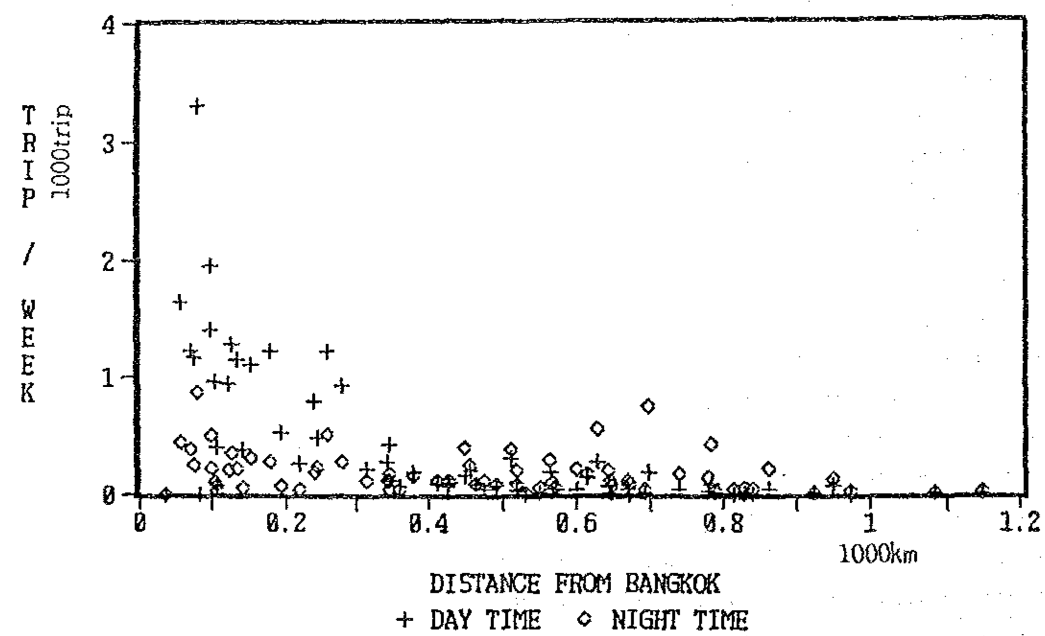


Figure 6.10 DAY AND NIGHT PASSENGER MOVEMENT—1988
(Source: Land Transport Department)

In carrying out the adjustment procedure for the other vehicle categories, which is carried out mainly to correct the effect of the high expansion factors of small samples, equality principle is used on regional base. For each vehicle category, the number of inter-division trips for any OD pair is first concluded according to trips recorded at stations on the selected region and division screen lines. Through another scanning procedure, these trips are compared with all other stations for this particular OD pair. When the first number of trips is found to be higher, it can be included into the OD matrix of that vehicle category. When it is lower, the other higher number of trips is included if the actual sample size is higher than designated minimum number of vehicles by which assigned traffic volumes at screen lines will meet the estimated values of the daily traffic.

6.3.2 Methodology of Future OD Tables

To forecast the future trip distribution, the next step is the determination of the future travel demand of the individual zones and the manner in which they interact. The procedure used for forecasting of the future inter-Changwat trip distribution per vehicle category is based on the resulted present OD tables in addition to the future socio-economic indicators which are highly associated with the travel demand. Another factor, which is the traffic generation due to other development plans, is considered in later stages.

Figure 6.11 shows the overall flow chart of the methodology used in the forecasting procedure for the future demand by origin and destination. From the present OD tables, the trip generation by zone is derived and analyzed by Changwat for each vehicle category. Next, the trip generation prediction model is developed through the application of stepwise approach of multiple regression analysis techniques. Future socio-economic indicators on sectoral and zonal base are introduced and applied in the model to predict the future trip generation.

In this forecasting procedure, trip generation only is used to produce triangular matrices based on the hypothesis of the equality between both future generated and attracted trips for each zone. Several iterative procedures of Frater method are

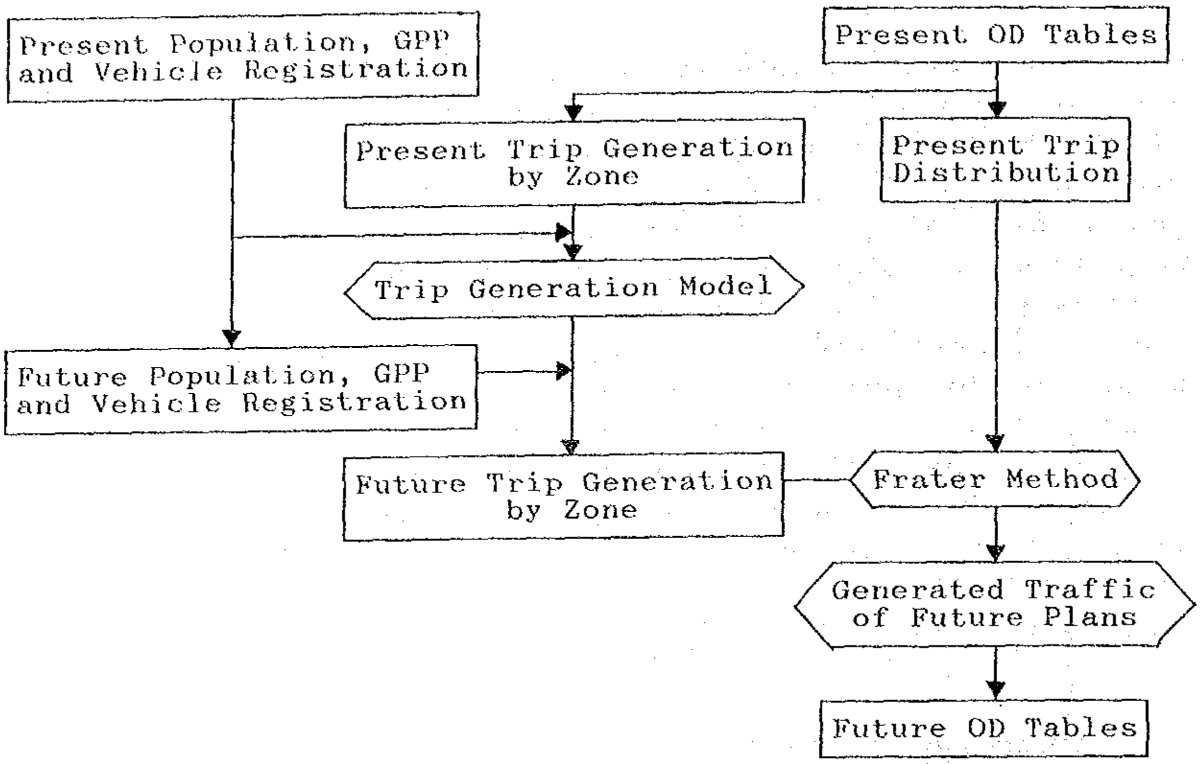


Figure 6.11 ESTABLISHMENT OF FUTURE OD TABLES

applied to synthesize the future trip interchange magnitudes and to overcome imbalances in the trip distribution so that interchanges ultimately balance by direction.

6.3.3 Development of Trip Generation Model

According to the traffic survey results, low volumes were recorded for the medium bus and light truck categories. Because these low volumes may result in mixed forecasting results and to simplify the analysis process, vehicle categories are re-classified into seven categories instead of the nine categories used in the traffic surveys. The seven categories, which are the base of forecasting future generated trips and OD tables, are as follows:

I : Passenger car
II : Light bus
III : Medium and heavy bus
IV : Pickup (passenger)
V : Pickup (cargo) and light truck
VI : Medium Truck
VII : Heavy Truck

For the purpose of model calibration and validity, and to produce total control limitations, vehicle categories I, II, III and IV are combined into Group A which belongs to the passenger vehicles, and Group B, which belongs to commodity vehicles, includes categories V, VI and VII.

Estimations of GPP breakdown per three sectors are concluded to be used in developing the trip generation model. The procedure used is the time series analysis for the sector-base GPP data of the years 1980 — 1987. The three sectors can be defined as follows:

Sector 1 (GPP1): Agriculture, Fishery and Forestry
Sector 2 (GPP2): Mining, Quarrying, Manufacture and Construction
Sector 3 (GPP3): Services and Others

1) Socio-Economic Indicators

To forecast the future trip generation by Changwat for the horizon year of 2010, a future socio-economic framework for the study area is established on the Changwat level. Details of this framework are included in Chapter 4 of this report. Following sections include an analysis for the three main socio-economic indicators of population, GPP and number of registered vehicles, to clarify their effect on the trip generation and attraction.

a. Population

Figure 6.12 gives the trend of the present relationship between the population and number of generated and attracted trips for all Changwats. Bangkok has a separate remote plotting with high values of both population and number of trips. Other Changwats with scattered results do not represent high association between both variables. The effect of population on the inter-Changwat trip generation and attraction can not be considered as a proportional relationship. Appendix 6.15 a gives the number of generated and attracted trips/1000 person/day in each Changwat at present. It is also clarifies that population, in this stage, is not highly associated with the inter-Changwat trip generation and attraction.

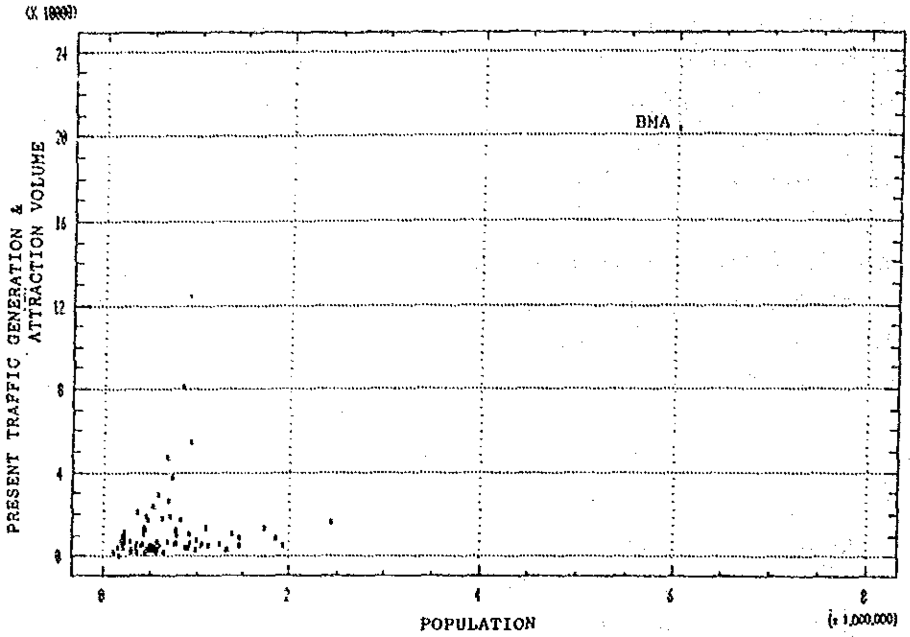


Figure 6.12 POPULATION AND PRESENT TRIP GENERATION AND ATTRACTION

b. Gross Provincial Products (GPP)

The relationship between present GPP of each Changwat and the corresponding trip generation and attraction is investigated and it is found that GPP is more interacted with inter-Changwat trips than population. The trend of the direct relationship between trips and GPP seems to be proportional as shown in Figure 6.13. Bangkok has its remote plotting with high GPP and trips. Other Changwats give a trend that can be considered as highly associated and gives the indicator GPP more potential to be used in the prediction model of the inter-zonal trip generation. Appendix 6.15-b gives the number of generated and attracted trips/million Baht of GPP/day for each Changwat at present, and shows the higher influence of GPP on the number of generated and attracted trips per Changwat.

c. Number of Registered vehicles

In general, the trend of growth in the number of registered vehicles is dependent to a very large extent on the growth in GPP, even with different magnitudes. Figure 6.14 shows the relationship between the present number of vehicles and inter-Changwat trip generation and attraction for all Changwats. As in other socio-economic indicators, Bangkok has its special

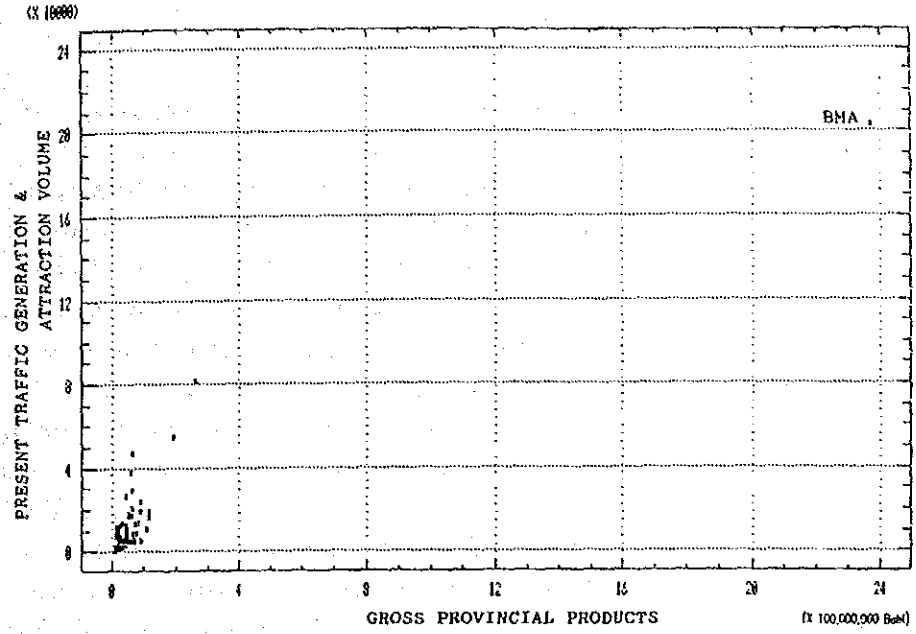


Figure 6.13 GPP AND PRESENT TRIP GENERATION AND ATTRACTION

location comparing with other Changwats. Appendix 6.15-c shows the number of present attracted and generated trips/vehicle/day for each Changwat separately. In conclusion, the overall trend of the effect of the number of registered vehicles on the trip generation and attraction per Changwat looks very similar to that of the GPP.

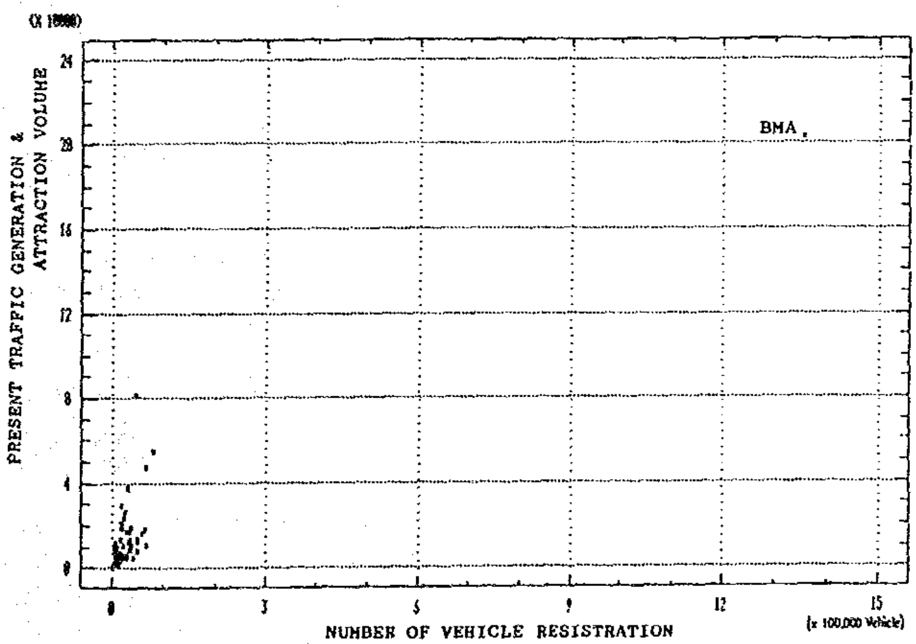


Figure 6.14 NUMBER OF REGISTERED VEHICLES AND PRESENT TRIP GENERATION AND ATTRACTION

2) Model Structure

Stepwise regression analysis programs for trip generation models allow to develop and test a large number of potential regression equations using various combinations and transformations of both the dependent and independent variables. To develop the trip generation model, the most appropriate prediction equations are selected using certain statistical criteria regarding the stability of the multiple correlation coefficients. The independent variables of Changwat population are examined and they do not show high degree of association with the dependent variable of trip generation. However, population is used later in estimating the intra-Changwat trips for traffic assignment purposes. The indicator of the number of registered vehicles is not used in developing the model, since it is found to be similar to the GPP which has the availability of being breakdowned into three sectors.

The model structure is developed for each vehicle category by the use of the highly associated independent variables of the zonal economic indicators of GPP1 and GPP2 in addition to their total GPPT. BMR has a special parameter (d) in the model designed to be used, with dummy BMR, for the trip generation of Changwats in BMR only since they have most of the economic activities with high potential in the trip pattern comparing with other Changwats. The prediction model can be expressed in the following regression equation:

$$Y_I = a * GPP1 + b * GPP2 + c\ GPPT + d * (BMR\ dummy) + e$$

Where, Y_I : No. of trips by vehicle category I
a, b, c, d & e : Parameters, which have the following values for each vehicle category:

Vehicle Category	*a*	*b*	*c*	*d*	*e*	Multiple Correlation Coefficient R^2
I	0.0	0.71758	0.0	6076.18	1060.2	0.93
II	0.0	0.0	0.04825	0.0	240.3	0.81
III	0.11291	0.24509	0.0	0.0	215.2	0.94
IV	0.83131	0.28047	0.0	2150.0	842.3	0.76
V	0.60922	0.16952	0.0	1870.3	673.3	0.76
VI	0.26994	0.18620	0.0	2744.5	271.6	0.91
VII	0.85102	0.28104	0.0	5296.3	324.9	0.69

3) Model Calibration and Validity

In order to calibrate and analyze the validity of the trip generation prediction model, the trip generation per Changwat in two groups of passenger vehicles and commodity vehicles is forecasted separately through the principal component method.

The method depends on analyzing the socio-economic indicators to develop a model for the forecasting of trip generation of the two vehicle groups. Generated trips are obtained by this model as a principal component score to avoid producing negative coefficients in the direct applications of multiple regression analysis. They are used as total control in the validity analysis of the trip generation of the seven vehicle categories by Changwat. The model can be put in the following expression:

$$Zi = a\,(\,\alpha 1 * GPP1i + \alpha 2 * GPP2i + \alpha 3 * GPP3i)^{b}$$

Where, Zi : first principal component score for zone i, represents the number of trips per vehicle group

GPP1,2 & 3 : GPP per sectors 1, 2 and 3 in 1000 Baht

a, b & $\alpha 1,2,3$: Parameters

Values of the parameters for both groups of passenger vehicles and commodity vehicles are as follows:

	a	$\alpha 1$	$\alpha 2$	$\alpha 3$	b	Multiple Correlation Coefficient R^2
Passenger vehicles	0.8722	0.0147	0.5284	0.8489	1.1278	0.87
Commodity vehicles	0.4243	0.0147	0.5284	0.8489	1.1300	0.88

6.3.4 Trips of Future Development Plans

Trip generation analysis and trip distribution procedures are applied to supplement trips due to other committed development plans related to the highway network in order to produce complete future trip distribution and OD tables. This travel demand is a portion of the future traffic volume due to special projects and improvements on land connected by the highway network. Increased traffic due to normal developments is a part of the normal traffic growth and is not considered as a part of this development traffic.

1) Eastern Seaboard Development Area

Primary data of the trips of the Eastern Seaboard Development Area till the year 2008 were obtained from the Road Development Study in the Central Region (JICA, 1989). The study, however, does not consider the rates of empty vehicles in estimating the future trips by commodity vehicles. Percentages of empty vehicles concluded in this study are used to adjust the trip generation and attraction data. Tables 6.11 and 6.12 give the adjusted generated and attracted trips for the two industrial complexes of Laem Chabang and Map Ta Phut per four vehicle categories which are highly affected by development of industrial projects. Data of the year 2010 is estimated by means of extrapolation.

Table 6.11 ADJUSTED GENERATED AND ATTRACTED TRAFFIC OF LAEM CHABANG INDUSTRIAL COMPLEX (vehicles/day)

Vehicle Category	2000	2010
Passenger Car	6295	10458
Heavy Bus	310	410
Medium Truck	1154	1683
Heavy Truck	5980	9263
Total	13739	21813

Table 6.12 ADJUSTED GENERATED AND ATTRACTED TRAFFIC OF MAP TA PHUT INDUSTRIAL COMPLEX (vehicles/day)

Vehicle Category	2000	2010
Passenger Car	3014	5847
Heavy Bus	182	292
Medium Truck	1940	2498
Heavy Truck	3149	4053
Total	8286	12690

For the Changwat base trip distribution of the generated traffic due to the Eastern Seaboard Development Area, a gravity model is applied for each of passenger vehicles and commodity vehicles. The structure of the gravity model is as follows:

$$T_{ij} = a\,(G_i^{b1} * A_j^{b2}) \,/\, D_{ij}^{c}$$

Where;

For Passenger Vehicles:

- Tij : inter-Changwat work purpose passenger car trips of i - j Changwat pair
- Gi : generated passenger car volume from Changwat i
- Aj : attracted passenger car volume to Changwat j
- Dij : inter-Changwat shortest road distance in km
- a, b1, b2 & c : parameters

For Commodity Vehicles:

- Tij : agriculture commodity trips to Bangkok from other Changwat (i)
  manufacture commodity trips from Bangkok to other Changwat (j)
- Gi : generated medium and heavy truck volume from Changwat i
- Aj : attracted medium and heavy truck volume to Changwat j
- Dij : shortest road distance between Bangkok and other Changwats in km

a,b1,b2 & c : parameters, which have the following values:

	a	b1	b2	c	R
Passenger Vehicles	933.25	0.29076	0.22076	1.46340	0.74880
Commodity Vehicles	1.9440E-3	0.68034	0.78562	0.64545	0.85953

Table 6.13 gives summarized results on division base for the future trip distribution from/to the development area. It is expected that the growth of trips by commodity vehicles will be higher than passenger vehicles for both industrial complexes at the year 2000. After that, and at the year 2010, the generated and attracted trips will be nearly equal for both vehicle groups.

Table 6.13 TRIP DISTRIBUTION FROM/TO EASTERN SEABOARD DEVELOPMENT AREA

i. YEAR 2000 (vehicles/day)

DIVISION	LAEM CHABANG			MAP TA PHUT			TOTAL		
	PC+HB	MT+HT	TOTAL	PC+HB	MT+HT	TOTAL	PC+HB	MT+HT	TOTAL
N1	15	19	34	11	14	25	26	33	59
N2	23	21	44	14	18	32	37	39	76
N3	58	61	119	35	51	86	93	112	205
NE1	29	60	89	19	52	71	48	112	160
NE2	21	26	47	14	23	37	35	49	84
NE3	22	31	53	14	30	44	36	61	97
NE4	48	85	133	30	74	104	78	159	237
C1	158	233	391	86	184	270	244	417	661
C2	1614	677	2291	768	448	1216	2382	1125	3507
C3	472	813	1285	232	619	851	704	1432	2136
BMR	700	1719	2419	278	1175	1453	978	2894	3872
S1	15	22	37	10	18	28	25	40	65
S2	16	30	46	11	24	35	27	54	81
S3	15	27	42	10	23	33	25	50	75
TOTAL	6605	7134	13739	3196	5089	8285	9801	12223	22024

ii. YEAR 2010

DIVISION	LAEM CHABANG			MAP TA PHUT			TOTAL		
	PC+HB	MT+HT	TOTAL	PC+HB	MT+HT	TOTAL	PC+HB	MT+HT	TOTAL
N1	26	21	47	20	14	34	46	35	81
N2	37	26	63	27	18	45	64	44	108
N3	96	74	170	71	52	123	167	126	293
NE1	47	72	119	37	53	90	84	125	209
NE2	32	32	64	26	24	50	58	56	114
NE3	33	41	74	27	30	57	60	71	131
NE4	79	106	185	58	76	134	137	182	319
C1	256	323	579	163	215	378	419	538	957
C2	2593	860	3453	1457	484	1941	4050	1344	5394
C3	781	1220	2001	453	784	1237	1234	2004	3238
BMR	1223	3075	4298	568	1795	2363	1791	4870	6661
S1	23	28	51	17	21	38	40	49	89
S2	25	36	61	20	27	47	45	63	108
S3	25	37	62	19	29	48	44	66	110
TOTAL	10868	10946	21814	6139	6551	12690	17007	17497	34504

2) Southern Seaboard Development Area

The forecasted number of generated and attracted trips per vehicle category of the Eastern Seaboard Development Area for the year 2010 is used here temporarily, and only as an assumption, for the case of the Southern Seaboard since there are no available estimations for its future trips. The total number of trips is used for the inter terminal movement on the landbridge connecting the two terminals of Krabi and Khanom. A supplement of 20% is added for trips from/to Bangkok, and another 10% for trips from/to Song Khla, representing trips to the north and south of the development area. Table 6.14 gives the total number of generated and attracted trips for the whole area, which is assumed to be equally divided between the two terminals.

Table 6.14 GENERATED AND ATTRACTED TRIPS OF SOUTHERN SEABOARD DEVELOPMENT AREA - 2010 (TOTAL FOR TWO TERMINALS)

Vehicle Type	Inter-Terminal * 1	to/from Bangkok * 2	to/from Song Khla * 3	Total
Passenger Car	16300	3260	1630	21190
Heavy Bus	700	140	70	910
Medium Truck	4200	840	420	5460
Heavy Truck	13300	2660	1330	17290
Total	34500	6900	3450	44850

Note : *1 Apply estimated daily trips of Eastern Seaboard
*2 Assume 20 % of (*1)
*3 Assume 10 % of (*1)

6.3.5 Trip Distribution Analysis

Trip generation estimates the number of trips originating and terminating in zones, while trip distribution is the process of computing the number of trips between one zone and all others. The developed trip distribution procedure provides a full matrix of trips between all zones in the given zoning system. This procedure is based on Frater Method which is widely used in future highway travel demand studies. The basic premise of this method is that the distribution of future trips from a zone is proportional to the present trip-distribution pattern modified by the growth factors of all the zones under consideration. Because of the special nature of the computation, successive iteration procedures are used as an adjusting steps in the trip distribution stage.

The method uses the following expressions to synthesize the future trip-interchange magnitudes and to overcome imbalances in the trip distribution so that interchanges ultimately balance by direction.

$$T_{ij} = (T_{ij}(i) + T_{ij}(j)) / 2$$

$$T_{ij}(i) = t_{ij} * F_i * F_j * L_i$$

$$T_{ij}(j) = t_{ij} * F_i * F_j * L_j$$

$$L_i = \Sigma t_{ix} / \Sigma t_{ix} * F_x$$

$$L_j = \Sigma t_{jx} / \Sigma t_{jx} * F_x$$

Where,

- T_{ij} : Future trips from zone i to zone j
- $T_{ij}(i)$: Future trips from zone i to zone j considering growth of zone i
- $T_{ij}(j)$: Future trips from zone i to zone j considering growth of zone j
- t_{ij} : Present trips from zone i to zone j
- F_i, F_j : Growth factors of trips for zones i and j
- L_i, L_j : Locational factors
- t_{ix}, t_{jx} : Present trips from zone i and j to another zone x
- F_x : Growth factor of trips for zone x

The iteration process continued until the trips generated through the generation model for each zone equal to the trips distributed to that zone from all other zones. During this procedure, the triangular shape of the matrices is transformed into the rectangular generation attraction pattern and due to the synthesizing process some inequalities are produced between generation and attraction trips. In this study five iteration were required to produce fully synthetic trip matrices represent the future OD tables for both years of 2000 and 2010.

6.4 PRESENT AND FUTURE TRIP PATTERN

The major purpose of the comprehensive OD studies is to obtain information on existing movements so that they can be modeled for making future projections on demand in order that strategic plans and policies can be developed. To summarize the resultant OD data, a graphical representation is prepared by desire line charts which show a number of trips routed directly between each zone centroid and all others, without taking any account of the routes taken by drivers.

6.4.1 Present OD Tables and Desire Line Charts

Results from OD tables are analyzed on three zoning levels. Basically, they are presented on the Changwat level which is the unit of OD movements and the base of planning the motorway network. Results on the division and region zoning levels, which are established for the analysis procedure in the stage of establishing the OD tables, are also presented.

1) Inter-Changwat Trips

The detailed inter-Changwat OD standard table for the total vehicles is presented in Appendix 6.16 as the total number of trips between all pairs of Changwats. Inter-Changwat desire line chart for the total vehicles in both directions is presented in Figure 6.15 for all Changwats with a separate presentation for trips from/to Changwats of BMR. As shown in this figure, Bangkok and surrounding Changwats in the Central Region have the highest share of trips in the whole country with some other lower potential of Changwats in other regions.

Generation and attraction of inter-Changwat trips are presented for each vehicle category in Appendix 6.17. Considering the number of generated or attracted trips for all vehicles, Samut Prakan is in the second place after Bangkok, and is followed by Chon Buri, Nakhon Pathom and Ratchaburi in the same order. The lowest number of trips for all vehicle categories belongs to Mae Hong Son.

2) Divisional Trips

The numbers of intra-division and inter-division trips for the total number of vehicles and per vehicle category are presented in Appendix 6.18, in which intra-division trips show high potential specially for divisions in the Central Region. Inter-division desire line chart for the total vehicles in both directions is illustrated in Figure 6.16. In general, divisional trips have some tendency to form regional blocks, i.e. trips between divisions in the same region are remarkably higher than trips with divisions in other regions.

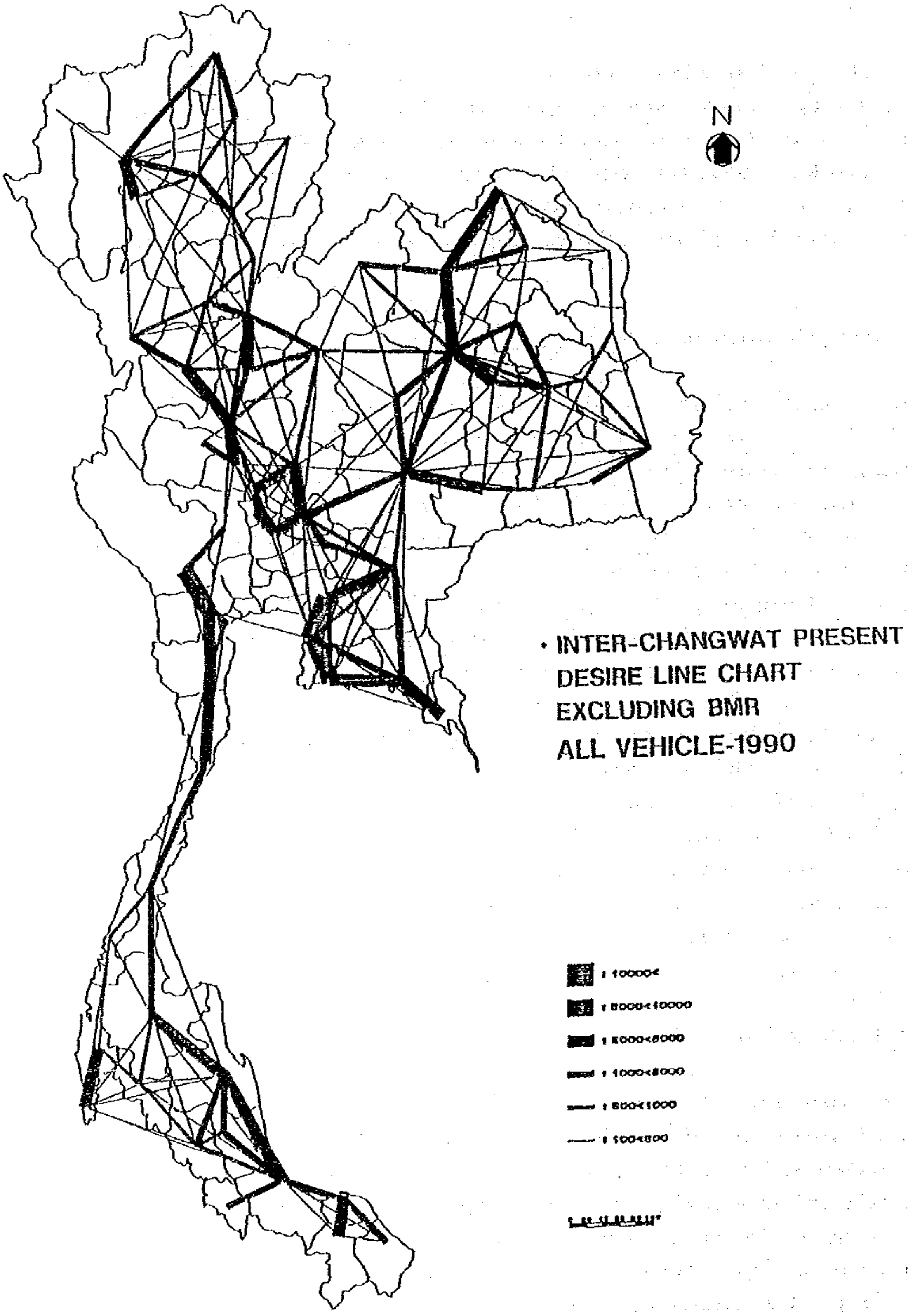


Figure 6.15 INTER-CHANGWAT DESIRE LINE CHART — 1990
i. WITHOUT CHANGWATS OF BMR (continued)

(continued)

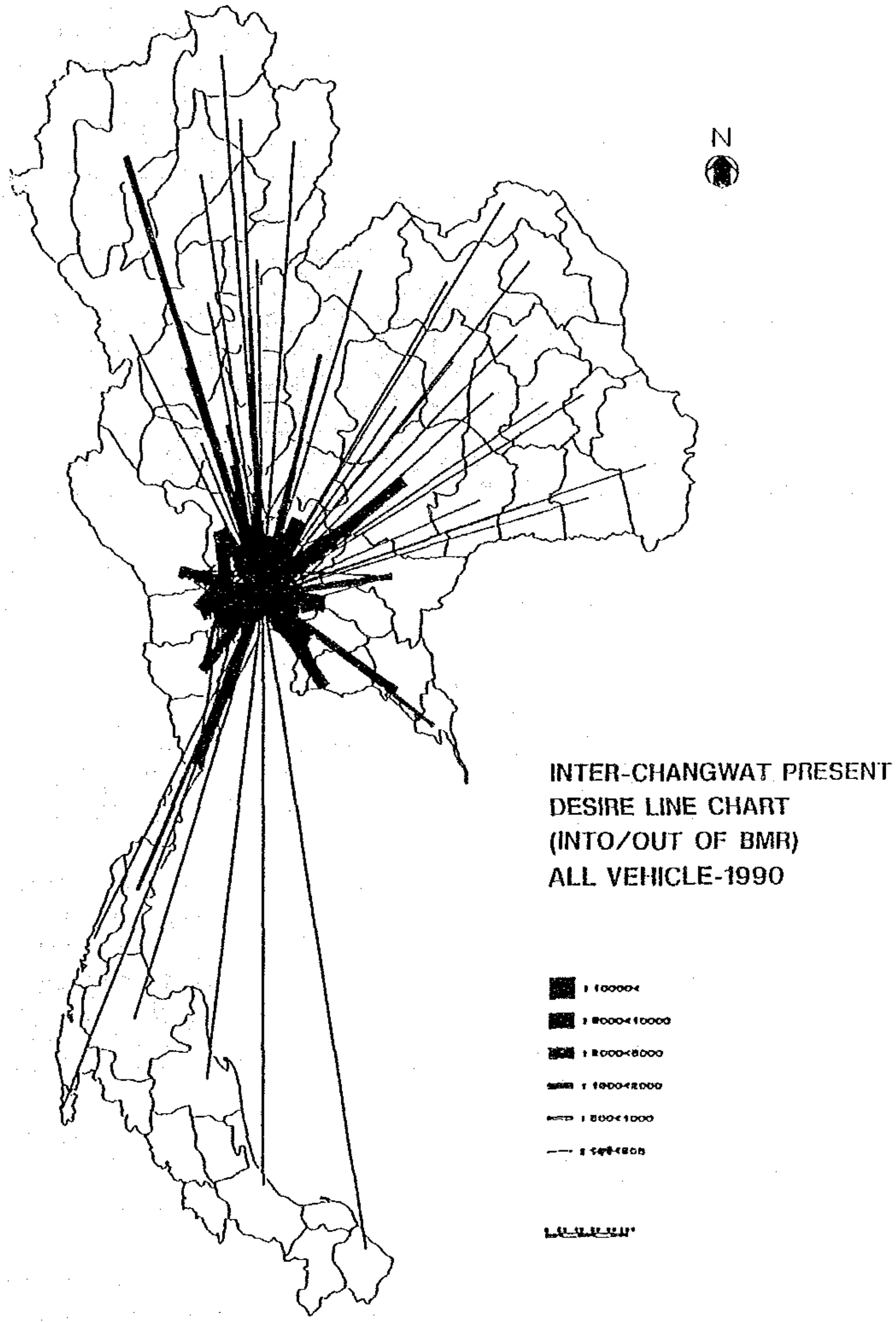


Figure 6.15 INTER-CHANGWAT DESIRE LINE CHART — 1990
ii. CHANGWATS OF BMR

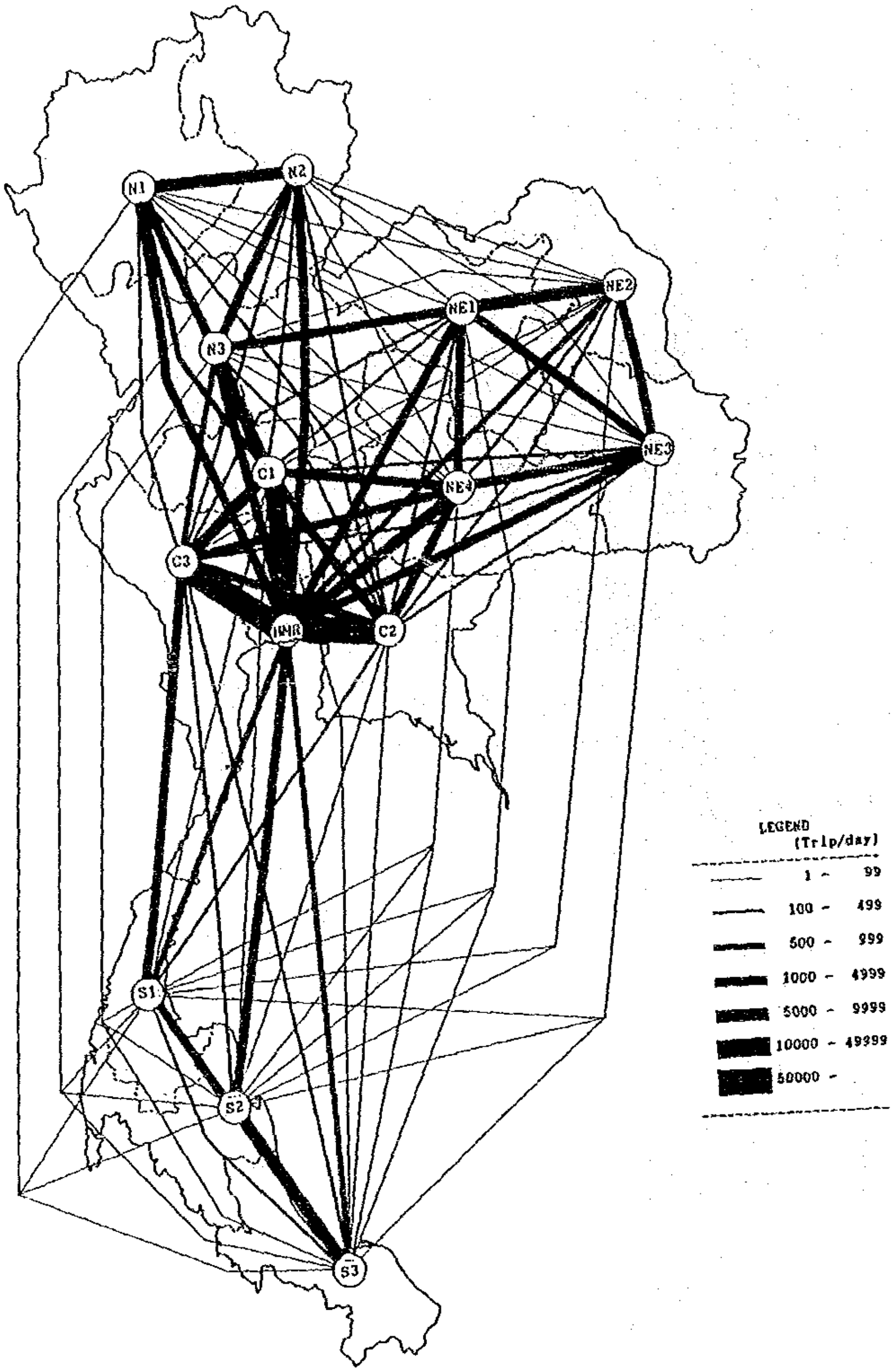


Figure 6.16 INTER-DIVISION DESIRE LINE CHART
FOR ALL VEHICLES — 1990

3) Regional Trips

Figure 6.17 shows the inter-regional desire line chart for both directions separately per vehicle category. Pick-up for passeners and heavy truck categories are the most used vehicles for inter-region trips. On the other hand, categories of the light bus, medium bus and light truck have the lowest number of trips. The regional OD tables for each vehicle category as well as for all vehicles are presented in Appendix 6.19.

Considering the total number of regional trips which includes both intra-region and inter-region trips, Appendix 6.20 gives the generated and attracted trips per vehicle category. For graphical presentation, the nine categories of vehicles are compacted into only five groups ; three groups for passenger vehicles which are passenger car (PC), all sizes of bus (B) and pickup (PP), and two groups for commodity vehicles which are pickup truck (PT) and all sizes of truck (T). Figure 6.18 shows the share of each vehicle group in the total number of trip-ends per region.

4) Regional Trips by Commodity Groups

Commodities are classified by the Land Transport Department (LTD) into 23 types. For macro-analysis purposes, the types of commodities are set into four groups as follows:

a. Agriculture products:
   Rice - Timber - Firewood - Vegetable and Fruit - Cassava - Maize - Sugar - Bean - Animal - Fish

b. Construction Products:
   Sand and Gravel - Cement and Products - Construction Materials - Steel

c. Manufacture Products:
   Petroleum Products - Minerals - Jute and Products - Beverages - Grocery - Fertilizer and Animal Feed - Household Appliances - Other Manufactures

d. All Others

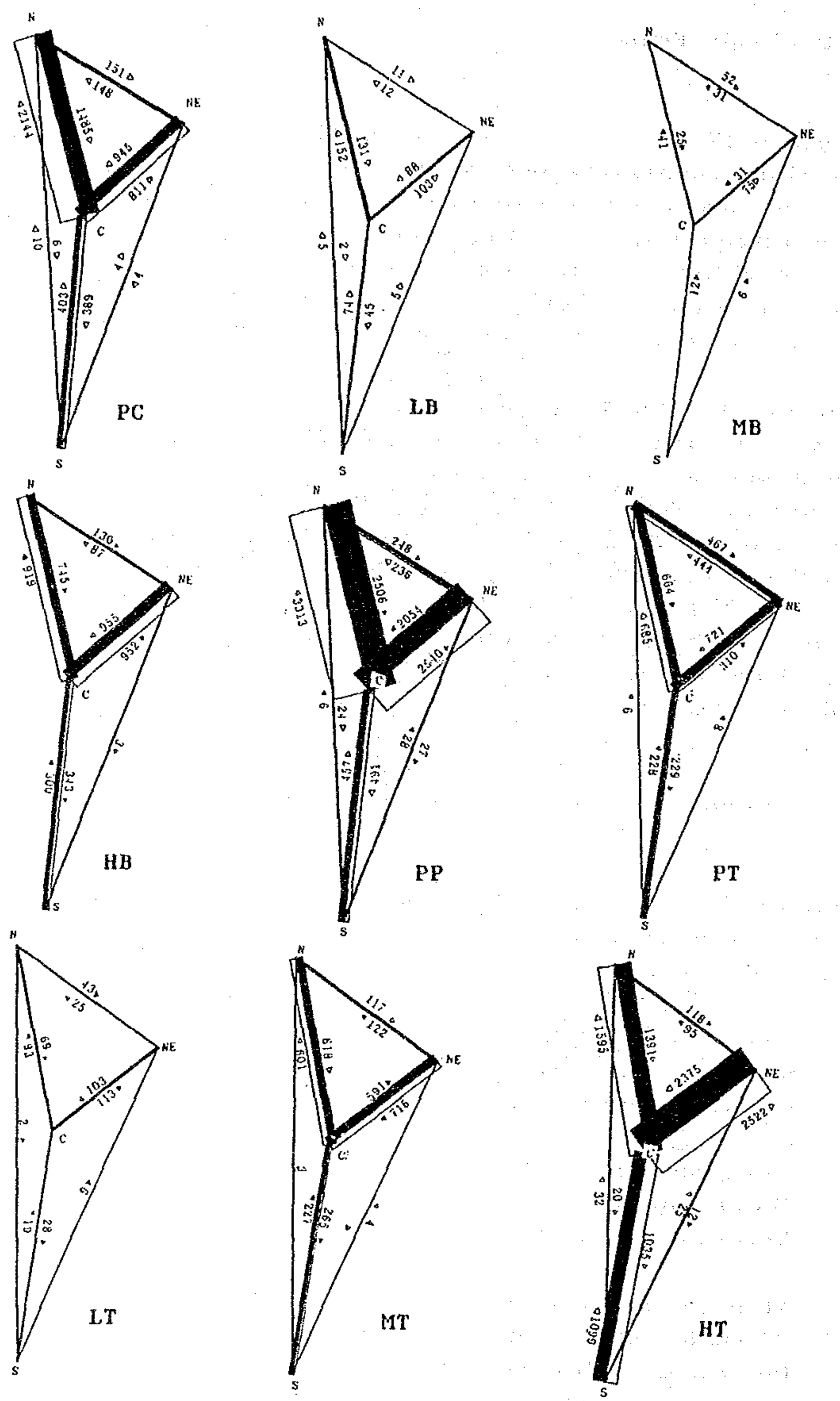


Figure 6.17 INTER-REGION DESIRE LINE CHART — 1990
i. PER VEHICLE CATEGORY (continued)

(continued)

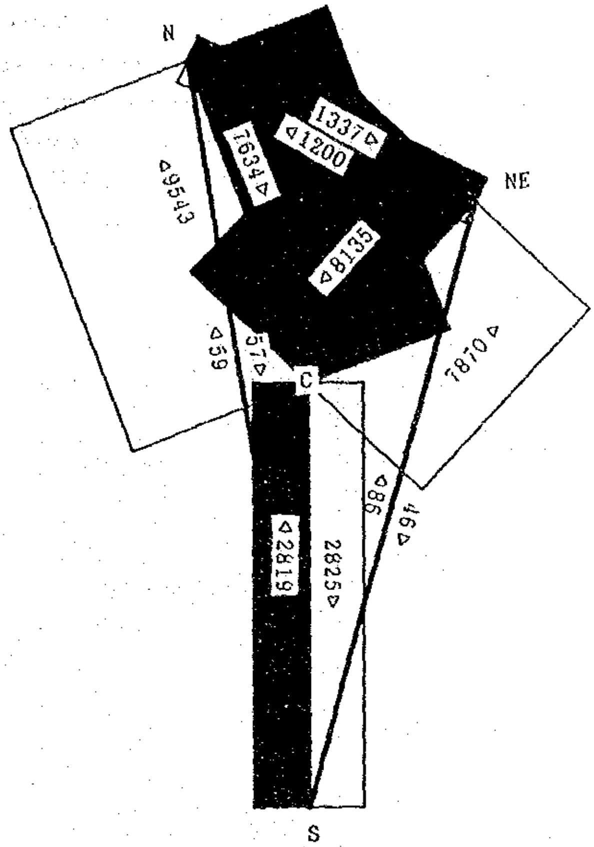


Figure 6.17 INTER-REGION DESIRE LINE CHART — 1990
ii. ALL VEHICLES

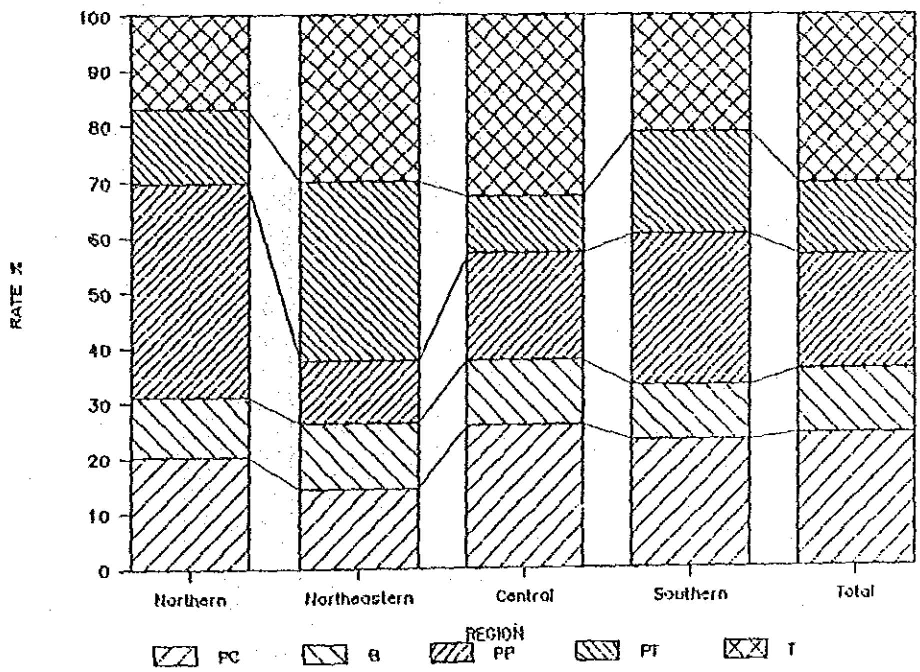
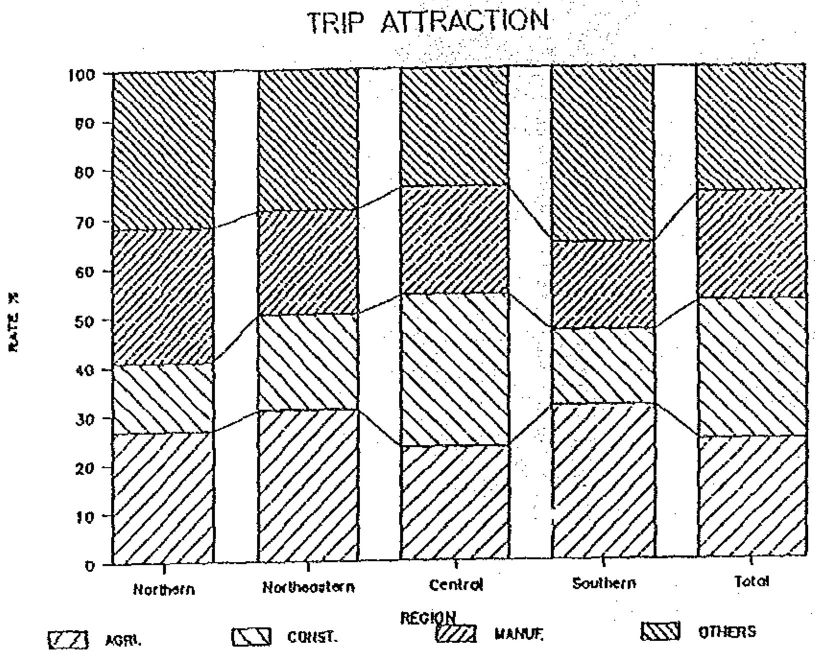


Figure 6.18 REGIONAL TRIP-END COMPOSITION BY VEHICLE GROUP — 1990

Appendix 6.21 gives the regional trip generation and attraction with the composition ratio of each commodity group in both units of trip/day and ton/day for the four categories (PT, LT, MT & HT) of commodity vehicles. The composition ratio for each commodity group per region is shown graphically in Figure 6.19.



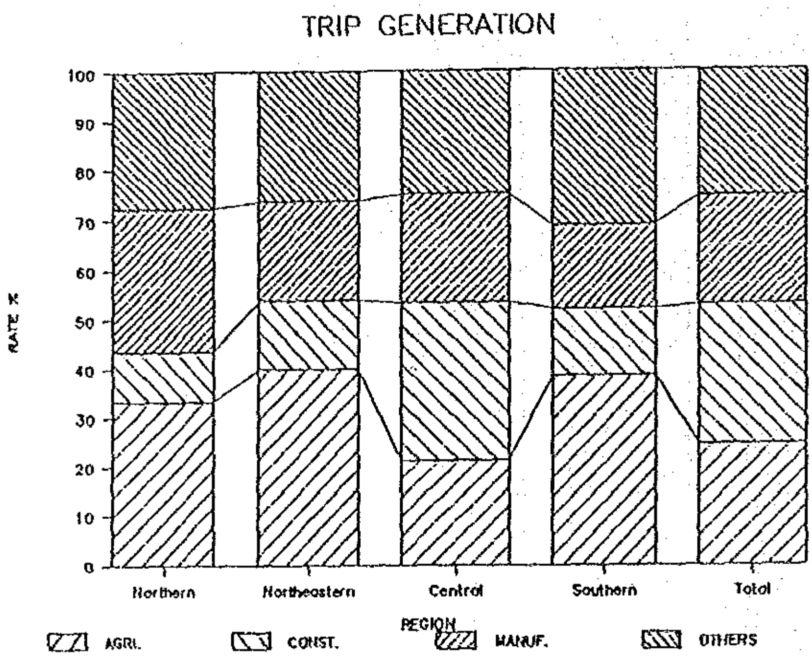
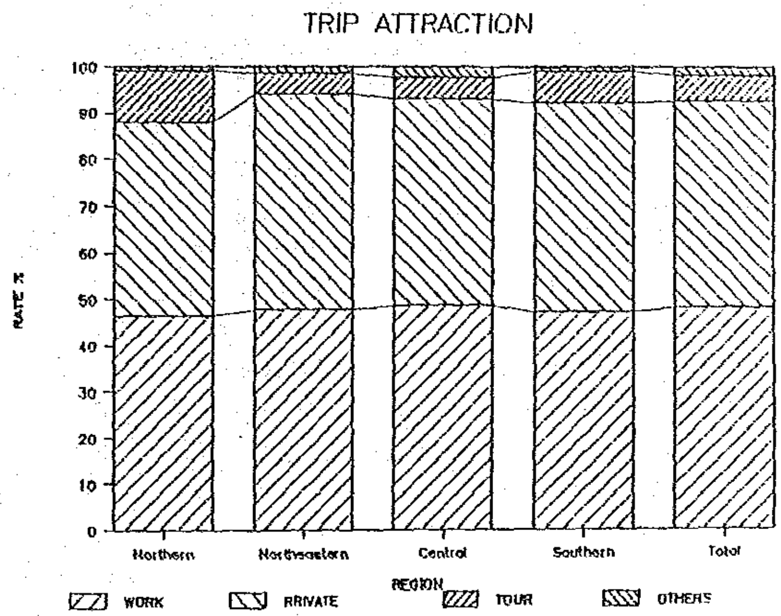


Figure 6.19 COMMODITY GROUP COMPOSITION FOR TRIP GENERATION AND ATTRACTION – 1990

5) Regional Trips by Trip Purpose

The composition of trip purpose, on the regional base, is clarified in Figure 6.20. Appendix 6.22 gives the regional distribution for the generated and attracted trips by the four types of trip purpose in trip/day and person/day.



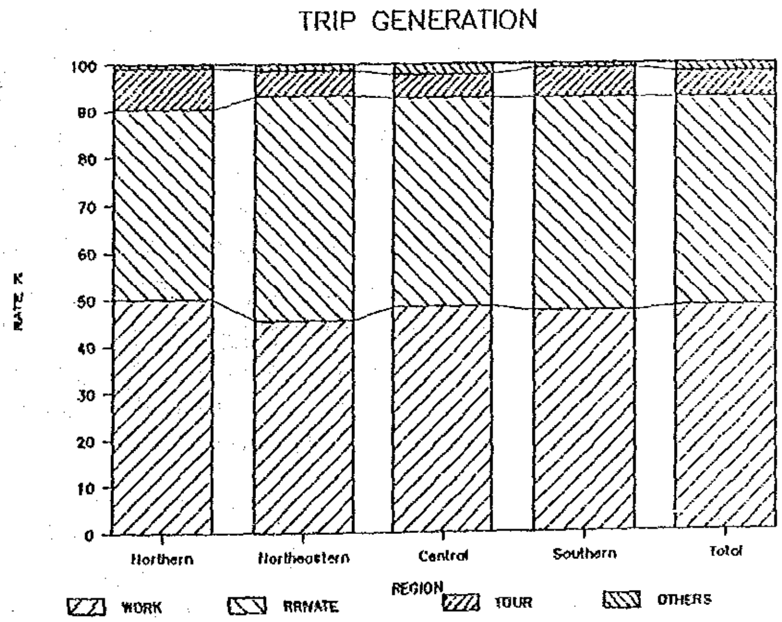


Figure 6.20 TRIP PURPOSE COMPOSITION — 1990

In this trip-purpose analysis, the total values of two categories of passenger vehicles (PC and PP) are only considered. The majority of both generation and attraction trips in the four regions are for the purpose of work or private.

6) Trips from/to BMR

As a special zone that contains high-volume of trip generator and attractor, Bangkok Metropolitan Region (BMR) is considered as the focal point of most trips specially in the Central Region. The total number of trips per day for the two cases of "From BMR" and "To BMR" is shown in Figure 6.21 in relation to all other divisions. According to the number of trips per day, the highest interaction is between BMR and other divisions in the Central Region in the order of C3, C2 and then C1. Regionally, the Northeastern has the highest number of trips with BMR, and is followed by the Northern and Southern Regions.

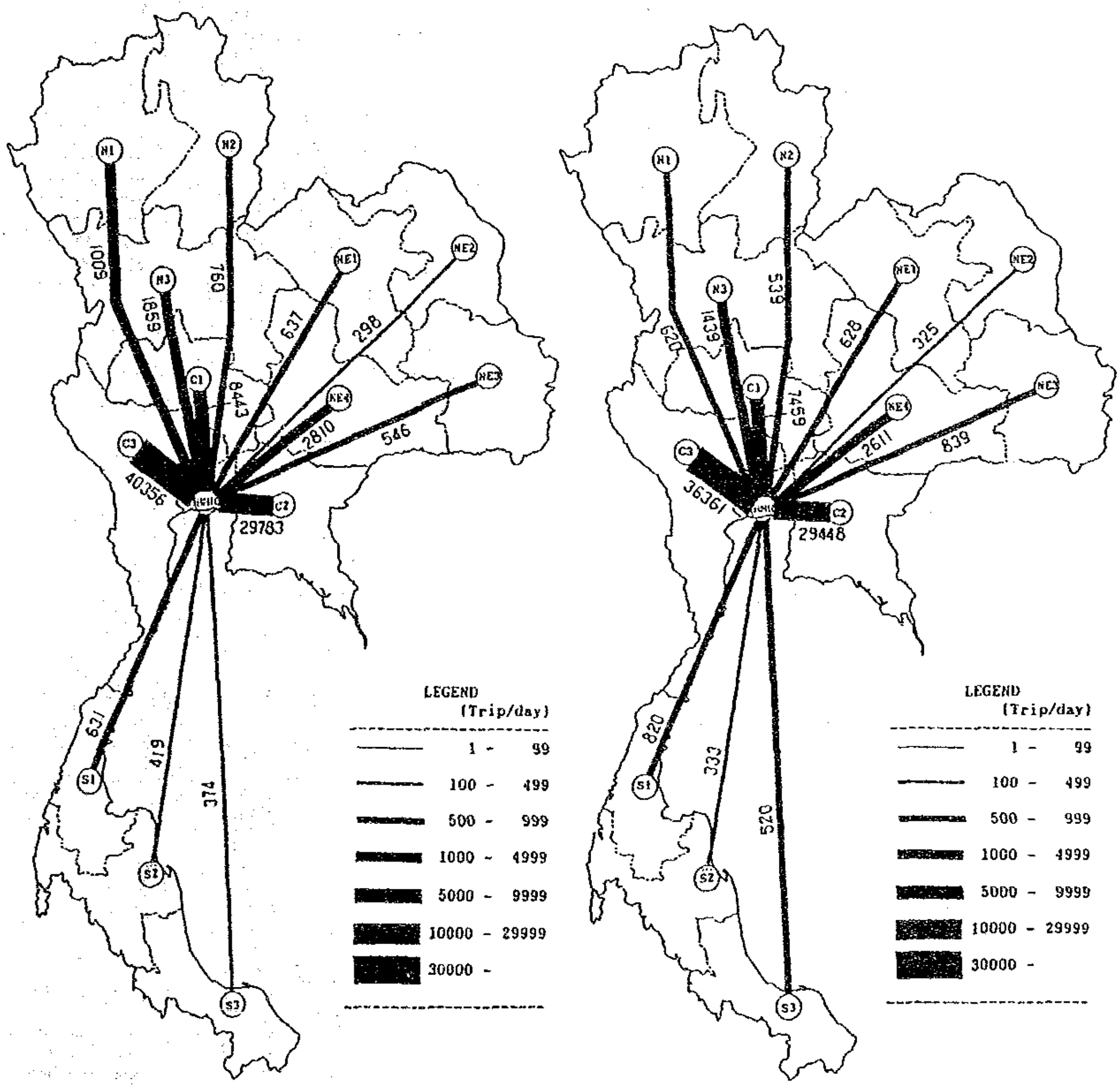
As most of the socio-economic activities of Thailand is concentrated in Bangkok Metropolitan Region (BMR), Figure 6.22 clarifies the commodity flow pattern in relation to all other divisions for all types of commodities in total. It is clear that the divisions of the Central Region, specially C2 and C3, have the highest potential in trading with BMR. Appendix 6.23 gives the commodity flow from and to BMR for the four commodity groups classified above. The same relationships are presented also graphically in Appendix 6.24.

6.4.2 Future Trip Pattern

Results of the trip distribution analysis produced the forecasted inter-Changwat trips in the form of future OD tables for all vehicle categories per Changwat for both target years of 2000 and 2010. The following sections present the main results obtained through analyzing the future trip pattern in the same process of the present OD tables.

1) Inter-Changwat Trips

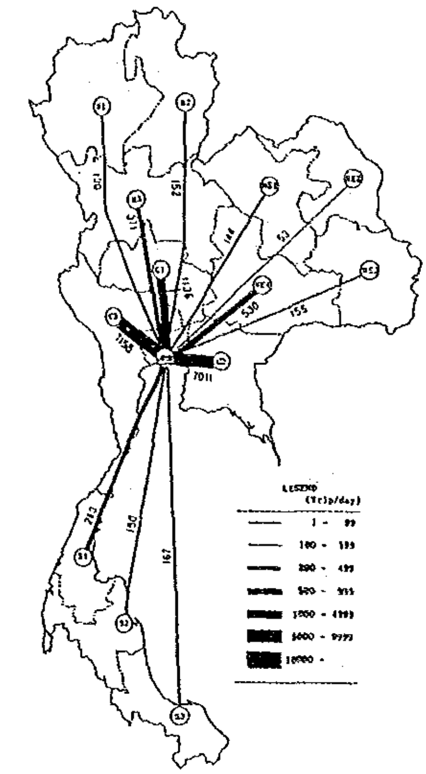
Inter-Changwat future O-D tables for the total vehicles per Changwat are presented in Appendix 6.25 for the year 2000 and Appendix 6.26 for the year 2010.



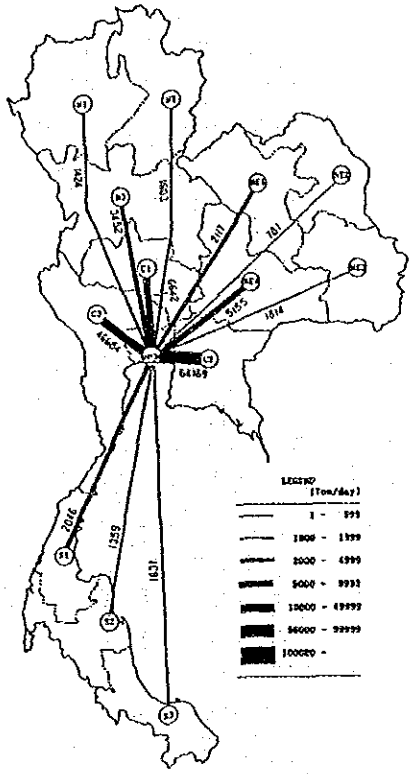
From BMR

To BMR

Figure 6.21 TRIP PATTERN FROM/TO BMR -- 1990

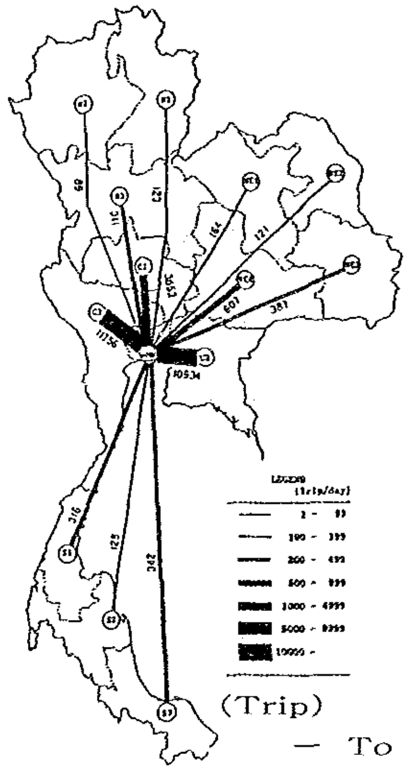


(Trip)

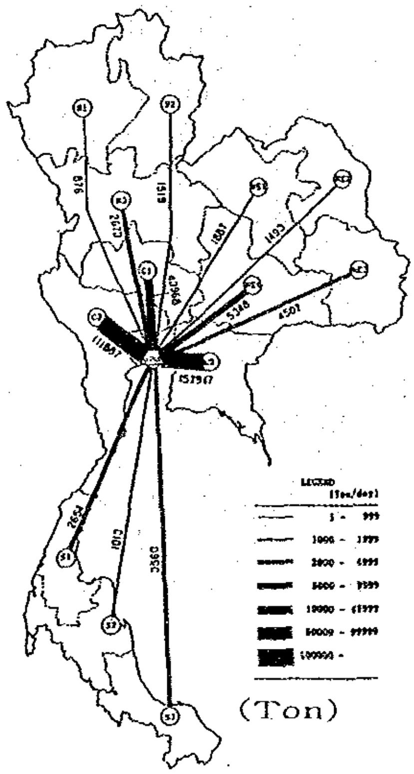


(Ton)

— From BMR —



(Trip)



(Ton)

— To BMR —

Figure 6.22 COMMODITY FLOW PATTERN FROM/TO BMR — 1990

Figure 6.23 shows the desire line chart for trips of the total vehicles between Changwats, with a separate presentation for trips of BMR in the year 2010. For purposes of comparison, Appendix 6.27 shows the present and future desire line charts in the years 1990, 2000 and 2010. Future forecasted generated and attracted inter-Changwat trips by Changwat per vehicle category are presented in Appendix 6.28 for the year 2000 and 6.29 for the year 2010.

2) Divisional Trips

The intra-division and inter-division future trips per vehicle category are presented in Appendices 6.30 for the year 2000 and 6.31 for the year 2010. Intra-division trips are expected to keep the high share comparing with inter-division trips.

The desire line chart of future inter-division trips for the total vehicles is shown in Figure 6.24 for the target year 2010. Appendix 6.32 shows the desire line charts for the inter-division trips in the three years 1990, 2000 and 2010 for the total vehicles.

3) Regional Trips

Future OD tables for intra-region and inter-region trips are presented in Appendices 6.33 and 6.34 for all vehicle categories in the two years of 2000 and 2010. Inter-region trips are clarified in the desire line charts for all vehicle categories in Figure 6.25 for the year 2010. Appendix 6.35 shows the desire line charts for inter-region trips by each vehicle category in the years 1990, 2000 and 2010.

Generation and attraction of future regional trips are presented per vehicle category for the two years 2000 and 2010 in Appendices 6.36 and 6.37 respectively. The graphical presentation of the share of vehicles in six categories, in which all buses are included in one category, is shown in Figure 6.26 for the year 2010.

4) Trips from/to BMR

Figure 6.27 clarifies the expected future inter-division trip pattern in the future year 2010. The highest interaction between BMR can be noticed with other divisions in the Central

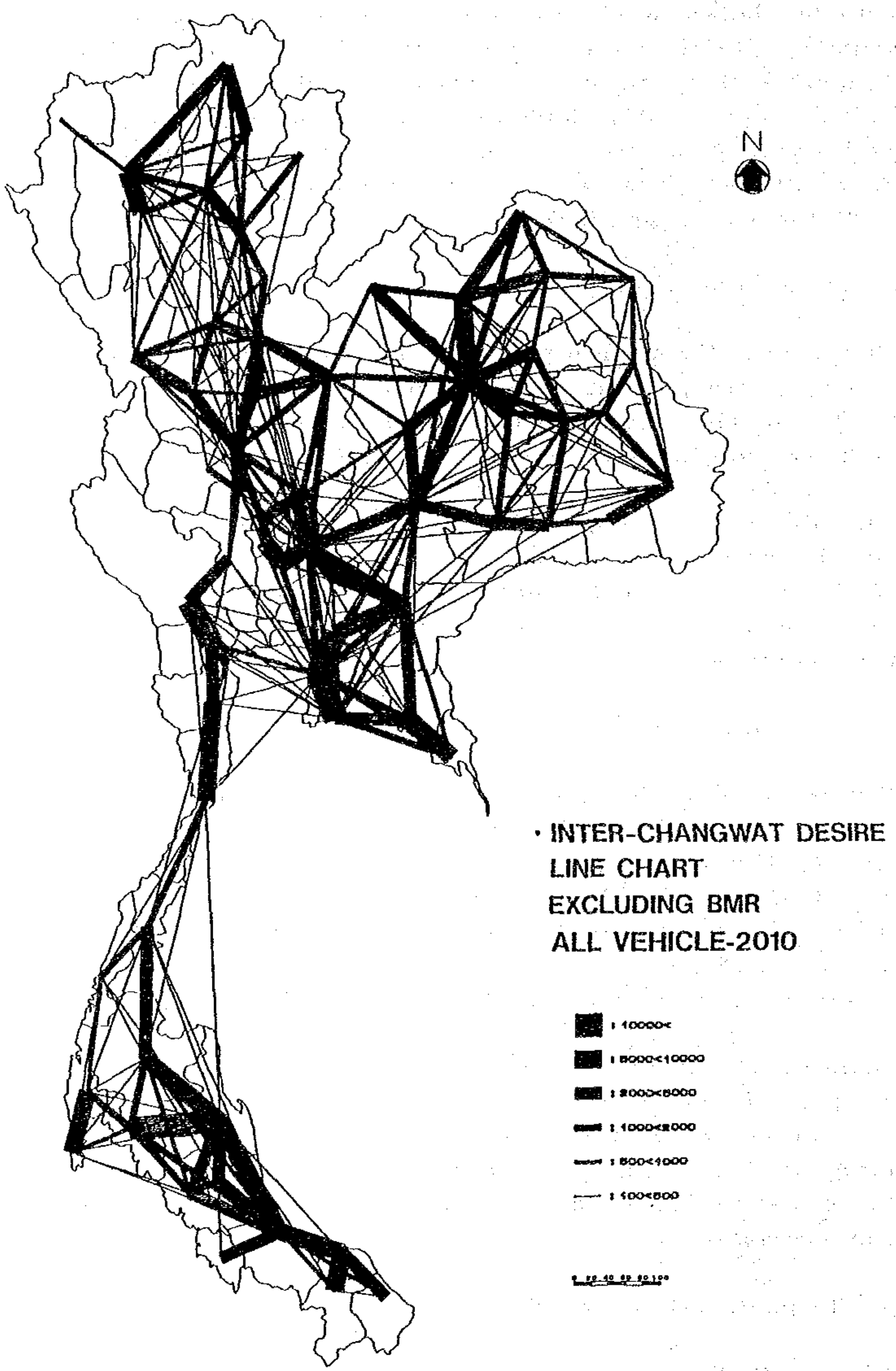


Figure 6.23 INTER-CHANGWAT DESIRE LINE CHARTS − 2010
i. WITHOUT CHANGWATS OF BMR (continued)

(continued)

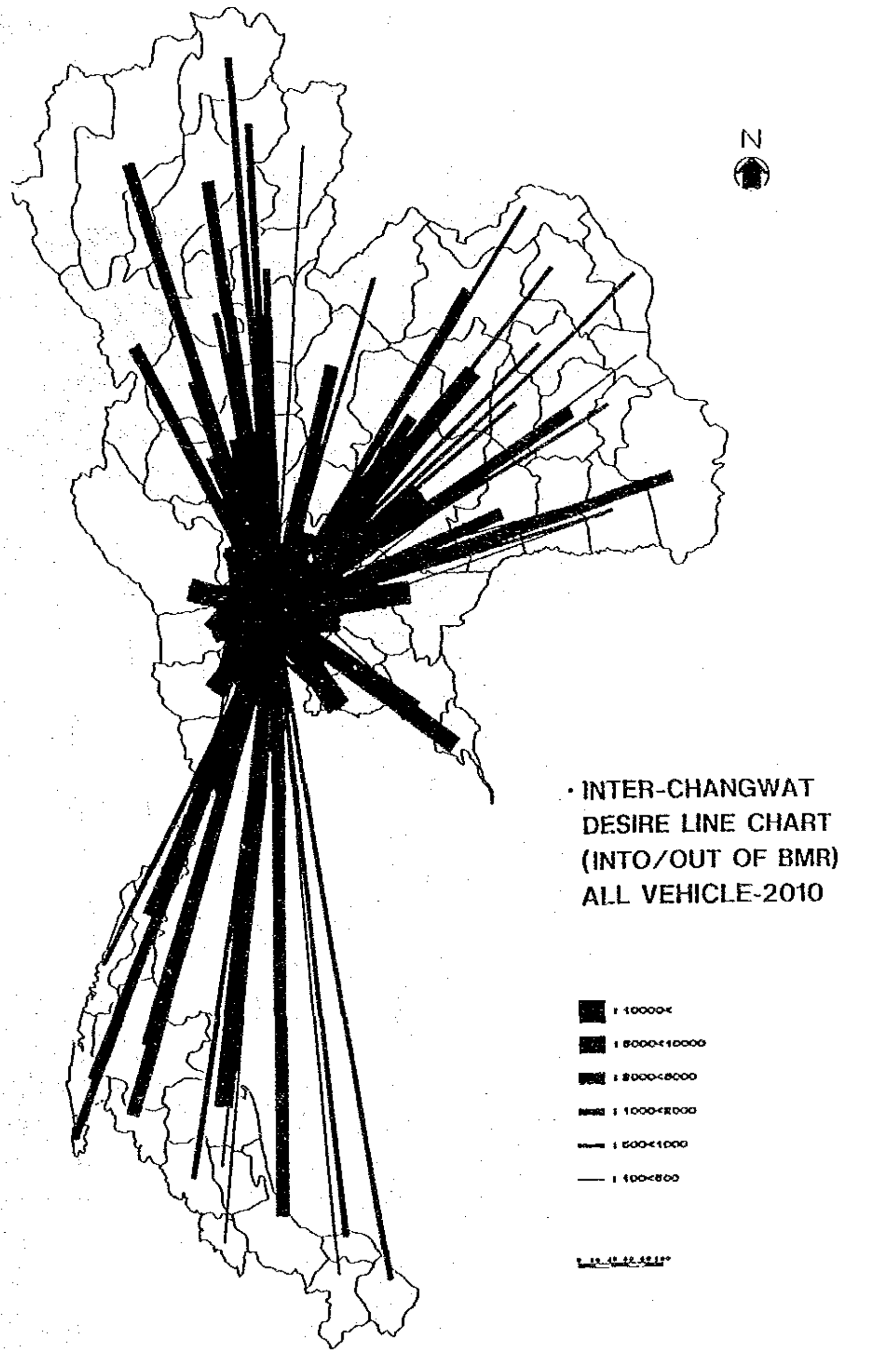


Figure 6.23 INTER-CHANGWAT DESIRE LINE CHARTS — 2010
ii. CHANGWATS OF BMR

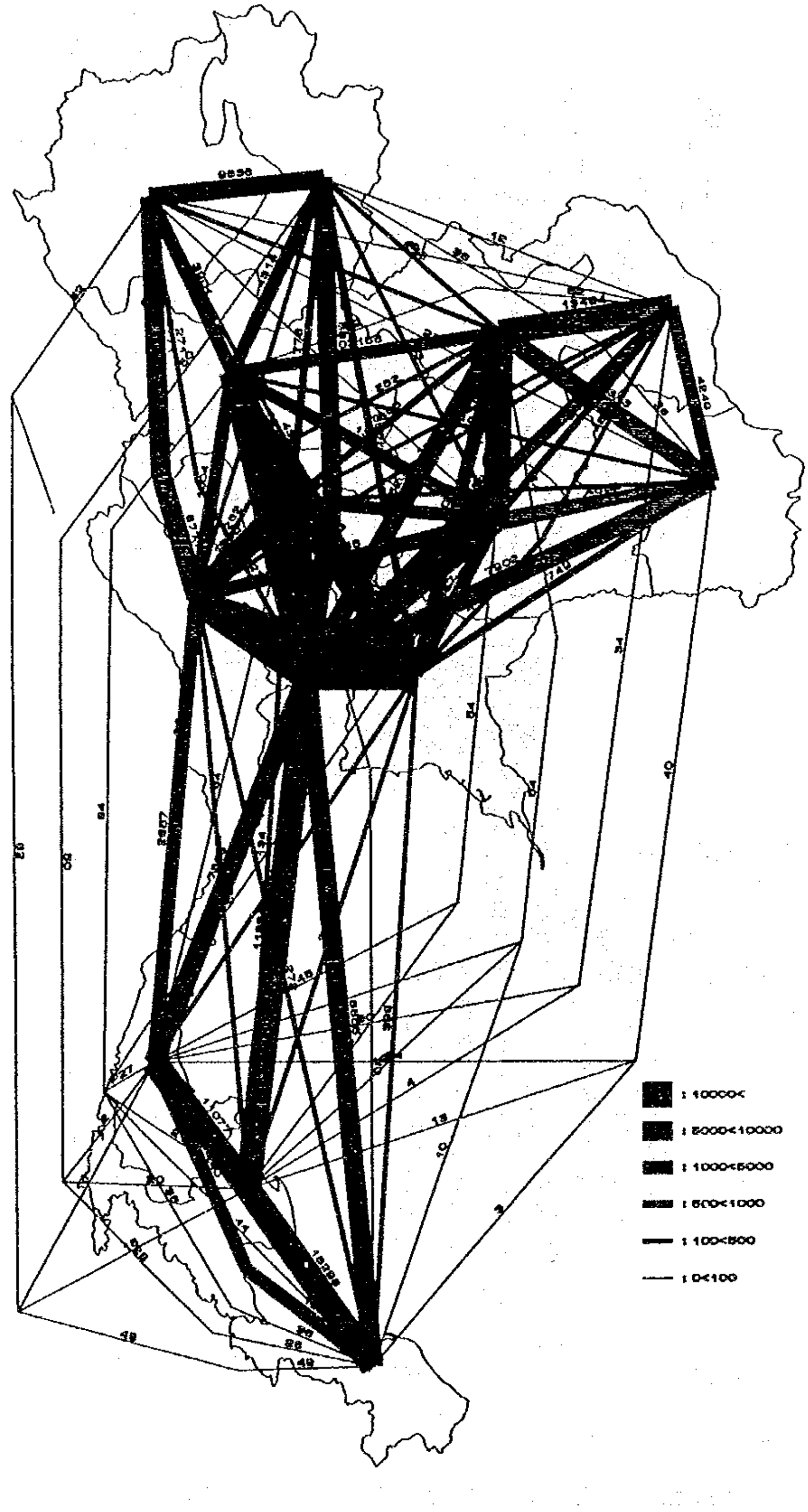


Figure 6.24 INTER-DIVISION DESIRE LINE CHART – 2010

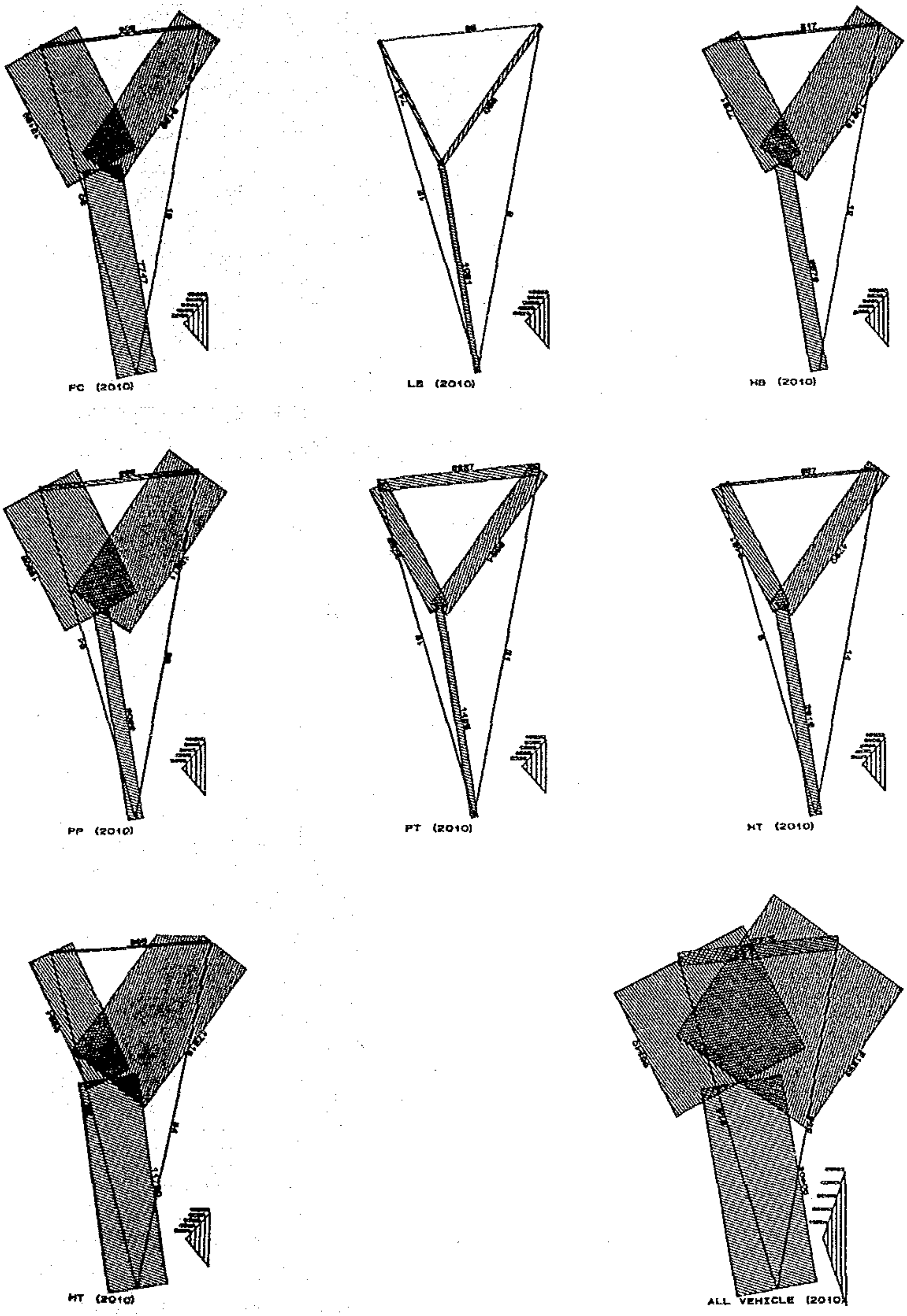


Figure 6.25 INTER-REGION DESIRE LINE CHART − 2010

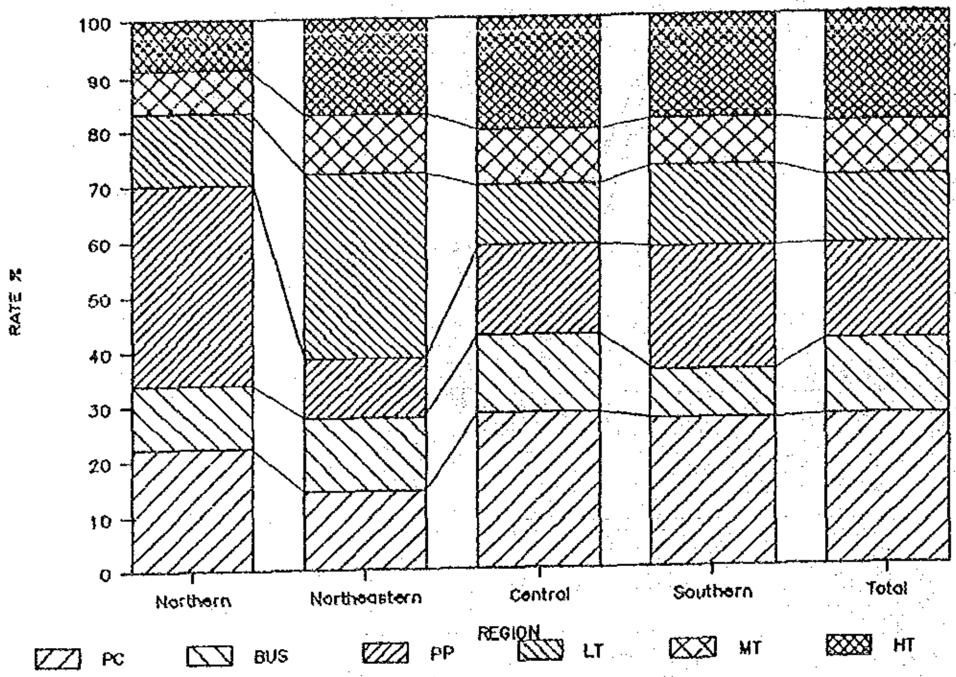


Figure 6.26 FUTURE REGIONAL TRIP-END COMPOSITION — 2010

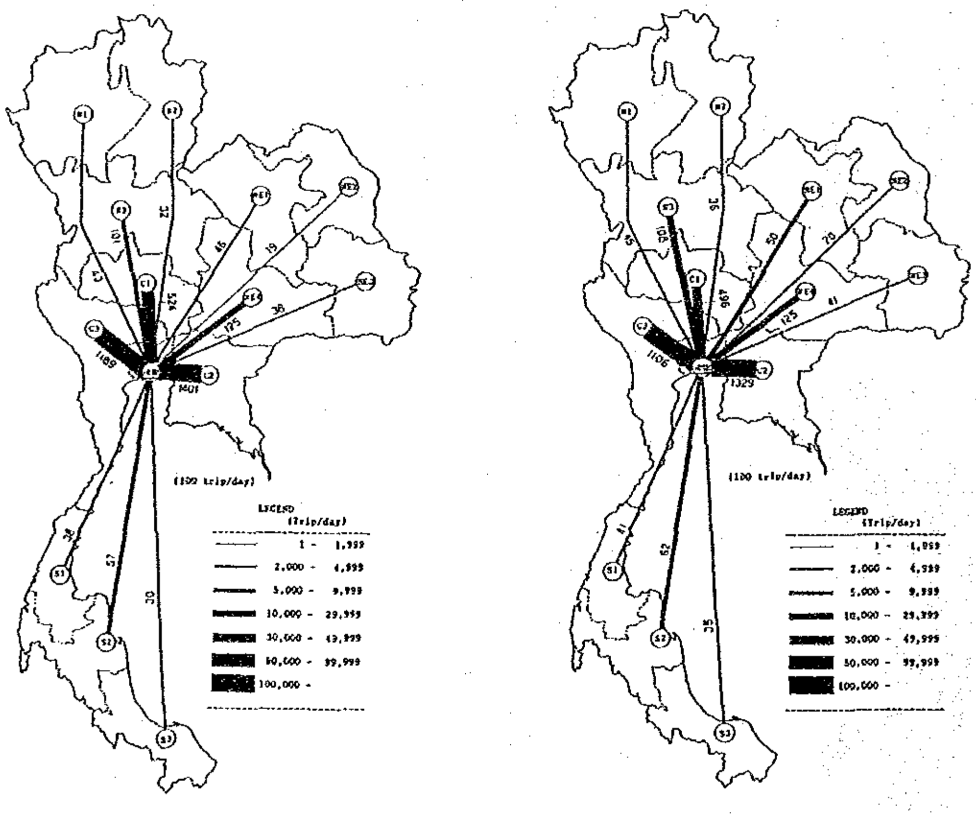


Figure 6.27 FUTURE TRIP PATTERN FROM/TO BMR — 2010

Region in the order of C2, C3 and C1, which is in different order than the present trip pattern. Divisions in other regions with considerably high trip numbers with BMR are NE4 in the Northeastern and N3 in the Northern Regions which are the nearest divisions in their regions to BMR. Highest number of trips with divisions in the Southern Region belongs to S1 in the year 2000 and to S2 in 2010.

6.4.3 Growth of Trip Generation and Attraction

Comparative analyses between the present and future OD trip tables are carried out to estimate the expected growth rates in the different trip patterns. Results of these analyses give indications on the expected growth in different trips during the next twenty years.

1) Inter-Changwat Trips

As for the growth in the inter-Changwat trips, Appendix 6.38 presents the growth rate per vehicle category considering that data of the year 1990 is the comparison level to equal 1.0. Main results in this appendix show that Bangkok is expected to have the highest growth rate for total vehicles till the year 2000, and is followed by Samut Prakan and Samut Sakhon respectively. Between the years 2000 and 2010, growth rate of Krabi in the Southern Region will be the highest, and to be followed by Samut Sakhon, Samut Prakan and Bangkok in the same order.

Highest growth in the number of trips per vehicle category till the year 2000 and 2010 is for heavy bus trips in Samut Sakhon. In general, the above mentioned four Changwats are sharing the highest growth rates of trips by all vehicle categories. Changwats with the lowest growth rates are Mae Hong Son, Uthai Thani and Ranong.

2) Divisional Trips

Present and future trip-ends by division are shown in Figure 6.28. Growth rates of trip-ends on the division level are presented in Appendix 6.39 for all vehicle categories and the comparison level is also the trip data of the year 1990. This appendix gives an indication for the divisional growth in which

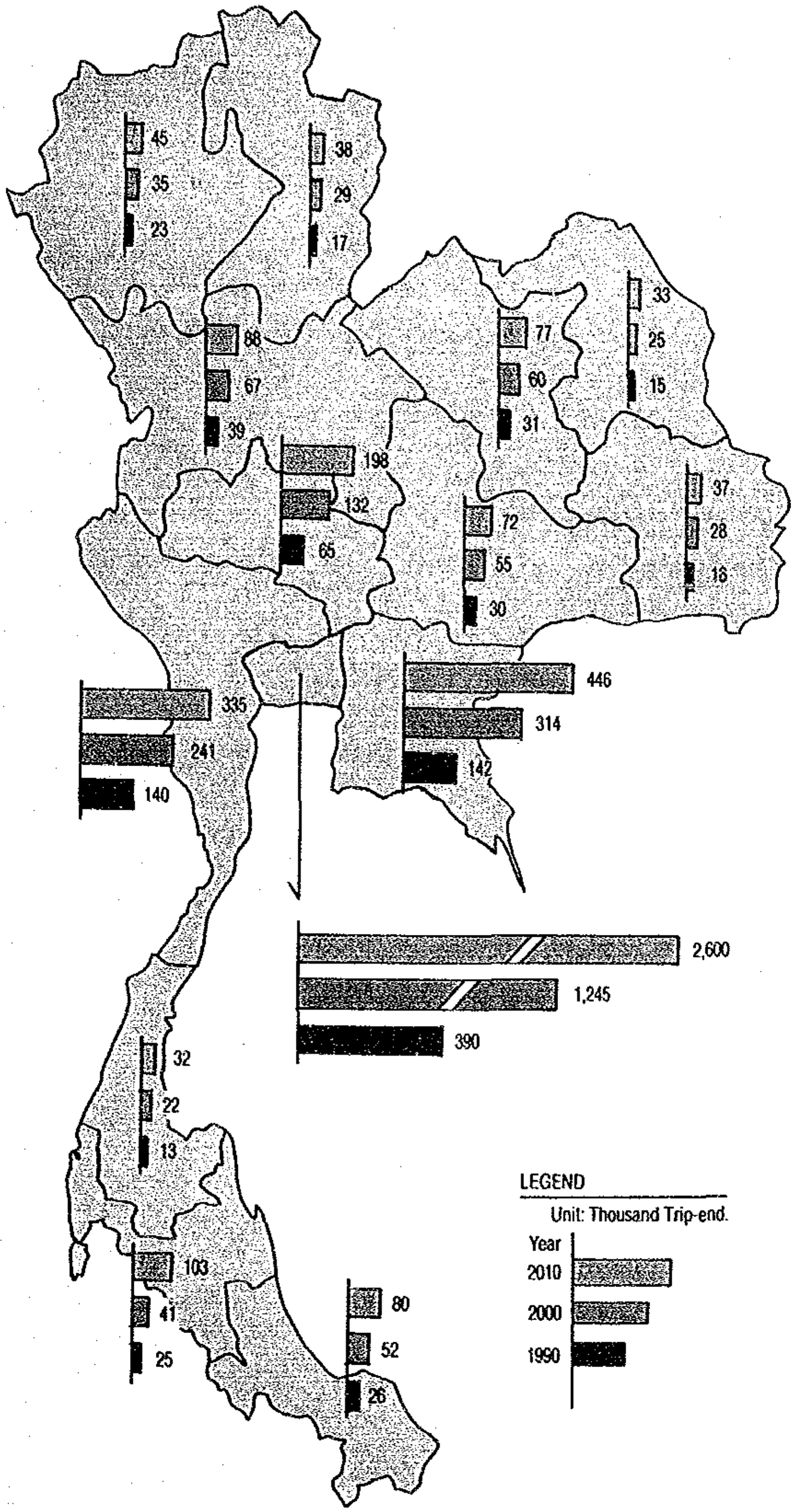


Figure 6.28 PRESENT AND FUTRE TRIP GENERATION AND ATTRACTION BY DIVISION

BMR has the highest growth rates for the total vehicle categories in both target years, and is followed by C2 in 2000 and S2 in 2010. As for divisions in other regions, N3 is expected to have the highest total growth rate in the Northern Region and NE1 in the Northeastern. In the Southern Region, S3 is expected to have the highest rate in 2000, however, and with the operation of the landbridge in the Southern Seaboard, trip-ends in S2 will increase rapidly to take the second place in all divisions after BMR in 2010. S2 will get also the highest growth rate for heavy trucks at that time.

3) Regional Trips

The growth rates of inter-region and intra-region trips for both target years per vehicle category are presented in Appendix 6.40. The results show that for both types of trips, and for the total vehicles, the highest growth rates are expected to be for trips related to the Central Region. In the year 2000, and for inter-region trips, the Northeastern Region shows the highest interaction with the Central Region. However, and going to the year 2010, the Southern Region is expected to replace it. On the other hand, the highest growth rates in the intra-region trips for almost all vehicle categories belong to the Central Region in the two target years.

The growth rates of the regional trip generation and attraction are presented in Appendix 6.41 per vehicle category. Following to the high growth of trips by all vehicle categories in the Central Region to the year 2000, trips by heavy buses show higher growth in the Northern and Northeastern Regions, and light buses in the Southern Region. Considering the growth to the year 2010, highest growth in only trips by heavy trucks belong to the Southern Region and by other categories to the Central Region. Trips by heavy buses will continue to have high growth in the Northern and Northeastern Regions comparing with other categories.

Figure 6.29 shows a summary for the growth rate trends of the total regional trips until the two future years. Another presentation for the regional transition in the number of trip-ends is clarified in Figure 6.30.

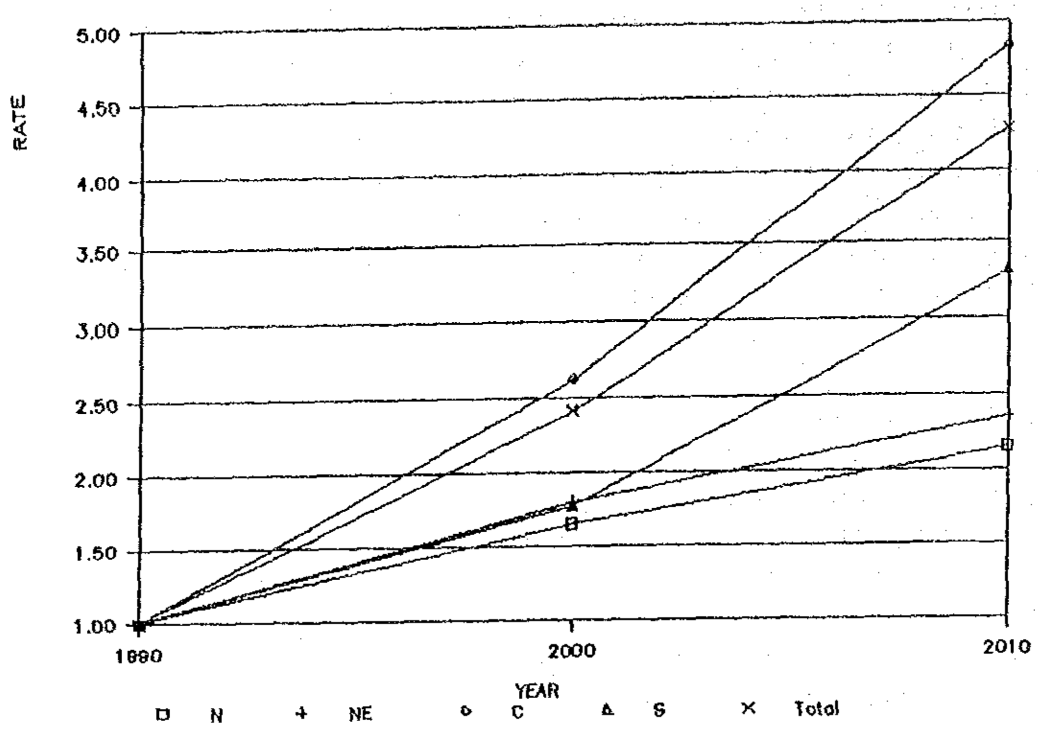


Figure 6.29 GROWTH RATES OF REGIONAL TRIP-ENDS

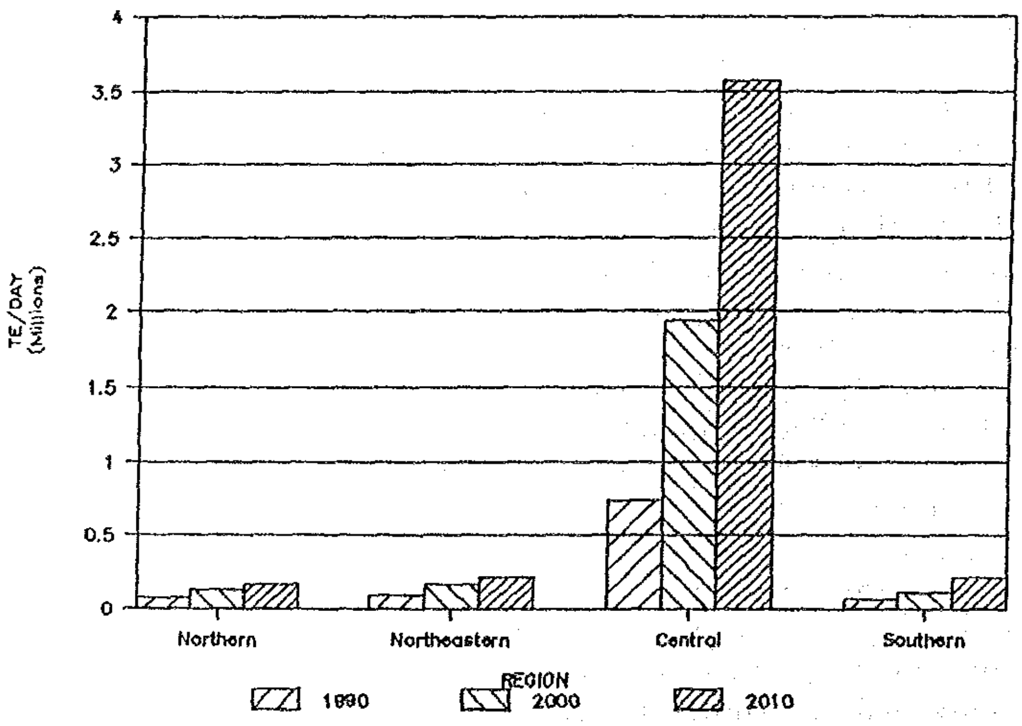


Figure 6.30 TRANSITION OF REGIONAL TRIP-ENDS

4) Growth in Trips by Vehicle Category

Growth rates of trip-ends by both passenger and commodity vehicles are clarified in Figures 6.31 and 6.32. For passenger vehicles, heavy buses show the highest trend and are followed by passenger cars and light buses respectively. Medium and heavy trucks are expected to produce the highest rates in growth of trip-ends by commodity vehicles.

Transition of trip-ends by vehicle category in million trip-end/day between the three years of 1990, 2000 and 2010 is shown in Figure 6.33. The share of trips by passenger cars is the highest through the twenty years. It is followed in 1990 by the

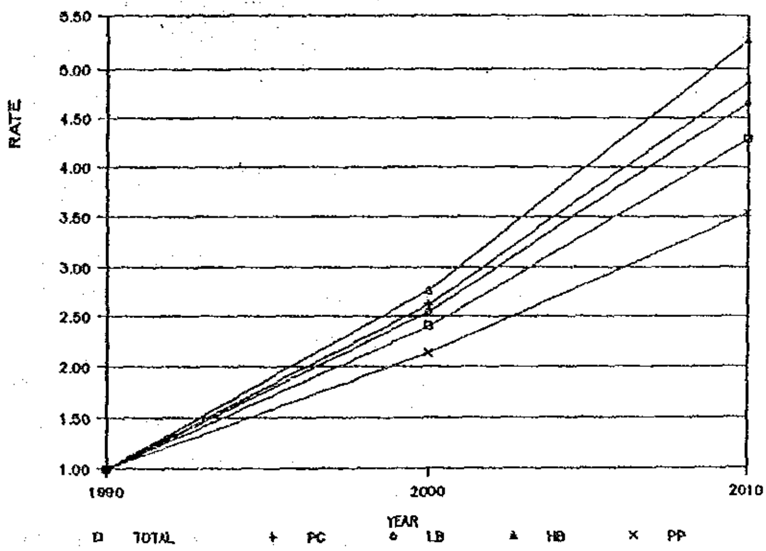


Figure 6.31 GROWTH RATES OF PASSENGER VEHICLE TRIP-ENDS

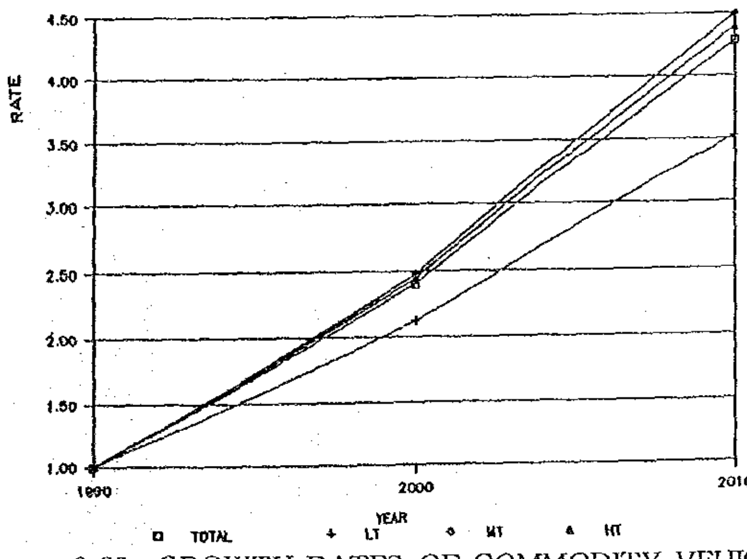


Figure 6.32 GROWTH RATES OF COMMODITY VEHICLE TRIP-ENDS

two categories of pickups for passengers and heavy trucks respectively. After that, and as a prediction for the future trip pattern, the two categories will replace each other.

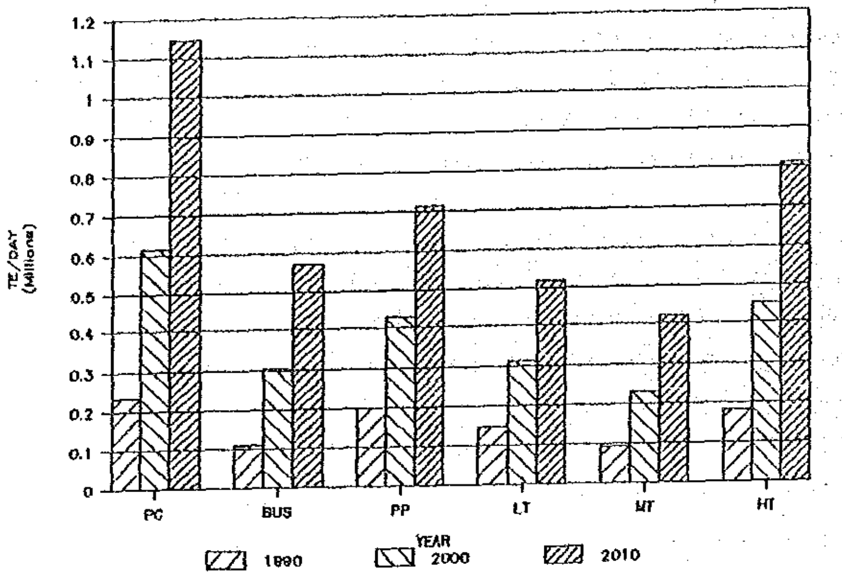


Figure 6.33 TRANSITION OF TRIP-ENDS BY VEHICLE CATEGORY

5) Growth in Trips from/to BMR

Growth rates and number of trips from/to BMR in relation to other divisions are presented in Table 6.15. Following to the other three divisions of the Central Region, NE4 and N3 have respectively the highest numbers of trips with BMR. Trips with some other divisions are expected to grow in the future in high rates, such as NE1 in 2000 and S2 in 2010.

Table 6.15 GROWTH RATE OF TRIPS FROM/TO BMR BY DIVISION

DIVISION	FROM/TO BMR TRIPS (trip/day)			GROWTH RATE (1990 = 1.0)	
	1990	2000	2010	2000	2010
N1	1629	4947	8771	3.04	5.38
N2	1299	3917	6808	3.02	5.24
N3	3298	11272	20924	3.42	6.34
NE1	1265	5209	9652	4.12	7.63
NE2	623	2043	3890	3.28	6.24
NE3	1385	4446	7902	3.21	5.71
NE4	5421	15196	24940	2.80	4.60
C1	15902	55911	102035	3.52	6.42
C2	59231	171611	273020	2.90	4.61
C3	76717	154496	229432	2.01	2.99
S1	1451	4108	7808	2.83	5.38
S2	752	2584	11894	3.44	15.82
S3	894	3257	6555	3.64	7.33

6.4.4 Trip Length Distribution

The length distribution of all the inter-Changwat trips is a main factor to be investigated in planning a motorway network to cover the whole country. Long trip vehicles usually compose high share in using the fully access control motorway networks. Analyzing the inter-Changwat origin and destination data according to the distances between all Changwat centers gives an estimation for the inter-zonal trip length distribution.

1) Present Trip Length Distribution

Figure 6.34 shows the cumulative frequency of trip length distribution for the inter-Changwat trips of total vehicles, while details per vehicle category are presented in Appendix 6.42. As for the average length of trips, passenger cars have a value of 93.4 km, while in the bus group, heavy bus category has the longest average trip length of 142.8 km. Heavy trucks have the longest average length of trips of 130.8 km comparing with other truck categories. Pickup for passenger use has an average of 118.7 km, and for commodity use the average is 107.6 km. The shortest average of trip length of 90.0 km belongs to the medium bus category. In total, the average trip length for all vehicles is 111.7 km.

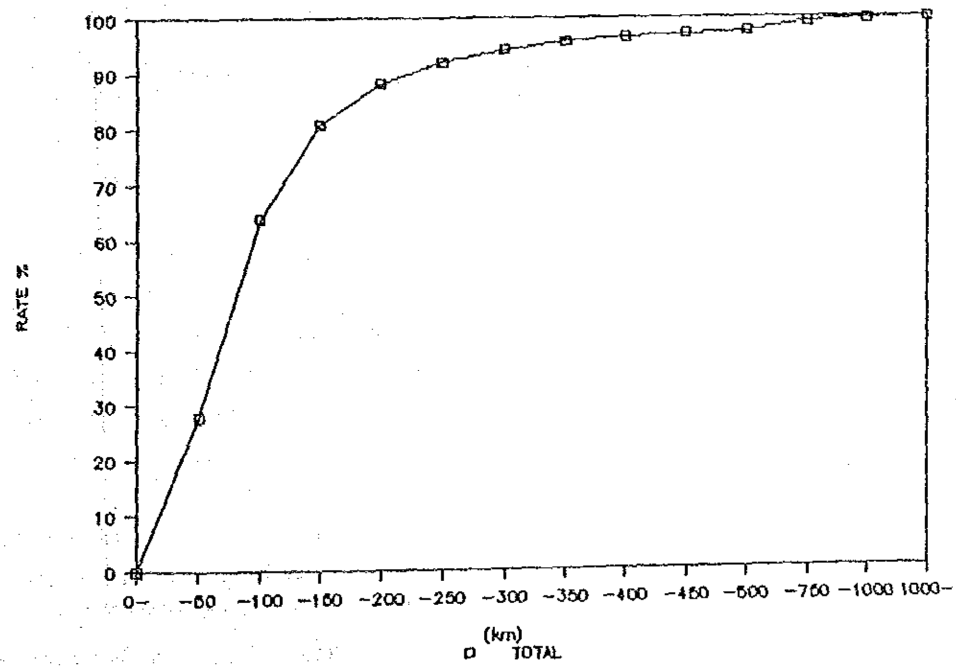


Figure 6.34 TOTAL TRIP LENGTH DISTRIBUTION – 1990

Considering the effect of the trip purpose for passenger vehicles, Appendix 6.43 gives the trip length distribution for each of the four purposes. On the other hand, trip length distribution of all categories of commodity vehicles is concluded for each of the four commodity groups as shown in Appendix 6.44.

2) Future Trip Length Distribution

The future average trip length distribution is presented in Appendices 6.45 and 6.46 for all inter-Changwat trips per vehicle category in the two years 2000 and 2010. In general, very high growth in the number of trips is expected to cover all Changwats in the future as shown in the OD tables, however, the average trip length is not expected to increase. Generation of high frequency of short trips may decrease the effect of longer trips when estimating the average trip length. In the year 2000, the total average is expected to be 107.5 km, then decreases to 102.6 km in 2010.

Analyzing the cumulative frequency of trips by length through the present and future patterns clarifies that long trips for both commodity and passenger vehicles are expected to keep their trip length distribution as shown in Figure 6.35 for all vehicles, and separately for commodity and passenger vehicles. Appendix 6.47 shows the present and future trip length distribution for the two groups of the passenger and commodity vehicles separately.

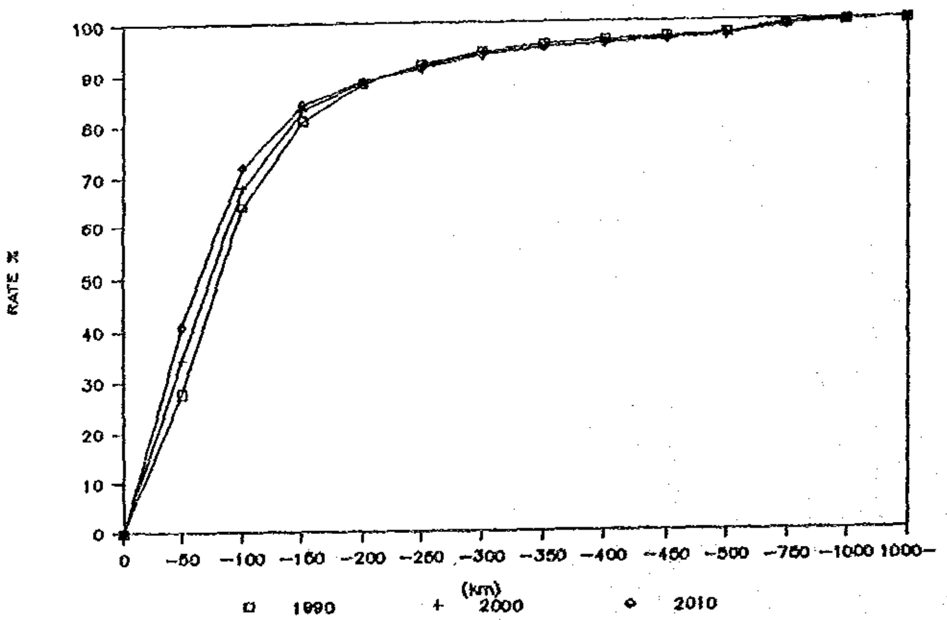


Figure 6.35 PRESENT AND FUTURE TRIP LENGTH DISTRIBUTION

6.5 ASSIGNED TRAFFIC VOLUMES

The objective of the assignment procedure is to allocate the trip matrices to the road network in order to reproduce traffic flows between zones, i.e. each origin and destination pair, on the actual links of the present and future road networks. This is done by fitting traffic on routes from each zone to all other zones, so that when all zone-to-zone movements from the trip matrix are aggregated, a reasonable representation of the traffic flows is obtained.

6.5.1 Methodology

The overall flow diagram of the methodology used in forecasting the traffic volumes on the toll motorway network, and the present and future national highway network in the two cases of "Without Project" and "With Project", is shown in Figure 6.36.

The normal traffic growth for generated and attracted trips of each Changwat is considered in the stage of estimating the future OD tables and depending on the estimated future socio-economic indicators. The construction of a new toll motorway network will generate other traffic that would not occur at all were it not for the new toll motorway. The main portion of this newly generated traffic comes through the induced trips. Induced trips are the trips which were not previously exist in any form and which result entirely due to the time saving by the introduction of the new toll motorway network.

In the case of "With Project", a diversion model is applied to assign traffic volumes first on the future national highway and a tentative toll motorway networks. Then, the tentative network is evaluated and modified in the form of a proposed network which is also subject to the same procedure in order to forecast traffic volumes for the two networks.

Traffic flow converted from other transportation modes is not considered in estimating traffic volumes on the toll motorway network. This traffic flow of the other modes is analyzed in Chapter 3 of this report, and it was found that flow, in these other modes of air, coast and inland water, is negligibly small

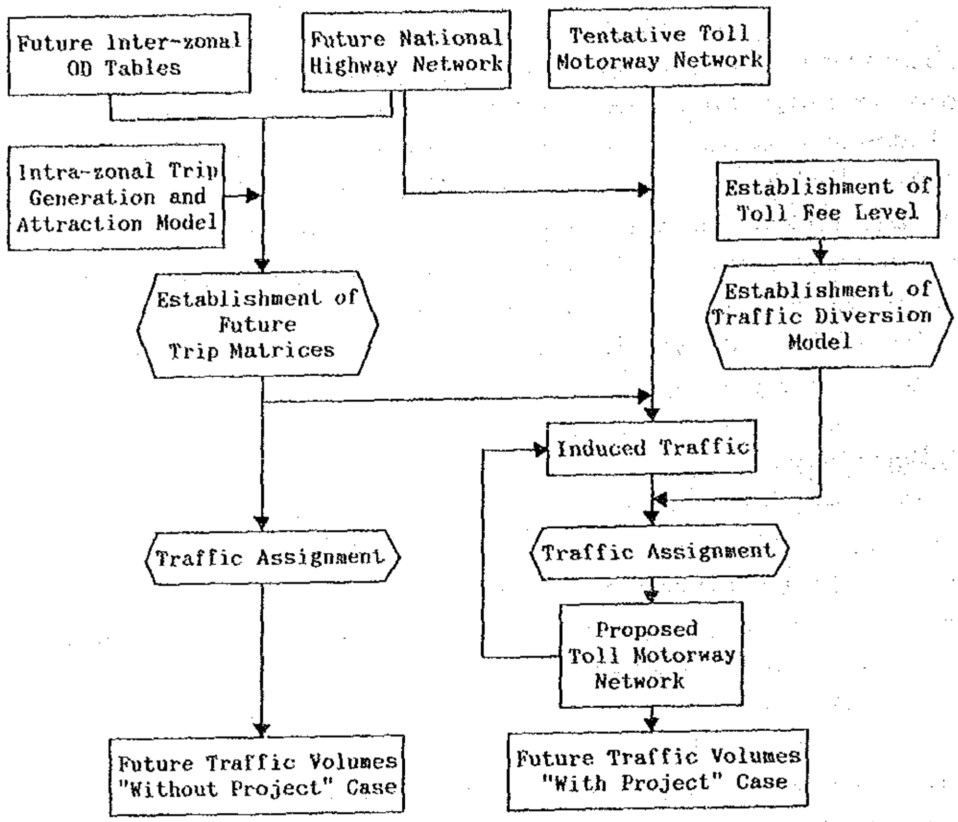


Figure 6.36 FORECAST OF TRAFFIC VOLUMES ON NATIONAL HIGHWAY AND TOLL MOTORWAY NETWORKS

with respect to road transport. Railway transport, with 9.1 billion passenger-km and 2.6 billion ton-km in 1987, is also very small compared with road transport. It does not show also any growth in recent years, as shown in Figure 6.37, and can not be expected to show significant leap in the near future.

To carry out the assignment of traffic volumes on both national highway and toll motorway networks, several items have to be defined and estimated first. Following is the description of the used assignment technique as well as the other items required for the application procedure.

1) Traffic Assignment Technique

Various assignment techniques are used ranging from manual methods for small problems to complex iterative procedures by computer programs. In this study, the used method is the capac-

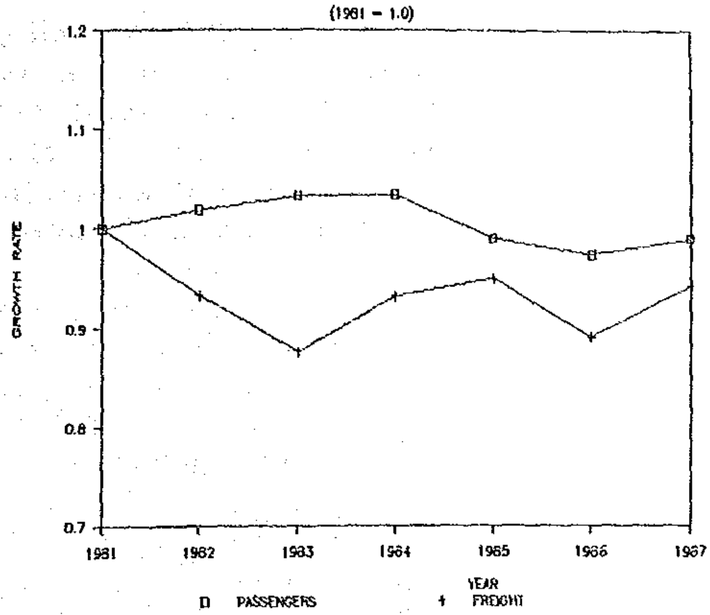


Figure 6.37 GROWTH OF RAILWAY FREIGHT AND PASSENGER TRANSPORT

ity restraint assignment which is the most straightforward for use in network models, and the most efficient particularly where the number of zones in the trip matrix is large. This assignment technique is based on the speed-flow relationship, and the flow chart of the applied methodology is shown in Figure 6.38.

In this assignment technique, and by calculating the required travel time for each link according to its travel speed and road conditions, the program determines the quickest routes between each origin and destination by evaluating the consuming time on links, and assigns the trips between the given origin and destination to these routes starting at the destinations and working back to the origins. As congestion increases till a certain level, alternative routes are introduced to handle the unassigned traffic. Zone-to-zone routing is built, which is the quickest path from each zone to any other, and all trips are assigned to these optimum routes.

Since the link-travel time varies with the traffic volume of vehicles using that link, which can be expressed as a degree of link congestion, the OD tables are divided to apply an iteration procedure on five stages. At each iteration, and depending upon the current link loadings, the flows are divided between all the shortest routes generated and a new travel time is computed for the average assigned link flow at each pass. The iteration continues to reestimate the speed on that links considering the assigned traffic on links, and to produce alternative routes so that more accurate allocation can be achieved. The accumulated assigned traffic volume from each OD pair on the links composes the total assigned traffic volumes per direction for the network.

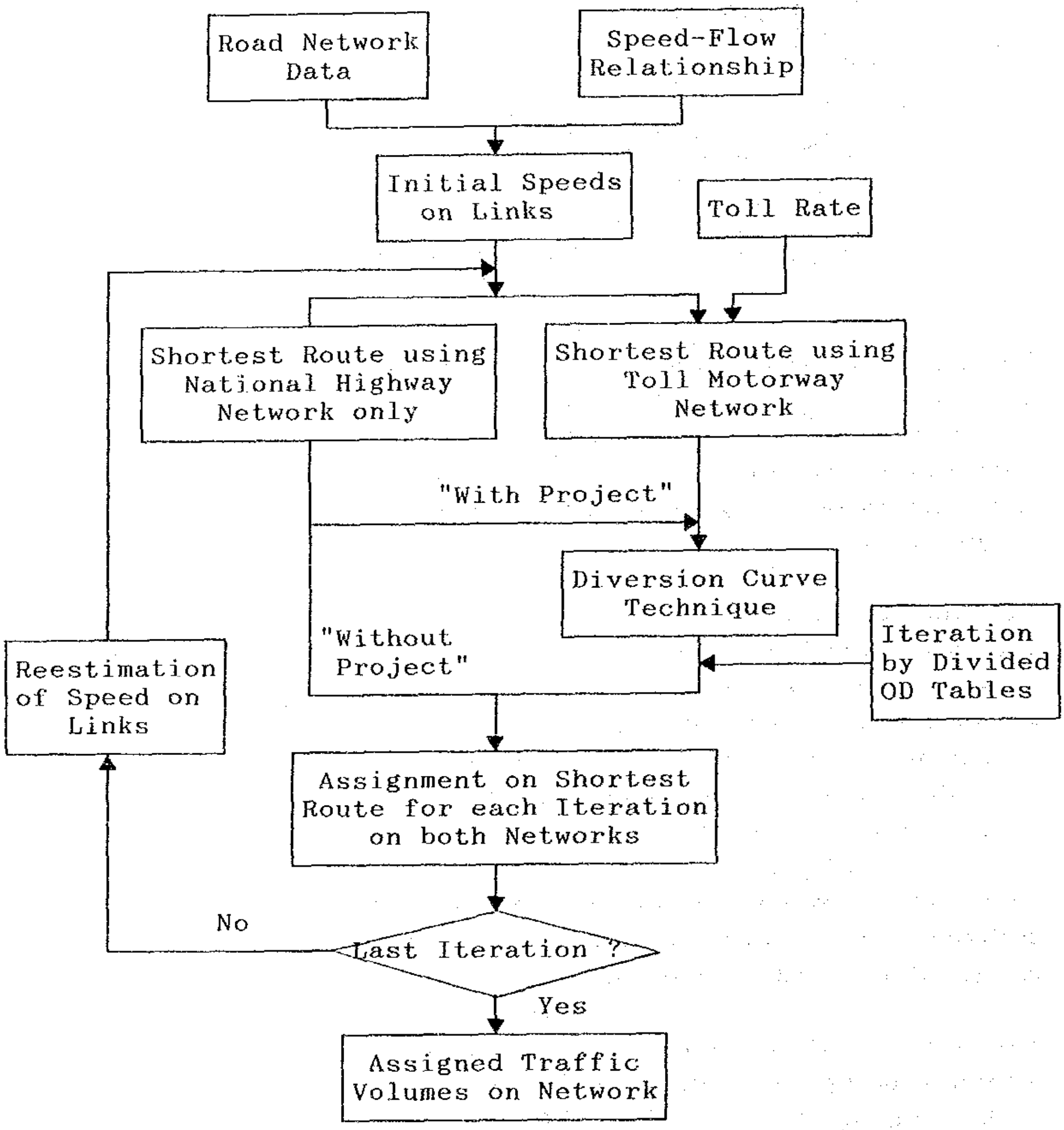


Figure 6.38 TRAFFIC ASSIGNMENT FOR NATIONAL HIGHWAY AND TOLL MOTORWAY NETWORKS

2) Zoning System and Link Data

The traffic zoning system for this study is established basically on the administrative base of the Changwat level, whereby a total number of 73 Changwats is considered as the total number of zones. However, it is necessary first to disaggregate the OD tables on a sub-zonal level of groups of Amphoes to estimate the intra-Changwat trip pattern so the concluded traffic volumes through the assignment procedure can represent both intra- and inter-Changwat trips.

The sub-zoning system, in which a total number of 317 sub-zones are used, has the main purposes of: 1) to facilitate more routes for assignment since each sub-zone has a centroid which is the most generated Amphoe, 2) to estimate intra-Changwat inter-sub-zone trips by the use of gravity model with population as an indicator, and 3) to get information for the location of interchanges for the toll motorway network. The number of sub-zones in each Changwat used in the assignment procedure is presented in Appendix 6.48, and the sub-zoning system of the study area is illustrated in Appendix 6.49.

Next, a gravity model is constructed to estimate trips on the sub-zoning level using the Amphoe population as an indicator. The model has the form of:

$$T_{ij} = a\,(P_i * P_j)^b \;/\; D_{ij}^{\,c}$$

Where, T_{ij} : Number of trips from sub-zone i to sub-zone j
P_i : Population of sub-zone i
D_{ij} : Space distance between sub-zones i and j
a, b & c : Parameters

For sub-zonal trips, two check procedures are carried out to insure the validity of the disaggregation technique, which are the link traffic volume check, and inter-Changwat vehicle-kilometer check. The ADT data of DOH are used here and an adjustment is done for invalid data as follows:

$$t_{ij}^{n} = t_{ij} * a_q$$

$$a_q = Q_D \;/\; Q_A$$

or,

$$t_{ij}^{n} = t_{ij} * a_{vk}$$

$$a_{vk} = VK_D \;/\; VK_A$$

Where, t_{ij}^{n} : Adjusted number of trips from sub-zone i to sub-zone j
t_{ij} : Number of trips from sub-zone i to sub-zone j
Q_D : Link traffic volume by DOH
Q_A : Link traffic volume by assignment
VK_D : Vehicle-kilometer estimated from DOH data of ADT
VK_A : Vehicle-kilometer estimated from assignment

The road network is split up into links which are lengths of road between important junctions known as nodes. Additional information typically needed in the assignment technique about the road and traffic conditions on each link are determined through the road inventory data base of DOH, and include road length, width, number of lanes, surface condition and terrain. The used link classification and information are presented in Appendix 6.50.

3) Speed-Flow Relationship

The speed-flow relationship used in the traffic assignment procedure is shown in Figure 6.39. This approximate relationship is based on the average measured values of link speeds during the traffic survey. When the traffic volume is below half of the maximum capacity Qmax, vehicles may be able to travel at the maximum speed Vmax. With the gradual increasing in traffic volume to exceed 0.5 Qmax, speed is decreasing gradually to reach Vmin which is about 0.25 Vmax at 1.2 Qmax. Constant minimum speed is assumed to continue after that capacity just as a control procedure to be considered in the assignment applications so unrealistic assignments can be avoided.

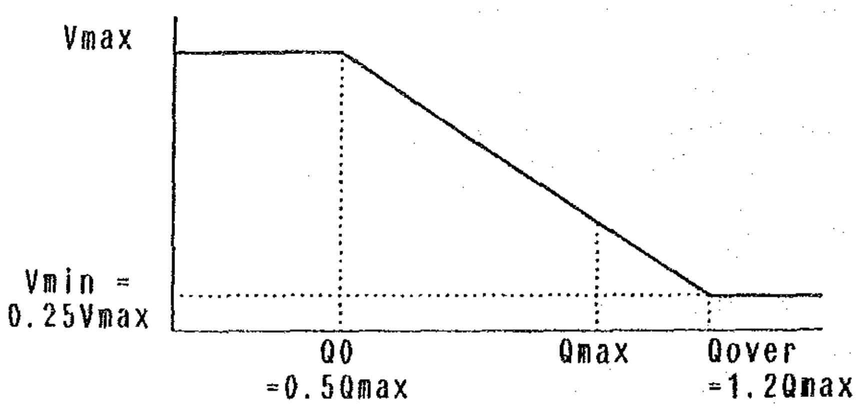


Figure 6.39 SPEED - FLOW RELATIONSHIP

In evaluating the volume/capacity ratio to select the running speed on the network links, values of the Highway Capacity Manual for the passenger-car units (PCU) on two-lane highways of the level of service (A) at level terrain are used, as presented in Table 6.16.

Table 6.16 PASSENGER-CARUNITS

Vehicle Type	PCU
Passenger Car	1.0
Light Bus	1.0
Heavy Bus	1.8
Pick-up	1.0
Light Truck	1.0
Medium Truck	2.0
Heavy Truck	2.0

Source: Highway Capacity Manual, Special Report 209, 1985.

4) Time Evaluation Value

The time evaluation value (TEV) method is used to evaluate the consuming time on links of toll motorways in use for persons, either passengers or assistants in trucks, in all vehicle categories. The procedure used to estimate the average TEV is based on the average time value per person in Baht per minute which is estimated as follows:

GDP per capita	(1988)	:	26,876	Baht/year
GDP growth rate	(1988-1989)	:	1.085	
	(1989-1990)	:	1.070	
GDP per capita	(1990)	:	31,202	Baht/year
Working hours		:	200	hour/month
Average time value per person		:	0.2167	Baht/minute

The average values of the number of passengers and assistants as well as the GDP growth rates concluded in this study are used, in addition to the inter-Changwat trip generation data per vehicle category, to get the time value per vehicle category and the average for all vehicles, which is estimated as 1.0652 Baht per minute.

5) Diversion Curve Technique

This technique is used here to estimate the proportion of traffic volumes diverted from the future national highway network to the new toll motorway network. The factors having the greatest influence on the routes taken by motorists are the comparative travel time and distance. Two formulas are applied to develop the diversion curves used in estimating the traffic volumes on both networks. The first, which is the AASHTO formula, is widely used for freeways in the United States without much applications on toll motorways. The second, which is used in Japan by the Nihon Doro Kodan (Japan Highway Public Corporation), is developed specially for toll highways and motorways, and is calibrated and upgraded continuously. In this formula, the diversion rate is determined by the toll-free and the time difference between the motorways and the national highways for trips of the future OD tables, in addition to a calculated factor for the increase use of the road resulting from the motorway construction. With a proposed fixed fee of the first year of operation, the diversion curve has the applicability to be shifted for future years.

According to the obtained preliminary results of the traffic assignments and the characteristics and flexibility of the two formulas, the second formula approved more creditability, so it is used as the basis of the diverted traffic estimations in the assignment procedure. Following is a brief explanation of the two formulas.

a. Formula of AASHTO

$$P = \{1 / (1 + (TH/TG)^6)\} - 0.05$$

Where,
- P : Diversion rate
- TH : Inter-zonal time distance using toll motorway in minutes (including fare resistance calculated by time evaluation value)
- TG : Inter-zonal time distance using ordinary highway in minutes (including fare resistance calculated by time evaluation value)

The concluded diversion curve using this formula is shown in Appendix 6.51.

b. Formula of Nihon Doro Kodan

$$P = K / \{1 + (a(C/T*S)^b / T^c)\}$$

Where, P : Diversion rate
K : Maximum diversion rate, assumed 0.9
C : Trip Fare in Yen (to be converted to Baht)
T : Time difference in minutes (TH - TG)
S : Shift factor
a, b, & c : Parameters, which have the following values:

Vehicle Group	Vehicle Category	*a*	*b*	*c*
Passenger Vehicle	Passenger Car Light Bus Heavy Bus	0.616	1.073	1.035
Light Truck	Pick-up Passenger Light Truck	0.978	1.068	1.088
Truck	Medium Truck Heavy Truck	0.049	1.505	0.542

The diversion rate is estimated from the concluded curve of the first year of operation, and the rates for the following years are obtained by shifting this curve to the right. As for the proposed fixed toll rate which will be applied in the future, it is expected that this rate will decrease in actual value in accordance with the increase in the gross domestic product. The formula is developed according the standards in Japan for the base year of 1980, therefore, some adjustments are necessary to make it applicable in Thailand for the base year 1990. The shift rate parameter of 1990 is adjusted by estimating a conversion ratio of fare burden (CRF) from Baht to Yen as follows:

GNP/Capita in Japan (1980) : 2096,000 Yen
GDP/Capita in Thailand (1990) : 31,202 Baht
(based on GDP/Capita in 1988 : 28,676 Baht with growth rates 8.5% & 7% for the two years 1989 and 1990)

CRF = 2096,000 / 31,302 = 67.175

Shift factor S (1990) = 1.0 / CRF
S (2000) = ((GDP/Capita in 2000)/(GDP/Capita in 1990)) * S (1990)
S (2010) = ((GDP/Capita in 2010)/(GDP/Capita in 2000)) * S (2000)

	1990	2000	2010	
Gross Domestic Product "GDP" (based on 1972 constant price)	575104	1073374	1766730	Million Baht
Population	57181	67017	74028	Thousand
GDP/Capita	10058	16016	23866	Baht
Shift factor "S"	0.01489	0.02371	0.03532	

Resulted diversion curves for the three vehicle groups are shown in Appendix 6.52 for the two years 2000 and 2010, and for different values of the time difference (T) in minutes.

6) Establishment of Toll Rate

There are many criterions, either economical, political or social, which may influence the establishment of a toll rate for any toll road system. In this stage of the study, it is difficult to establish an accurate toll rate to be used in the traffic assignment procedure. Therefore, preliminary assignments are done first for different assumed rates starting from 0.0 Baht to 10.0 Baht per kilometer as shown in Table 6.17. The purpose of establishment this toll rate system here is just to enable the assignment procedure and to study the effect of increasing the toll rate on the traffic volumes which the toll motorways will handle in terms of vehicle-kilometer. More financial details on the toll rate are included in Chapter 11.

Table 6.17 ESTABLISHMENT OF TOLL RATE

Vehicle Category	DOH Toll Highways	ETA Expressway	Vehicle Grouping for Toll Motorways	Established Toll Rates
4-Wheel	3 Baht (1.0)	10 Baht (1.0)	Passenger Car Light Bus Pick-up Passenger Light Truck	0.0 - 0.25 - 0.5 - 0.75 - 1 - 3 - 5 - 10 Baht/km (1.0)
6-Wheel	8 Baht (2.67)	20 Baht (2.0)	Heavy Bus Medium Truck Heavy Truck	0.0 - 0.5 - 1 - 1.5 - 2 - 6 - 10 - 20 Baht/km (2.0)
10-Wheel	10 Baht (3.33)			
More than 10-Wheel		30 Baht (3.0)		

Note: Figures between brackets show toll rates based on first group as 1.0.

Figure 6.40 shows this relationship between vehicle-kilometer values and the toll rate when applying the two diversion formulas of AASHTO and Nihon Doro Kodan. The big difference in the vehicle-kilometer values between the two formulas at the high toll rates is resulted because the AASHTO formula does not consider the time savings for commodity vehicles. Consequently, a sharp reduction in the traffic volume of commodity vehicles will result with the increase of the toll rate.

Considering the results of the second formula, the slope of the

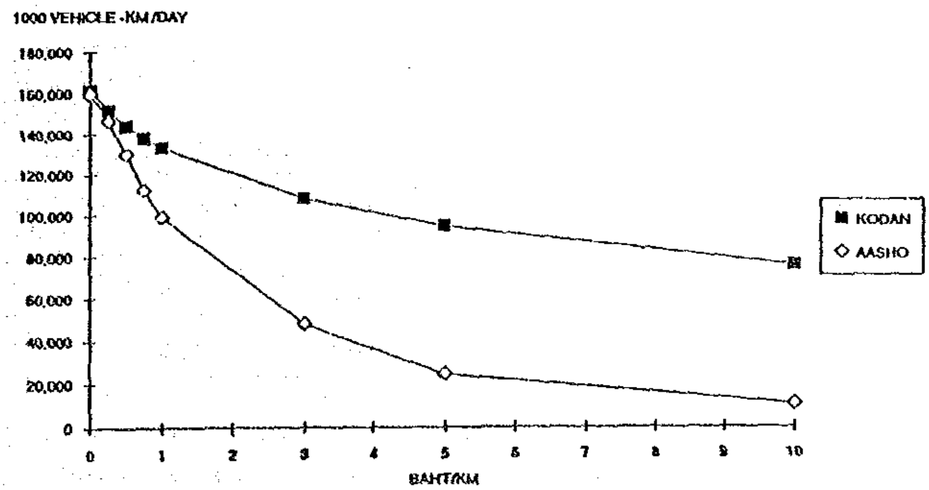


Figure 6.40 EFFECT OF TOLL RATE ON VEHICLE-KILOMETER

curve is decreasing nearly at the toll rate of 1.0 Baht/km which gives some reasonability in selecting this toll rate to be as a temporary rate for assignment purposes based on the formula of the Nihon Doro Kodan.

7) Estimation of Induced Trips

Parameters to be applied in the model used to estimate the induced trips are calculated first through a gravity model. Next, the induce trip model is built based on the estimated parameters to produce induce rate matrices for all vehicle categories which are multiplied in the corresponding inter-zonal future trip matrices to conclude the number of induced trips between each origin and destination.

a. Estimation of Induce Trip Model Parameters

A gravity model is used first only for the purpose of estimating one parameter (c) required to develop a model for the estimation of the induced trips in the case of "With Project" per vehicle category. This model has the following form:

$$T_{ij} = a\,(GA_i * GA_j)^b \,/\, D_{ij}^{\,c}$$

Where, T_{ij} : Number of trips from Changwat i to Changwat j

GA_i, GA_j : Generated and attracted trips of Changwat i, j

D_{ij} : Minimum travel time distance between Changwat i and j in minutes

a, b & c : Parameters; which are estimated on the basis of the present national highway network and the present inter-zonal OD tables for each vehicle category. Values of the estimated parameters are:

Vehicle Category	*a*	*b*	*c*	Multiple Correlation Coefficient *R*
Passenger Car	7.6619	0.22440	1.53070	0.54458
Light Bus	5.5658	0.19403	1.04240	0.40263
Heavy Bus	1.8157	0.39858	0.76101	0.34524
Pick-up Passenger	7.2839	0.26719	1.56300	0.59341
Light Truck	7.9158	0.25007	1.64260	0.59168
Medium Truck	7.6062	0.19333	1.43240	0.57854
Heavy Truck	3.9926	0.32668	1.08620	0.52052

Values of the multiple correlation coefficient R for this model are relatively low, however, they do not have much effect on the value of parameter c which will be used in building the induce trip model.

b. Structure of Induce Trip Model

To estimate the rate of induced trips per vehicle category between each origin and destination, the future national highway and toll motorway networks are used to conclude the travel time distance in the case of "With Project". The used model has the following structure:

$$TI_{ij} = T_{ij} * \{(D_{ij}(0) / D_{ij}(1))^{c} - 1 \} * A$$

Where, TI_{ij} : Number of induced trips from Changwat *i* to Changwat *j*

T_{ij} : Number of future trips Changwat *i* to Changwat *j*

$D_{ij}(0)$: Minimum travel time distance in minutes from Changwat *i* to Changwat *j* - without project c

$D_{ij}(1)$: Minimum travel time distance in minutes f Changwat *i* to Changwat *j* - with project case

A : Adjustment factor

c : Parameter estimated by means of gravity model

It is considered, in this study, that the potential traffic demands will not fully appear as other transport modes have not great effect on road transport, so that the adjustment factor "A" is assumed to be 0.5.

c. Procedure

The procedure used in estimating the induced traffic is shown in Figure 6.41. The travel time distance between each OD pair is concluded based on the future national highways only in the case of "Without Project", and on both of the future national

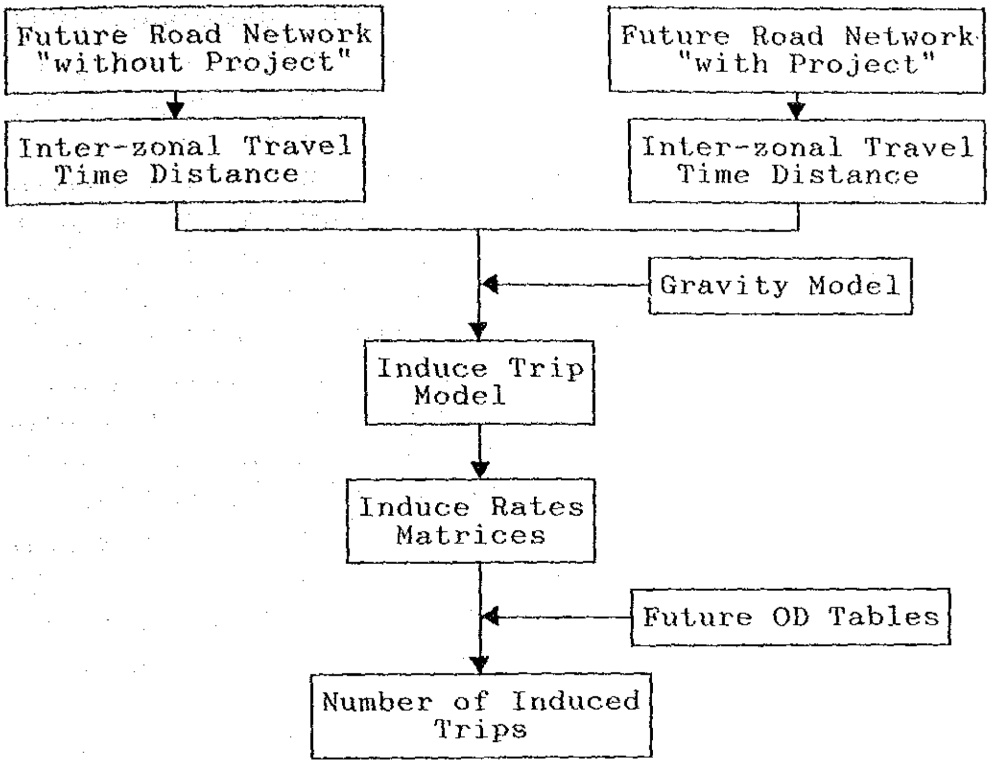


Figure 6.41 METHODOLOGY OF ESTIMATING INDUCED TRAFFIC

highway and toll motorway networks in the case of "With Project". The two values are used to estimate the induce rate through the induce trip model. The future OD tables are applied on the induce rate matrices to get the number of induced trips between each origin and destination for each vehicle category. Then, induced trips are added to the future OD tables to compose trips to be assigned as traffic volumes on both road networks for the case of "With Project".

8) Assignment Cases

Traffic volume assignments are carried out for different cases and purposes. First, assignments are done for the present and future national highway networks for the case of "Without Project". Next, traffic volumes are assigned on the tentative toll motorway network and then on the proposed network. Many preliminary assignments are done for the tentative network with different toll rates to conclude the effect of the toll rate on the vehicle-kilometer values and to select a temporary rate for further assignments. In these preliminary assignments, the two diversion techniques are applied and the formula of the Nihon Doro Kodan is selected, for its high response to the toll system and time saving principle, to be the base of the assignment procedure.

The proposed network is used also for several assignments through the selected diversion technique and toll rate. To study the effect and magnitude of the induced traffic on the two networks, all assignment cases are done for both "with" and "without" the estimated induced trips. Traffic volumes are assigned first on a 4-lane toll motorway network, and sections with volumes more than 48,000 vehicle/day are modified to be 6-lane in the final assignments. In the final stage, and for the purpose of developing an implementation plan for the toll motorway network, additional assignments are required for the selection and financial analysis of motorways in different priority stages in the short and long term plans. Appendix 6.53 gives a summary for all the different cases applied in the traffic volume assignment procedure.

9) Assignment Validation

In general, trips between individual pairs of zones are uncertainly estimated by aggregation of the trip matrices cells and then allocated through assignment techniques to routes cover large number of zone pairs. Therefore, it is necessary to examine the results of the assignment so as to ensure that trips are assigned in a realistic pattern well matching to the actual situation.

To check the assignment validity, the OD matrices are first calibrated using the traffic volume data of DOH. The total number of survey stations is 123 stations, in which the field surveys are carried out only in 117 stations. The data of the other six stations are obtained from a previous study done for the Central Region. Actually there are a few more crossing points between Changwat boundaries and the national highway network which are excluded from the traffic survey plan. Reasons differ from the very low traffic volumes at present on some of these highways, to the low potential in future development plans in that area of others. OD data of some excluded points have also been collected from other nearby stations. This situation created some uncovered links without enough OD samples in the national highway network.

To match the existing traffic conditions and to produce synthetic matrices, the calibration procedure is carried out for inter-Changwat links uncovered by survey stations. Traffic volumes produced by trips of OD pairs other than the pair connected directly by the link are first assigned in an explanatory procedure. Then, the all-or-nothing assignment method is applied and a comparative analysis is done by the use of factored ADT data of DOH to supplement the missing portion of that OD pair. In future nationwide OD surveys, it is recommended to include stations at Changwat boundaries on links uncovered in this survey to the existing 123 stations. Uncovered links are identified as follows:

Route No.	309	Sec.	200	between	Ang Thong	and	Ayutthaya
	333		100		Chai Nat		Uthai Thani
	225		401		Phetchabun		Nakhon Sawan
	12		100		Sukhotai		Tak
	12		801		Phitsanulok		Phetchabun
	11		1000		Phrae		Uttaradit
	212		600		Nong Khai		Nakhon Phanom
	222		300		Nong Khai		Sakhon Nakhon

Two levels of comparison are carried out between the assigned and observed traffic volumes on both region and division screen lines as an evaluation for the assignment validity. Counted traffic volumes during the survey are used in this comparative analysis with the assigned volumes after accumulated at boundaries as inter-region and inter-division trips, and vehicle categories are combined here into three groups of passenger cars, trucks including all pickups, and buses. Appendix 6.54 gives the inter-region counted and assigned traffic volumes on region boundaries with the matching rates between both, and Appendix 6.55 gives both traffic volumes and matching rates on division boundaries.

6.5.2 Traffic Volumes on Present and Future National Highway Networks Case of "Without Project"

Present and future OD tables are respectively assigned here on the existing national highway network, and after adding future plans of DOH for the years 2000 and 2010 to compose the future networks without taking into consideration the project of the toll motorway network.

1) Present and Future National Highway Networks

The present road network, which serves as one of several inputs in the assignment stage, is the nationwide national highway network in addition to one provincial highway (Route No. 4035) in the Southern Region and some other road sections necessary for applying the assignment procedure.

To compose the future network for the year 2000, the existing road network is supplemented by many additional roads either as ongoing newly structured roads, or upgrading from provincial to national highways, or widening from two-lanes to four-lanes or more according to the future plans of DOH.

The future network for the year 2010 includes the plan of DOH to widening the four main trunk roads from Bangkok to each of Chiang Mai, Nong Khai, Chantha Buri and Hat Yai from 2-lane to 4-lane or more. Route No. 1 will be 10-lane from Bangkok to OBRR, 6-lane to Saraburi and then 4-lane to Lampang. From Lampang to Chiang Mai Route No. 11 will be 4-lane instead of 2-lane highway. In the northeastern direction, Route No. 2 from Saraburi to Nong Khai will be also 4-lane highway. To the east, Route No. 3 will be 4-lane from Bangkok to Chantha Buri. And to the south, Route No. 4 between Bangkok and Chumphon and again between Phatthalung and Hat Yai will be 4-lane, while in the distance between Chumphon and Phatthalung Route No. 41 will be 4-lane highway.

The present and future national highway networks are illustrated in Appendix 6.56. Table 6.18 presents a summary for the lengths of the three plans of the present and future national highway network used in the assignment procedure.

Table 6.19 gives some details of the length of widened links of the two future plans of the national highways, and Table 6.20 presents the modified lengths of the newly constructed links used in the assignment procedure.

2) Assigned Traffic Volumes

The assigned traffic volumes on the national highway network are illustrated for the case of "Without Project" in Figure 6.42 for the year 1990. Appendix 6.57 shows the situation of the network based on the design ADT of DOH and assigned traffic

Table 6.18 PRESENT AND FUTURE LENGTH OF ASSIGNED ROAD NETWORK (Km)

Class	Function	1990	2000	2010
Primary	2-lane	5881	5239	3847
	4-lane	549	1329	2721
	6-lane & over	49	156	156
	Sub-total	6479	6724	6724
Secondary*	2-lane	8939	10591	10591
	4-lane	328	753	753
	6-lane & over	28	59	59
	Sub-total	9295	11403	11403
Others**	2-lane	24	31	31
	4-lane	31	31	31
	6-lane & over	100	207	207
	Sub-total	155	269	269
Total		15929	18396	18396

* Including some sections of provincial highways which are necessary for assignment procedure.
** ETA and ordinary roads in Bangkok.

Table 6.19 LENGTH OF future WIDENED LINKS (Km)

Class		2000	2010	Route No.
Primary	4-lane	679	2071	1,2,3,4,32,33,35,41
	6-lane & Over	80	80	1
Secondary	4-lane	288	288	110,224,304,314,327, 340,407,411
Total		1047	2439	

Table 6.20 LENGTH OF NEWLY CONSTRUCTED LINKS – 2000 (Km)

Class	Lanes				Route No.
	Two	Four	Six & over	Total	
Primary	62	164	16	242	4,24,31,36
Secondary	11	132	22	165	340 (OBRR),343,345
Others	7	–	121	128	Future Plan of ETA
Total	80	296	159	535	

volumes in 1990. Assigned traffic volumes for the year 2010 are shown in Figure 6.43. Table 6.21 gives the assigned traffic volumes per day for the inter-region trips crossing the regional boundaries in the years 1990, 2000 and 2010 in three vehicle groups. The growth in these regional traffic volumes is presented in Table 6.22 considering the year 1990 as the base of these estimations. Highest growth in the regional trips at the target year 2010 is expected between the Central and Southern regions due to trips generated after the development of the Southern Seaboard.

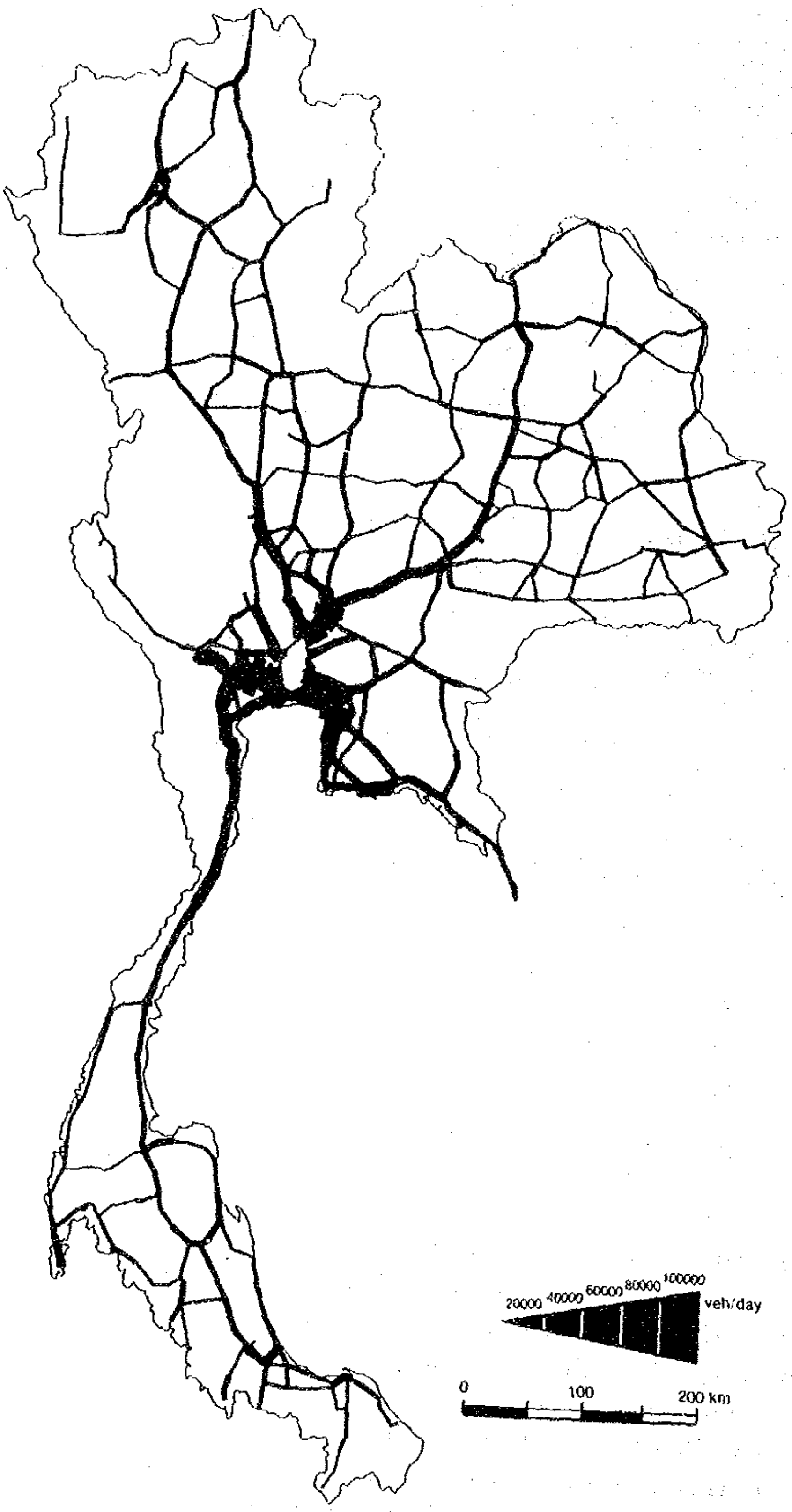


Figure 6.42 ASSIGNED TRAFFIC VOLUMES ON NATIONAL HIGHWAY NETWORK — 1990

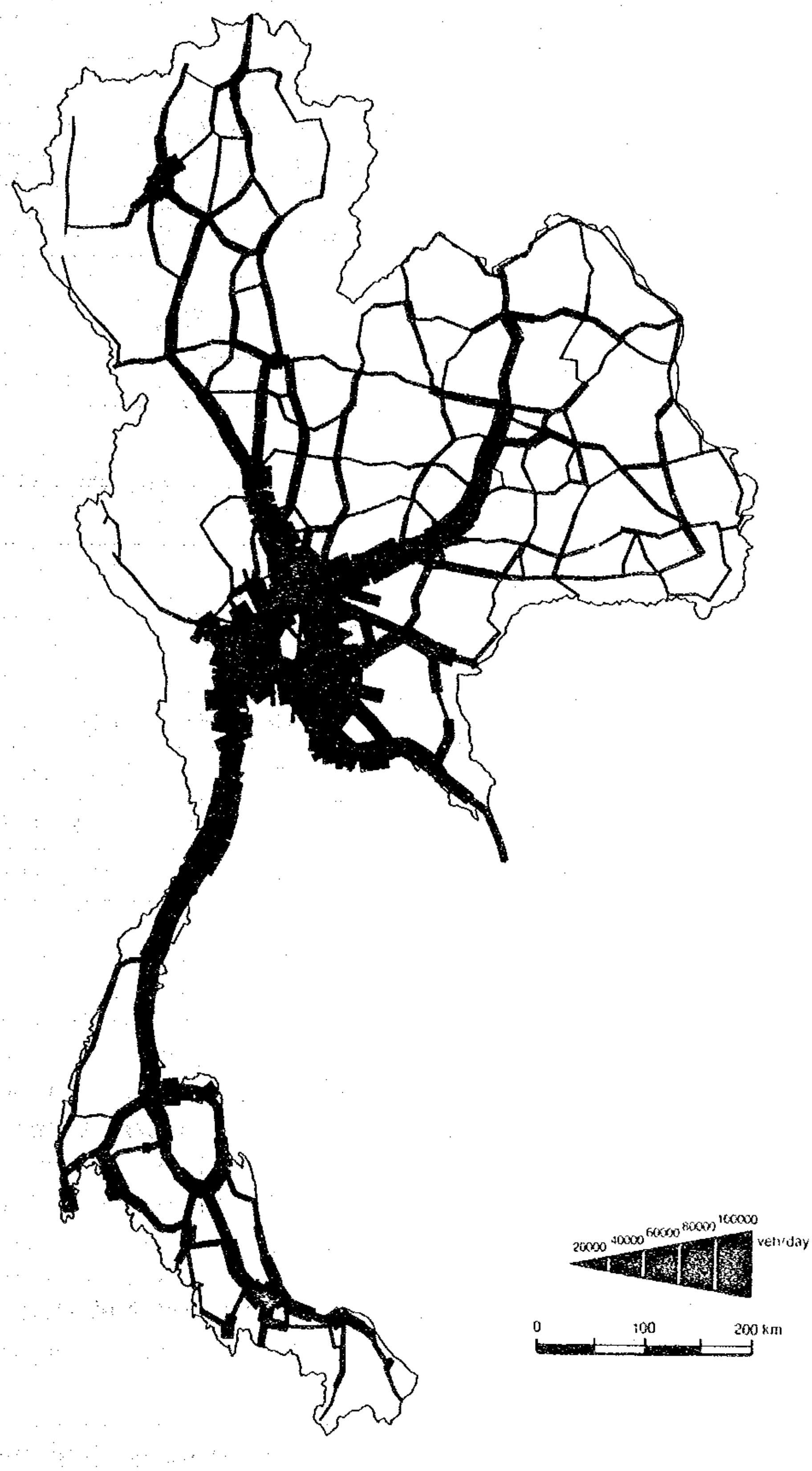


Figure 6.43 ASSIGNED TRAFFIC VOLUMES ON NATIONAL HIGHWAY NETWORK ("Without Project" Case) – 2010

Table 6.21 PRESENT AND FUTURE ASSIGNED TRAFFIC VOLUMES ON REGION BOUNDARIES (vehicle/day)

INTER-REGION	2000/1990				2010/2000				2010/1990			
	PC	BUS	PU+T	TOTAL	PC	BUS	PU+T	TOTAL	PC	BUS	PU+T	TOTAL
N - NE	1.72	1.78	1.58	1.62	1.08	1.09	1.18	1.15	1.87	1.95	1.86	1.87
C - N	2.47	2.52	1.88	2.08	1.63	1.57	1.42	1.50	4.03	3.97	2.67	3.11
C - NE	3.17	3.20	2.30	2.52	1.47	1.69	1.48	1.54	5.40	5.41	3.39	3.89
C - S	3.01	2.96	2.17	2.40	3.17	1.91	2.05	2.22	9.55	5.65	4.45	5.32
TOTAL	2.67	2.79	2.06	2.25	1.34	1.65	1.52	1.60	4.91	4.62	3.13	3.60

Table 6.22 GROWTH OF ASSIGNED TRAFFIC VOLUMES ON REGION BOUNDARIES (1990=1.0)

INTER-REGION	1990				2000				2010			
	PC	BUS	PU+T	TOTAL	PC	BUS	PU+T	TOTAL	PC	BUS	PU+T	TOTAL
N - NE	351	390	2260	3001	605	695	3570	4870	656	760	4203	5619
C - N	4080	2331	13317	19728	10073	5879	25004	40956	16458	9258	35584	61300
C - NE	1766	2184	12123	16073	5601	6999	27880	40480	9545	11814	41138	62497
C - S	816	795	4281	5892	2460	2356	9299	14115	7796	4494	19057	31347
TOTAL	7013	5700	31981	44694	18739	15929	65753	100421	34455	26326	99982	160763

3) Trip Length Distribution

The trip length distribution for the total of intra- and inter-Changwat trips is presented in Table 6. 23 for the case of national highways only "Without Project" in present and future years. There is a slight increase in the long trips of more than 500 km, by the year 2010, which will result in increasing the total average trip length from 62.5 km to 65.0 km.

6.5.3 Traffic Volumes on Future National Highway and Toll Motorway Networks Case of "With Project"

In this case of "With Project", traffic volumes are assigned on both of the future national highway and toll motorway networks together for each assignment case. Preliminary assignments are

Table 2.23 PRESENT AND FUTURE TRIP LENGTH DISTRIBUTION OF INTRA - AND INTER-CHANGWAT TRIPS (Without Project)

Trip Length (Km)	1990		2000		2010	
	Trip/day	%	Trip/day	%	Trip/day	%
0.0 - 10	101469	10.28	217757	8.68	421212	8.90
10.1 - 20	244835	24.81	457640	18.23	903168	19.08
20.1 - 30	180227	18.26	676131	26.94	998051	21.08
30.1 - 40	66828	6.77	213546	8.51	544173	11.49
40.1 - 50	44017	4.46	118529	4.72	248199	5.24
50.1 - 60	47879	4.85	120551	4.80	239166	5.05
60.1 - 70	36853	3.73	80881	3.22	191375	4.04
70.1 - 80	40168	4.07	90378	3.60	178979	3.78
80.1 - 90	32290	3.27	79468	3.17	150243	3.17
90.1 - 100	24901	2.52	61004	2.43	116998	2.47
100.1 - 120	43735	4.43	107171	4.27	181628	3.84
120.1 - 140	26029	2.64	59311	2.36	108109	2.28
140.1 - 160	18612	1.89	40088	1.60	71203	1.50
160.1 - 180	14786	1.50	30972	1.23	56397	1.19
180.1 - 200	11885	1.20	25905	1.03	43592	0.92
200.1 - 250	17219	1.74	40162	1.60	77162	1.63
250.1 - 300	10012	1.01	24349	0.97	55087	1.16
300.1 - 350	6139	0.62	14015	0.56	33316	0.70
350.1 - 400	4109	0.42	11152	0.44	21239	0.45
400.1 - 450	2612	0.26	6837	0.27	15978	0.34
450.1 - 500	2261	0.23	5912	0.24	12692	0.27
500.1 -	9983	1.01	28047	1.12	66466	1.40
Total	986850	100.00	2509805	100.00	4734437	100.00
Av. Length (km)	62.5		61.9		65.0	

done first for the tentative toll motorway network which is evaluated and modified to produce the proposed toll motorway network. Other assignments are done in later stage for cases of different alternatives of the priority routes to be used in the implementation plan of the motorway network.

1) Traffic Volumes on Tentative Toll Motorway Network

The tentative toll motorway network with a total length of 5851 km is first established by applying the concepts of the toll motorway development policy. The network is shown in Appendix 7.5 and the details of the procedure used in establishing the network and its routes are explained in Chapter 7.

a. Induced Generated and Attracted Trips

Taking into consideration the tentative toll motorway network, induced trip-ends are estimated here for each OD pair and per vehicle category for the year 2010. Regional induced trip-ends are presented in Table 6.24 with the percentages of induced trips to the regional trips estimated from the future OD tables.

Table 6.24 REGIONAL INDUCED TRIP-ENDS BY VEHICLE CATEGORY
—With Tentative Network (2010)

(trip-end/day)

Region	Vehicle Category							
	PC	LB	HB	PP	LT	MT	HT	Total
Northern	15589	993	1778	19270	5937	4421	2968	55956
Northeastern	11312	1768	3012	9002	27580	7863	8074	68611
Central	62265	10321	10339	61808	41453	26356	56605	269147
Southern	14508	1776	1663	15486	16370	4794	5737	60334
Total	103674	14858	16792	105566	91340	43434	73383	449048
								(%)
Northern	40.8	15.3	13.1	31.0	25.8	31.6	21.5	29.8
Northeastern	35.7	26.5	13.6	37.0	37.7	32.5	21.7	31.3
Central	6.1	5.4	3.3	10.7	10.6	7.2	7.8	7.5
Southern	25.0	23.6	14.3	32.5	52.0	25.2	14.4	28.0
Total	9.0	7.0	4.7	14.8	17.6	10.3	9.0	10.7

b. Assigned Traffic Volumes

Assignment procedure is applied to allocate traffic volumes on the national highway and tentative toll motorway networks after adding the estimated induced trips to the future OD tables of the year 2010. Results of the assignment are presented in Table 6.25 in vehicle-kilometer for the total length of motorways and as average traffic volumes for each motorway.

The assigned traffic volumes are illustrated on the tentative toll motorway network in Appendix 6.58 and on the national highway network in Appendix 6.59 for the year 2010. Table 6.26 gives a summary for the values of vehicle-kilometer and vehicle-hour for both the tentative toll network and the future national highway network in the year 2010.

c. Trip Length Distribution

Trips to be handled by each of the national highways and the tentative toll motorways are analyzed to get the trip length distribution on the target year 2010. Table 6.27 gives this distribution for the total of intra- and inter-Changwat trips.

National highways are expected to handle trips with an average length of 51.8 km, while the average length of trips by the toll motorways is 162.6 km. It is also clear that the longer the trips are, the more are handled by the motorways.

Table 6.25 VEHICLE-KILOMETER AND AVERAGE TRAFFIC VOLUMES OF TENTATIVE NETWORK BY ROUTE – 2010

Toll Motorway No.	Length (km)	Vehicle-km (1000)	Average Traffic Volume (vehicle/day)	Induced Traffic Rate (%)
1	578	17070 (4614)	29533 (7983)	27.0
2	534	12614 (2596)	23621 (4860)	20.6
3	196	9775 (1195)	49871 (6097)	12.2
4	941	22928 (5201)	24366 (5527)	22.7
5	170	8654 (432)	50907 (2544)	5.0
6	184	3945 (204)	21440 (1106)	5.2
11	363	3412 (1065)	9400 (2934)	31.2
12	696	5934 (1476)	8526 (2121)	24.9
31	101	3385 (327)	33511 (3234)	9.6
32	222	7173 (908)	32312 (4090)	12.7
33	230	2262 (420)	9834 (1826)	18.6
41	143	1424 (443)	9957 (3098)	31.1
42	208	1873 (439)	9003 (2111)	23.4
101	146	1453 (504)	9949 (3451)	34.7
201	146	1059 (283)	7255 (1936)	26.7
202	299	3810 (1220)	12743 (4080)	32.0
301	168	3631 (1149)	21615 (6838)	31.6
302	187	3886 (346)	20778 (1851)	8.9
303	62	2192 (1005)	35351 (16215)	45.9
401	36	529 (122)	14704 (3400)	23.1
2001	78	300 (66)	3850 (842)	21.9
3001	98	1836 (234)	18733 (2384)	12.7
4001	65	687 (148)	10563 (2272)	21.5
Total	5851	119830 (24395)	20480 (4169)	20.4

Notes: - Toll Rate = 1.0 Baht/km
- Figures between brackets show the induced traffic

Table 6.26 VEHICLE-KILOMETER AND VEHICLE-HOUR OF TENTATIVE TOLL MOTORWAYAND NATIONAL HIGHWAY NETWORKS – 2010

	National Highway		Toll Motorway	Total
	"Without Project"	"With Project"		
Vehicle-kilometer in 1000 veh-km/day:				
Normal Traffic	307,718	214,481	95,435	309,916
Induced Traffic	0	19,641	24,395	44,036
Total	307,718	234,122	119,830	353,952
Vehicle-hour in 1000 veh-hr/day:				
Normal Traffic	9,411	5,807	918	6,725
Induced Traffic	0	691	283	974
Total	9,411	6,498	1,201	7,700

Note: Toll Rate = 1.0 Baht/km

Table 6.27 TRIP LENGTH DISTRIBUTION OF INTRA- AND INTER-CHANGWATS TRIPS WITH TENTATIVE NETWORK — 2010

Trip Length km	National Highway Trip/day	National Highway %	Toll Motorway Trip/day	Toll Motorway %	Total Trip/day	Total %
- 10	393645	9.64	0	0.00	393645	7.94
10.1 - 20	780980	19.12	18838	2.16	799819	16.13
20.1 - 30	1049431	25.69	51277	5.87	1100708	22.20
30.1 - 40	503837	12.33	25450	2.91	529287	10.67
40.1 - 50	229378	5.61	50524	5.78	279902	5.64
50.1 - 60	201426	4.93	47866	5.48	249292	5.03
60.1 - 70	147136	3.60	57041	6.53	204177	4.12
70.1 - 80	142956	3.50	60501	6.92	203456	4.10
80.1 - 90	114721	2.81	53328	6.10	168049	3.39
90.1 - 100	76047	1.86	41975	4.80	118022	2.38
100.1 - 120	130457	3.19	82360	9.43	212818	4.29
120.1 - 140	65617	1.61	64557	7.39	130174	2.63
140.1 - 160	45600	1.12	42921	4.91	88521	1.79
160.1 - 180	35460	.87	38004	4.35	73465	1.48
180.1 - 200	28465	.70	43508	4.98	71973	1.45
200.1 - 250	42126	1.03	48273	5.52	90399	1.82
250.1 - 300	25989	.64	33578	3.84	59567	1.20
300.1 - 350	15610	.38	18400	2.11	34010	.69
350.1 - 400	10434	.26	18651	2.13	29085	.59
400.1 - 450	7476	.18	12713	1.45	20189	.41
450.1 - 500	6071	.15	8873	1.02	14944	.30
500.0 -	32362	.79	55095	6.31	87457	1.76
TOTAL	4085224	100.00	873733	100.00	4958957	100.00
Av. Length (km)	51.8		162.6		71.3	

2) Traffic Volumes on Proposed Toll Motorway Network

The tentative toll motorway network is evaluated and a proposed network is developed with a total length of 4345 km. The proposed network is explained in full details in Chapter 7.

a. Induced Generated and Attracted Trips

The same procedure of estimating the induced trips is used here to estimate the induced trip-ends by Changwat considering the proposed toll motorway network. As the proposed network is shorter than the tentative one, estimated number of induced trip-ends has been decreased as shown in Table 6.28 which gives also the percentages of the induced trips to the total regional trips concluded from the future OD tables. In total, the average rate is 9.3% for the proposed network compared with a higher rate of 10.7% for the tentative network.

Table 6.28 REGIONAL INDUCED TRIP-ENDS BY VEHICLE CATEGORY
With Proposed Network (2010)(trip-end/day)

Region	Vehicle Category							
	PC	LB	HB	PP	LT	MT	HT	Total
Northern	7819	480	1242	10889	2733	1667	1870	26700
Northeastern	8434	1330	2075	7785	15884	4897	6748	47153
Central	61476	10282	10125	60972	41219	26219	56056	266349
Southern	10977	1296	1450	12676	11752	3827	4836	46814
Total	88706	13388	14892	92322	71588	36610	69510	387016
								(%)
Northern	20.5	7.4	9.1	17.5	11.9	11.9	13.3	15.6
Northeastern	26.6	19.9	9.4	32.0	21.7	20.2	18.2	21.5
Central	6.0	5.4	3.2	10.5	10.5	7.2	7.8	7.4
Southern	18.9	17.2	12.5	26.6	37.4	20.1	12.1	21.7
Total	7.7	6.3	4.1	12.9	13.8	8.7	8.6	9.3

b. Assigned Traffic Volumes

Traffic volumes are assigned here on the proposed toll motorway network and Table 6.29 gives the results of the assignment in vehicle-kilometer and average traffic volumes per day for each route in the network at the target year 2010. Two traffic volume maps for this case of assignment are shown in Figure 6.44 for the toll motorway network, and in Appendix 6.60 for the future national highway network.

Table 6.29 VEHICLE-KILOMETER AND AVERAGE TRAFFIC VOLUMES OF PROPOSED NETWORK BY ROUTE – 2010

Toll Motorway No.	Length (km)	Vehicle-km /day (1000)	Average Traffic Volume (vehicle/day)	Induced Traffic Rate (%)
1	756	18874 (4318)	24966 (5797)	23.2
2	535	12174 (1640)	22755 (3065)	13.5
3	292	12049 (702)	41262 (2404)	5.8
4	951	22922 (5172)	24103 (5438)	22.6
21	301	4292 (1843)	14260 (6122)	42.9
31	168	11374 (1268)	67702 (7547)	11.1
32	100	3827 (342)	38269 (3424)	8.9
33	62	1336 (699)	21548 (11271)	52.3
34	211	6734 (2113)	31916 (10015)	31.4
35	239	2178 (1327)	9115 (5552)	60.9
36	366	6477 (1773)	17698 (4844)	27.4
41	191	4042 (194)	21161 (1016)	4.8
42	136	1324 (411)	9736 (3021)	31.0
43	37	470 (92)	12711 (2475)	19.5
Total	4345	107991 (22060)	24854 (5077)	20.4

Notes: - Toll Rate: 1.0 Baht/km
- Figures between brackets show the induced traffic

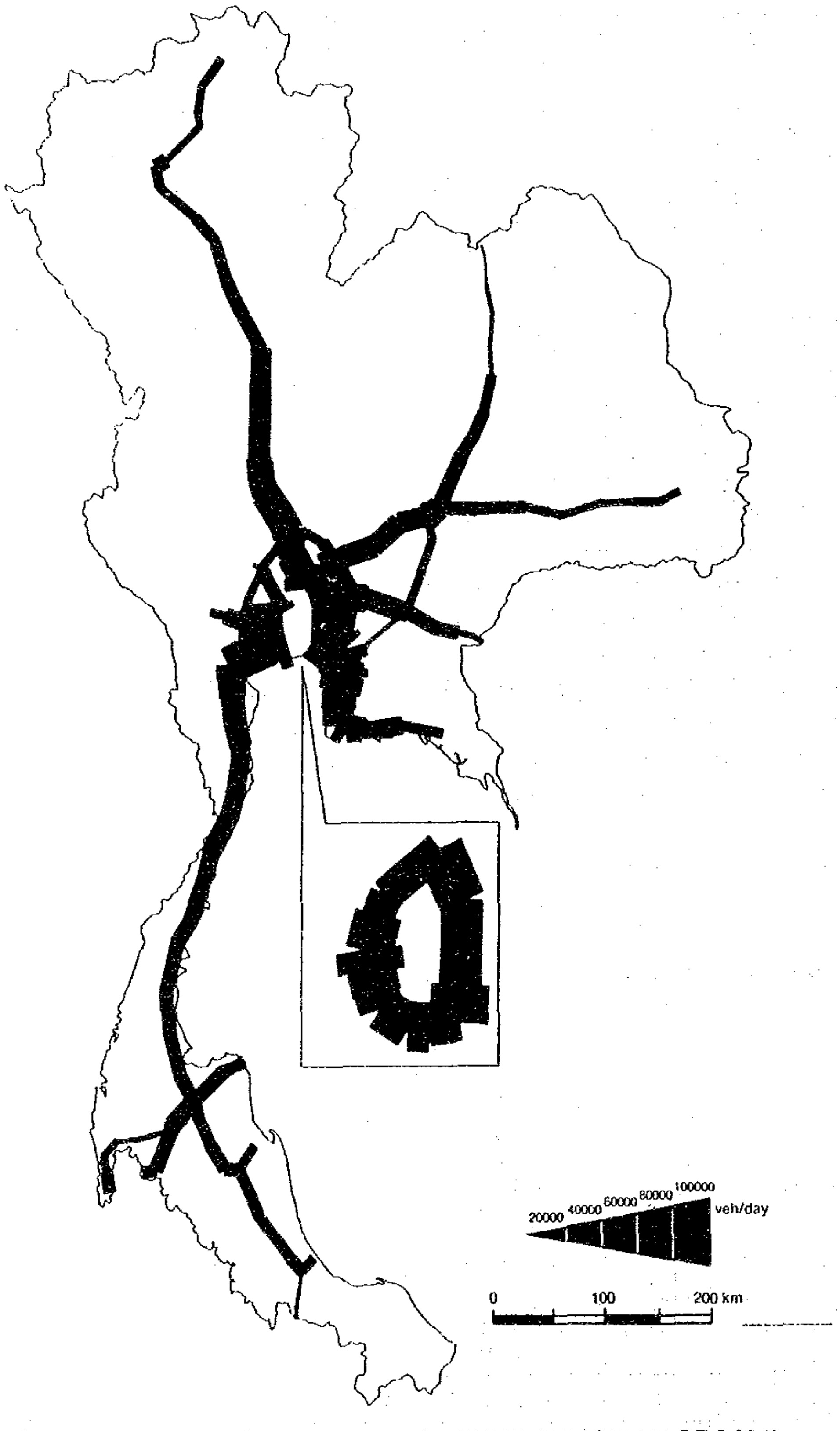


Figure 6.44 ASSIGNED TRAFFIC VOLUMES ON PROPOSED MOTORWAY NETWORK — 2010

As a summary for the traffic conditions of the two networks, and in the two cases of with and without the project, Table 6.30 gives the values of vehicle-kilometer and vehicle-hour for the two networks in 2010.

Table 6.30 VEHICLE-KILOMETER AND VEHICLE-HOUR OF PROPOSED TOLL MOTORWAY AND NATIONAL HIGHWAY NETWORKS – 2010

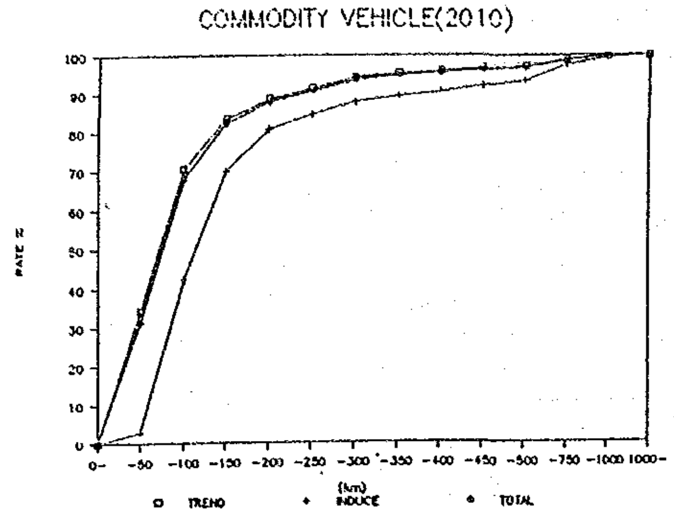
	National Highway		Toll Motorway	Total
	"Without Project"	"With Project"		
Vehicle-kilometer in 1000 veh-km/day:				
Normal Traffic	307,718	222,606	86,247	308,853
Induced Traffic	0	16,448	21,252	37,700
Total	307,718	239,054	107,499	346,553
Vehicle-hour in 1000 veh-hr/day:				
Normal Traffic	9,411	6,184	826	7,010
Induced Traffic	0	565	223	788
Total	9,411	6,749	1,048	7,798

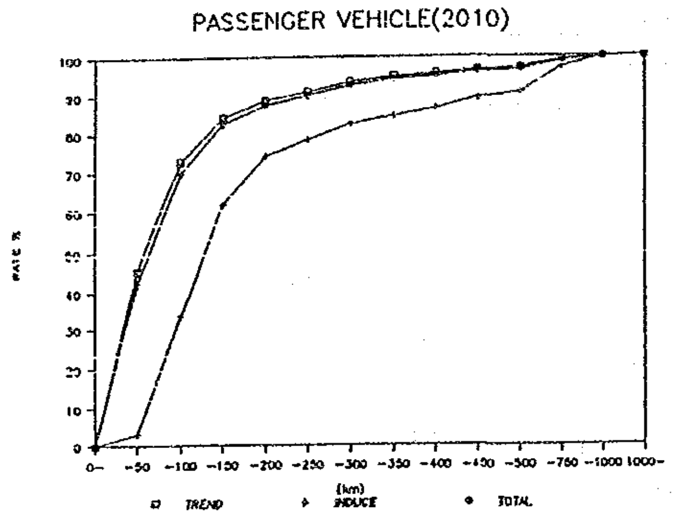
c. Trip Length Distribution

Introducing the induced trips has its effect on the trip length distribution. With the introduction of the toll motorway, it is expected to generate longer trips than before. Appendix 6.61 gives the trip length distribution for induced trips.

Figure 6.45 shows the trip length distribution of the originally forecasted trend trips, induced trips and total trips for both commodity and passenger vehicle groups and for all vehicles for inter-Changwat trips in the year 2010.

Adding intra-Changwat trips will cause in reducing the total average trip length. Table 6.31 gives the overall distribution of trip length for the total of intra- and inter-Changwat trips on the national highway and proposed toll motorway networks. Short trips of length less than 10 km are not expected to use the motorway, but with the increase in trip length the toll network is expected to handle more trips than the national highway network.





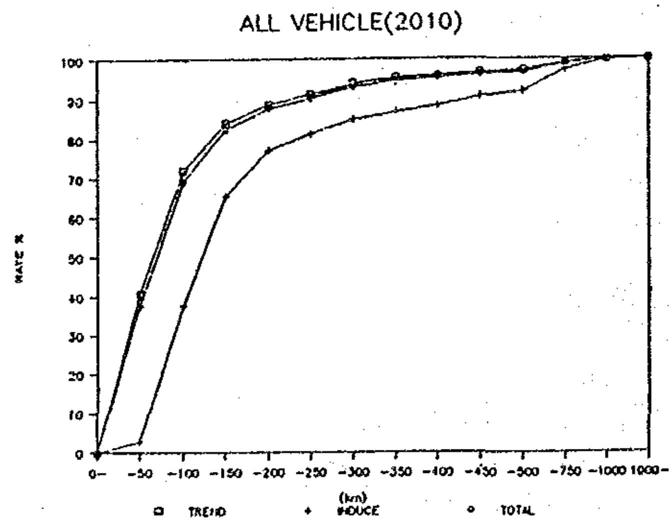


Figure 6.45 TRIP LENGTH DISTRIBUTION FOR TREND, INDUCED AND TOTAL INTER-CHANGWAT TRIPS — 2010

Table 6.31 TRIP LENGTH DISTRIBUTION OF INTRA - AND INTER - CHANGWAT TRIPS WITH PROPOSED NETWORK – 2010

Trip Length km	National Highway Trip/day	%	Toll Motorway Trip/day	%	Total Trip/day	%
- 10	393645	9.57	0	0.00	393645	7.99
10.1 - 20	780511	18.97	21360	2.63	801870	16.27
20.1 - 30	1056231	25.67	40842	5.03	1097073	22.26
30.1 - 40	501902	12.20	25016	3.08	526918	10.69
40.1 - 50	229583	5.58	48130	5.92	277714	5.64
50.1 - 60	201350	4.89	50065	6.16	251415	5.10
60.1 - 70	147079	3.57	47674	5.87	194752	3.95
70.1 - 80	142076	3.45	57528	7.08	199603	4.05
80.1 - 90	112140	2.72	54841	6.75	166981	3.39
90.1 - 100	79094	1.92	42562	5.24	121656	2.47
100.1 - 120	130418	3.17	82200	10.11	212619	4.31
120.1 - 140	70080	1.70	63446	7.81	133525	2.71
140.1 - 160	49026	1.19	37583	4.62	86608	1.76
160.1 - 180	38685	.94	33844	4.16	72530	1.47
180.1 - 200	29567	.72	38653	4.76	68219	1.38
200.1 - 250	48944	1.19	38428	4.73	87372	1.77
250.1 - 300	28667	.70	27355	3.37	56022	1.14
300.1 - 350	16788	.41	16446	2.02	33234	.67
350.1 - 400	11425	.28	17521	2.16	28946	.59
400.1 - 450	7646	.19	11638	1.43	19284	.39
450.1 - 500	6330	.15	8597	1.06	14927	.30
500.1 -	34059	.83	48964	6.02	83024	1.68
TOTAL	4115245	100.00	812693	100.00	4927938	100.00
Av. Length (km)	53.00		159.50		70.00	

In total, the average length of trips using the toll motorways is about 160 km, while the national highways has an average of 53 km.

3) Traffic Volumes on Priority Routes

Three scenarios including five alternative staging plans are established as explained in Chapter 10 for the implementation of the toll motorway network during a total period of twenty years. The toll motorways of the alternative staging plans are illustrated in Figure 6.46.

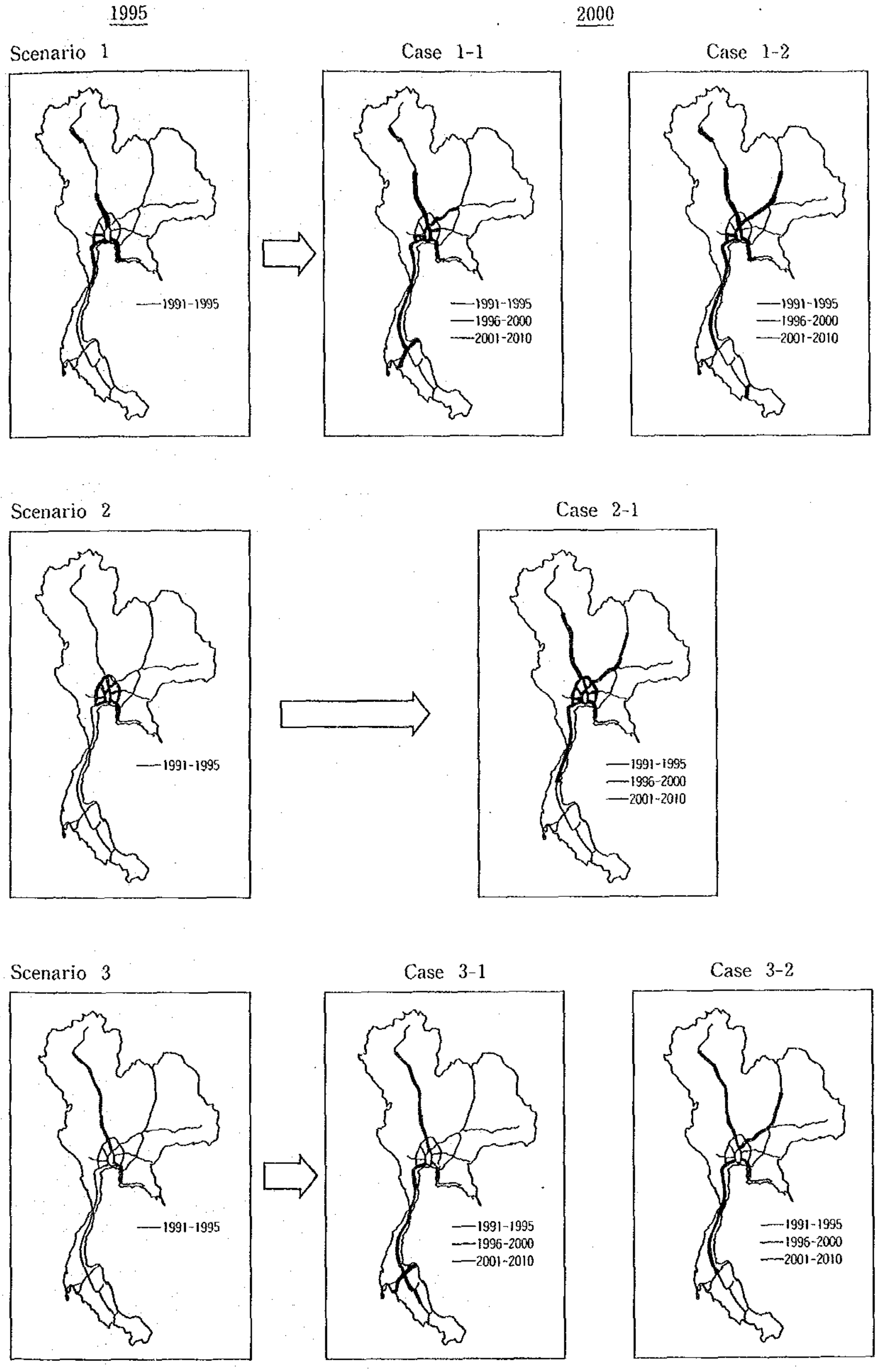


Figure 6.46 ALTERNATIVE STAGING PLANS FOR IMPLEMENTATION

To evaluate these cases economically and financially and to conclude the priority of routes or sections of the network, traffic volume assignments are required for each of the short- and long-term plans. The assignment procedure considers the years 1995 and 2000 for the short-term plans and the year 2010 for the long-term plan. OD tables for the year 1995 are lately established to be applied for the short-term plan of that year. Table 6.32 presents a summary for the traffic assignment total results for the different implementation plans, and Table 6.33 gives the number and length of trips to be handled at each stage of implementation for the motorways. Assignment results are presented for each route in Appendix 6.62.

Table 6.32 ASSIGNMENT RESULTS FOR IMPLEMENTATION PLANS

Implementation Plan	National Highways		Toll Motorways		Total	
	Trip/day	ATL	Trip/day	ATL	Trip/day	ATL
Scenario 1 (1995)	2542545	56.5	86353	178.8	2628897	60.6
Case 1-1 (2000)	2898127	52.1	239128	181.7	3137266	62.0
Case 1-2 (2000)	2920597	53.0	216656	172.5	3137254	62.0
Scenario 2 (1995)	2492941	55.2	135957	147.5	2628897	59.9
Case 2-1 (2000)	2872107	51.7	265149	172.6	3137256	61.9
Scenario 3 (1995)	2576139	56.8	52759	237.1	2628898	60.5
Case 3-1 (2000)	2984189	53.7	153065	214.9	3137254	61.6
Case 3-2 (2000)	2945822	51.9	191432	211.1	3137254	61.6
Total Network (2010)	4115245	53.0	812693	159.5	4927938	70.0

Note: ATL is the Average Trip Length in km.

Table 6.33 NUMBER AND LENGTH OF TRIPS FOR IMPLEMENTATION PLANS

Implementation Plan	Length (km)	1000 Veh-km	Veh-hr	Av. Vol.
Scenario 1 (1995)	701	6989	61831	9970
Case 1-1 (2000)	1891	29930	264656	15828
Case 1-2 (2000)	1201	22640	200190	18851
Scenario 2 (1995)	1004	9323	81873	9286
Case 2-1 (2000)	2126	31274	276129	14710
Scenario 3 (1995)	704	7834	70721	11128
Case 3-1 (2000)	1668	21940	195973	13154
Case 3-2 (2000)	1497	24726	220936	16517
Total Network (2010)	4345	107499	1048000	24913

Note: Toll rate is 1.0 Baht/km.