Executive Summary

1 Introduction

Chiang Mai, located 700km north of Bangkok, is the regional center of the Upper North Region of Thailand. The city is the largest in Chiang Mai Province. It is a major center of economic growth, as well as a regional trade, public administration, education, communications, transportation hub, and tourism. It occupies approximately 40 km^2 and has witnessed a steady growth in population.

As a result of the growing population and economic prowess of Chiang Mai, the number of vehicles on municipal roadways has jumped nearly 37 percent since 1993. Moreover there is no public bus service in Chiang Mai and shared taxis services using pick-up truck with roof provide the closest form of pseudo-public transportation. This fact combined with the inherently narrow and curvy roadways as well as the presence of numerous historical heritage sites has produced heavy traffic congestion, increased accidents and reduced traffic speeds in the city.

Under these circumstances, in late 2000, the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, decided to conduct and initiate this study (Study on Improvement of Road Traffic Environment in Chiang Mai City). Accordingly, JICA engaged a consortium of PADECO, Co., Ltd. and Fukuyama Consultants Co., Ltd. to carry out this study.

On the part of the Government of Thailand, the Royal Thai Police (RTP) and the Municipality of Chiang Mai (MOCM) act as the counterpart agencies. In addition, Department of Highway (DOH), Northern Technical Center for Traffic System Management of Chiang Mai University, and Traffic Sub-Committee of OCMLT provided various support to the study.

General objectives of the Study are as follows:

- to formulate road traffic environment improvement plans for alleviating traffic congestion as well as for securing road safety in the model city of Chiang Mai; and
- to implement technology transfer to the Thai counterpart personnel within the Study through a seminar and informal workshop.

The Study Area covers the Municipality of Chiang Mai and adjoining areas, with a size of about 60km^2. The Study itself commenced in July 2001 and was completed in August 2002.

2 Analysis of Transport/Traffic Issues

(1) Road Network Issues

- As a natural barrier, The Mae Ping River affects the traffic flow between the east and western part of the city.
- The main deficiency within the road network system is the collector roads.
- The Super Highway has several conspicuous faults that require attention: (i) Access Control; (ii) U-turn; and (iii) Incomplete Ring.
- Some inconsistency exists in design of road facilities.
- Many of the intersections have the following problems; (i) lack of pedestrian signals facility; (ii) geometric design problems; (iii) inadequate signage; (iv) lack of stop lines; (v) poor visibility of signs or signals; (v) no clear indication of main road from minor roads; (vi) confusing road markings; (vii) lack of channeling islands or markings; (viii) inappropriate locations for sign posts, signal posts, or lamp posts; (ix) obstruction of view by foliage or untidy wires; and (x) broken signal equipment.
- There are several traffic bottlenecks around the city

(2) Demand Forecasting Analysis

The results of the analysis is as follows:

- Although traffic is concentrated at certain locations, it is found that in 2001, the V/C ratio of most roads is less than 1.50. Furthermore no continuous congested section of roadway exists within the Inner Area, implying that the existing road network can largely accommodate existing traffic loads.

- In 2010, the V/C ratio is expected to worsen on most roads due to increased traffic volumes. On the other hand, road traffic is expected to decrease in some as traffic shifts to new roads. Overall however, the new network may be able to reduce congestion along some main roads, but it cannot relieve the existing congestion problems.

- It is expected that Sections with serious congestion, possessing V/C ratios larger than 2.0 in 2010, will become network bottlenecks in the future.

(3) Traffic Signal System

The overall ATC system seems to work properly. However there are several issues.

- When the traffic volume is saturated, queue lengths are not balanced in some intersections.
- The right turn stage has some waste green.
- There are some conflicting phase plans and signs.
- The MTBF values are too low for controllers, bulbs and the communication line.

(4) Traffic Safety Facilities and Devices

- Traffic Accidents

The traffic accident rate in Chiang Mai City is alarmingly high. The reasons are attributable to: (i) at-grade junctions of Super Highway; (ii) unlicensed driving and drunken driving; (iii) motorcyclist without helmets and driving with 3 or more persons; (iv) little regard for the pedestrians on roads.

- Sidewalk

Safe and comfortable sidewalks for pedestrians in the city are grossly inadequate.

- Road Signs

A thorough review on the suitability and the exact installation location of road signs especially on the city streets is urgently needed.

- Road Markings

Visibility of road markings in Chiang Mai is generally not satisfactory.

- Other Traffic Safety Devices

Guardrails are insufficient and should in fact be installed for the purpose of protecting pedestrians along narrow sidewalks or corners from the possibility of impact from vehicles. The reflective material for the chatter bar currently installed in the central belt of roads is hardly reflective.

(5) Public Transport in Chiang Mai

Besides private vehicles, the primary means of transport are shared-taxis (*songtaews*), minibuses, buses, and vans. Primary issues relating to public transport are as follows:

- Over-Supply of Red *Songtaews*
- Duplication of Route Network
- Problems with Cooperative Management Style
- Minibus Failures in the Past
- Poor Vehicle Maintenance
- High Level of Fares
- Resistance to Change
- Lack of Public Transport Enforcement
- Unlicensed Transport Operators

(6) Other Traffic Management Issues

There are some issues of traffic management.

- Parking Facilities and Control
- Motorcycle Safety Issues
- Traffic Accident Investigation and Record System
- Traffic Management Around School Areas
- Pedestrian Safety around Night Bazaar Area
- Environmental and Social Considerations

3 Recommendations

(1) Summary of Recommendations

Based on the findings of the Study Team, the table below presents a summary of recommendations.

Table 1 Summary of Recommendations

Issue Item	Proposed Measures
Road Network	• Develop clearer hierarchy of road network • Develop design/installation standards for on-street facilities
Intersections	• Introduce channelization, traffic islands, and traffic signals to reduce traffic conflicts • Improve markings and signs at intersections
Traffic Signal System	• Change detector configurations • Resolve conflicts between phase plans and traffic signs • Improve maintenance system • Install additional signal, expand ATC controlled signals and install pedestrian signals • Upgrade signal control software
Traffic Safety Issues	• Change name of Super Highway and speed limit • Improve pedestrian environment • Improve traffic signs and pavement markings • Develop traffic safety facilities • Develop pedestrian and bicycle network in Old City • Improve hazardous locations
Public Transport System	• Promote coordination among agencies • Promote stricter enforcement of rules and regulations for public transport • Promote corporate management style • Standardize vehicle design • Adopt fleet renewal programs • Introduce bus priority measures • Secure funding for sustainable operations of public transport • Promote private financing for transport development
Other Traffic Management Measures	• Develop database/analyses system on parking facilities and refine parking management policy • Introduce measures for improving motorcycle safety • Introduce traffic management measures around school areas • Improve pedestrian safety in Night Bazaar Area • Introduce TDM measures for controlling traffic demand
Environmental Improvement	• Formulate action plan for air qualities • Improve noise sensitive locations

Source: This study

(2) Priority Projects

Priority projects have been selected based on the following criteria:

- no land acquisition is required;
- project is ready for implementation; and
- medium to large benefits are expected.

Projects that meet the criterion above have been selected. They are listed in Table 2.

Table 2 Priority Projects

	Projects	**Estimated Cost (million Baht)**	**Remarks**
1	Intersection improvements	42.1 (15.8)[1]	20 intersections including 8 new signals and additional pedestrian lanterns at 7 existing signals
2	New signal installation	(27.9)[2] 10.4	12 signals 4 signals only
3	Signal upgrading (Connection to ATC)	14.5	10 existing signals
4	Addition of pedestrian lantern	18.1	26 existing signals
5	Pedestrian/bicycle network in Old City	39.8	Total length: 7,270 m
6	Hazardous location improvement	0.9	16 locations
	Total	**126.1**	
	-Done by Chiang Mai Municipality	110.3	
	-Done by DOH	15.8	

Notes: 1) The cost of the works to be done by DOH.

2) The figure includes cost of eight (8) new signals under Intersection improvements

Source: Study Team

4 Pilot Project

Improvements of Wat Chet Yod intersection including installation of a new signal, was implemented as a pilot project.

Improvements

The main geometric improvements were:

- construction of corner islands and median on Wat Chet Yod approach at right angle to Super Highway;
- extension of median on the east side of Super Highway;
- construction of sidewalk on the south side of Super Highway for 50 meters; and
- improvement of vertical alignment and pavement overlay on Wat Chet Yod approach.

Both safety and efficiency was considered in the design of signals. The design basically follows DOH standards but some enhancements were also introduced.

(a) Local Controller

A microprocessor based local controller with very high reliability was installed.

(b) Detector

Ultrasonic vehicle detector, Doppler type ultrasonic, and an image type vehicle detector were installed.

(c) Lantern

A signal head using LED (light emitting diode) was installed, and the primary/secondary signal layout was employed for all movements.

(d) Phase design

The vehicle detectors actuate every stage. For the pedestrians to cross Super Highway, push button actuated pedestrian signal was employed.

Effectiveness Evaluation

Based on the survey results shown in Table 3, the pilot project is judged highly successful in terms of safety enhancement.

Table 3 Summary of Impact Analysis

Survey Type	Evaluation Results		
	Before	During	After
Running Time Survey	Average loss time of observed vehicles: 13.2 second	Average loss time of observed vehicles: 14.6 second	Average loss time of observed vehicles: 32.8 second
Queue Length Survey	Queue of 50 – 120 meter long observed on Super Highway and disappeared in 90 – 266 sec. On Soi, maximum 20 meter long queue appeared and disappeared in 50 – 90 sec.	Queue of 20 – 90 meter long formed on all approaches and took 20 – 380 seconds to disappear.	Queue of 110 – 310 meter long observed on Super Highway and queue of 35-45 m long formed on Soi. All queues discharged in 90-175 seconds.
Traffic Conflict Survey	A total of 1,175 conflicts observed.	A total of 446 conflicts observed during the same duration. A 62% reduction compared with "before."	A total of 88 conflicts observed, 1/13 of the "Before" situation.
Interview Survey	95.10% of respondents felt dangerous at the intersection.	79.8% of respondents felt safer at the intersection, and 75.4% said easier to make turn.	98.5% of respondents feel safer at the intersection, and 92.0% said easier to make turn.

Source: This Study

Lessons Learned by Implementation of the Pilot Project

There are both positive and negative lessons learnt from the project. They are:

- measures implemented are extremely effective for traffic safety;
- drivers' behavior becomes more disciplined if intersection and signal are well designed;
- construction took much longer time than expected; and
- quality of work was not satisfactory.

5 Economic Evaluation

(1) WCY Intersection Improvement

The project is expected to produce a B/C ratio of 3.6 and an Internal Rate of Return of 49%. The project has a NPV of Baht 17.1 million.

(2) Other Five Intersection Improvements (Table 4)

Table 4 Economic Evaluation

	Intersection Number				
Evaluation Indicator	**No.1**	**No.5**	**No.7**	**No.13**	**No.18**
B/C	18.3	2.8	37.9	21.5	53.0
EIRR (%)	243	41	660	339	572
NPV (mil. Baht)	36.98	3.71	117.62	24.45	170.37

Source: This study

Chapter 1

Introduction

1.1 Background

Chiang Mai, located 700km north of Bangkok, is the regional center of the Upper North Region of Thailand. The city is the largest in Chiang Mai Province. It is a major center of economic growth, as well as a regional trade, public administration, education, communications and transportation hub. Chiang Mai is also one of the regional centers for tourism for well-conserved cultural heritages in Thailand. In 1998, about 2.9 million foreign tourists visited the city. Chiang Mai City Proper is a 700-year old city constructed within the confines of a city wall, with a moat running around the perimeter of the city. It occupies approximately 40 km^2 and has witnessed a steady growth in population, fueled by rural migration from hillside regions making it the eighth most populated city in the country.

As a result of the growing population and economic prowess of Chiang Mai, the number of vehicles on municipal roadways (including private cars and motorbikes) has jumped nearly 37 percent since 1993 (from around 398,000 vehicles in 1993 to nearly 546,000 in 2000). This fact combined with the inherently narrow and curvy roadways as well as the presence of numerous historical heritage sites has produced heavy traffic congestion, increased accidents and reduced traffic speeds in the city.

There is no public bus service within the city, however, as operators found service to be financially unsustainable as riders found more convenient and faster modes of transport. Currently, taxis services provide the closest form of pseudo-public transportation in Chiang Mai. There are three types of taxis: (i) *songtaews* (essentially pick-up trucks with a roof), which pick up passengers heading to the same general vicinity and drop passengers off at specific destinations, acting as shared-taxis;[1] (ii) motorized vehicles called *tuk tuks*, which are generally faster than *songtaews*, but have capacity for only two to three persons; and (iii) pedicabs or *samlors*, which are considerably slower and bulkier than *tuk-tuks*, and are mainly used by tourists or the elderly. The ubiquity of these taxis serves to further complicate congestion within Chiang Mai. Although plans for a subway or light-rail network in Chiang Mai are in the offing, no commitment has been made, and completion is not expected for at least another decade. The inability to widen or expand roadways due to the densely crowded city severely limits the potential remedies to improve the traffic/transportation situation within Chiang Mai in the near future.

Under these circumstances, in 1995 the Office of the Commission for the Management of

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[1] *Songtaews*, which have the capacity of a bus, but the service qualities of a taxi, are difficult to qualify into a certain transport mode type. Although here it is referred to as a form of taxi, in Chapter 7 it is referred to as a component of the pseudo-bus network serving the Municipality as well.

Road Traffic (OCMRT)[2] implemented a study called the Master Plan for the Management of Traffic in the City of Chiang Mai. The study is the first of its kind to focus on the development of integrated traffic management policies in the city and the region, and recommended the following short- and medium-term policies:

- traffic management;
- safety and environment management;
- public transport development;
- road network development;
- expansion of traffic control systems and improvement in maintenance system; and
- capacity building for traffic police.

Some of these recommendations have been successfully implemented in the past several years, but it has become clearer that a continued effort in developing more specific plans and policy measures is necessary.

In late 2000, the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, decided to conduct and initiate this study (Study on Improvement of Road Traffic Environment in Chiang Mai City). Accordingly, the first mission arrived in Chiang Mai in mid-July 2001.

Considering Chiang Mai's distinctive features, this study is expected to contribute to enhancing the attractiveness of Chiang Mai City for tourists as well as residents. In addition, the Study will be fashioned as a model case for major local cities that have faced the same traffic congestion as Chiang Mai. In fact, the rapidly growing Thai economy has increased the traffic demand and caused heavy traffic congestion not only in the capital Bangkok but also in the major regional cities. Such congestion has a negative impact on the economy and deteriorates the environment. In effect, the Study will also contribute to alleviating an increasing and unsustainable concentration of business and population in Bangkok and in the long run, enhance living standards in major local cities. This Final Report describes the activities and major findings of the Study.

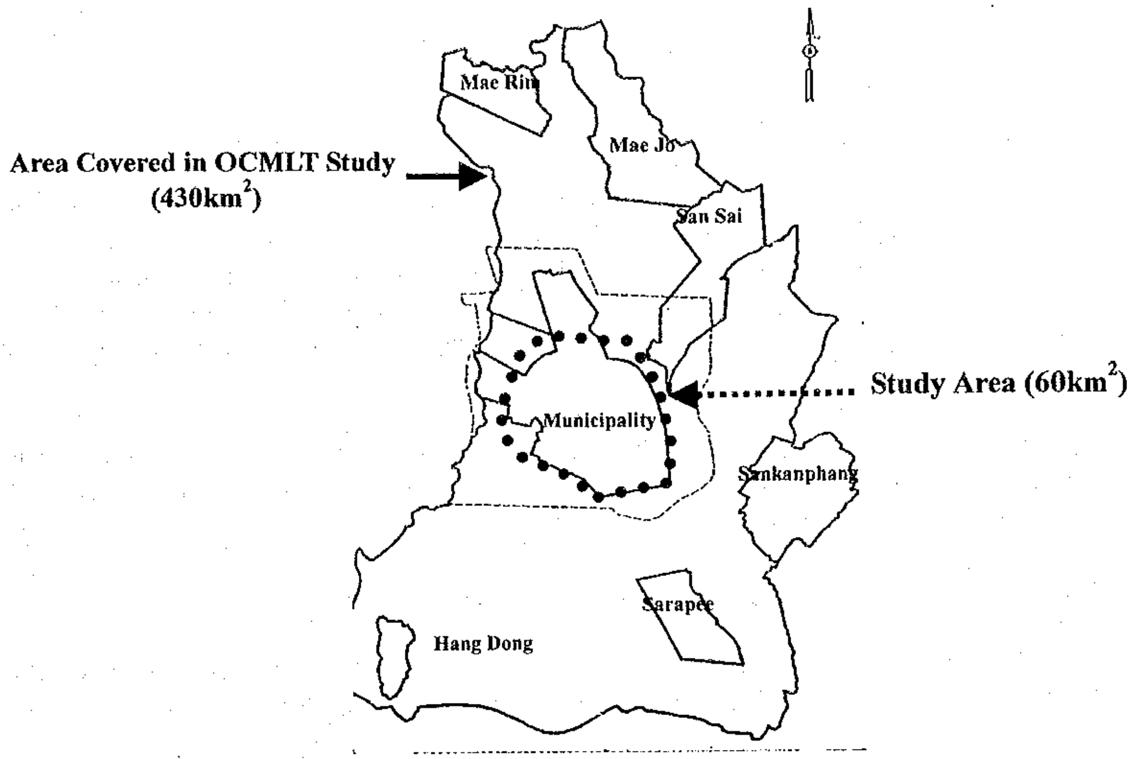
1.2 Objectives of the Study

General objectives of the Study are as follows:

- to formulate road traffic environment improvement plans for alleviating traffic congestion as well as for securing road safety in the model city of Chiang Mai; and
- to implement technology transfer to the Thai counterpart personnel within the Study through a seminar and informal workshop.

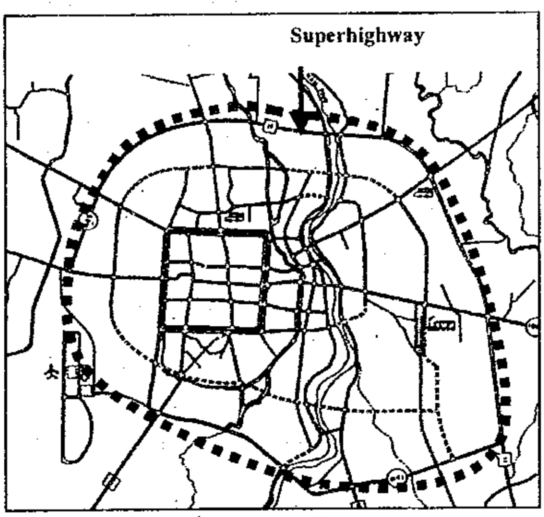
The Study Area covers the Municipality of Chiang Mai and adjoining areas, with a size of about $60km^2$. This area is depicted in Figure 1-1 as well as in Figure 1-2.

[2] This organization is now called OCMLT.



Source: OCMLT Study, 1994

Figure 1-1 Map of Chiang Mai Municipality and Surrounding Suburbs



Source: This study

Figure 1-2 Depiction of Proposed Study Area

1.3 Organization

The organization of this Study include the following:

(1) Thai Counter Part Agencies

On the part of the Government of Thailand, the Royal Thai Police (RTP) and the Municipality of Chiang Mai (MOCM) act as the counterpart agencies. They also serve as a coordinating body with other governmental and non-governmental organizations, as well as the public, concerned with the smooth implementation of the Study. The RTP and the MOCM provide the Study Team with counterpart personnel who are currently working with the Study Team.

In Addition, Department of Highway (DOH), Northern Technical Center for Traffic System Management of Chiang Mai University, and Traffic Sub-Committee of OCMLT provided various support to the study.

(2) Japan International Cooperation Agency (JICA)

JICA Headquarters in Tokyo organized an Advisory Committee to give advice on the Study. The JICA Thailand Office will represent JICA Headquarters in Thailand.

Members of the JICA Advisory Committee include:

- **Atsushi Fukuda** (Chairperson), Associate Professor, Department of Transportation Engineering, College of Science and Technology, Nihon University
- **Naoki Suetsugi** (Traffic Control Planning), (replaced **Mikio Sugimoto**), Assistant Director, Traffic Management and Control Division, Traffic Bureau, National Police Agency

Members of the JICA Secretariat include:

- **Takanori Jibiki**, Managing Director of Social Development Study Department
- **Toshio Hirai**, Director of First Social Development Study Division
- **Satoshi Umenaga**, Deputy Director of First Social Development Study Division
- **Akihito Sanjo** (replaced **Jitsuya Ishiguro**), First Development Study Division, Social Development Study Department
- **Masaru Morimoto**, Resident Representative of JICA Thai Office
- **Hiroaki Takashima**, Deputy Resident Representative of JICA Thai Office
- **Yuichi Ohashi**, Assistant Resident Representative of JICA Thai Office

(3) Study Team

The Study Team, headed by Chiaki Kuranami, is comprised of members of PADECO Co., Ltd. and Fukuyama Consultants Co., Ltd. The Study Team has worked in close collaboration with the Thai counterparts, the RTP and the MOCM.

The members of the Study Team include:

- **Chiaki Kuranami** (Team Leader)
- **Seiya Mastuoka** (Traffic Management Plan)
- **Mok You Chua** (Traffic Survey/ Forecast 1)
- **Yoshiya Nakagawa** (Traffic Survey/ Forecast 2)
- **Kazuhiko Arimoto** (Signal Control)
- **Yutaka Yamaguchi** (Road Safety Facility Design/Cost Estimate)
- **Christopher Rose** (Social and Environmental Assessment)
- **Takuji Shimamura** (Screen Sensor Adjustment)
- **Masaki Toba** (Other Sensor Adjustment)
- **Junichi Ohashi** (Signal Control Adjustment)
- **Satoshi Ogita** (Coordination)

1.4 Types of Traffic Surveys Conducted in This Study

Several types of traffic surveys have been conducted in this Study for better understanding of current traffic problems and for the preparation of improvement plans. Table 1-1 shows the list of surveys conducted with reference to the name of the Survey Reports produced under this Study.[3]

Table 1-1 List of Traffic Surveys

Type of Survey	Description	Survey Reports
Intersection Traffic Movement Survey (ITM)	• Conducted turning movement counts at 20 selected intersections, including U-turns at T-shaped intersection locations • Vehicle types broken into seven classes • Counting performed on weekdays from 6.00 to 20:00 (14 hours)	• MAIN REPORT on Intersection Traffic Movement Surveys, Traffic Volume Counting Surveys, Vehicle Occupancy Surveys, Pedestrian Traffic Count Surveys (September 2001) • Appendix 1 Detail on Hourly Volume for Intersection Traffic Movement Survey (September 2001) • Appendix 2 Detail on 15 Minute Volumes for Intersection Traffic Movement Surveys (September 2001) • Supplementary Report on Intersection Traffic Survey Intersection J8 (September 2001)

[3] The surveys listed in this table are those of sub-contracted surveys, and the survey TORs and forms are presented in Appendices A and B.

Table 1-1 List of Traffic Surveys (continued)

Type of Survey	Description	Survey Reports
Intersection Queue Length Survey (IQS)	• Measured maximum queue lengths/queue development profiles at 20 selected intersections • Surveys conducted on weekdays and during peak periods (6:30 to 9:30 and 16:30 to 19:30) as well as off-peak (13:00 to 14:00).	• Report on Intersection Queue Length Survey, Volume 1 (September 2001) • Report on Intersection Queue Length Survey, Volume 2 (September 2001)
Cross-section Traffic Volume Survey (TVS)	• Conducted cross-section traffic volume counts by direction at 26 mid-block locations, 15 of which sat along the 2 screen lines and 11 of which were selected by Study Team • Counts performed on weekdays, with survey duration varying according to station • Vehicle types broken into eight classes	Appendix 3 Detail on 15-Minutes Volumes for Cross Section Traffic Movement Surveys (September 2001)
Vehicle Occupancy Survey (VOS)	• Counted the number of vehicle occupants (passengers and driver) passing survey locations (there are 16 of them) according to direction • Counts performed on weekdays, with survey duration varying according to station • Vehicle types broken into eight classes • Sample size approximately 30% of total traffic.	• MAIN REPORT on Intersection Traffic Movement Surveys, Traffic Volume Counting Surveys, Vehicle Occupancy Surveys, Pedestrian Traffic Count Survey (September 2001) • Vehicle Occupancy Survey (September 2001)
Parking Facility Survey (PFS)	• Conducted in vicinity of Warorot Market • Survey consisted of two components: (1) Parking Inventory Survey; and (2) Parking Demand Survey • Parking Demand Survey counted the number of vehicles using on/off-street parking, in 20 minute intervals • Parking Demand Survey conducted on weekdays, from 6:00 to 20:00 (14 hours); vehicle types broken into eight classes	Report on Chiang Mai Parking Survey (October 2001)

Table 1-1 List of Traffic Surveys (continued)

Type of Survey	Description	Survey Reports
School Trip Interview Survey (STS)	• Survey participants include teachers and parents/guardians • Collected basic data on school structure, school policy on collective transport for student and information trips • Collected opinions other issues such as collective school transport.	Report on School trip Interview Survey (November 2001)
School Area Entry & Exit Volume Survey (EVS)	• Surveyed mid-block traffic volumes at 11 specified locations around the two school areas targeted • Surveys conducted on weekdays, during peak hours (6.00 to 8.30 and 3.00 to 5.30) • Vehicle types broken into eight classes	Report on School Area Traffic Volume Counting Survey (September 2001)
Public Transport Operation and Utilization Survey (PTS)	• Interviewed 2% of passengers using red *songtaews*, other fixed route *songtaew* and other minibuses • Information gathered such as origin/destination, fare payments, general opinion towards public transport, etc. • Also interviewed 10% of minibus divers for their general opinion regarding system operation and organizational characteristics.	• Report on Chiang Mai Public Transportation Passengers Survey (September 2001)
Pedestrian Traffic Volume Survey (DTS)	• Counted the numbers of pedestrian crossing at 26 selected intersections by direction • Counts conducted on weekdays during morning and afternoon peak periods, with survey duration varying by location	• MAIN REPORT on Intersection Traffic Movement Surveys, Traffic Volume Counting Surveys, Vehicle Occupancy Surveys, Pedestrian Traffic Count Survey (September 2001) • Pedestrian Crossing Survey at Intersection (September 2001) • Pedestrian Crossing Survey at Road Mid-block (September 2001)

Source: This study

In addition to these surveys, there are other small-scale surveys conducted directly by the Study Team, which are mentioned within relevant chapters in this Report. Survey Reports are produced by Northern Technical Center for Traffic System Management, OCMLT – Chiang Mai University on behalf of the Study Team.

1.5 Study Tasks and Schedule

The tasks and schedule of the Study Team are depicted in Figure 1-2. The Study itself commenced in July 2001 and completed in August 2002.

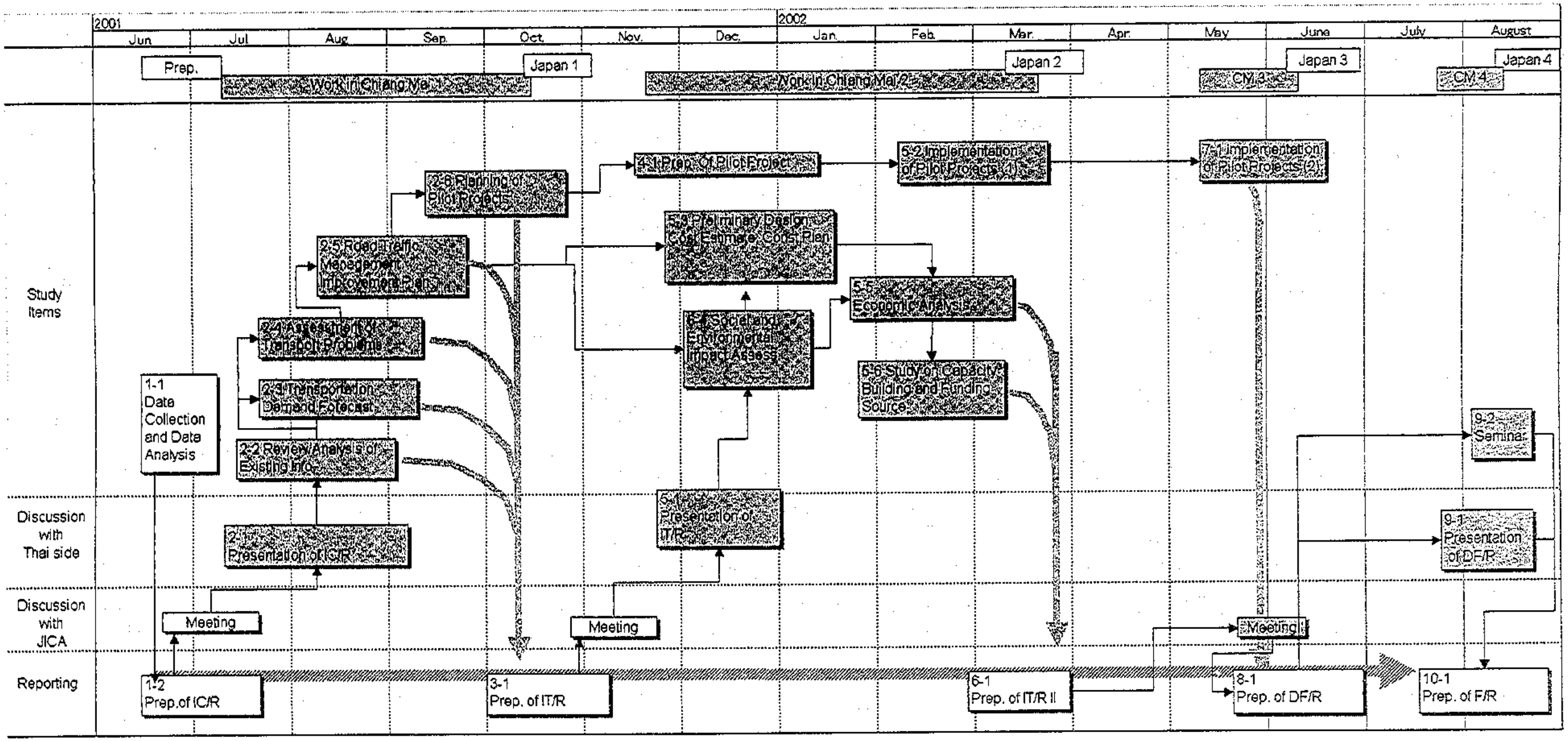


Figure 1-3 Study Tasks and Schedule

Chapter 2

Overview of Existing Traffic Condition in Chiang Mai

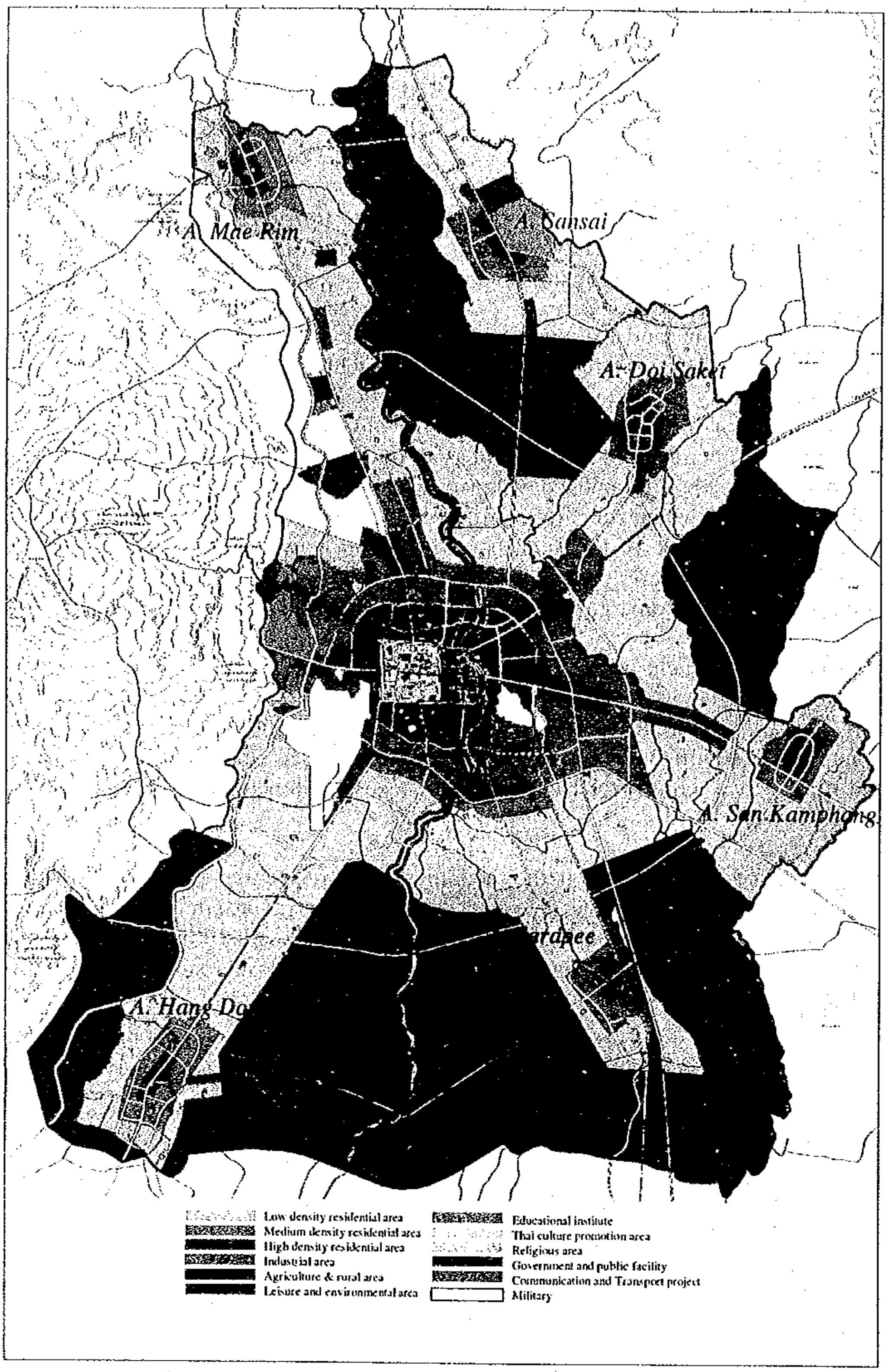
2.1 Introduction

General information on land use patterns and existing traffic conditions in Chiang Mai is presented in this chapter. A more specific description of the conditions, problems and issues are discussed in the following chapters.

Figure 2-1 is existing land use map prepared by the Department of Town and Country Planning in 1999. A unique feature of land use in Chiang Mai is the old city area at the center surrounded by a moat, which has been specified as a Thai culture preservation area. Several temples of historical value exist in the old city and development is restricted. High density commercial and business areas surround the moat. Among the four sides of the moat, the east side is the most developed, with a commercial area that expands beyond the Mae Ping River, which runs from north to south and divides the province into east and west. The northern side of the moat is also developed, with several markets and a bus terminal located here, while the Chiang Mai University and other educational institutions, as well as hospital and some government offices are situated on the west side.

Commercial development is also seen along the radial arterial streets such as Suthep Road (west direction), Huay Kaew Road (northwest) Chotana Road (north), Chiang Mai – Prao (north), Kaew Nawarat Road (northeast), Charoen Muang Road (east), Chiang Mai – Lamphun Road (south), and Chiang Mai – Hang Dong Road (south). Although not shown on the map, a new commercial complex has been developed along the circumferential Super Highway.

Outside of the commercial area is the medium density residential area, which follows the same pattern as the commercial area and extends along radial arterial roads. Areas of industrial land use are also found along the radial arterial roads. Low density residential areas occupy much of the outlying areas and along radial arterial roads except on the west side, which is bounded by Doi Suthep.



Source: Department of Town and Country Planning

Figure 2-1 Existing Land Use of Chiang Mai Region

2.2 Characteristics of Traffic in Chiang Mai

(1) Traffic Volume

Under this study, an intersection turning movement count survey was conducted in August 2001 at 20 locations and a road section traffic volume counting survey was conducted in August 2001 at 26 locations. The traffic volume based on these surveys is schematically shown in Figure 2-1. The five intersections with the highest 14-hour intersection traffic volumes are listed in Table 2-1.

Table 2-1 Five Highest Traffic Volume Intersections

Rank	Code	Intersection	14-hour Volume (PCU)
1	J18	Super Highway - Charoen Muang Road	81,514
2	J12	Huay Kaew Road – Hadsadhi Sawee Road	64,805
3	J1	Huay Kaew Road-Super Highway	58,095
4	J13	Charoen Muang Road - Charoen Rat Road	50,787
5	J7	Chiang Mai Land Road-Aom Muang Road	43,312

Source: This study

The busiest intersection is Charoen Muang Raod - Super Highway, with a 14-hour total of about 81,500 PCU. The intersection located at the northwest corner of the moat recorded the second highest traffic volume. As for approach volumes, Bunruangrit Road, which runs along the western stretches of the moat, carries more than 32,000 PCU over 14-hours.

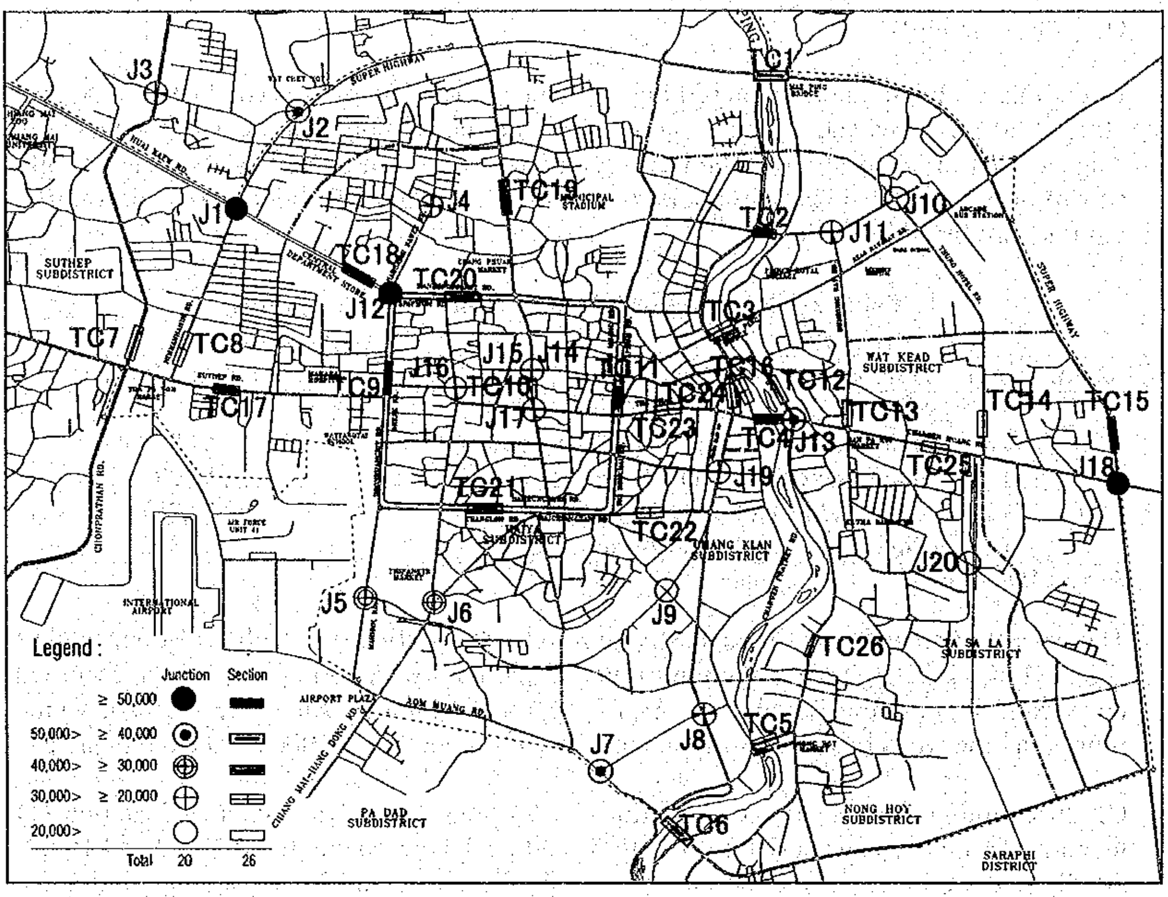
Of 26 counting stations for road sections, a 24-hour count was conducted at one (1) location; 14-hour counts at five (5) locations and peak hour counts (6:00-10:00 and 16:00-20:00) at the others. Using the data from the 24-hour and 14-hour counting stations, a factor to expand 8-hour counts to 14-hour counts was estimated and applied to the 8-hour count data. The top five most-heavily traveled road sections are listed in Table 2-2.

Table 2-2 Five Highest Traffic Volume Sections (Over 14-Hour Period)

Rank	Code	Road	Volume (PCU)
1	TC9	Bunruangrit Road/Arrak Road	55,762
2	TC15	Super Highway Road	53,836
3	TC1	Super Highway North Bridge	48,381
4	TC20	Maneenoparat/Sri Phum Road	47,973
5	TC21	Bamrungburi/Changloh Road	45,476

Source: This study

The highest sectional volume was recorded at Bunruangrit Road and Arrak Road, which is a one-way thoroughfare along the west moat, 55,800 PCU over a 14 hour period. The second and third most busiest locations were two points along the Super Highway. Ranked fourth and fifth are a pair of one-way roads that run along the north and south sides of the moat respectively. This traffic volume data shows the important role that these two circumferential roads are playing.



Source: This study

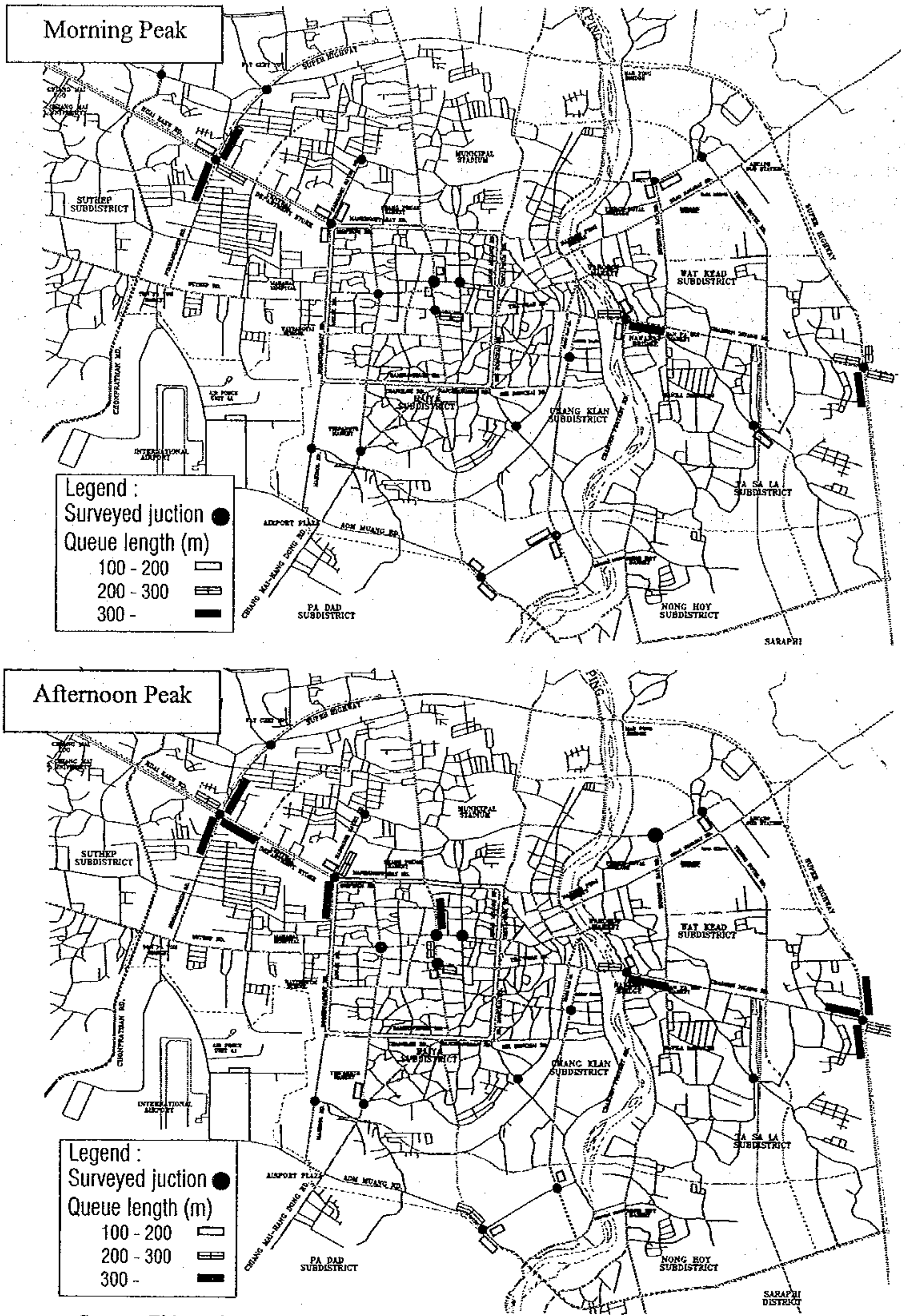
Figure 2-2 14-Hour Traffic Volumes (PCU) in Chiang Mai Municipality

(2) Extent and Characteristics of Congestion

Congestion in Chiang Mai is less severe than in Bangkok, but still exists. A queue length survey was conducted at 20 selected intersections, as mentioned in the prior section. It was found that there are four prominent congested intersections in Chiang Mai, namely the Super Highway – Huay Kaew, Super Highway – Charoen Muang, Huay Kaew – Hadsadhi Sawee Road and Charoen Muang – Charoen Rat intersections. The first two intersections are located at the gateway to the city center and along Super Highway, while the third intersection is at the northwest corner of the moat. The fourth is located on the east side of the Nawarat Bridge over the Mae Ping River. Interestingly, congestion locations are at symmetric locations on the east and west sides of the city, one at the gateway to the city and another at the entrance of CBD.

Congestion occurs at the first two locations during the morning peak and nearly throughout the entire afternoon until the end of the afternoon peak. On the other hand, queues at other locations are observed only during morning and afternoon peaks.

The observed queue lengths are shown in Figure 2-3 for the morning and afternoon peaks.



Source: This study

Figure 2-3 Observed Queue Lengths for the Morning and Afternoon Peaks

(3) Pedestrian Traffic

Walking is not a preferred form of transport in Chiang Mai and few pedestrians are seen on the streets except at specific areas such as markets, schools, and the Night Bazaar. The light pedestrian traffic may be attributable to the hot climate and to the sub-standard pedestrian facilities (e.g. narrow sidewalks occupied by obstacles, and lack of pedestrian signals at signalized intersections). Drivers also fail to yield to crossing pedestrians and often fail to stop, even at pedestrian crossings.

A pedestrian crossing survey was conducted at 16 intersections, 15 of which were also counted in the volume surveys, and at 19 mid-block points during (pedestrian) peak hours in the morning and afternoon.

Table 2-3 shows locations that witnessed more than 200 pedestrian crossings per hour.

Table 2-3 Locations with a High Volume of Pedestrians Crossing

Code	Location	Approach/Location	Peak	Possible Cause
DJ14	Ratchawithi – Ratchaphakhinai	North Approach	15:00-17:00	School Area
		West Approach	16:00-17:00	
DJ15	Ratchawithi Road – Phra Pokklao Road	North and East Approaches	7:00-8:00	School Area
		North Approach	15:00-18:00	
		West Approach	16:00-17:00	
DJ16	Inthawarorot – Singharat Road	South Approach	15:00-16:00	
DJ19	Chang Klan – Loi Kroh	North and East Approaches	17:00-18:00	Tourist Area
D4	Ratchiangsan Road	Near Chiang Mai Gate	7:00-8:00	
			16:00-18:00	
D7	Chang Klan Road	Night Bazaar Building	16:00-20:00	Tourist Area
D21	Chang Moi Road	Warorot Market	8:00-10:00	Market Area
			16:00-18:00	
D21N	Chang Moi Road	Warorot Market	8:00-11:00	Market Area
			14:00-18:00	
D25	Charoen Prathet Road	Pratharuthai	7:00-8:00	School Area
			15:00-18:00	
D991	Huay Kaew Road	Kad Suan Kaew	14:00-18:00	Shopping Center

Source: This study

(4) Traffic Accidents

There are no comprehensive and reliable accident records in the study area. However, the traffic accident rate in Chiang Mai City is alarmingly high. Comparing the casualty rates of Chiang Mai to the national average of Japan, the fatality ratio is over 5 times greater and the injury ratio is over 3 times greater. Ten accident-prone locations are shown in Table 2-4.

Table 2-4 Accident-Prone Locations in Chiang Mai

Rank	Location	# of Casualties
1	Super Highway - Wat Chet Yod	106
2	Super Highway - Kaw Klang Road	70
3	Super Highway - Charoen Muang	60
4	Super Highway - Kaew Nawarat	57
5	Super Highway - Chotana Road	37
6	Rattanakosin - Muang Samut Road	29
7	Phra Sing Road	28
8	Hadsadhi Sawee - Chang Puak 4	23
9	Moon Muang - Ratchdamnoen	22
10	Super Highway - Chiang Mai	15

Sources: Ruam Jai Foundation (Au Paw Po Raw).

It is significant that six locations along the Super Highway are listed among those in Table 2-4, indicating high risk of accident on this road. Rattanakosin – Muang Samut Road is a 4 lane undivided road, where vehicles tend to speed. The Hadsadhi Sawee – Chang Puak 4 intersection has an irregular layout and the main flow must make right turns at the intersection. Two locations, Phra Sing Road and Moon Muang – Ratchdamnoen, are located in the old city, where vehicle speed is generally low, thus more detailed investigation is needed to analyze the cause of accidents at these locations.[1]

(5) Driver and Pedestrian Behavior

Inappropriate or unsafe behavior of drivers and pedestrians within Chiang Mai is often observed. The most notable practice is non-compliance of drivers/passengers to wear seat belts. Furthermore, many motorcyclists do not wear helmets. In fact the Study Team found the 31% of drivers and front seat passengers failed to wear a seat belt, while 41% of motorcycle drivers and passengers failed to wear helmets.

Many motorcyclist ride vehicles lacking license plates, a common site on the streets as enforcement is severely lacking. Furthermore, the level of safety awareness is relatively low among drivers, motorcycle riders and pedestrians. Examples of this lack of awareness include vehicles and motorcycles that fail to stop at intersections when required, three or more persons that ride on a single motorcycle, as well as pedestrians that cross the street without regard to crosswalks. This behavior is the result of a lack of safety awareness. Furthermore, road users may not have received sufficient training when obtaining their driving licenses.

2.3 Existing Traffic Control Measures

Various control measures that restrict vehicle movements are in place within the study area. They include:

- Speed limits (90 km/h on Super Highway and 45 km/h on other roads)

[1] More data on traffic safety and accidents are presented and analysis is made in Chapter 6.

- One-way system (extensively introduced to the area between east moat and Ping River)
- Parking controls (no parking zones, time-based prohibition, day based (odd-even) prohibition)
- Truck/lorry bans (no entry inside Super Highway; restricted hours depend on the type of vehicle)

Although large vehicles are restricted, *tuk tuks* are not controlled. In large cities, small and slow moving motorized vehicles are often prohibited on arterial streets. For instance, tricycles (motorcycles with side cabins) are prohibited in Manila, while Bajajs, three-wheelers, are prohibited in Jakarta on arterial streets.

Turning movement restrictions are also applied at some intersections and are necessary because of the one-way system. Prohibition of right turns is in effect at intersections in Chiang Mai to increase intersection capacity.

2.4 Traffic Enforcement

(1) Organization and Operation

Traffic enforcement is handled by the Traffic Police in the Chiang Mai Province, consisting of 224 traffic police officers in Chiang Mai Province.[2] The Muang District of Chiang Mai is separated into two zones, a northern zone and a southern zone. There are 71 traffic police officers in the northern zone and 78 in the southern zone. There are another 56 officers concerning to enforcement, who is not full-time.

The operation of enforcement is shifted in morning (from 6 a.m. to 9 a.m.) and afternoon (from 3 to 6 p.m.). In each shift, several numbers of spots for traffic enforcement are directed. The number of the position is summarized in Table 2-5. At least, 4 policemen are assigned to each location.

Table 2-5 Number of Site for Traffic Enforcement

Area	Number of Enforcement Site	
	Morning	Afternoon
North	6	7
South	8	9

Source: This study and Chiang Mai Provincial Police

[2] This force consists of 19 commissioned police officers (made up of a superintendent, 3 inspectors, and 15 sub-inspectors) and 205 non-commissioned police officers. The starting salary for a non-commissioned police officer is 5,100 baht per month, while that for a commissioned police officer is 6,360 baht per month.

Additionally, the force keeps several types of vehicles including motorbikes (74 vehicles), marked cars (2), pickup trucks (2), wrecker truck (3) and a truck for technical maintenance operation (1).

(2) Ticketing Procedure for Traffic Violations

When traffic police officers catch violators of traffic regulations, they will issue a ticket and seize their driving license. Ticketed drivers have 7 days to pay their fine at a police station in the zone where they were arrested.[3] The ticket consists of 3 parts that are denoted according to color, in addition to the original ticket stub:

- White Portion: This is retained as a "receipt" by the ticketed individual, providing proof of payment and permitting the individual to retrieve his driving license.
- Yellow Portion: This is retained by traffic police officers as a record to input into the computer system.
- Pink Portion: This is retained by the office of the particular zone in which the individual was stopped.

After 7 days has elapsed, the officer will issue an arrest warrant if the fine has not been paid. However, in practice this does not often take place because traffic violations are considered petty offenses and the available police resources are limited. There is no exact punishment that may be meted, and an officer may choose to reprimand and lecture an offender instead of fining him. Usually if an offender is fined, the total amount is less than 1,000 baht.[4]

(3) Operational Problems

The Traffic Police has several operational problems that have been noted. These problems are as follows:

- There are too few police vehicles (motorbikes for instance) considering the size of the force. Some officers even use their own motorbikes.
- The fuel allowance is insufficient to cover the average operating costs for on-duty officers.
- There is not enough communication equipment for all officers, including portable radios, forcing some officers to use their own.
- The Chiang Mai Traffic Police does not have its own budget to solve traffic problems, but must depend on allotments from the Municipality or Province.
- The department lacks engineering specialists to handle works.
- There are too few traffic police officers to adequately enforce the law.

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[3] In Muang District for instance, there are 4 stations: Muang Station, Phuping Station, Chang Puak Station, and Mae Ping Station.

[4] The violation fine is apportioned as follows: 50% to the local police officer and 50% to the arresting agency (35% to the officer and 15% to the central budget).

(4) Issues on Enforcement

Several problems are apparent in the existing violation/punishment system. These problems are as follows:[5]

- Many drivers do not have the authority/right to drive (do not have drivers' license).
- Only local police officers have the right to fine traffic violators caught in their zone of jurisdiction, therefore even if traffic police catch violators, they lack the authority to fine them.
- When ticketing a traffic violator, the traffic police must bring all information and the driving license to local officers.
- For traffic accident litigation trials, traffic police lack the authority to directly participate in the proceedings. Instead, they are only permitted to help the local police officers in the case.

According to some individuals, the existing laws permitting traffic police officers to lecture or reprimand violators instead of fining them permits the public and the traffic police officers to have greater interaction, which makes them more comfortable around the officers and understand of their duties and responsibilities. In fact, this may contribute to a higher public opinion and acceptance of the officers.

Others have noted that although the driver information collected when an individual is ticketed, is not sent to the Office of Provincial Land Transportation, which is the issuing agency for driving licenses. This gap in information sharing impedes law enforcement efforts aimed at reducing such behavior.

2.5 Environmental and Social Concerns

(1) Air Quality

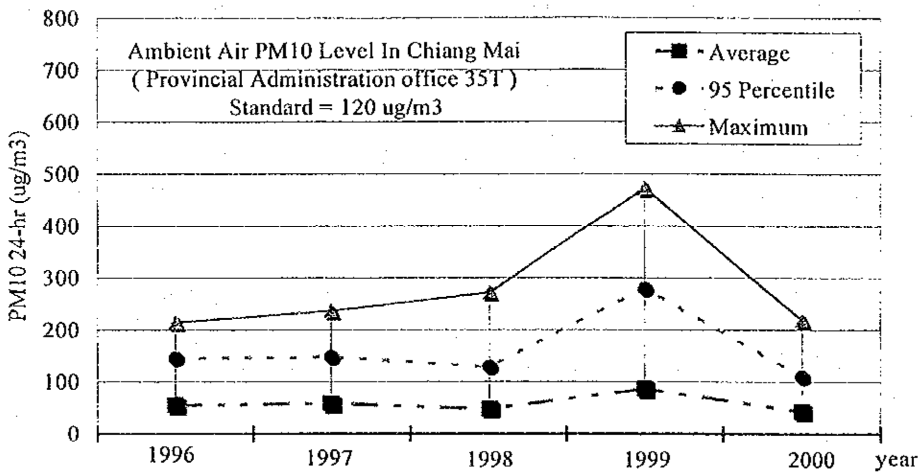
Air pollution is a recognized problem in Chiang Mai and a substantial amount of investigation has already been initiated in the city including permanent air quality monitoring and partnerships with international governments/institutions aimed at formulating appropriate policy. Three monitoring stations measure air quality in Chiang Mai and the results indicate that the city is at 'caution level' for pollution. The most serious concern is the high level of dust and particulate matter (PM-10) which often exceeds Thailand's designated standards.

While there are several sources of particulate pollution including industry, construction (including transportation of construction materials) and garbage burning, traffic pollution is accepted as the major contributor. In this respect, high volumes of traffic are exacerbated by a lack of mass transit. However, other factors such as the misconceived adjustment of vehicle engines by owners to increase fuel efficiency, have also been identified as a prime cause of pollutant emissions. Black exhaust smoke is a common site

[5] This information was taken from an interview with a Police Captain in the force.

in the city and a survey of diesel vehicles revealed that 93% of the sample exceeded the standard for black smoke. Moreover, respiratory disease is a common cause of death in Chiang Mai and is no doubt exacerbated by the high level of particulate matter in the city.

The figure below shows high annual recordings of PM10. Other pollutants are presently within acceptable levels.



Source: Department of Environment (10th Region)

Figure 2-4 Ambient Air PM10 Level in Chiang Mai

An initiative called the "Black Smoke Checking Project", is a collaborative effort between the Traffic Police and the Chiang Mai Land Transportation Office to check and find diesel vehicles emitting high amounts of pollutants. While this is considered an effective on-going measure, the project does not have a formal program to ensure its viability. Following on from a partnership with the Maryland Department of the Environment of USA, an Air Quality Action Plan is also currently being developed by LTD, Municipality, and Police, and it is important that this includes practical means of implementing initiatives and methods to monitor their success.

(2) Road Cleaning

Given the high level of particulate matter existing within the city, the effectiveness and applicability of the road cleaning equipment and methods employed are questionable. While much of the vehicle equipment is relatively new and does not appear sub standard, conventional sweeping may not be appropriate for Chiang Mai. The cleaning vehicles in use employ a wet method of vacuum dust collection. Water spray is utilized to reduce the dispersal of dust from the brushes. However, application of dry methods is generally considered more effective and is possible with specialized equipment. While addressing pollution at its source is essential for a long-term sustainable strategy, preservation of particulate matter in the environment is a serious concern.

(3) Noise and Vibration

The high level of traffic and proximity to residential areas not only causes a dusty environment but also a substantial level of noise. Many public and sensitive establishments, such as hospitals, schools and homes for the elderly and blind, are located close to busy carriageways and junctions. Recent measurements of traffic noise recorded at twelve receptor locations including sensitive establishments were all close to the Community Noise Standard of Thailand of 70 dBA (24 hours) and two sites exceeded the standard. The tendency for properties to front major roads, and the lack of ameliorative measures in respect of noise intrusion is a concern to the well-being of society. Vibration is less of a concern due to restrictions on large vehicles entering the city and there is no evidence that road traffic causes excessive vibration in the vicinity of historic buildings.

(4) Pedestrian Environment

Chiang Mai is clearly a city that has developed in consideration of the motor vehicle rather than the pedestrian. There are few areas within the city center or even the superhighway boundary that provide tranquility and relief from traffic. The pedestrian environment has been neglected and areas such as the moat surrounds are predominantly to distribute road traffic. A recent measure to raise pedestrian awareness is the Tha Phae Walkway Scheme, which closes the road to permit only pedestrians on Sundays. The city urgently requires such measures to be expanded and complimented with physical construction that allocates greater space for pedestrian access and amenity.

2.6 Summary of Issues

Unlike a mega city such as Bangkok, the traffic congestion in Chiang Mai are still at a manageable level. The traffic volume is high on limited roads, while congestion occurs at several intersections only. Although inadequate, traffic management facilities such as traffic signals, regulatory signs and pavement markings are provided. Nonetheless, there are several traffic management issues to be addressed.

Lack of Safety Awareness

The compliance rate for seat belt and helmet usage is significantly low. Drivers and riders pay little attention to the increased road safety risks of not using these safety devices. Such a situation is clearly caused by the lack of safety awareness, consequently more education is urgently needed for all road users.

Insufficient Traffic Management Facilities

There are some intersections where signals are warranted. There are also signalized intersections where pedestrian signals should be added. The quality of pavement markings is sub-standard, failing to perform their functions, particularly at night. With the expansion of the developed area and the increase in vehicles and motorcycles, more facilities must be provided.

Need for Pedestrian-Friendly Environment

Streets and traffic in Chiang Mai are not pedestrian friendly. In terms of facilities, narrow sidewalks blocked by obstacles as well as a lack of safe pedestrian crossings discourage people from walking. In addition, drivers often disregard the presence of pedestrians and fail to yield to them, though walking and bicycle usage is well suited to a small city like Chiang Mai and must be promoted.

Chapter 3

Demand Forecasting Analysis

3.1 Introduction

The objective of the traffic demand forecasting analysis in this study is twofold:

- To understand general traffic conditions in the *target year of 2010* to assess potential improvement plans; and
- To facilitate knowledge and technology transfer of traffic analysis techniques to counterpart personnel in Thailand.

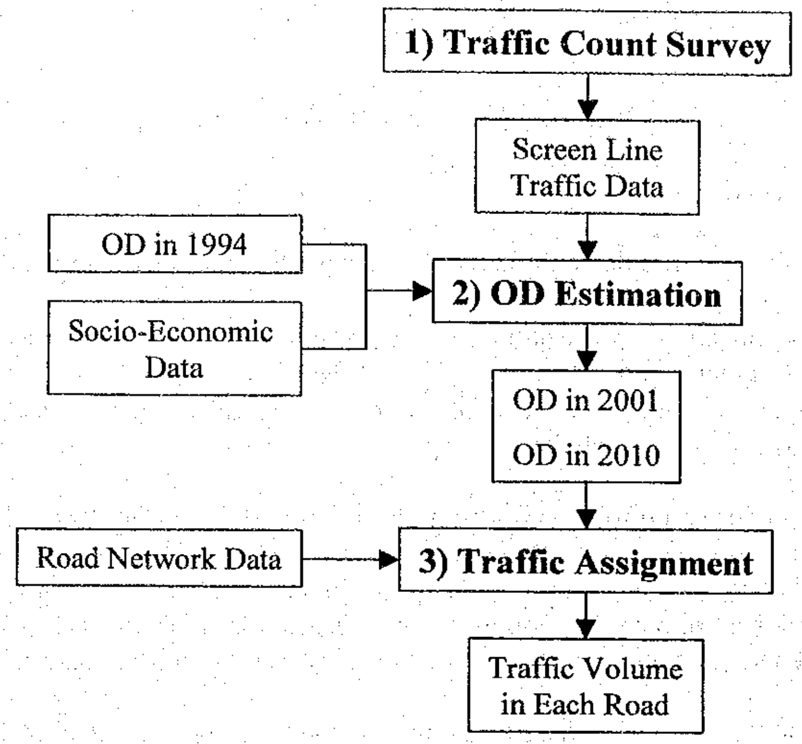
The OCMLT produced a traffic survey study for Chiang Mai City in 1994.[1] This study, hereinafter referred to as the "OCMLT Study", produced an OD matrix on person-trip based home interviews and roadside interviews in 1994. Furthermore a matrix was estimated for 2004 from socio-economic data. Traffic assignment calculations were based on these OD estimations and were used to analyze future traffic conditions.

Traffic demand forecasting generally follows a four-step process that includes trip generation and attraction projection, trip distribution estimation, modal split calculation and finally traffic assignment. For this study, OD data is already available from a prior OCMLT study, thus it is possible to streamline this process. Traffic demand analysis for this study is estimated based on the following sequential steps:

- *Traffic Count Surveys*: Traffic surveys are conducted in this study to calculate screen line traffic volumes, which are used to update the 2001 OD matrix.[2]
- *OD Matrix Estimation*: Two OD matrices are necessary for estimating the present (2001) and the future (2010) traffic conditions. The process uses 1994 OD matrices, updating them based on updated traffic count data and socio-economic figures.
- *Traffic Assignment*: Present and future traffic volumes on each link are calculated based on the traffic assignment method. The requisite road network data needed for simulation are obtained from the OCMLT Study. The results of the calculations for present conditions are compared with observed traffic volumes. This permits the model parameters to be revised for improved accuracy and lower variance between calculated and observed results. Steps for this analysis are summarized in Figure 3-1.

[1] The official name of the OCMLT study was, *Traffic Survey Chiang Mai Area,* Thailand, 1994

[2] Screen lines traffic counts at particular locations are used to minimize the effect of assignment errors.

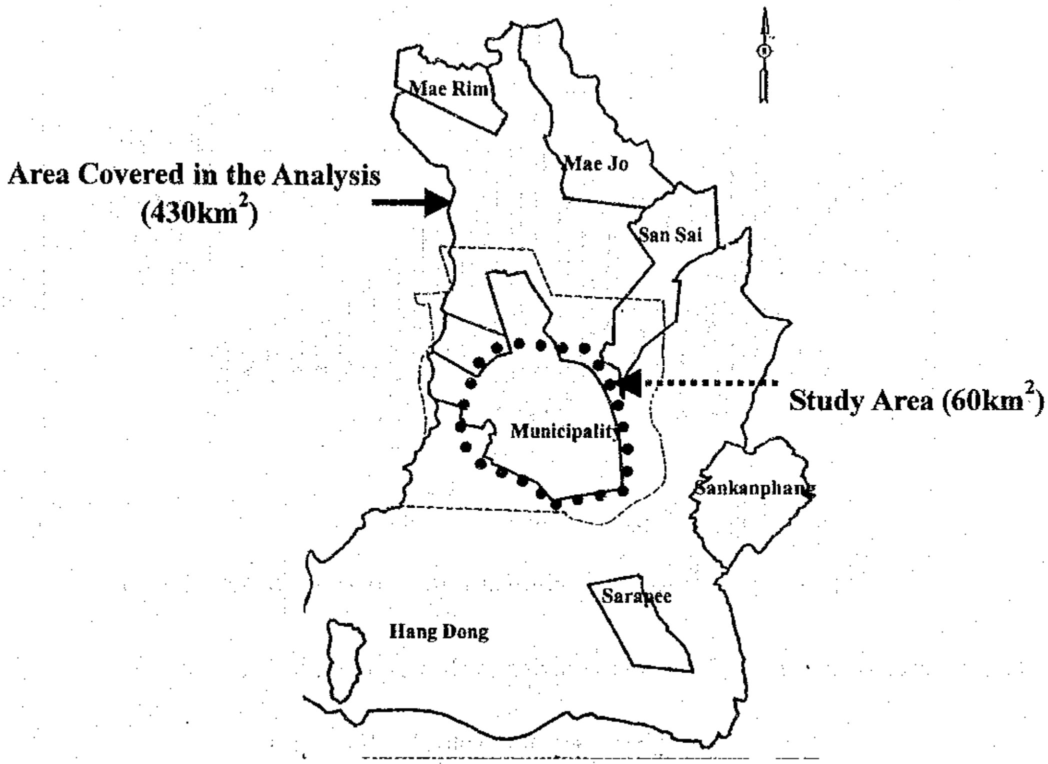


Source: This study

Figure 3-1 Traffic Demand Analysis Process

The area for demand analysis covers both the municipal area and surrounding suburbs, totaling about 430 km². This area is the same as that defined in previous studies, most notably the Town Planning Office of Thailand and the aforementioned OCMLT Study. This demarcated area is depicted in Figure 3-2.[3]

[3] Figure 3-2 shown here is the same as Figure 1-1.



Source: OCMLT Study, 1994.

Figure 3-2 Proposed Study Area

3.2 Traffic Count Survey

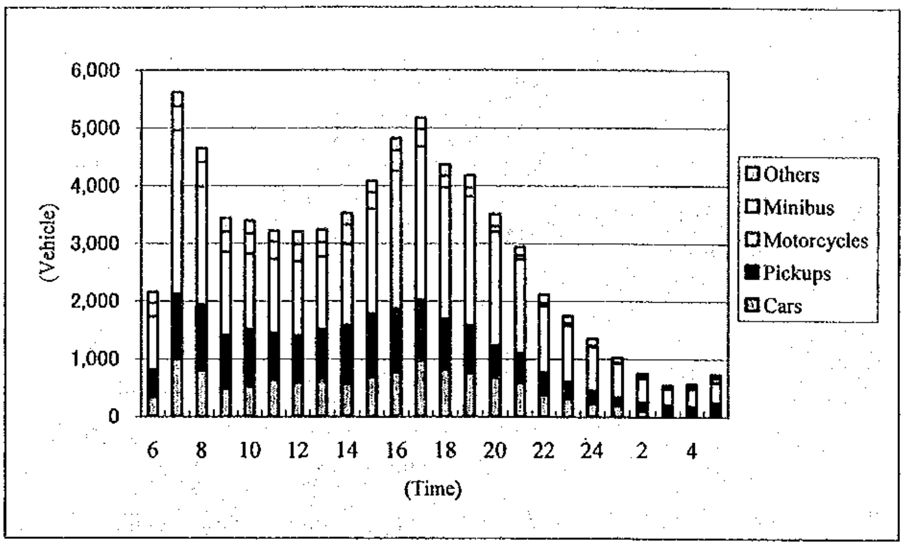
This section analyzes the data collected from traffic surveys conducted between 20th and 25th August 2001.[4]

Figure 3-3 shows the hourly fluctuation of traffic volumes on TC-4.[5] The morning and afternoon peak periods are quite evident in this figure, having significantly more traffic than during non-peak periods throughout the day.[6] The most utilized vehicle regardless of the time of day is the motorcycle, while the use of pickup trucks is the second-most utilized mode.

[4] The details of the survey methods employed are shown in Appendix A.

[5] TC-4, located at the Nawarat Bridge, is the only station where traffic counting is conducted for a 24 hour period.

[6] The morning peak is defined as the period between 7:00-9:00 and the afternoon peak as the period between 16:00-18:00.



Note: Others includes Buses and Trucks.
Source: This study.

Figure 3-3 Hourly Fluctuation of Traffic Volumes (TC-4)

The average occupancy of various vehicles is shown in Table 3-1.

Table 3-1 Average Vehicle Occupancy

Vehicle Type	Occupancy (Persons/Vehicle)
Passenger Car	1.6
Pickup/Van	2.2
Motorcycle	1.4
Minibus	2.8
Bus/Coach	13.1
Light Truck	3.2
Medium/Heavy Truck	1.9
Others	1.4

Source: This study.

Table 3-2 shows the observed traffic composition based on number of vehicles, according to trip distance.[7] It is apparent that traffic composition is dependent upon trip distance (long or short distance).

[7] Long-distance trips are considered to be those trips that utilize Super Highway, Chang Muang Road, Chiang Mai-Rumpun Road, and Chang Phuak Road and are greater than 10 km in length. All other trips are considered short-distance trips.

Table 3-2 Traffic Composition Based on Vehicles Counts

Vehicle Type	Long-Distance Trips	Short-Distance Trips
Passenger Car	23%	21%
Pickup/Van	30%	22%
Motorcycle	40%	46%
Minibus	3%	7%
Bus and Coach	1%	0%
Light Truck	2%	0%
Medium/Heavy Truck	1%	0%
Others	2%	3%

Source: This study.

From the estimation of average vehicle occupancy in Table 3-1, it is possible to estimate the traffic composition based on the passenger volume, instead of the number of vehicles. This is shown in Table 3-3.

Table 3-3 Traffic Composition Based on Passenger Volume

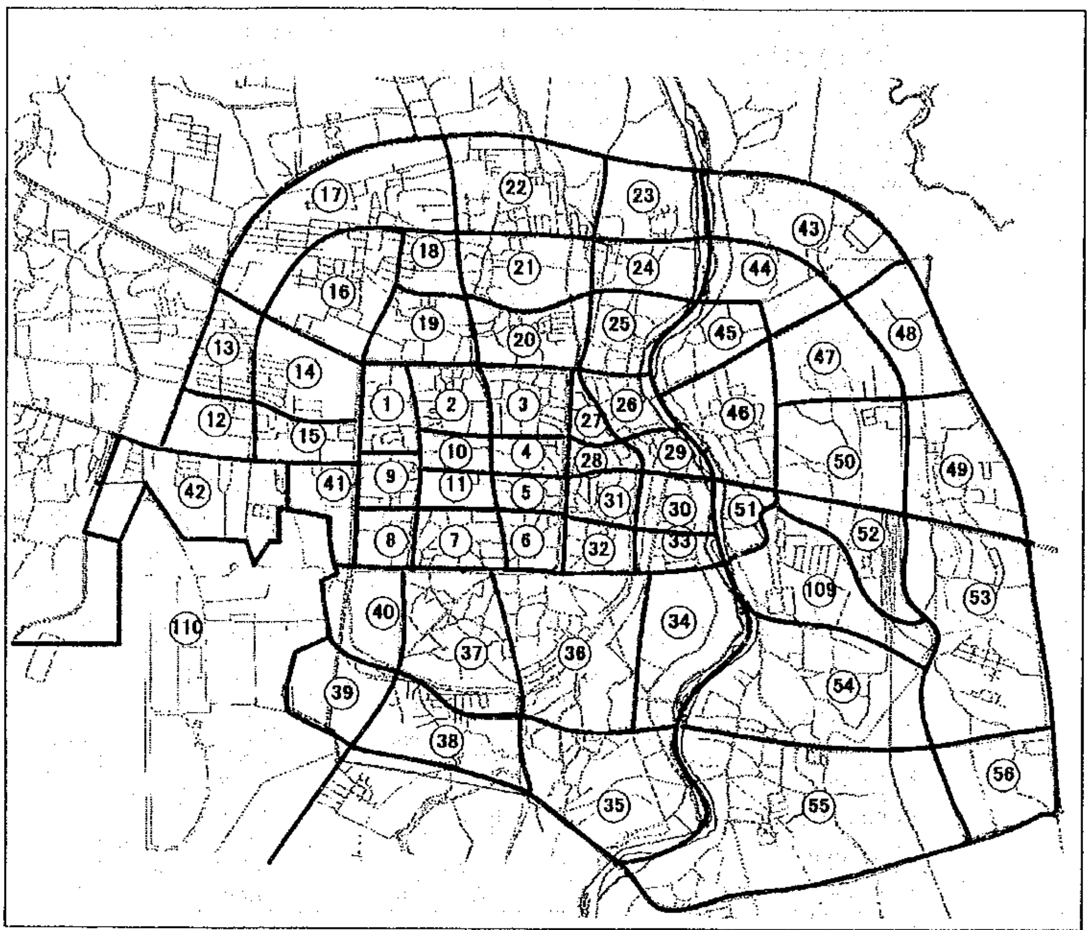
Vehicle Type	Long-Distance Trips	Short-Distance Trips
Passenger Car	21%	19%
Pickup/Van	36%	27%
Motorcycle	31%	37%
Minibus	4%	12%
Bus/Coach	4%	2%
Light Truck	3%	1%
Medium/Heavy Truck	1%	0%
Others	1%	3%

Source: This study.

3.3 Methodology for OD Estimation

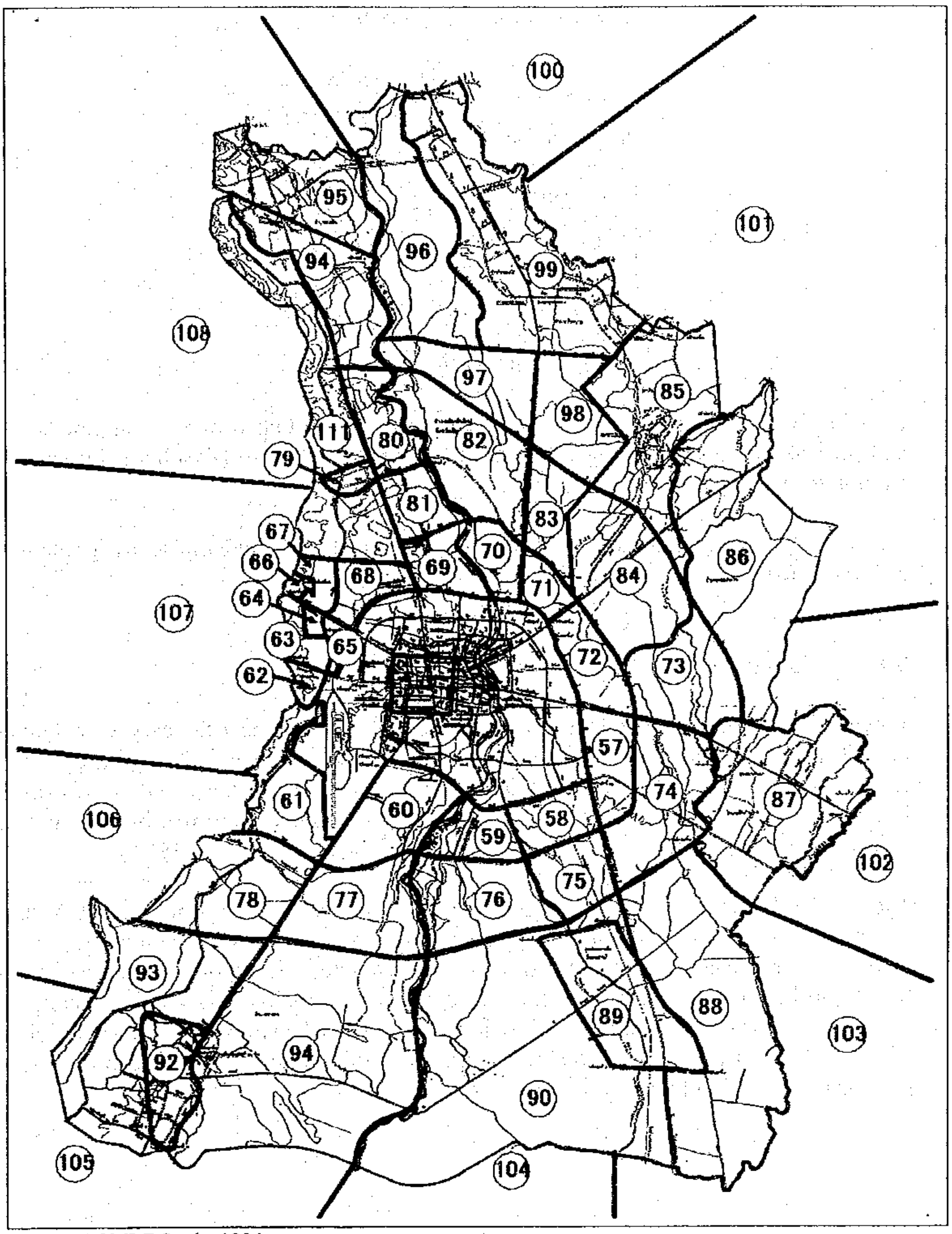
Estimation of an OD matrix consists of two steps. The first step involves calculating the 2001 OD by updating the 1994 OD, while the second step involves estimating the 2010 OD from the 2001 OD. The estimation process utilizes traffic count data as well as socio-economic data to update these projections.

There are 111 designated zones within the analysis area. The analysis area is similar to the OCMLT Study, including the Chiang Mai Municipality and 6 neighboring regions, and is divided into 58 zones inside Super Highway (deemed the "Inner Area") and 53 zones outside Super Highway (deemed the "Outer Area"). These zones are shown in Figure 3-4 and Figure 3-5.



Source: OCMLT Study, 1994

Figure 3-4 Map of Inner Area by Zone



Source: OCMLT Study, 1994

Figure 3-5 Map of Outer Area by Zone

In the traffic assignment model, the number of vehicles is converted to equivalent Passenger Car Units (PCU) according to Table 3-4.

Table 3-4 Coefficient for PCU Conversion

Vehicle Type	Coefficient (PCU/Vehicle)
Passenger Car	1.00
Pickup/Van	1.00
Motorcycle	0.33
Minibus	1.50
Bus/Coach	2.50
Light Truck	2.00
Medium/Heavy Truck	3.00
Others	0.50

Source: OCMLT Study, 1994

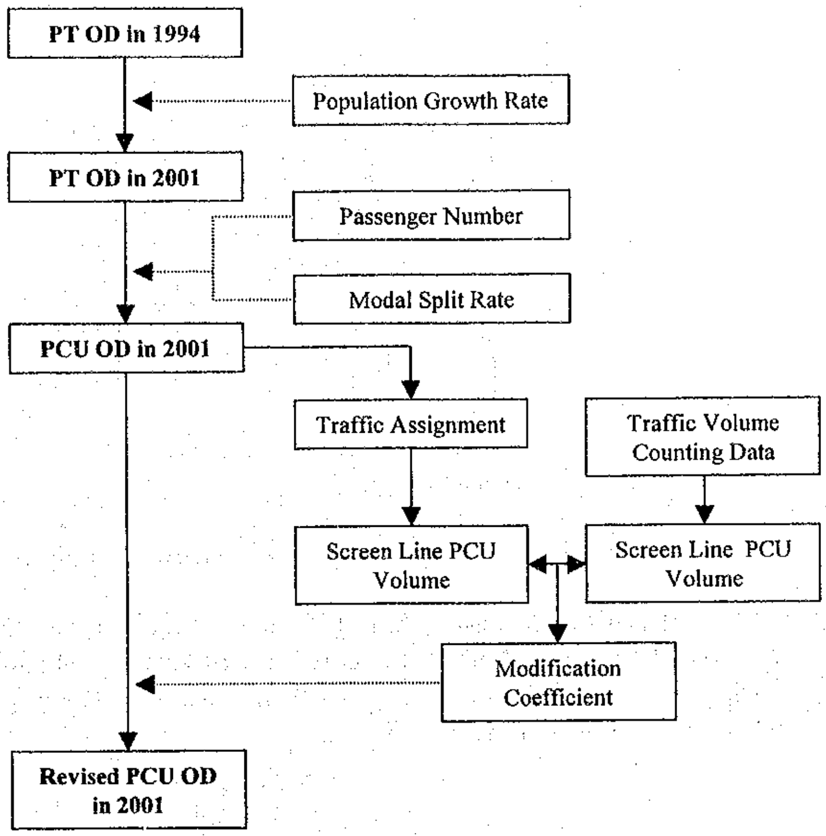
All trips throughout the day are analyzed (thus there is no bias towards peak hour trips) and all trips are analyzed, regardless of their purpose (thus work, school, leisure and shopping-related trips are not separated).

The OD matrix estimation is calculated using MS-Excel, and traffic assignment is calculated using the JICA STRADA 2 Model.

3.4 Estimation of 2001 OD

When updating the 1994 OD to produce the 2001 OD, it is necessary to calculate modification coefficients. The coefficients may be calculated by comparing the observed and simulated traffic volumes at a particular screen line location. This however is insufficient to reflect the zonal differences, therefore population growth by zone is also used for this coefficient.

The 1994 OD, estimated in the OCMLT Survey, is based on person-trips (PT), thus permitting the OD to be multiplied by the population growth rate of each zone. On the other hand, traffic count data is based on vehicle volumes. Therefore it is necessary for the OD to be converted to equivalent PCU with corresponding passenger occupancies, traffic composition rates and PCU coefficients. The OD is then multiplied by a coefficient, which adjusts for the observed and the estimated traffic volume at the screen line. This process is outlined in Figure 3-6.



Source: This study

Figure 3-6 Process to Update the 2001 OD

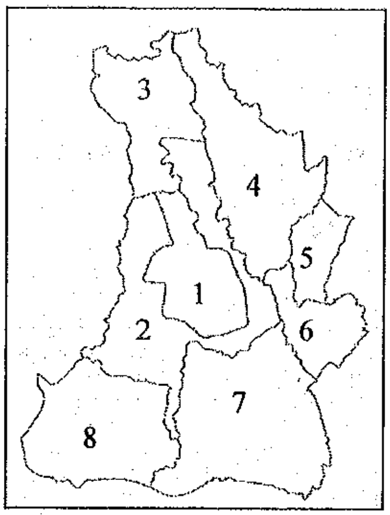
Population growth rates by zones are shown in Table 3-5.[8] Zones are divided into 8 areas, which are composed of the original 111 zones. This is depicted in Figure 3-7.

Table 3-5 Zonal Growth Rates

#	Zone	1994	2000	Growth Rate
1	Amper Muang	170,348	171,712	1.01
2	Not Amper Muang	76,544	85,549	1.12
3	Mae Rim	75,755	77,642	1.02
4	Sansai	85,027	93,488	1.10
5	Doi Saket	61,794	63,049	1.02
6	Sankanphang	72,060	73,285	1.02
7	Sarapee	75,974	75,158	0.99
8	Hangdong	63,442	67,197	1.06

Source: National Statistics Office, Statistics Report 1995 and 2001

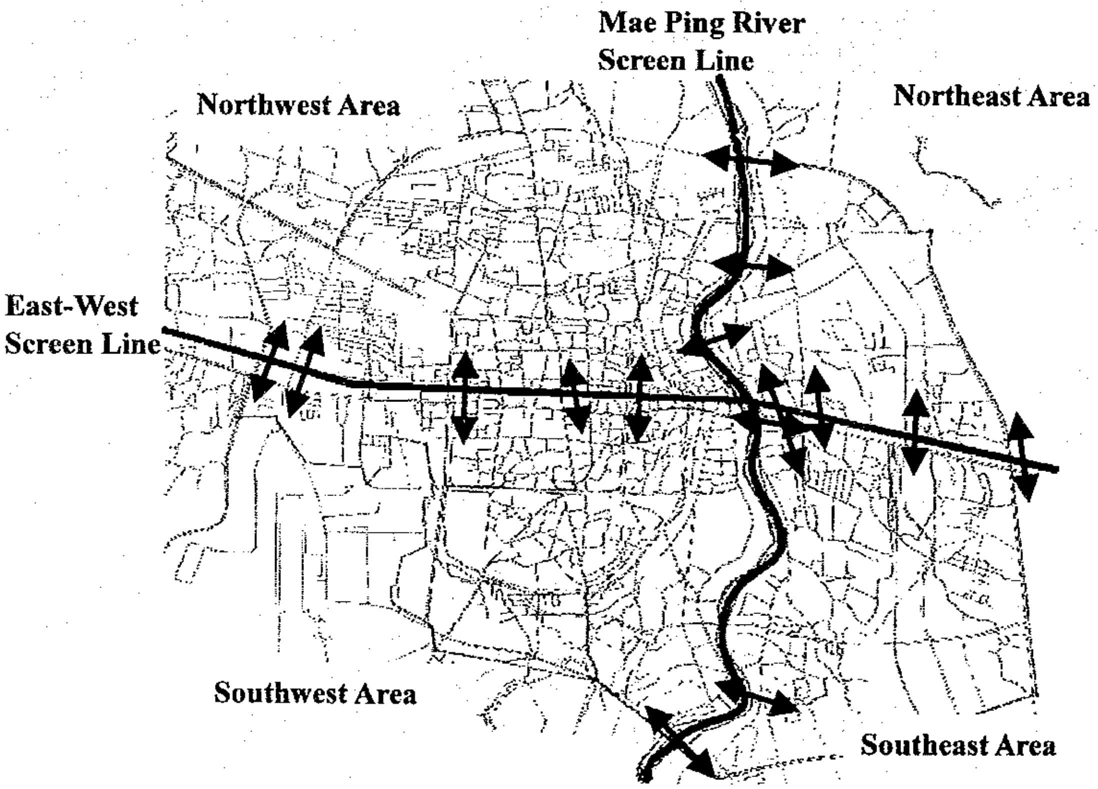
[8] The 2000 population figures are used in calculations since the 2001 figures are unavailable.



Source: This study.

Figure 3-7 Zones for Population Growth Analysis

There are two screen line locations, Mae Ping River Screen Line along the Mae Ping River, and East-West Screen Line on the north side of Charoen Muang Road, Tha Phae Road, Ratchadamnoen Road, Phra Sing Road, Inthawarorot Road, and Suthep Road. These locations are shown in Figure 3-8.



Source: This study.

Figure 3-8 Location of Screen Line

The observed (from the traffic survey) and estimated (from the model) traffic volumes (in PCU) at the screen lines are shown in Table 3-6.

Table 3-6 Traffic Volumes along Screen line

Screen line Location	Direction	Observed (PCU)	Estimated (PCU)	Growth Rate
Mae Ping River	West to East	121,730	98,027	1.24
Screen Line	East to West	139,810	106,847	1.31
East-West	North to South	167,167	127,754	1.31
Screen Line	South to North	174,259	122,285	1.43

Source: This study

The study area is divided into 4 areas by these screen lines, Northeast, Northwest, Southeast, and Southwest, as shown in Figure 3-8. The growth rate for each area is calculated from above result as shown in Table 3-7.

Table 3-7 Traffic Growth Rates According to Area

Area	Growth rate
Northeast	1.31
Northwest	1.28
Southeast	1.37
Southwest	1.34

Source: This study.

3.5 Estimation of 2010 OD

Generally traffic demand is dependent on factors such as population, vehicle ownership, and household income, etc. It is difficult to forecast these indicators because of the lack of data within these study areas. Therefore it is assumed that the number of PCU trips increases proportionally with GDP growth. [9] This assumption is considered too conservative an estimate since the real GDP growth rate from 1994 to 2001 was 14%, while the increase in total PCU trips was 50% over the same period. As regarding traffic composition, it is assumed that the rate in 2001 remains in 2010 because of difficulty to forecast, though the possibility cannot be dismissed that the rate of traffic composition, such as public transport, will undergo drastic changes in the future.

Table 3-8 shows forecasts for real GDP growth rates for Thailand. Positive economic growth is expected in 2002.

[9] Prior studies have shown that transport demand is correlated to economic growth, which may be represented by indicators such as GDP and industrial/agricultural production, etc.

Table 3-8 Real GDP Growth Rate Forecasts

Year	EIU	IMF
1999/2000	4.8%	4.4%
2000/2001	3.0%	2.0%
2001/2002	4.0%	4.0%

Source: IMF, *World Economic Outlook Database*, October 2001;
The Economist Intelligence Unit Limited (EIU*), Country Report*, February 2001

In this analysis, it is assumed that the annual real GDP growth remains constant from 2002 until 2010 (thus real GDP growth rate in 2010 is also 4.0%). The cumulative growth rate from 2001 to 2010 is thus assumed to be 42.3%.

The 2010 OD is then calculated by multiplying each 2001 OD pair by the growth rates indicated above.

3.6 Traffic Assignment

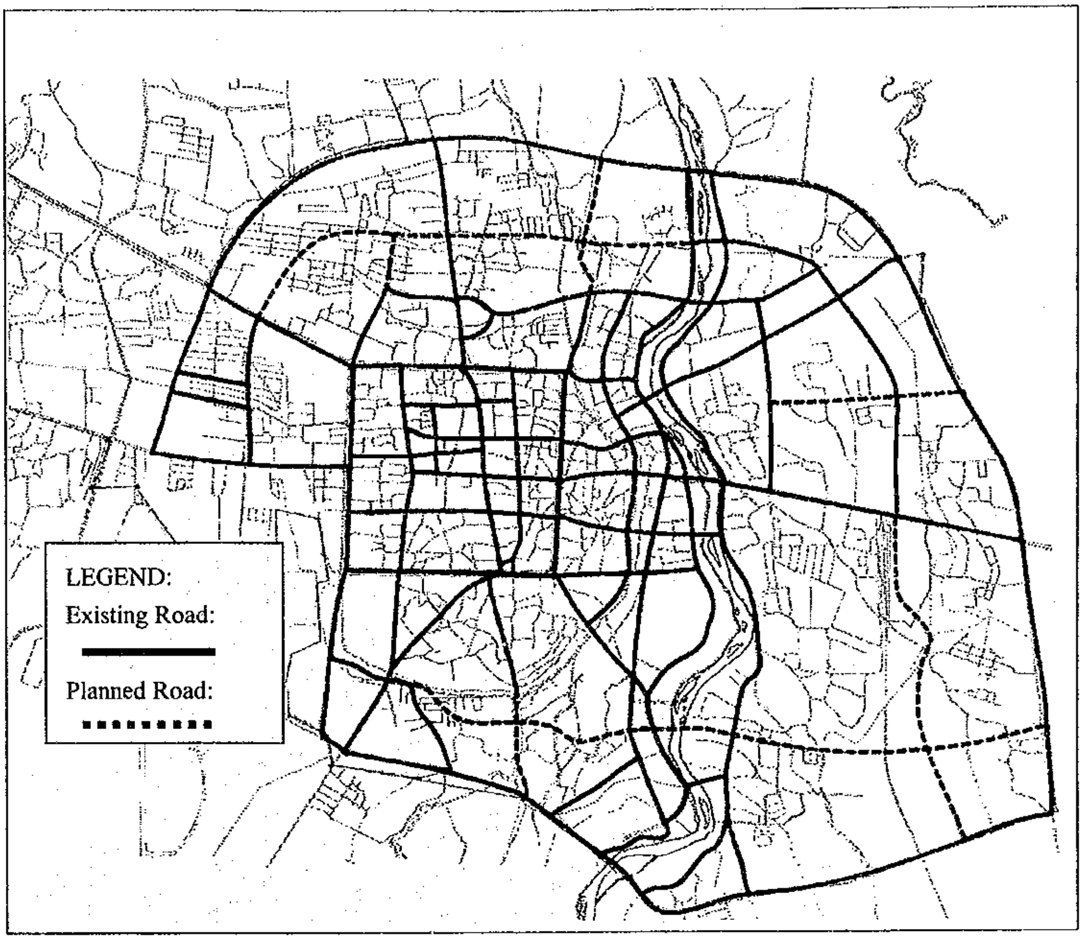
Traffic volume for each link is calculated by traffic assignment. OD data, network data, and several parameters are necessary for calculation. The simulation is carried out using the Traffic Assignment Module in the JICA STRADA 2 Model.

Traffic assignment estimates the traffic volumes for each target road, which are defined as arterials roads or those with heavy traffic levels, and shown in Figure 3-9 and Figure 3-10. Traffic capacities (daily PCU) and the maximum allowable speeds (V_{max}) for various roadway classification categories are defined in Table 3-9.

Table 3-9 Traffic Capacity and Maximum Velocity

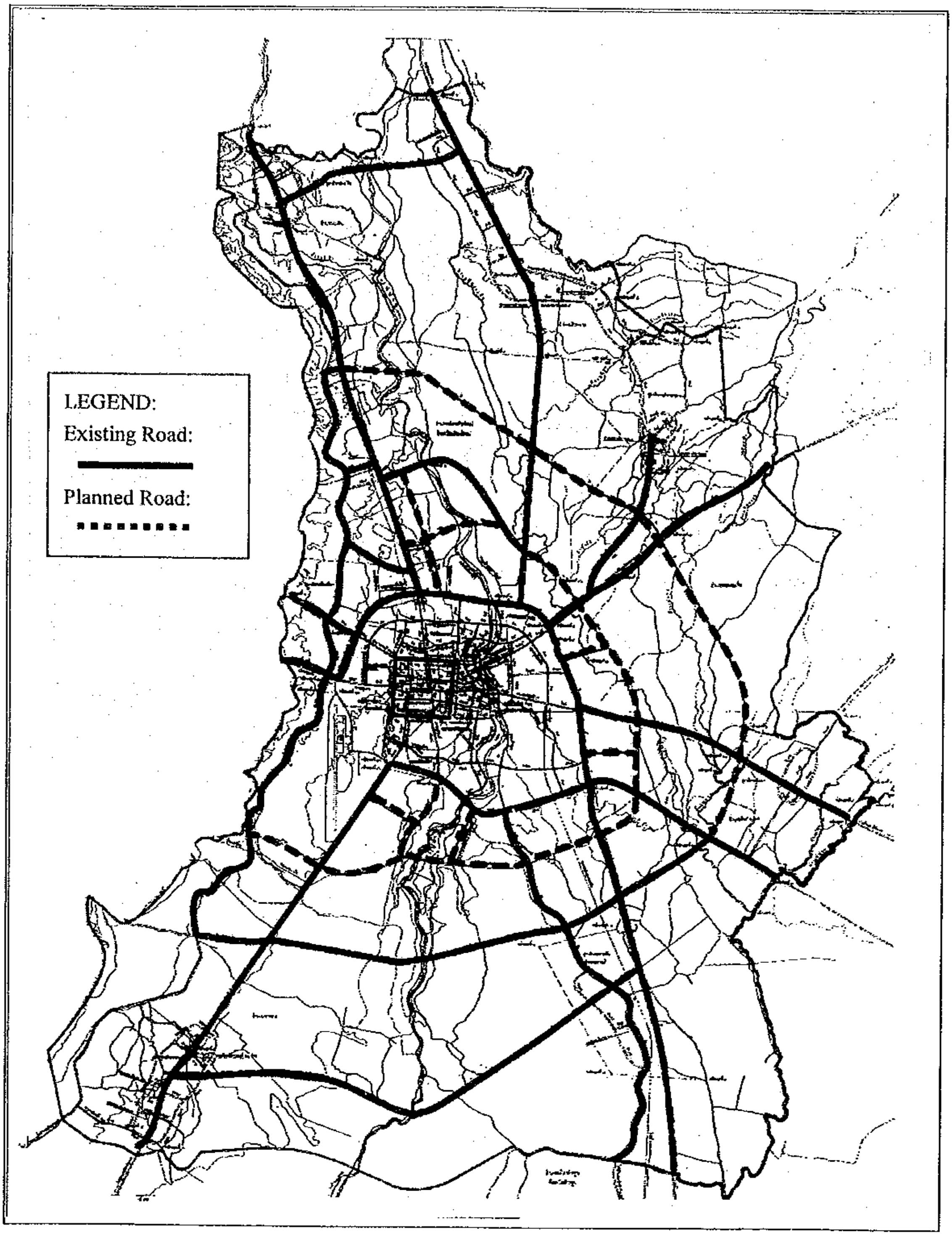
Area	Number of Lanes	V_{max} (km/h)	Capacity (PCU/day)
Urban Area	No lane	30	12,000
	2 (both-ways)	40	16,000
	4 (both-ways)	50	48,000
	6 (both-ways)	50	72,000
	2 (one-way)	40	24,000
	3 (one-way)	50	36,000
	4 (one-way)	50	48,000
Rural Area	2	50	17,000
	4	60	68,000
	6	60	102,000
Super Highway	4	70	68,000
	4 (with frontage road)	70	116,000

Source: JICA, *The Study on Medium to Long Term Improvement/Management Plan of Road and Road Transport in Bangkok in The Kingdom of Thailand*, 1990.



Source: OCMLT Study, 1994

Figure 3-9 Assignment Network in Inner Area

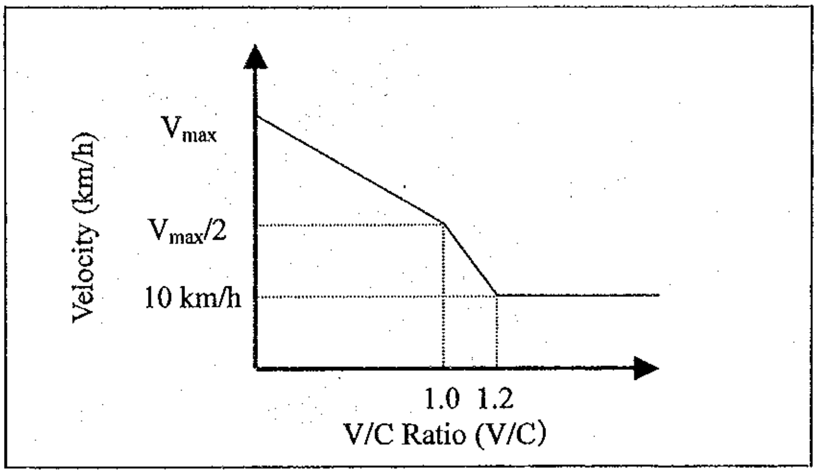


Source: OCMLT Study, 1994

Figure 3-10 Assignment Network in Outer Area

The relationship between the volume and capacity (traffic volume/road capacity) of a road, known as the V/C ratio, and the velocity of vehicles on a particular road is shown in

Figure 3-11. This curve shows that as the V/C ratio increases (meaning traffic congestion), velocities correspondingly decrease. Furthermore, if the V/C ratio is 0 (no traffic), theoretically the corresponding velocity is the maximum speed (V_{max}) of the road.[10] This curve has been estimated by JICA, with slight revisions from comparisons between the observed and calculated volumes.[11]



Source: This study.

Figure 3-11 V/C vs. Velocity Curve

The assignment is based on the multi-step shortest path method. Incremental assignment, the method chosen, distributes the OD several times based on the relationship between traffic capacity, traffic volume, and vehicular speed for each road. The assignment process is performed ten times by assigning 10% of the OD traffic volume each time and is carried out using the Incremental Assignment Module of the JICA STRADA 2 Model.

The results of the assignment model with the 2001 OD and network are compared with the traffic count data in order to examine the validity of the simulation in Figure 3-12. There are 49 data points, which each represent a survey station and show the relationship between the observed and the estimated traffic volumes (for each point, the X-axis value represents the observed traffic volume at a certain station, Z for instance, while the Y-axis value represents the estimated traffic volume at Station Z).[12] Points lying to the left of the unit line (of slope = 1.0) represent stations that had lower observed traffic volumes than were estimated. Correspondingly, points lying to the right of the line represent stations that had greater observed traffic volumes than were estimated.

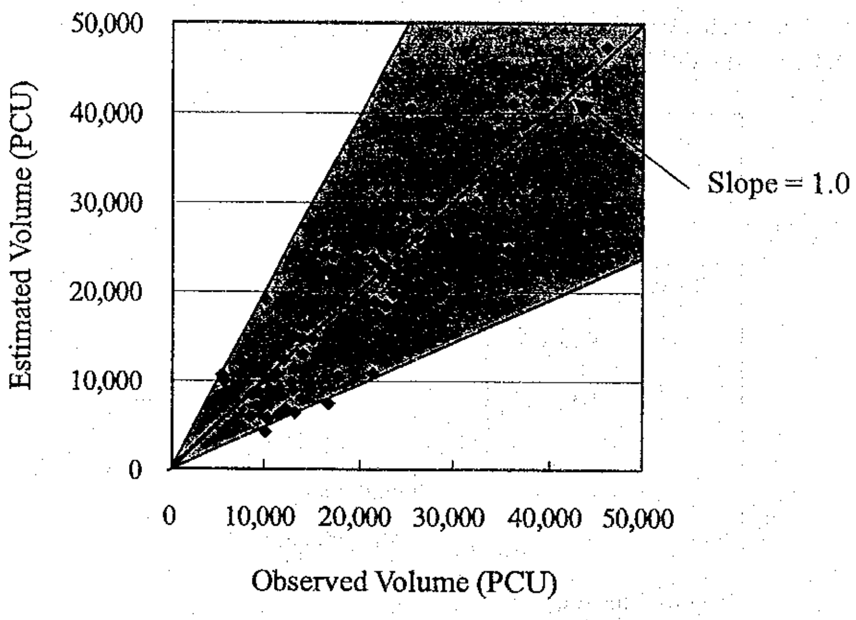
From Figure 3-12, it is graphically evident that the observed and the estimated volumes have a high correlation. In fact, the data sets had a correlation coefficient of 0.863.

[10] It should be noted however that the velocity denoted by the curve does not represent the actual vehicle speeds exactly since the curve is generally modified for improved accuracy and a lower variance between the calculated and observed traffic volume, not vehicle speeds.

[11] This curve is from JICA, *The Study on Medium to Long Term Improvement/Management Plan of Road and Road Transport in Bangkok in The Kingdom of Thailand*, 1990

[12] 23 stations had two-way traffic counts, whereas only 3 had one-way traffic counts.

Furthermore, 85% of the calculated data fell within a range of 0.5-1.5 times the observed data.



Note: Shaded area represents all stations with a traffic ratio of between 0.5 and 1.5.
Source: This study

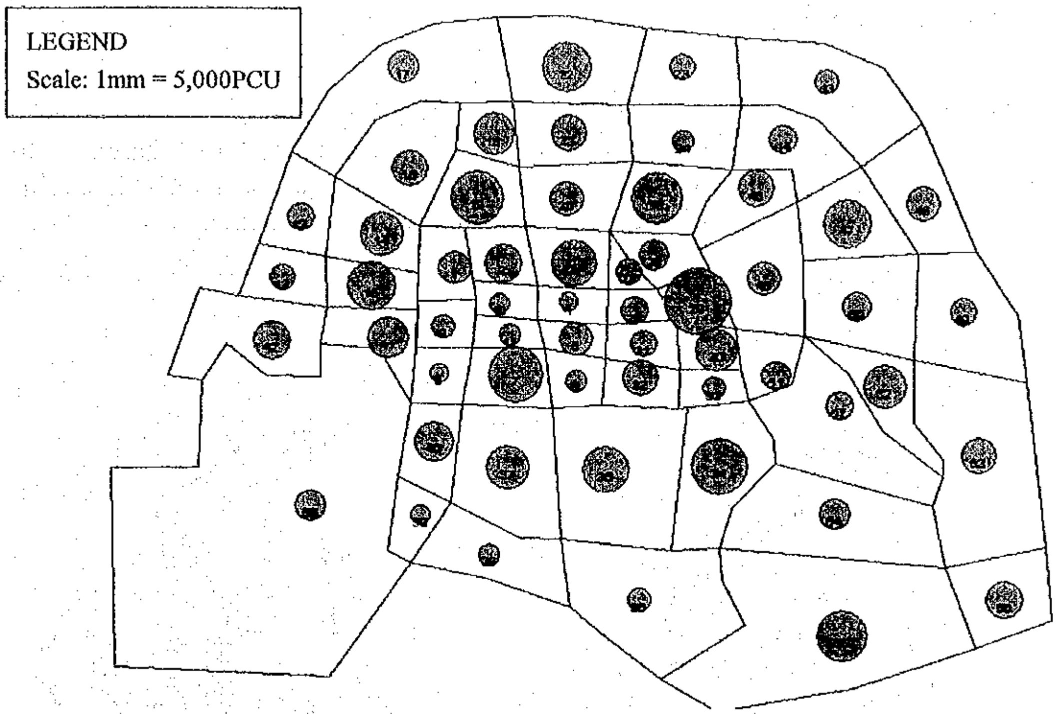
Figure 3-12 Comparison between Estimated and Observed Traffic Volume

3.7 Summary of Results

The results of the analysis are as follows.

(1) Trip Generation and Attraction

As shown in Figure 3-13, the trips that are generated and attracted within the Inner Area show significant differences from zone-to-zone. In general, the zones with large numbers of trips, have markets, schools or hospitals within their vicinities.



Note: Produced by Zone Graph Module, JICA STRADA 2.
Source: This study.

Figure 3-13 Trip Generation and Attraction by Zone

Table 3-10 shows the number of trip estimated (both generated and attracted) for certain zones in 2001, with more than 25,000 trips.

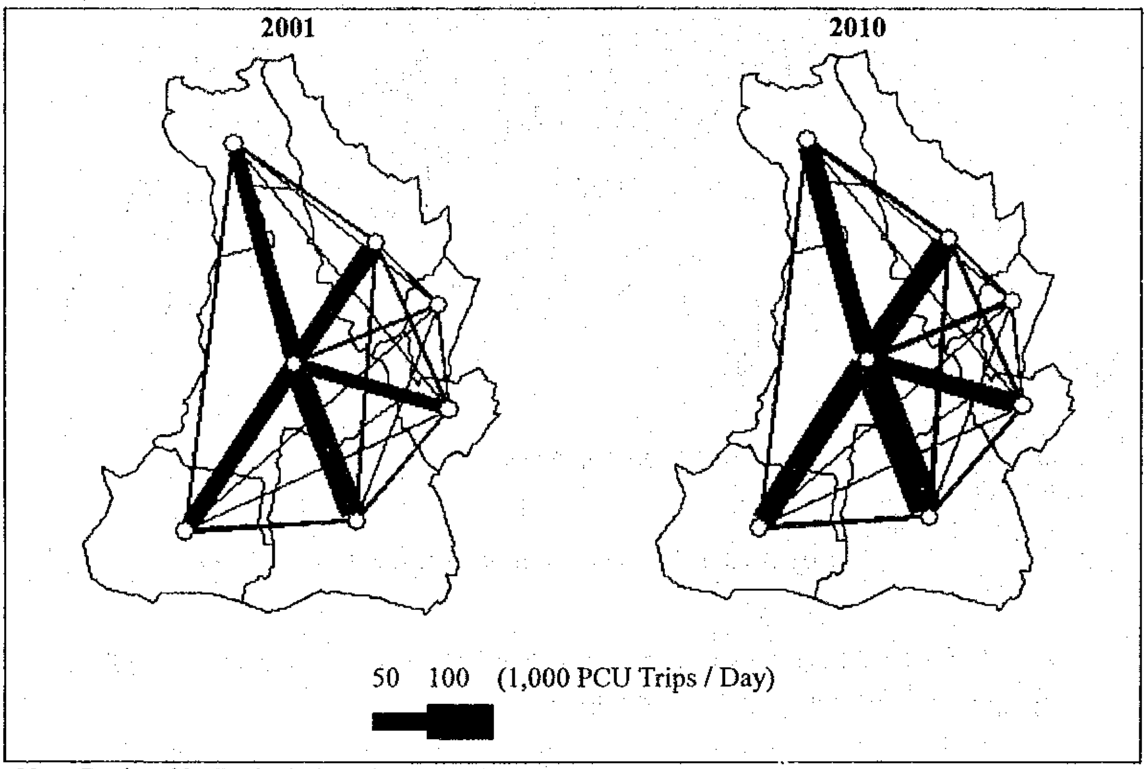
Table 3-10 Zones with 25,000+ Trips in 2001

Zone No.	No. of Trips	Facilities in Zone
7	35,957	Chiang Mai Gate Market
15	26,828	Maharaj Hospital, Chiang Mai University
19	30,849	Chang Puak Market
22	26,533	Rajabhat Institute Chiang Mai Teacher College
25	28,485	Muang May Market
29	47,294	Warorot Market
34	35,855	Regina School, Sacred Heart School, Monfort School
47	25,542	Mc Cormick Hospital, Dara Academy School
55	29,182	Nong Hoy Market

Source: This study.

(2) OD Demand Patterns

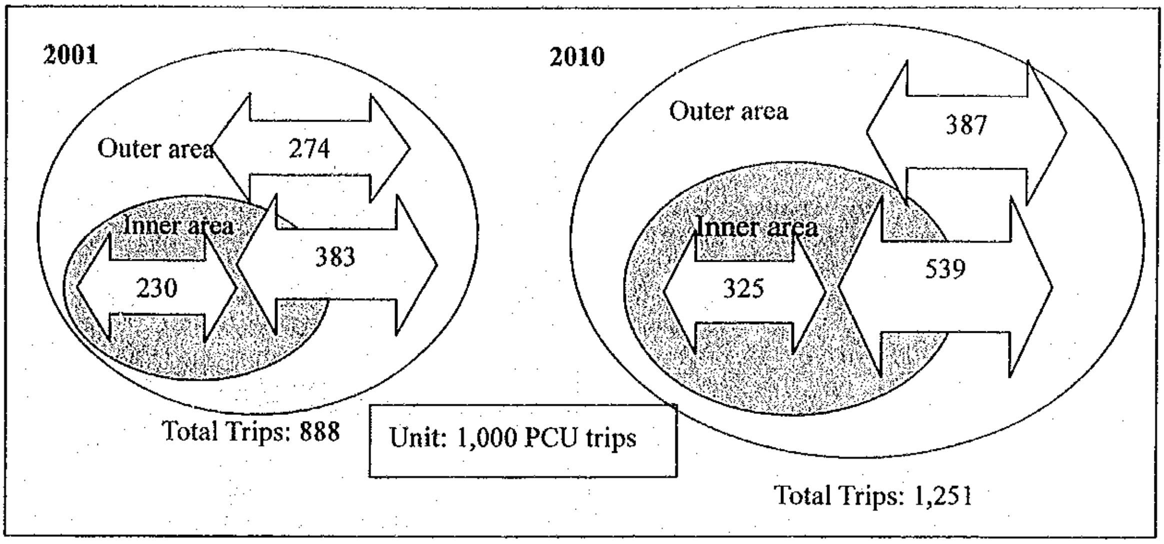
The total number of daily trips in the analyzed area was 0.89 million PCU trips in 2001, and 1.25 million PCU trips in 2010. Figure 3-14 shows the trip distribution based on the 7 integrated zones that again includes the Chiang Mai Municipality and 6 neighboring districts. A total of 82% of all trips were concentrated within the municipal area.



Note: Produced by Desired Line Viewer, JICA STRADA 2.
Source: This study.

Figure 3-14 Trip Distribution Patterns in 2001 and 2010

Figure 3-15 compares trips in the Inner and Outer Areas in 2001 and 2010. In 2010, the Inner Area has an especially high concentration of trips as shown in Figure 3-15. The figure shows that 69% of trips involve the Inner Area. This figure is composed of trips only within the Inner Area (26% of all trips) and trips between the Inner and Outer Areas (43% of all trips). The remainder of the trips, 31%, only involves the Outer Area. These percentages don't change between 2001 and 2010 since the 2010 OD is calculated by multiplying each 2001 OD pair by the same growth rates.



Source: This study.

Figure 3-15 Trips in Inner Area and Outer Area

(3) Traffic Volume Analysis

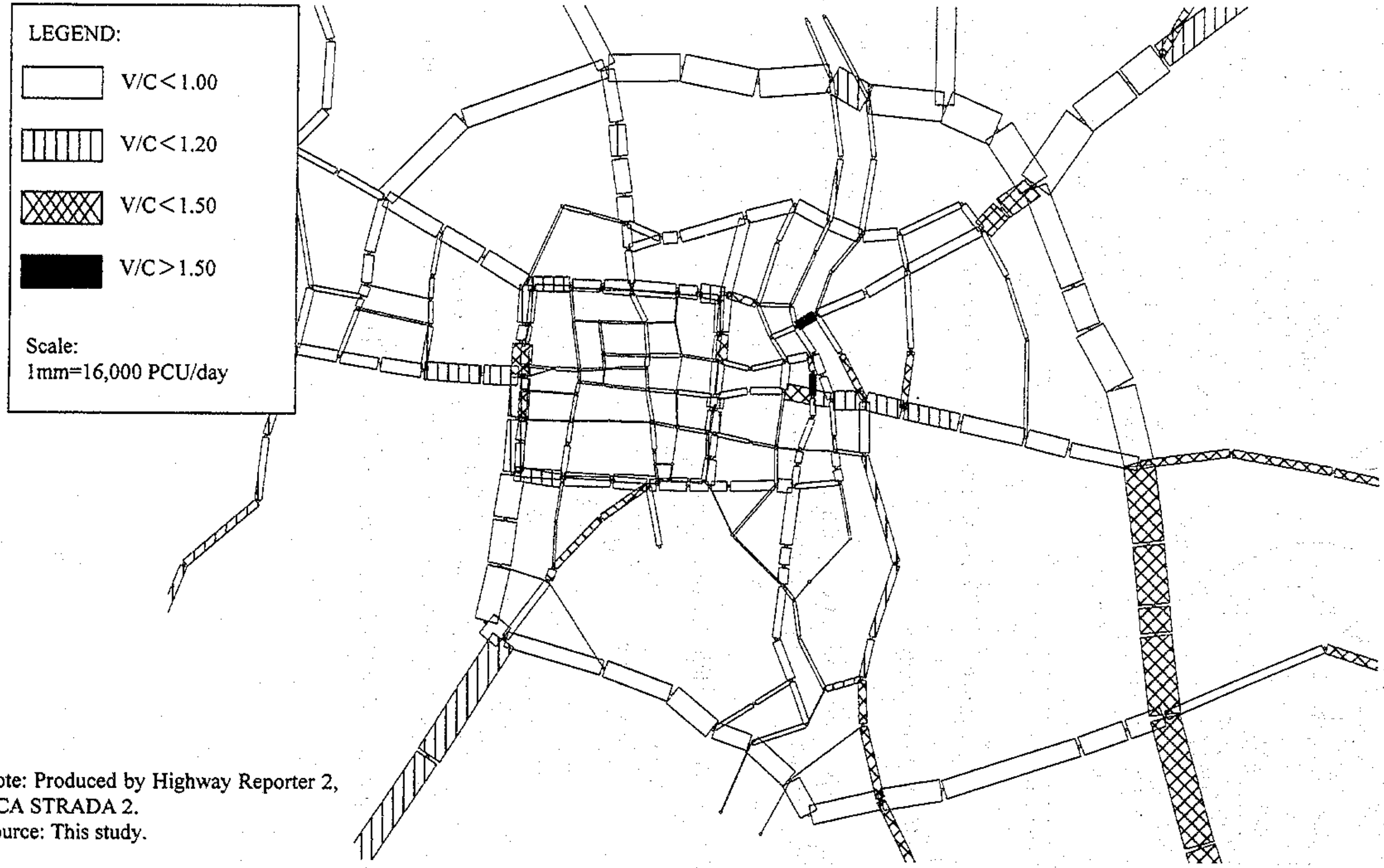
The V/C ratio is an indicator of congestion. The corresponding travel speeds and traffic conditions associated with a particular V/C ratio is shown in Table 3-11.

Table 3-11 Relationship between V/C Ratio and Travel Speed

V/C Ratio	Travel Speed (km/hr)	Traffic Conditions
0.5	50-30	Good
1.0	25-15	Fair
1.2	12-8	Bad
1.5	5-3	Serious

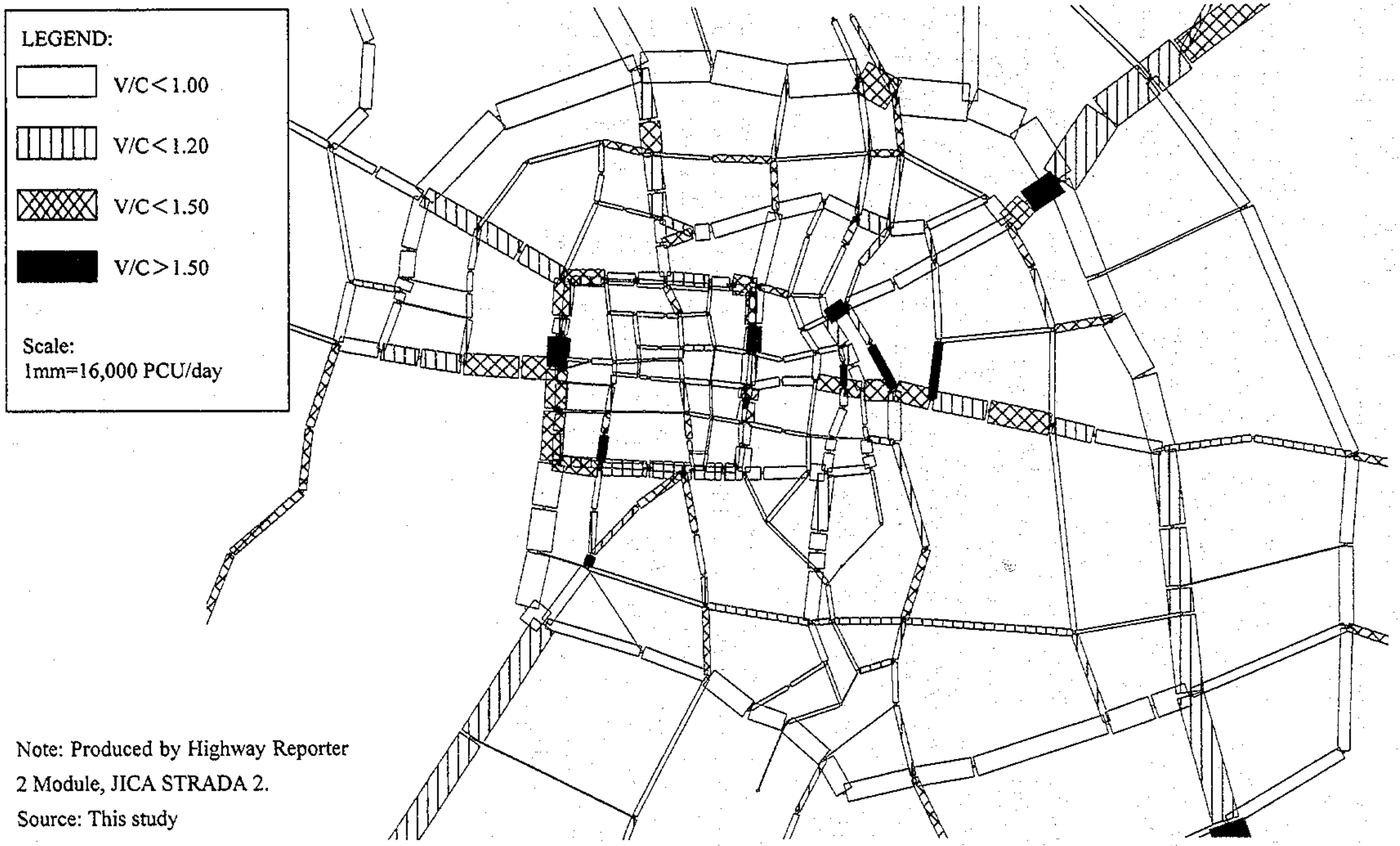
Source: JICA, *The Study on Medium to Long Term Improvement/Management Plan of Road and Road Transport in Bangkok in The Kingdom of Thailand*, 1990

The traffic volume and V/C ratio on assigned links is shown in Figure 3-16 and Figure 3-17.



Note: Produced by Highway Reporter 2, JICA STRADA 2.
Source: This study.

Figure 3-16 Traffic Volume and V/C Ratio in 2001



Note: Produced by Highway Reporter 2 Module, JICA STRADA 2.
Source: This study

Figure 3-17 Traffic Volume and V/C Ratio in 2010

(4) Assessment

Comparisons between estimated and observed traffic volumes imply that the assignment is reasonable because of the large correlation coefficient (which is in fact larger than some found for other similar studies).

Although traffic is concentrated at certain locations, it is found that in 2001, the V/C ratio of most roads is less than 1.50. Furthermore no continuous congested section of roadway exists within the Inner Area, implying that the existing road network can largely accommodate existing traffic loads. Super Highway for instance, has a large traffic handling capacity, and is able to reduce congestion in the area by absorbing additional traffic.

In 2010, the V/C ratio is expected to worsen on most roads due to increase traffic volumes. Not surprisingly, the number of section with V/C ratios greater than 1.5 is also expected to increase. Seriously congested sections in 2001 are also not expected to improve. On the other hand, road traffic is expected to decrease in some sections including along Super Highway (East and South section) and Chiang Mai-Lamphun Road (between Super Highway and the Mengrai Bridge), as traffic shifts to new roads such as the Inner Ring Road and the Middle Ring Road. Overall however, the new network may be able to reduce congestion along some main roads, but it cannot relieve the existing congestion problems.

Table 3-12 shows sections with serious congestion, possessing V/C ratios larger than 2.0 in 2010, and ones that have special problems. It is expected that such sections are likely to become network bottlenecks in the future. In some cases traffic regulations, permitting U-turns or instituting one-way traffic, produces traffic concentration and interrupts traffic flow at specific section (around the Warorot Market for instance). In examining the traffic improvement plans, it is important to consider these congestion points and the underlying reasons for the traffic congestion. Lastly, it is also necessary to make efforts to reduce the traffic load placed on them.

Table 3-12 Sections with Serious Congestion

Congested Section	Direction (to)	2001 V/C Ratio	2010 V/C Ratio	Comment
Nakhon Ping Bridge	Southwest	1.90	3.12	In the morning peak there is heavy congestion from up to Keao Nawarat Road.
	Northeast	1.23	1.78	
Wichayanon Road (in Warorot Market)	South	1.63	2.49	This road has low capacity because of many parked cars and pedestrian crossings, but heavy traffic volumes are expected.
Wichayanon Road (between Chayaphum Road and Ratchawong Road)	East	1.65	2.03	This is a narrow 2 lane road without sidewalks.
Tippanet Road (between Wualai Road and Haiya Road)	South	1.55	1.69	This is a very dangerous section because cars merge from a Y-junction.
	North	1.29	1.79	
Keao Nawarat Road (between Super Highway and Thung Hotel Road)	Southwest	1.31	1.70	Traffic from the northeast area is dense, in addition to traffic from ramps from Super Highway, further reducing capacity.
Tha Phae Road (between Wichayanon Road and Chang Moi Tud Mai Road)	West	1.22	1.63	Traffic from the east area/ Warorot Market, to the Old City and Chang Moi Area is concentrated.
Boonruangrit Road (North of Suthep Road)	North	1.33	1.61	Traffic from Sutep Road to the south must make U turns here, although heavy through-traffic is expected.
Arrak Road (North of Suthep Road)	South	1.30	1.64	
Chayaphum Road	South	1.35	1.75	Traffic flow is interrupted by U-turn traffic.

Source: This study.