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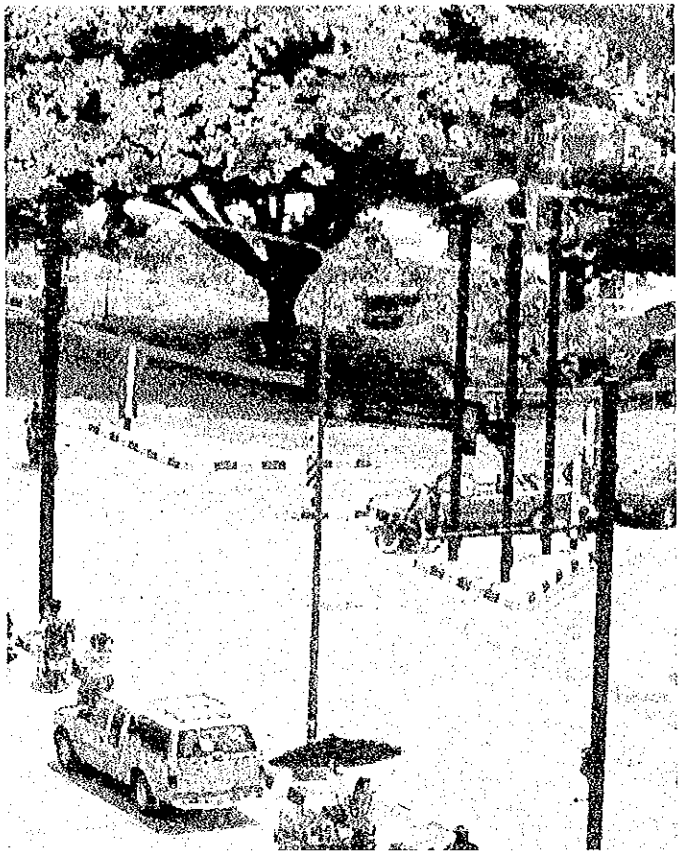
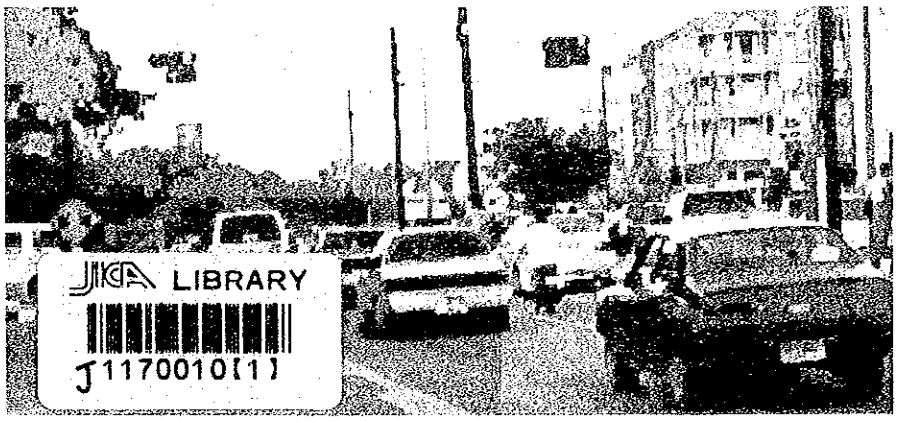
KINGDOM OF THAILAND
ROYAL THAI POLICE
AND MUNICIPALITY OF CHIANG MAI

JAPAN INTERNATIONAL COOPERATION AGENCY



THE STUDY ON IMPROVEMENT OF ROAD TRAFFIC ENVIRONMENT IN CHIANG MAI CITY IN THE KINGDOM OF THAILAND

Final Report
Summary



September 2002

PADECO Co., Ltd.
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For the currency conversion, in case necessary
Exchange rate in July 2002 is applied

JPY 1 = THB 0.35

PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a study on "The Study on Improvement of Road Traffic Environment in Chiang Mai City in the Kingdom of Thailand" and entrusted the study to the Japan International Cooperation Agency (JICA).

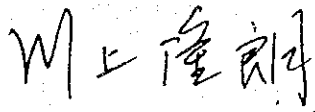
JICA selected and dispatched a study team headed by Mr. Chiaki Kuranami of PADECO, Co., Ltd. and Fukuyama Consultants Co., Ltd. to the Kingdom of Thailand, three times between July 2001 and August 2002. In addition, JICA set up an advisory committee headed by Mr. Atsushi Fukuda, Associate Professor, Nihon University, between July 2001 and August 2002, which examined the study from technical points of view.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the study team.

September 2002



Takao Kawakami
President
Japan International Cooperation Agency

September 2002

Mr. Takao Kawakami
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit herewith the final report of "The Study on Improvement of Road Traffic Environment in Chiang Mai City in the Kingdom of Thailand".

This report presents the results of the study, which was undertaken in the Kingdom of Thailand, from July 2001 to August 2002 by the Study Team, organized jointly by PADECO Co., Ltd. and Fukuyama Consultants Co., Ltd.

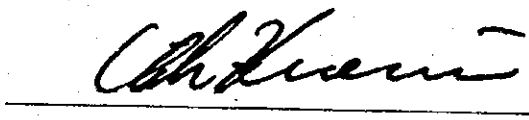
The Study Team recommended projects for improving traffic environment based on the present traffic situation of Chiang Mai and made an implementation plan of the recommended projects until the target year of 2010. Furthermore, the signal system was installed in a dangerous intersection as a pilot project, and contributed greatly to the improvement of traffic safety at the site.

We owe a great deal to many people for the completion of this report. We would like to express our deep appreciation and sincere gratitude to all those who extended their kind assistance and cooperation to the Study Team, in particular, the concerned officials of the Royal Thai Police and Chiang Municipality in the Kingdom of Thailand.

We are very much thankful to the officials of your agency, the JICA Advisory Committee, the Ministry of Foreign Affaires, and Japan National Police Agency.

We do hope that the report will contribute to facilitating further socio-economic development in the Kingdom of Thailand.

Very truly yours,



Chiaki Kuranami
Team Leader
The Study on Improvement of Road Traffic Environment
in Chiang Mai City in the Kingdom of Thailand

Table of Contents

1. Introduction

1.1 Background and Objectives of the Study

(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, 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.

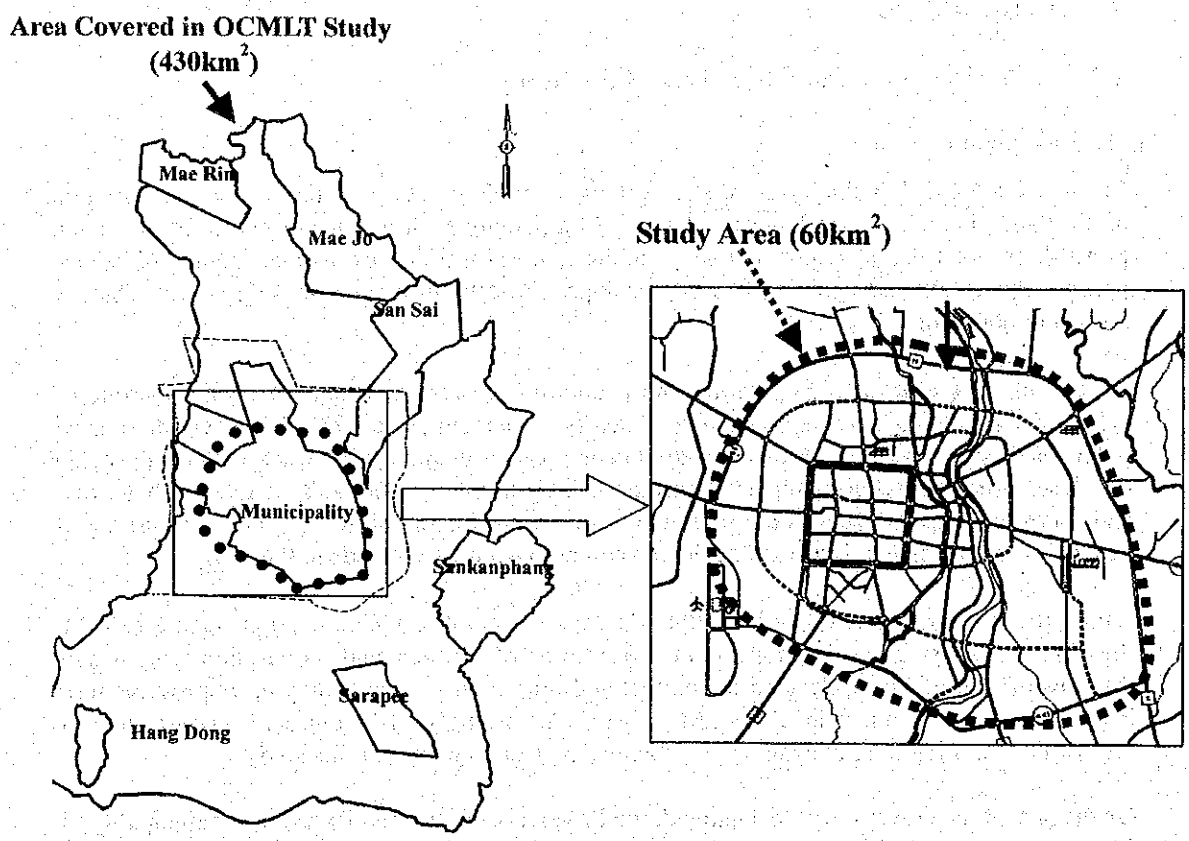
On the part of the Government of Thailand, the Royal Thai Police (RTP) and the Municipality of Chiang Mai (MOCM) act as the counterpart agencies. In addition, Department of Highway (DOH), Northern Technical Center for Traffic System Management of Chiang Mai University, and Traffic Sub-Committee of OCMLT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

(2) Objective

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.



Source: OCMLT Study, 1994.

Figure 1-1 Map of Chiang Mai Municipality, Surrounding Suburbs, and Study Area

1.2 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 was completed in August 2002.

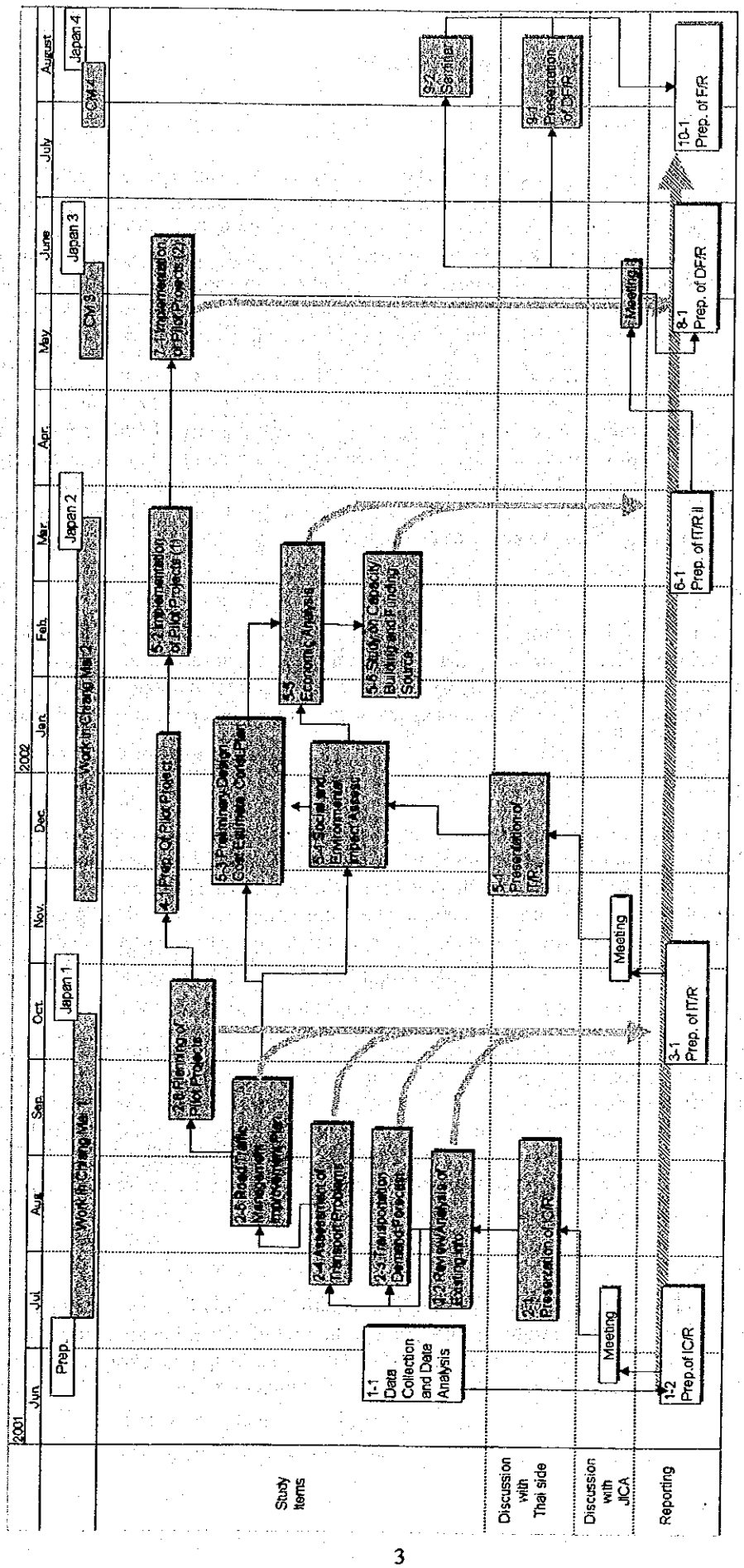


Figure 1-2 Study Tasks and Schedule

2. Analysis of Transport/Traffic Issues

2.1 Road Network Issues

The existing road network pattern in Chiang Mai is clearly that of a ring and radial roads system. The system is said to have evolved largely from the structure of the ancient walled city with radial roads branching out from its city gates. The old city moat now divides a pair of one-way streets (with the outer road having a clockwise flow and the inner road anti-clockwise) now forming an important circulation road. It also demarcates the ancient city of about 1.6 km^2. Streets within the old city are narrow and laid out in a pseudo-grid pattern. Figure 2-1 shows the existing road system and important issues that affect the road network are as follows:

(1) Mae Ping River

The Mae Ping River, which flows from north to south through the city of Chiang Mai, has an important effect on road network development in the city. As a natural barrier, it affects the traffic flow between the east and western part of the city. As the city expands towards the eastern frontier, traffic to and from this area is likely to increase in the future. This will add further pressures on the existing bridges over the Mae Ping.

(2) Collector Roads

The arterial road system in Chiang Mai is adequate, but the main deficiency within the road network system is the collector roads, especially in less developed sub-districts. The result is that many smaller access roads connect directly to the major thoroughfares without first linking to the collectors, and traffic to and from these numerous access roads disrupts the otherwise smooth flow of the main traffic.

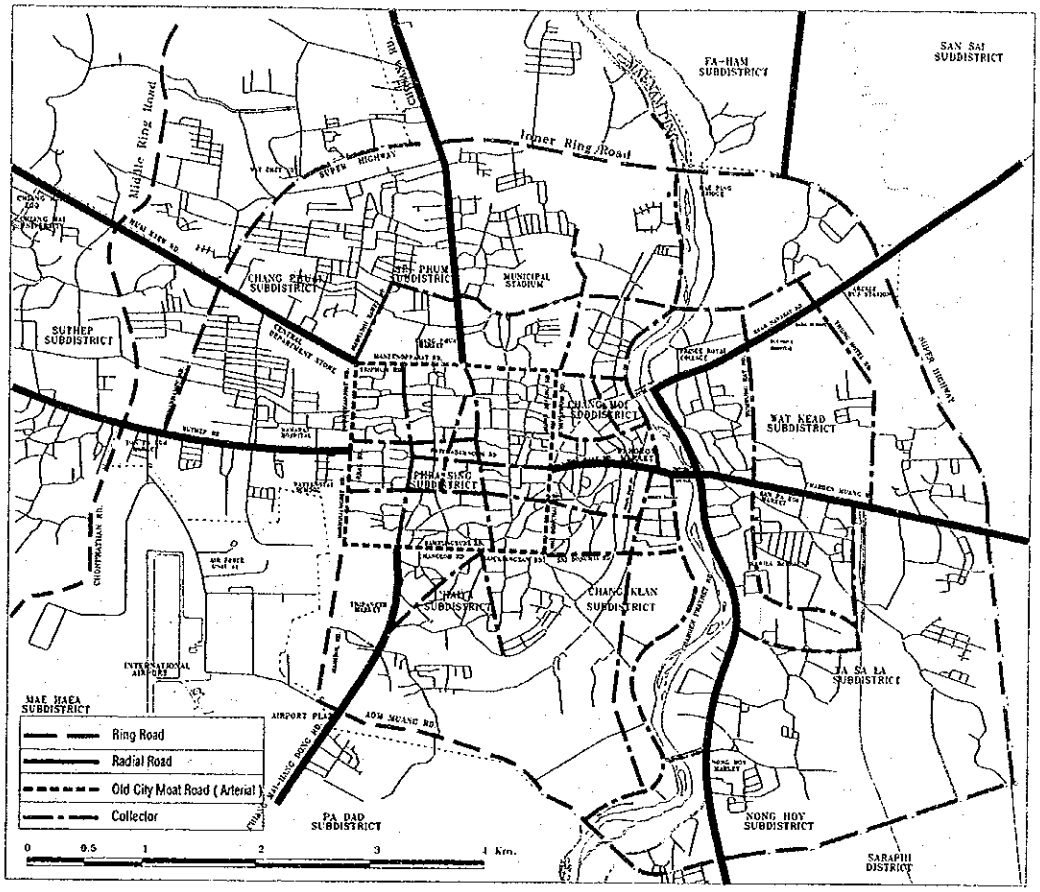
(3) Super Highway

The modern city proper, under the management of the Municipality of Chiang Mai, is chiefly represented by the built-up area within the National Route No.11 and 1141 or commonly called Super Highway. Functionally it can be called the Inner Ring Road. This is an area with a radius of about 2.5 km to 4 km from the old city center. The Outer Ring, which is nearing completion (expected by 2002), is much further out at about 8 to 10 km from the city center, and demarcates the main city planning area of Chiang Mai. Between this Outer Ring and Super Highway is the Middle Ring Road.

Although the Super Highway is of vital importance to Chiang Mai, it has several conspicuous faults that require attention: (i) *Access Control:* despite high speed traffic, there is direct access to some buildings or other areas lacking proper controls; (ii) *U-turn:* there are several breaks at the median that allow for u-turns at grade thus providing conflict with fast on-coming vehicles; (iii) *Incomplete Ring:* Super Highway as a ring road is physically incomplete. Due to this discontinuity, traffic from the ring road tends to continue along Huay Kaew road, Boonruangrit Road, thus contributing to city center congestion.

(4) On-Street Facilities

Design of roads in Chiang Mai by the DOH and Municipality basically follows that of AASHTO (American Association of State Highway and Transportation Officials), but some inconsistency exists. The installation of urban facilities such as road marking, lamp posts, wayside trees, and traffic signs requires more consistent specifications and requirements.



Source: This study

Figure 2-1 Existing Road System in City Area

(5) Intersection Problems

Twenty intersections are selected for further investigation in this study. The 20 selected intersections are deemed to require some improvements in order to upgrade their traffic safety levels or to improve their traffic handling capacity. Based on the data collected and observation of traffic conditions at the site, particular problems and issues have been identified.

In short, many of the intersections in the city of Chiang Mai have the following problems.

- Lack of pedestrian signals facility
- Geometric design problems (small turning radii, off-set intersections)
- Inadequate signage
- Lack of stop lines
- Poor visibility of signs or signals
- No clear indication of main road from minor roads
- Confusing road markings
- Lack of channeling islands or markings
- Inappropriate locations for sign posts, signal posts, or lamp posts
- Obstruction of view by foliage or untidy wires
- Broken signal equipment (controller boxes)

(6) Traffic Bottlenecks

There are several traffic bottlenecks around the city that deserve further studies and investigation to formulate appropriate solutions or mitigating measures. Most of them are at intersections with unequal entry and exit lanes or at bridges on the Ping River.

2.2 Demand Forecasting Analysis

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

(1) To understand general traffic conditions in the *target year of 2010* to assess potential improvement plans; and

(2) To facilitate knowledge and technology transfer of traffic analysis techniques to counterpart personnel in Thailand.

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 was already available from a prior OCMLT study, thus it was possible to streamline this process using the following sequential steps for traffic demand:

(i) *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.[1]

(ii) *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.

(iii) *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 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 as shown in Fig 2-2. 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 increased traffic volumes as shown in Fig 2-2. On the other hand, road traffic is expected to decrease in some 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.

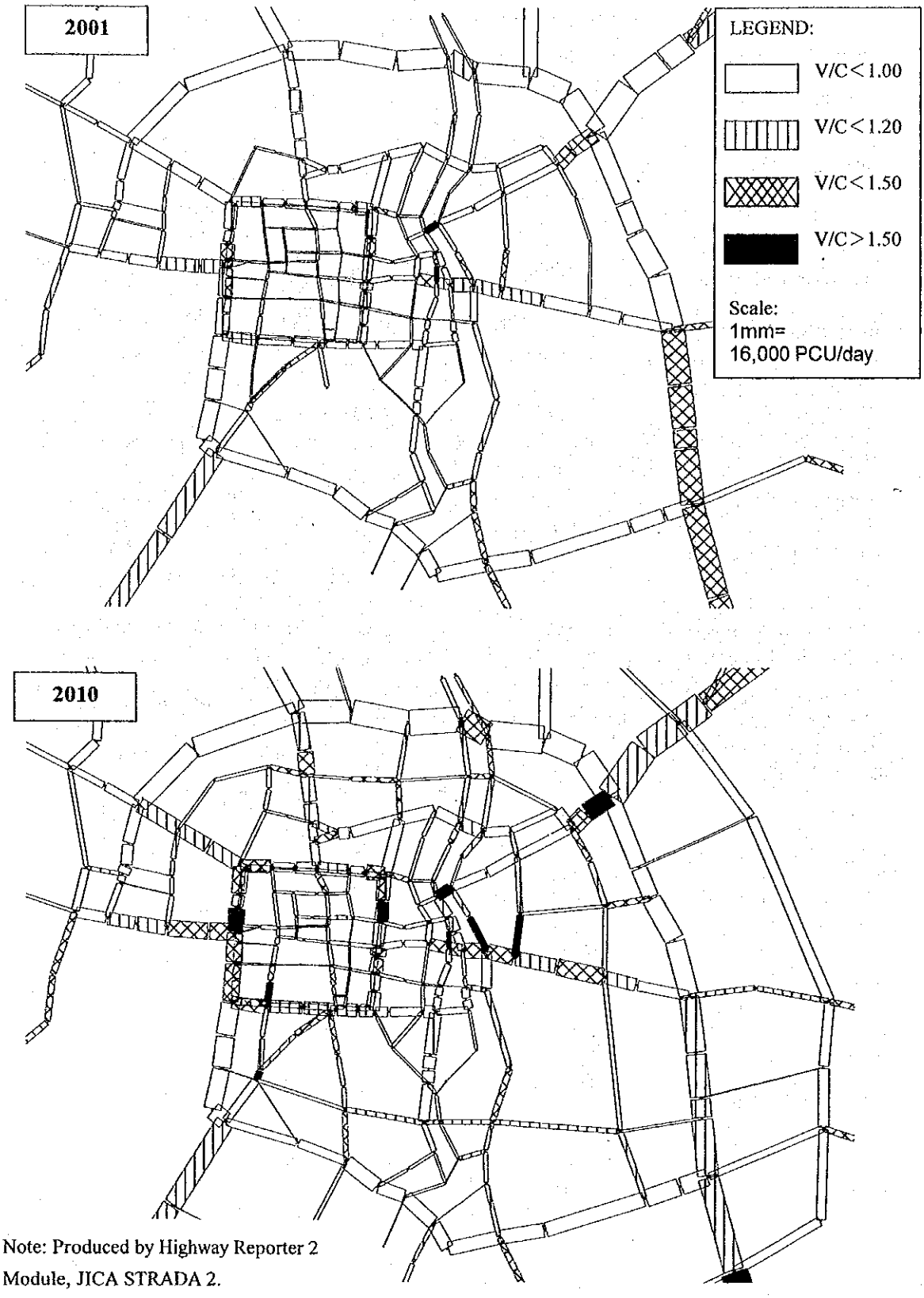
- Table 2-1 shows sections with serious congestion, possessing V/C ratios larger than 2.0 in 2010, and ones that have special problems. It is expected that such sections will become network bottlenecks in the future.

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

Table 2-1 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.



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

Source: This study

Figure 2-2 Traffic Volume and V/C Ratio

2.3 Traffic Signal System

An ATC system in Chiang Mai was originally designed by DOH in 1994 and in July 2001, 38 intersections were operating under the system. Management moved to Chiang Mai Municipality in February 2000 and since this time, maintenance of the system has been undertaken by Traffic Engineering Division of Chiang Mai Municipality.

In general, the overall ATC system seems to work properly. However there are several issues.

(1) The Balance of Queue Lengths

When the traffic volume is saturated, a queue tends to form in only one direction. Once the queue grows beyond the detector, which is installed at 100 – 150m from the stop line of the intersection, the SCOOT system is no longer able to react and reduce the queue length. This may be one reason that policemen sometimes manually operate the signals, isolating the controller from the center.

(2) Waste Green Time in the Right Turn Lane

The right turn stage has some waste green. It is considered that the location of the detector to detect right turn vehicles is inappropriate because it is installed at the leaving outlet of the intersecting lane and cannot count the approaching traffic.

(3) Conflicts in the Phase Plan and Sign

From observation of sample intersections, there are some conflicting phase plans. These conflicts may lead to traffic accidents. Also, there is some conflict in the information of signposts in some areas. Usually the time of the period when the traffic regulation becomes effective is conflicting between signposts. Such conflicts may cause motorists to behave in a way that ignores traffic regulations.

(4) Maintenance

The MTBF (Mean Time Between Failures) values are too low for controllers, bulbs and the communication line. They should be improved by at least two digits. Otherwise the reliability and trust in the system may be lost by the vehicle drivers and police, and police officers will resort to manual operation. It takes time to improve MTBF but this does not mean the current failure rate is acceptable.

2.4 Traffic Safety Facilities and Devices

(1) Traffic Accidents

The traffic accident rate in Chiang Mai City is alarmingly high. Based on the collected accident data by the Province and City Governments, the fatality ratio of traffic accidents in 1997 was 40 per 100,000 population, and the injury ratio was 2,353 per 100,000 population. In Japan, the corresponding ratios were 7.6 and 760 per 100,000 population respectively. Thus, comparing Chiang Mai to the national average of Japan, the fatality ratio is over 5 times greater and the casualty ratio is over 3 times greater.

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.

(2) Sidewalk

Safe and comfortable sidewalks for pedestrians in the city are grossly inadequate even outside the old city. The average width is found to be only 1.5 m. Moreover most sidewalks are interrupted by trees, telephone and light poles, sign posts and are at a substantially higher level than the roads, making them difficult for elderly citizens and people with handicaps.

(3) Road Signs

A thorough review on the suitability and the exact installation location of road signs especially on the city streets is urgently needed. The size, figures and reflectivity of road signs require enlargement to improve legibility.

(4) Road Markings

Visibility of road markings in Chiang Mai is generally not satisfactory, and center line, lane line, pedestrian crossing and stop lines are not provided or worn out sometimes.

(5) 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.

2.5 Public Transport in Chiang Mai

There are several kinds of transport service available in and around Chiang Mai. Besides private vehicles (including automobiles, bicycles, motorcycles, etc.), the primary means of transport is via the broadly-defined bus system, estimated to account for about 12% of all trips taken.[2] There are four types of buses:

- **Shared-taxis**, also referred to as *songtaews*, are essentially customized pick-up trucks, with seating space for 10 passengers, and are delineated by different colors according to their operator.[3]
- **Minibuses** are smaller than regular buses and provide around 30 seats.[4]
- **Buses** are used for inter-city transport and provide between 60 to 70 seats.
- **Vans** provide up to 15 seats and are used primarily for transport to/from school as well as for tourism-related purposes.

In addition to the four types of buses, Chiang Mai also has motorized tricycles (locally as *tuk tuks*), cycle rickshaws (locally known as *samlors*), motorcycles (acting as taxis), and airport limousines. It should be specifically noted however, that Chiang Mai is quite unique in that no metered-taxis exist.

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[2] The modal split (by total trips) is broken down as follows: Motorcycles (51%); Private Vehicles/Pickup Trucks (34%); Bus/Minibus (12%); and Others (3%). Songtaews average about 165,000 trips per day, and minibus about 16,000 trips per day. Source: Office of Commission for the Management of Road Traffic (OCMRT) and Chiang Mai University (CMU), Traffic and Transport System Management Model for Regional City: Chiang Mai (Executive Summary), 1995, p. 6.

[3] *Songtaews*, the local name for shared-taxis, will henceforth be used to refer to shared-taxis.

[4] Intracity minibus services were cancelled as operators were financially unable to sustain their operations.

Primary issues relating to public transport are as follows:

(1) Over-Supply of Red *Songtaews*

As of 1997, the Red *Songtaew* Cooperative had over 3000 drivers. To reduce redundancy and promote efficiency, the cooperative focused restructuring efforts on reducing the number of existing operators and restricting the entry of new drivers into the force.

(2) Duplication of Route Network

Although the nominal operating jurisdiction for each *songtaew* cooperative is different, there is still a problem with route duplication between *songtaew* cooperatives.

(3) Problems with Cooperative Management Style

A cooperative is a loosely-bound group of individual operators and several weaknesses within this management structure quickly emerge as it lacks the definitive power to enforce certain operating rules that govern other public transport service observed in other cities throughout the world.

(4) Minibus Failures in the Past

Minibus operations in Chiang Mai have floundered in the past for several reasons. Prempracha Motors Co., one of the minibus operators, cited traffic congestion, rising gasoline costs, fare structures, difficulty in keeping drivers and competition from red *songtaews* as the primary reasons for the poor performance of minibuses.

(5) Poor Vehicle Maintenance

The Land Transport Act (1979) failed to spell out the specific details governing vehicle maintenance. Maintenance is left to the whims of the vehicle inspection system and the conscientiousness of drivers.

(6) High Level of Fares

The fare level for the red *songtaews* is extremely high compared to other Thai cities. The high fare levels are a barrier dissuading residents reliant upon public transport as well as those in lower-income brackets from utilizing the public transport system.

(7) Resistance to Change

The proud history and tradition of *songtaews* was started in Chiang Mai. As both a relic of the past and a key transport cog of present-day Chiang Mai, *songtaews* have proven to be quite popular with foreign tourists as well.

(8) Lack of Public Transport Enforcement

It is quite clear that in terms of *songtaew* operation, the Land Transport Department (LTD) has failed for over 20 years to enforce the Land Transport Act (1979), stipulating fixed-route operations.

(9) Unlicensed Transport Operators

Licensed transport service providers must register their operations with LTD, according to the

Land Transport Act of 1979, which regulates service level, vehicle size, as well as oversee safety requirements. Despite this fact, several unregistered (unlicensed) operators have reportedly been active in providing transport services for school and tourism related-activities.

2.6 Other Traffic Management Issues

(1) Parking Facilities and Control Measures

There is a problem between the perspectives regarding on-street parking taken by Financial Bureau of the Municiplaity and the Traffic Police. While the Financial Bureau wants to expand public parking to maximize revenues, the Traffic Police considers the prevention of traffic jams caused by on-street parking as its highest priority, thereby wishing to prohibit on-street parking during peak hours.

(2) Motorcycle Safety Issues

Motorcycles as a mode of transport has grown rapidly in recent years and comprised 72% of the number of automobiles registered in Chiang Mai Province for the year 2000. In 1997, 85% of all injured were motorcyclists. Additionally, it may be assumed that the probability of injury to motorcyclists is very high when they are involved in an accident.

The probable reasons for the high casualty risk from motorcycles compared to passenger cars are as follows:

- Many motorcyclists are known to drive dangerously and recklessly.
- The younger-age groups compose the majority of motorcycle users. Many of them in fact are driving without valid licenses.
- Motorcyclists have little protection and mass absorb the majority of the impact resulting from an accident with a larger vehicle;
- Although motorcyclists are required to wear safety helmets by law, many do not.
- Many motorcycles carry more than two riders (three or sometimes four as well).

(3) Traffic Accident Investigation and Record System

The creation of a comprehensive traffic accident database for Chiang Mai is an outstanding issue for the city, which requires further investigation and detailed study.

(4) Traffic Management Around School Areas

The high concentration of educational institutions in Chiang Mai has placed a strain on the city's roadways as high traffic volumes in the morning and afternoon are produced. Two areas are particularly congested due to the dense concentration of schools and colleges within their locales and were chosen for detailed study:

(i) The area defined by Charoen Prathet Road, Sri Donchai Road, Pracha Sampha Road, Rakaeng Road, Chang Klan Road and Chiang Mai Land Road; and
(ii) The area along Kaew Nawarat Road from Super Highway to Charoen Rat Road

There are several constraints which obstruct initiatives toward traffic improvement around the schools including a lack of public transport, students using their own vehicles, chauffeuring by parents, and a reluctance to relocate schools.

(5) Pedestrian Safety around Night Bazaar Area

The major thoroughfare in the Night Bazaar Area is Chang Klan Road, along which many large hotels exist and is one of the busiest pedestrian areas in Chiang Mai. One-way traffic flow has been adopted on the three-lane road, heading southwards. The Night Bazaar itself is held nightly from 6:00 to 11:30PM. It is estimated that pedestrian traffic volumes may be double those witnessed during the peak hour. Sidewalks however are narrow, producing significant congestion and potentially making tourist trips less enjoyable due to the crowding.

(6) Environmental and Social Considerations

Air Pollution

In Chiang Mai the high number of vehicles due to both a lack of mass transit and low usage of non-motorized modes creates congestion and driving characteristics that exacerbate pollution. Poor engine maintenance causes sub-standard emissions and black smoke from exhaust pipes is a common sight in the city. This is confirmed by a survey of diesel vehicles in Chiang Mai in 2000, which revealed that 93% of the sample exceeded the standard for black smoke. Moreover, it is widely accepted that Chiang Mai's greatest problem in pollution is the high level of dust and particulate matter (PM-10). A high level of respiratory disease is no doubt exacerbated by the high level of particulate matter in the city.

It is considered that the road cleaning equipment and methods employed within Chiang Mai are not sub standard. However, given the high level of particulate matter existing within the city, the efficiency and applicability of the equipment is questionable.

Noise Pollution

Vehicles in Chiang Mai tend to be old and engines, such as those of motorcycles and *tuk tuks*, are small and noisy. Noise survey results reveal generally high L_{eq} 24 hour levels ranging between 62.6 dB(A) and 74.2 dB(A). Two sites at Wat Chet Yod and Tha Phae Road exceeded the Thai standard 24 hr L_{eq} of 70.0 dB(A).

Social Considerations

The pedestrian and historic environment of Chiang Mai has been neglected while accommodating high volumes of motorized traffic. The pedestrian environment is generally inadequate in that road space is provided at the expense of walking space and there are few areas within the city center or even the superhighway boundary that provide tranquility and relief to traffic noise and pollution.

3. Recommendations

3.1 Summary of Recommendations

Based on the findings of the Study Team, the table below presents a summary of recommendations. Some of the measures within these recommendations are further discussed in the paragraphs that follow:

Table 3-1 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

3.2 Road Network and Intersections

(1) Develop Clearer Hierarchy of Road Network

Traffic from access roads should be channeled into collectors, and then on to arterials. Collector roads should be developed by upgrading small access roads that connect to the arterials, while at the same time reducing the number of access points that connect small access roads to the arterials, especially those leading to the Super Highway and the radial roads. Direct connections for access roads or buildings to arterials should be avoided in road network development.

(2) Develop Design/Installation Standards for On-Street Facilities

The design of roads in Chiang Mai by the DOH and Municipality basically follows that of AASHTO, but some inconsistency still exists. It is recommended that the Municipality develop good design and installation standards for the various facilities as well as road markings and traffic signs.

(3) Intersection Improvement

Improvement plans were prepared for each of the 20 intersections as summarized in Table 3-2 and Figure 3-1. Only short-term measures that do not require substantial capital investment are considered. The improvement measures are classified into seven groups:

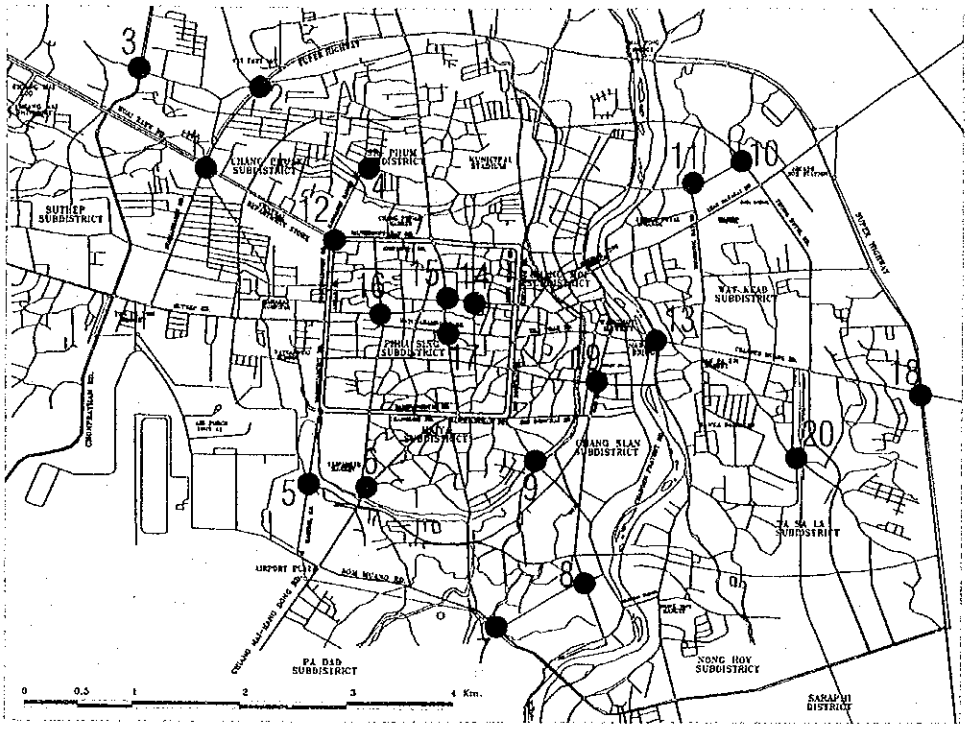
(i) Geometric improvement to correct physical deficiencies
(ii) Traffic signals at intersections with high traffic volumes
(iii) Review of signal phase and timing plan.
(iv) New pavement marking to comply with Thai Industrial Standards: 542-2530
(v) Improved traffic regulation i.e. prohibition of right-turns
(vi) Traffic signs, mostly stop signs for minor roads
(vii) Others

Table 3-2 Proposed Improvement Measures at 20 Selected Intersections

No.	Intersection	Proposed Improvement Measures						
		Geometric Improvement	Signal or Flasher Note[2]	Signal Phase/ Timing	Pavement Parking	Traffic Regulation	Traffic Sign	Others
1*[1]	Huay Kaew Road-Super Highway	✓		✓	✓	✓		
2	Super Highway-Soi Wat Chet Yod	✓	S		✓			
3	Klong Chonpratan Road - Soi Chet Yod Khian…		F		✓			
4	Hadsadhi Sawee Road-Chang Phuak Soi 4		F		✓		✓	
5	Mahidol Road - Haiya Road		S		✓		✓	
6	Thipanet Road - Wua Lai Road		S		✓		✓	
7	Chiang Mai Land Road-Aom Muang Road		S		✓			
8	Chiang Mai Land Road/Soi 15-Chang Klan Road		S		✓		✓	
9	Rakhang Road - Kamphang Din Road				✓		✓	
10	Rattanakosin Road - Trat Wong Road	✓	S		✓		✓	
11	Rattanakosin Road - Bumrung Rat Road	✓	S		✓		✓	
12*	Huay Kaew Road - Hadsadisawee Road	✓			✓			
13*	Charoen Muang Road - Charoen Rat Road			✓	✓	✓		
14+	Ratchawithi Road-Ratchaphakhinai Road	✓			✓			
15+	Ratchawithi Road - Phra Pokklao Road	✓		✓	✓	✓		
16+	Inthawororot Road - Singharat Road	✓			✓			
17+	Phra Sing Road - Phra Pokklao Road				✓			
18+	Super Highway - Charoen Muang Road	✓		✓	✓			
19	Chang Khlan Road - Loi Kroh Road[3]		S		✓			
20	Rot Fai Road - San Na Lung Road[4]				✓			

Notes: 1) (*) sign attached to No. denotes existing ATC signal, while (+) existing isolated signal.
2) S denotes signal is required and F denotes warning flasher is required.
3) Traffic management measures in Night Bazaar Area are separately discussed.
4) Railroad crossing improvement to be carried out by State Railway of Thailand.

Source: This study



Source: This study

Figure 3-1 20 Selected Intersections

3.3 Traffic Signal System Improvement

(1) Change Detector Configurations

To improve the balance of queue lengths and to reduce wasted green time, the configuration of detectors needs to be changed. Detectors should be installed every 100–200 m from the stop line to measure queue length. To detect right-turning vehicles, a detector in the right-turn lane is essential for more accurate control.

(2) Resolve Phase Plan and Sign Conflicts

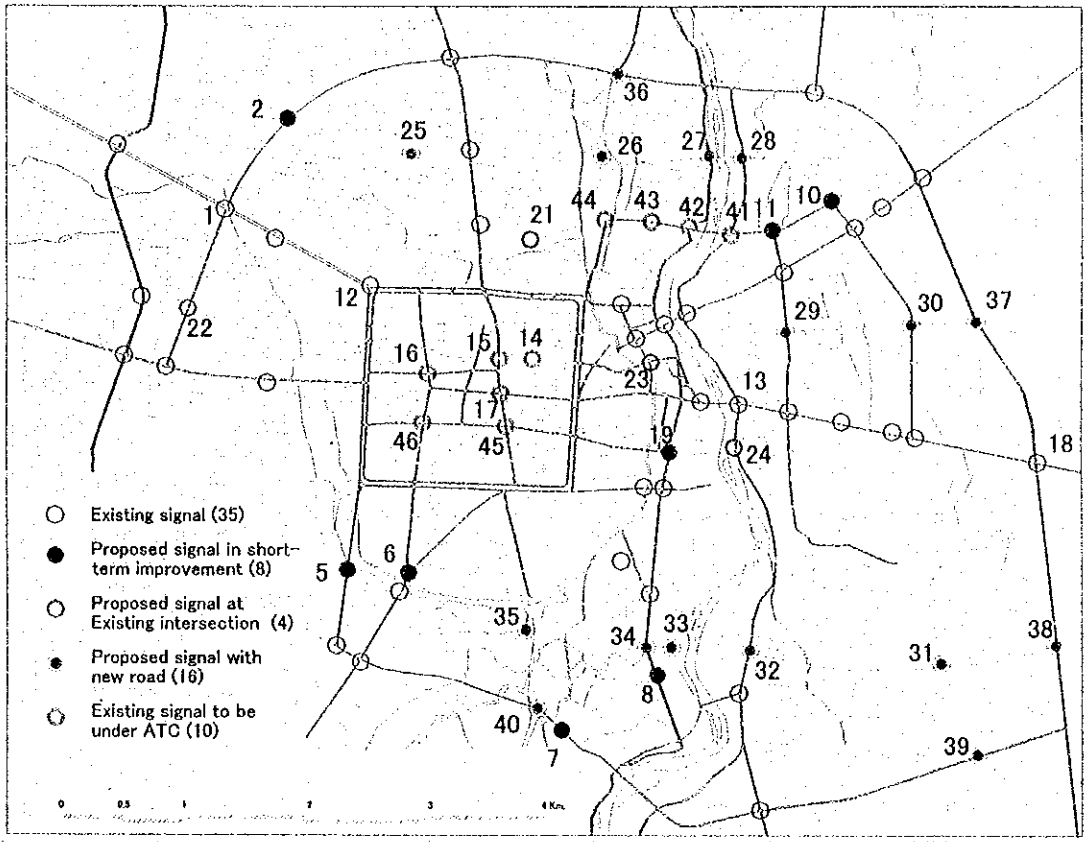
All phase plans at intersections should be reviewed to find out if there are any conflicts. Improvements to the existing plans should be flexible enough to be implemented quickly and without delay. The process of approving such plans and other installation designs should be kept clear. Furthermore, documents pertaining to the intersection design should be filed properly and any resulting construction or amendments to the configuration should be clearly noted.

(3) Improve Maintenance System

The biggest problem related to signal system maintenance is the low MTBF (Mean Time Between Failures). To reduce the failure rate, analysis of all failures should be commenced. Also, with the adoption of a more refined system, so-called preventive maintenance regimes could be adopted and the resulting MTBF would be improved.

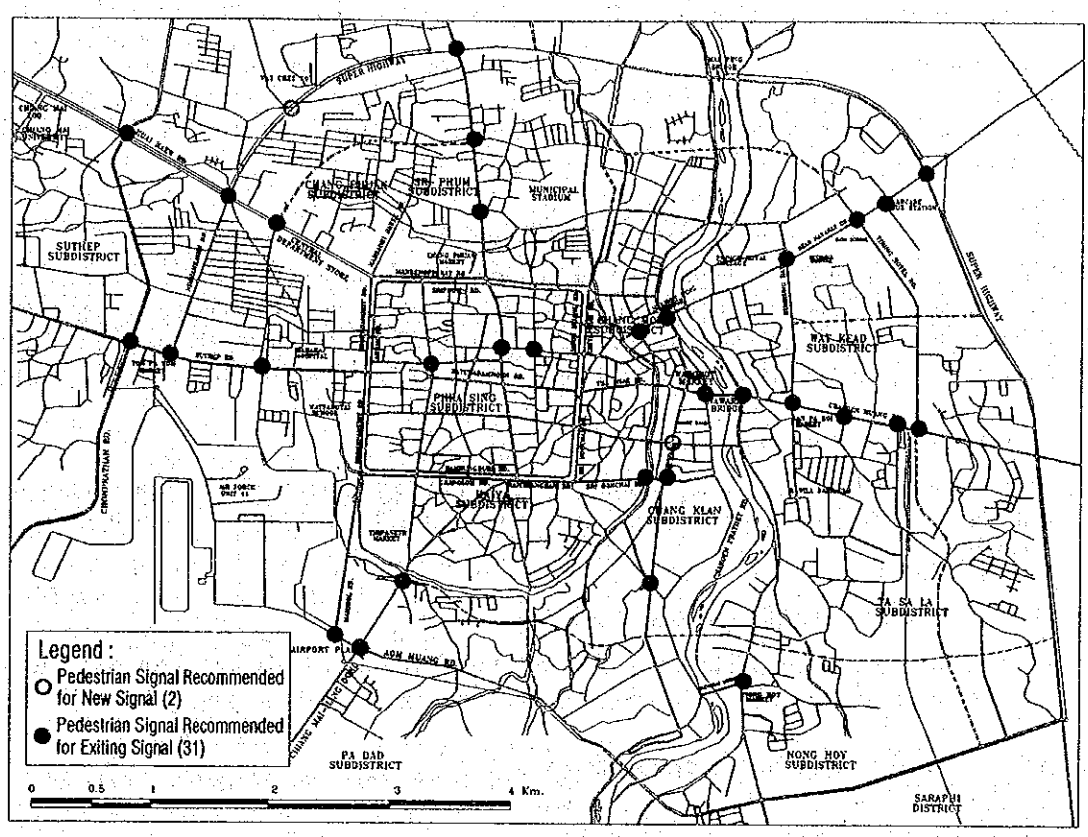
(4) Install Additional Signals

More signals are needed as summarized in Figure 3-2 and 3-3. There are three types of improvement namely, 1) installation of new signal, 2) upgrading of existing isolated signal to ATC signal, and 3) installation of pedestrian lantern.



Source: This study

Figure 3-2 Proposed New Signals



Source: This study

Figure 3-3 Proposed New Pedestrian Signals

(5) Upgrade Signal Control Software

The current SCOOT system is not responding adequately to heavy traffic conditions and long queues appear. The SCOOT system could be improved to solve this problem, but this would take time and money. On the other hand, there are new signal control technologies such as MODERATO developed in Japan, which has the standard function of balancing queue lengths even at heavy traffic periods. From this standpoint, the partial implementation of MODERATO system should be considered.

3.4 Traffic Safety Enhancement

(1) Change Name of Super Highway and Speed Limit

Super Highway is the most dangerous road in Chiang Mai. As one of the measures to enhance its safety, the Study Team recommends changing the name of Super Highway to Inner Ring Road. It is also recommended to reduce the speed limit from 90 km/h to 60 km/h for 300 meter on the approach and for 200 meter on the exit of intersections.

(2) Pedestrian Environment Improvement

A number of measures are required to improve safety of sidewalks. These include setting up a maintenance program for sidewalks, upgrading sidewalks, installing additional pedestrian lanterns and crossing signals, installing refuge islands, and improving driver education with regard to pedestrian rights of way.

(3) Traffic Signs and Pavement Markings

The basic reason for the inadequacy of road signs and markings in the Municipality is a lack of national standards and installation guidelines. The Study Team recommends development of Road Signs and Marking Manuals. Strict compliance of marking materials to Thai Industrial Standard 542-2530, which stipulates thermoplastic materials for road markings, must be ensured.

(4) Other Traffic Safety Devices

Other recommended devices are guardrails along narrow sidewalks, road mirrors at intersections with poor visibility, improvement of reflectivity of concrete barriers as well as standing pins and guardrails.

(5) Pedestrian and Bicycle Network in Old City

A bicycle/pedestrian network plan should be developed within the Old City to provide a safe and comfortable environment for both locals and tourists.

3.5 Public Transport Improvement

(1) Promote Coordination among Agencies

The attitudes of public transport operators (primarily between *songtaew* cooperatives and minibus cooperatives) must shift from one of confrontation and in-fighting, to one of cooperation and collaboration. They need to unite to form a powerful political block to push ordinances or legislation that favors their operation and sustainability.

(2) Stricter Enforcement of Rules and Regulations for Public Transport

A first step towards improved enforcement/regulation of public transport is the reduction of the total number of red *songtaews* in operation. LTD should improve its license renewal/verification system and the number of vehicles operating on a particular route should be reduced. Another step would be the creation of a new organization to supercede or replace part of the functions and responsibilities of the LTD. As noted previously, it lacks "real" jurisdictional powers over the Chiang Mai Provincial Planning Office.

(3) Promote Corporate Management Style

The cooperative management style of the *songtaews* has contributed to a weakening of the enforcement capabilities of LTD. Accordingly, it is recommended that cooperatives corporatize themselves in which case more direct control will be asserted over drivers (mostly in the form of regulated working hours and fixed-route service networks) or divide themselves further into smaller cooperatives, based on the route.

(4) Standardize Vehicle Design

A standard "bus type" is envisaged for future bus services in Chiang Mai, especially if services are operated on a fixed route basis. It is recommended that a bus standard, fully compliant with

the technical specifications for public transport vehicles as set down under the Law of Transport Act 1979, be developed.

(5) Adopt Fleet Renewal Programs

In order to improve the quality of service and the level of safety while rationalizing the total number of bus units in operation, it is proposed that a maximum age for buses (chassis) be established. However, as individual companies are known to have great difficulty in obtaining the necessary financial guarantees (letters of credit, etc.), it is important that the Municipality and other related government agencies also lend adequate and appropriate support to a comprehensive fleet renewal strategy. The mandatory introduction of air-conditioned vehicles for the Red *Songtaew* Cooperative provides a good opportunity to reduce the number of redundant and deteriorated vehicles in operation.

(6) Feasibility Study of Bus Priority Measures

Assessments should be conducted to analyze the feasibility of bus priority lanes within the Municipality. Lanes in which buses have exclusive priority access are designated as "Bus-Only Lanes," and provide improved public transport service in terms of speed, reliability, frequency, and operational costs. Such measures would likely go into effect after fixed route bus networks are established.

(7) Secure Funding for Sustainable Operations of Public Transport

It is essential that financial strengthening of the public transport sector be improved to create more sustainable operations. Some suggestions included the ear-marking of fees related to public transport vehicle registration and terminal usage fees paid by operators towards the development of the public transport industry. For example, the privatization of terminal operations may contribute further towards increasing revenues. Furthermore the subsidization of gasoline purchases to keep them at stable price levels by the public sector as well as a vehicle leasing system operated by the public sector, would also serve to improve solvency.

(8) Private Financing for Transport Development

Partnerships with other private enterprises, outside of the transport-related realm, may be one solution to the funding problem that has historically arisen. Thus privately financed transport facilities and services may be introduced in Chiang Mai, from non-transport related sources.

Examples of privatization in the public transport sector are shown below:

- The construction of joint-terminal facilities (i.e. all *songtaew* cooperatives hubbed at one location) at large supermarkets for school-based transfer trips to/from the suburbs.
- The construction of separate terminals for red, white, and yellow *songtaews* to eliminate route duplication. As public funding for such construction is lacking, however supermarkets could provide basic terminals within their parking lots.
- The creation of new transport routes to/from the supermarkets (fully or partially funded by the supermarkets themselves of course) to give customers direct access to their stores.

3.6 Other Traffic Management Measures

(1) Parking Facilities Improvement

Although currently not a problem, parking may soon become a particularly significant issue

increasing traffic congestion if vehicle ownership rates continue to increase along with economic development and per capita wages. In order to deal with the expected demand, the Study Team recommends the following measures.

- A reduction in parking supply or higher parking fees will not reduce vehicle usage by themselves. It is recommended that an adequate supply of parking must be ensured to avoid worsening congestion.
- A parking management policy must be formulated, based on estimates of future modal shares.
- A review and possible revision of on-street parking regulations is necessary.
- Both public and private sectors should contribute to the supply of parking. Parking must be supplied by the private sector, while the public sector may supply parking where the private sector is unable/unwilling to do so.
- The Municipality and the Traffic Police must reach a consensus on a unified approach and vision for parking in Chiang Mai.

(2) Traffic Safety Measures for Motorcycle

The following measures are recommended for improvement of motorcycle safety:

- Strengthening of enforcement of motorcyclists such as the introduction of more stringent punishment.
- Improving public support and awareness through the use of public relation campaigns.
- Promote safe driving and introduce safety education at school.
- Adopting more stringent measures for license application and renewal.
- Introducing education and counseling for repeat offenders involved in serious accidents.
- Enforcing regulations and rules, especially the compulsory use of safety helmet for motorcyclists,
- Adopting additional measures to improve motorcycle safety including systematic widening of road shoulders to accommodate motorcycle traffic, as well as better enforcement of speed limits for other vehicles.

(3) Traffic Accident Investigation and Recording System

A better traffic accident recording system is required in Chiang Mai. The objectives are:

- To construct a computerized traffic accident data processing system that quickens the compilation of traffic accident records, statistical analyses, and reporting; and
- To undertake a comprehensive macro and micro-analysis when formulating various mitigation measures.

(4) Traffic Management Around School Areas

Measures proposed to improve traffic around schools are:

- Collective Services - The Study Team proposes that morning service for trips from suburban areas shall be offered as a first step of collective transport service adoption. According to the interview with officials from the Red Bus Cooperative as well as nearby supermarkets, both have a positive opinion towards participating in such participation.

- One-Way System - An alternative one-way system is proposed for the Chang Klan Area to improve traffic congestion and safety. Essentially, the proposal will utilize Soi 12 as a new

entrance for Charoen Prathet Road for both Sacred Heart and Monfort School, so that traffic may be distributed in two different directions.

(5) Traffic Management in Night Bazaar Area

The pedestrian environment must be improved to increase the attractiveness of the Night Bazaar Area. The following measures should thus be examined:

- Adopting outright or partial restrictions (according to time of day) on vehicle traffic[5]
- Adopting improved means of controlling vehicle speeds such as installing signals and/or speed humps
- Installing pedestrian signals
- Prohibiting vehicular parking
- Allotting adequate sidewalk space for pedestrian to walk comfortably
- Decreasing curb height between sidewalk and roadway
- Leveling sidewalks to create a flat, consistent, and contiguous surface
- Extending pedestrian crossings

(6) Traffic Demand Management

It is likely in the *short-term* that the following TDM initiatives will have the greatest effect upon improving the traffic congestion situation in Chiang Mai and potentially stemming the high growth of private vehicles on its roadways (not in any particular order):

- Improvement and the creation of existing/new transfer/interchange facilities
- Vehicle restrictions such as limits on the issuance of permits as well as the prohibition of certain vehicles from busy urban areas
- Encouragement of car-pooling and ride share facilities.
- Increased provision of parking meters as well as higher parking fees
- Establishment of public relations campaigns to alert the public to the problems posed by traffic congestion
- Establishment of a fuel tax

3.7 Environmental Improvements

A summary of recommendations to improve the environment of Chiang Mai is as follows:

(1) General Environment

- Introduce Action Plan for Environment integrated with a Traffic Management Plan
- Consider earmarking special funds for environmental measures, possibly through parking income/fines.

(2) Air Quality

- Introduce Action Plan for Air Quality with quantifiable targets and verifiable indicators
- Reduce the qualifying age of vehicles requiring vehicle inspection (currently 7 years for motor cars)
- Allocate resources for Smog Verification Project to ensure permanent routine checking

[5] The Study Team regards banned vehicles in this instance to consist of motorcycles, private cars and small freight vehicles. Public buses and other forms of transport will be permitted however.

- Introduce publicity campaign to ban private engine re-tuning/tampering that causes pollution, with penalties for violators.
- Investigate dry suction road cleaning methods and consider purchasing specially-equipped vehicle
- Prohibit public retrieval and use of dust collected from road sweeping. Arrange environmentally acceptable method for disposing of such road dust
- Analyze deposited dust from road cleaning to determine sources and relative proportions

(3) Noise

- Review noise level standards to bring them into accordance with standards in other counties
- Prepare prioritized list of noise-sensitive locations for ameliorative measures, such as low noise pavement, noise barriers, and consideration of noise shielding in new property development

3.8 Priority Projects

Measures that do not cost much, that are relatively easy to implement without acquiring land, and are expected to yield benefits immediately, are considered high priority and must be implemented in the near future. More specifically, priority projects have been selected based on the following criteria:

- No land acquisition is required
- Project is ready for implementation
- Medium to large benefits are expected

Projects that meet the criterion above have been selected. They are listed below with estimated costs.

Table 3-3 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 -Done by Chiang Mai Municipality -Done by DOH	126.1 110.3 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

(1) Background

Implementation of one or more of the recommended traffic improvement measures during the study was envisaged as a pilot project. The purposes of the pilot project are to:

- demonstrate the effect of the recommended measures,
- reflect the results of the implementation to the measures to be recommended; and
- transfer the technology to counterpart agency.

Pilot projects are also beneficial to the counterpart agencies, as they can learn more about technical and management aspects of the measures through their actual implementation.

Criteria developed for the selection of a pilot project to be implemented, were as follows:

- consistency with policy and plans of Chiang Mai Police and Chiang Mai Municipality;
- traffic and pedestrian volume affected;
- size/ratio of expected benefits in terms of congestion alleviation and traffic safety improvement; and
- time required for implementation.

Several candidate projects covering different aspects of the traffic problems in Chiang Mai were conceived. Table 4-1 summarizes the candidate projects.

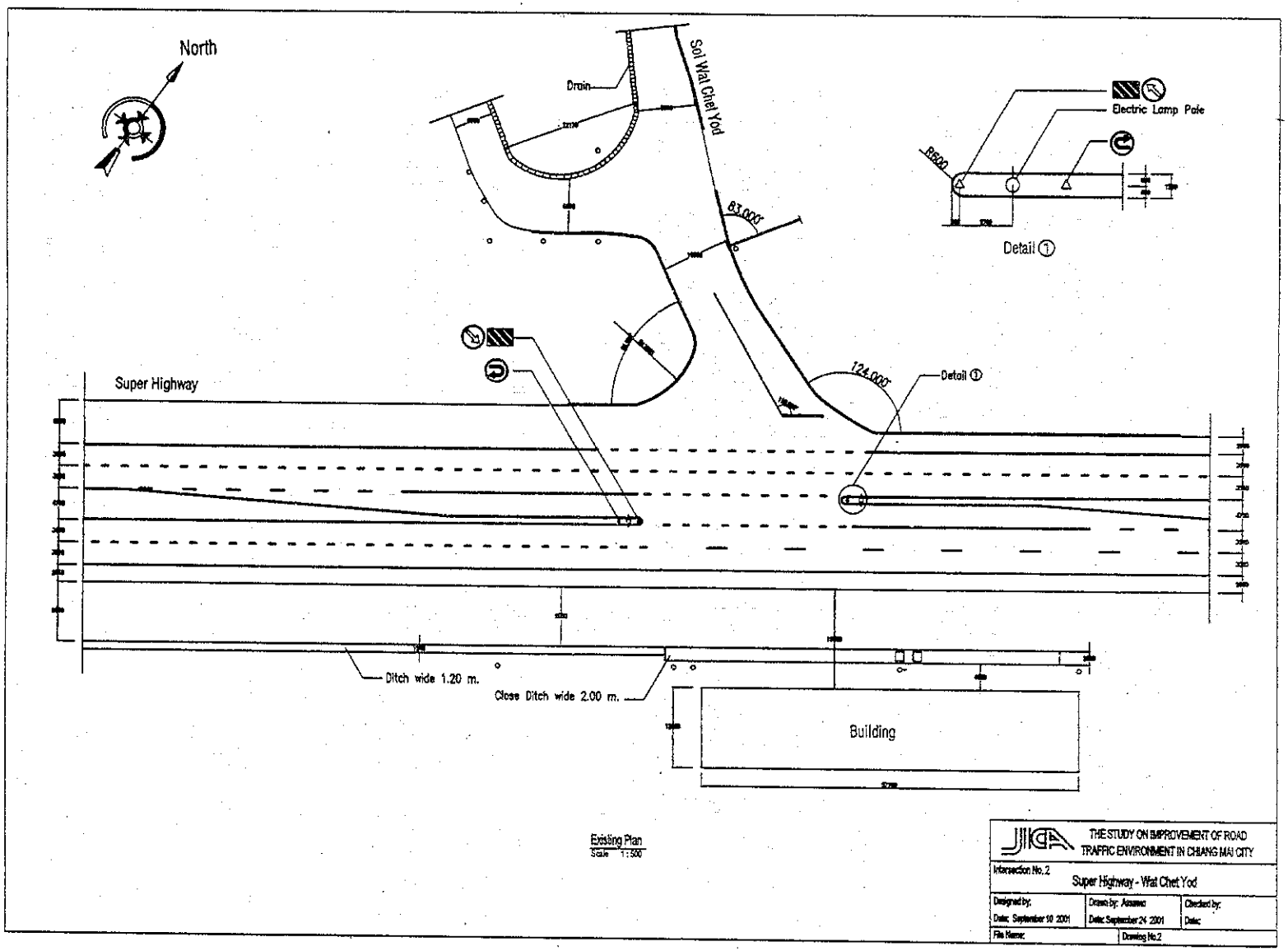
Table 4-1 Candidate Pilot Projects Considered

	Project	Contents	Candidate Location
1	New signal installation	Installation of new signal	Wat Chet Yod
2	Improvement of existing signal	Review of signal phase and timing	Several locations identified by the team
3	Geometric improvement	Modification of intersection geometry and layout	Several locations identified by the team
4	Transit/pedestrian mall	Conversion of road section to transit/pedestrian mall on a trial basis	Chang Khlan Road
5	Traffic improvement at school area	Various measures to ease congestion around school	Kaew Nawarat Road Charoen Prathet Road,
6	Traffic safety campaign	Promotion of the use of seat belt and helmet	City wide

Source: This study

Chiang Mai needs more traffic signals, and are urgently required at some locations. One such location was Wat Chet Yod intersection, where many accidents have happened. In addition, the traffic volume at this intersection is high and large benefits were expected from signalization. As the scope of work is clear and the number of agencies, among which coordination is required, is limited, implementation was considered to be relatively easy. For these reasons, installation of a new signal at Wat Chet Yod intersection was selected as a pilot project.

Figure 4-1 shows the layout of the intersection prior to improvement.



Source: This study

Figure 4-1 Existing Condition in Wat Chet Yod Intersection

(2) Recommended Improvement Measures at WCY Intersection

The intersection had poor geometry and the main improvements were thus:

- 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. Figure 4-2 shows the signal equipment for Wat Chet Yod Intersection and features of signal design are summarized below.

(a) Local Controller

A microprocessor based local controller with very high reliability was installed. The nominal MTBF (meantime between failures) is 50,000 hours, while the actual record exceeds 200,000 hours. The controller operates in an isolated mode and signal timing will be selected based on the time-of-day (TOD control) and day of the week. In addition, vehicle and pedestrian actuation is adopted for efficient signal operation. The nearest two intersections where traffic signal of ATC system is installed is Super Highway -Huay Kaew intersection and Super Highway -Chotana Intersection. They are 850 meters and 1.3 Kilometers away so that isolated operation was not a problem.

(b) Detector

Several different types of vehicle detectors were proposed. An ultrasonic vehicle detector was used for detection of vehicles and motorcycles at three locations. The advantage of an ultrasonic detector is that, unlike the inductive loop detector, it doesn't receive any physical force on its sensor so the device is not susceptible to damage and is therefore highly reliable. Adjustment of its sensing zone and relocation of detector are also easy. These detectors were used to detect the vehicles on Super Highway and right and U-turn vehicles.

To detect a group of motorcycles, a Doppler type ultrasonic detector was employed. Although this type of detector can detect motorcycles it can only detect moving objects. As it cannot detect the presence of motorcycles, it is installed several meters before the stop line. Also as an experiment, an image type vehicle detector was proposed. This detector was proposed to detect cars and motorcycle on the right turn lane on Super Highway.

(c) Lantern

A signal head using LED (light emitting diode) was installed. In addition to the uniform brightness of the lens, an LED type signal head has the advantage of a much longer life expectancy (up to 10 times compared with incandescent) and lower power consumption (up to 80% less against incandescent).

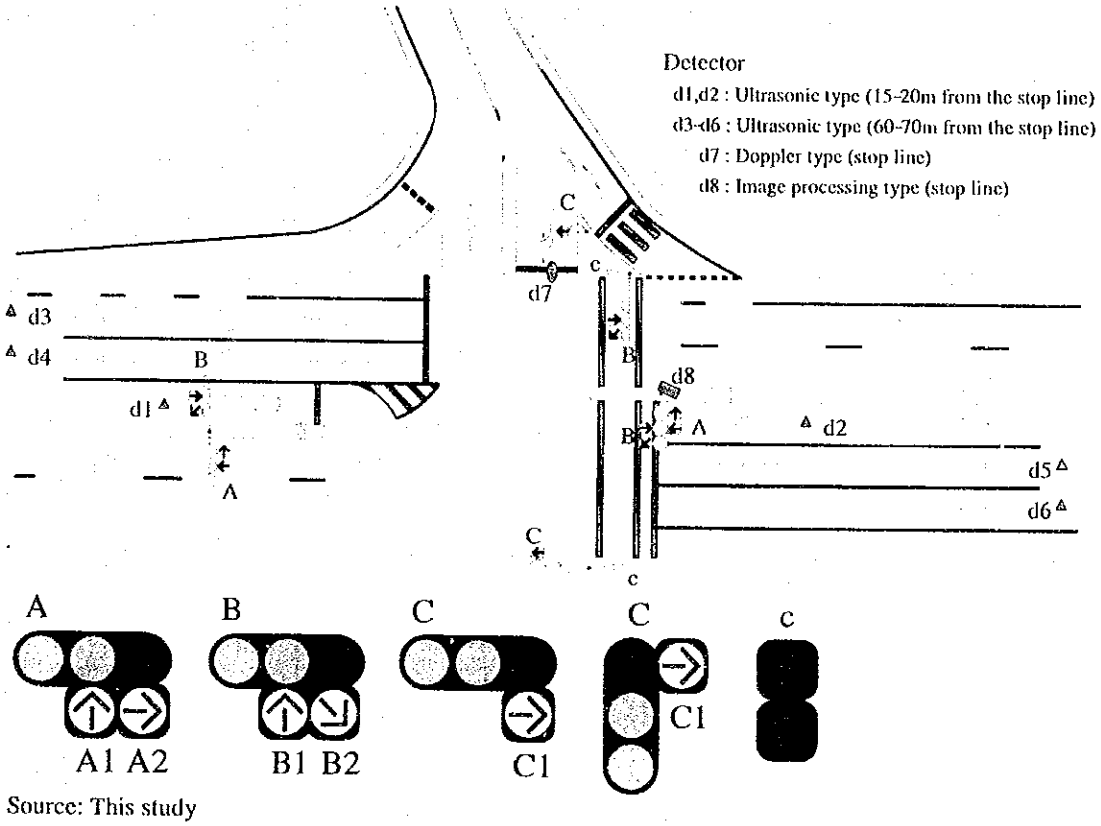
The primary/secondary signal layout was employed for all movements. The primary signal was

installed on the near side of the intersection at stop line, while the secondary signal was installed at the far side of intersection. An overhang pole with a long arm was used.

(d) Phase design

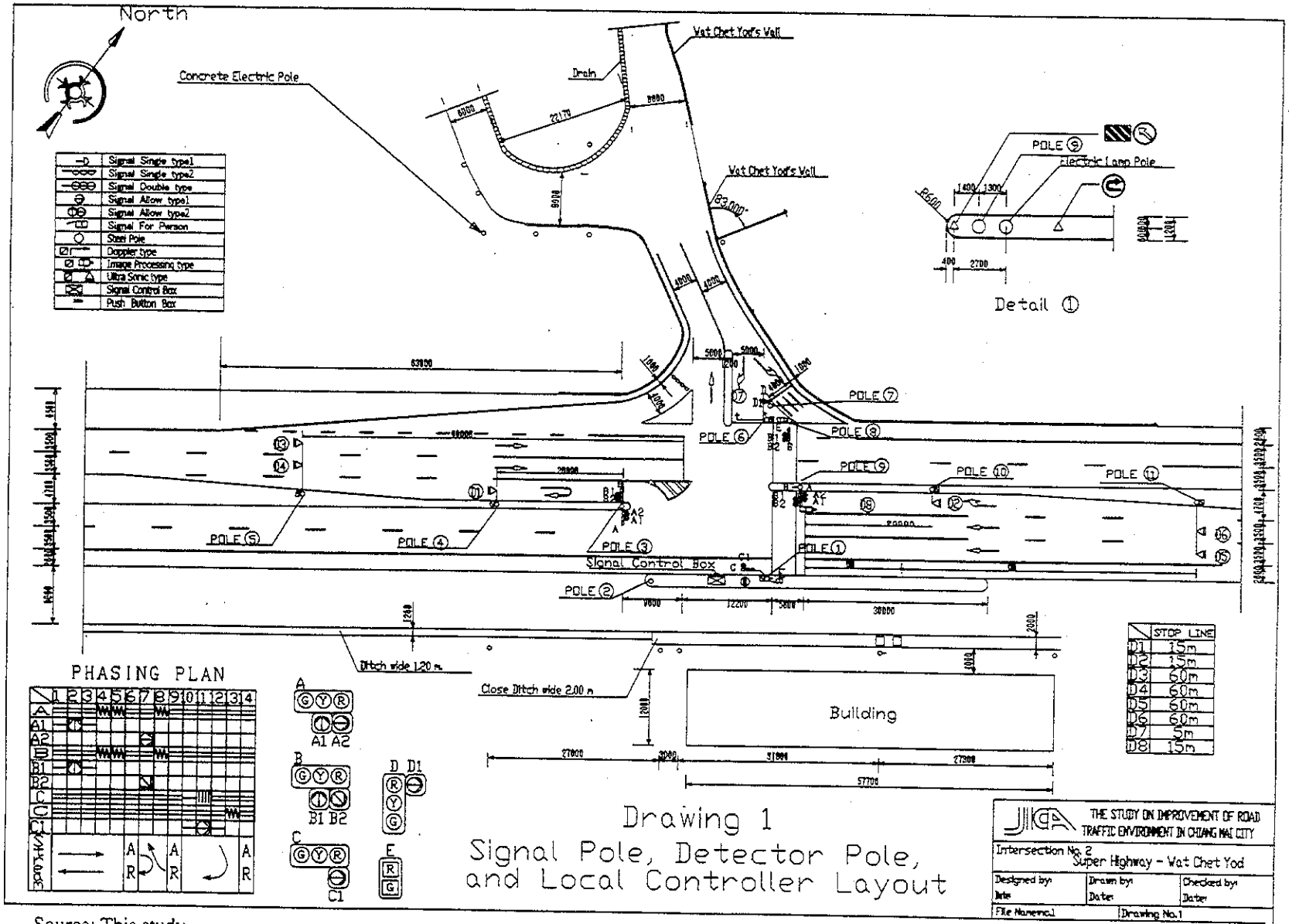
The vehicle detectors actuate every stage so that if there is few traffic, the stage moves to the next stage early, and if there are many vehicles, it prolongs the stage by a predetermined increment. The minimum and maximum time is also predetermined according to the time of day. For the pedestrians to cross Super Highway, push button actuated pedestrian signal was employed. If there is no pedestrian the pedestrian signal stays in red and length of the second stage is less than 20 seconds. If any pedestrian pushes the button, the pedestrian signal turns green for them to be able to cross the Highway safely. The time was estimated at 20 to 30 seconds. Vehicles from the Northwest could make a right turn to the Highway at the same time.

The adopted signal phase with a pedestrian consideration is shown in Figure 4-3. Vehicle actuation is employed at all stages while pedestrian actuation is used at the third stage. Pedestrian actuation enables safe pedestrian crossing by indicating pedestrian green long enough for pedestrian to cross. Efficient signal operation is maintained by suppressing the pedestrian green when there is no pedestrian demand.



Source: This study

Figure 4-2 Location of Controller and Detector



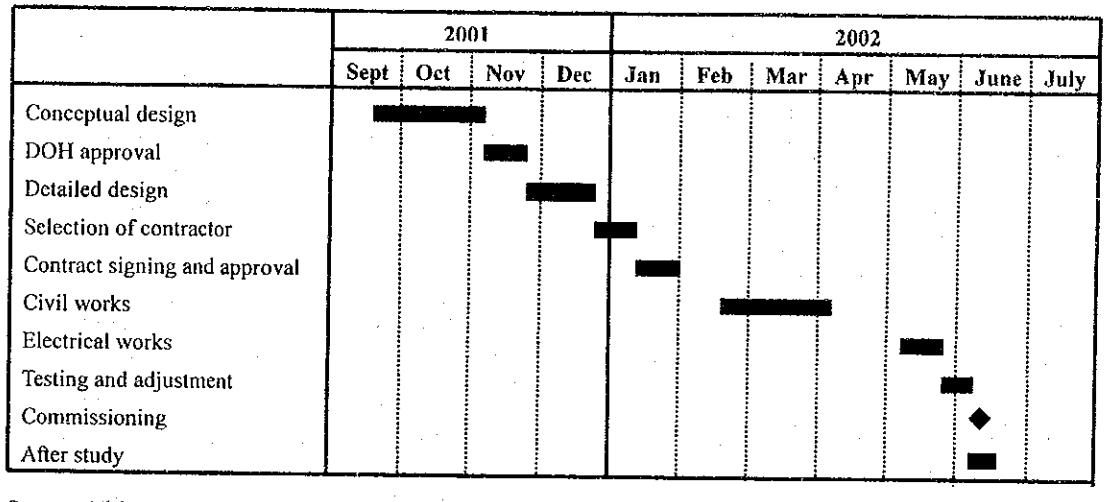
Source: This study

Figure 4-3 Signal Equipments for Wat Chet Yod Intersection

(3) Implementation Schedule

The pilot project was implemented according to the schedule shown in Table 4-3 below.

Table 4-2 Implementation Schedule of Traffic Signal



Source: This study

(4) Evaluation of the Pilot Project

Five kinds of surveys were conducted before, during and after the Pilot Project. The intersection turning movement survey was intended to check whether there was any change in traffic volume for the three survey periods. The results showed that the traffic volume remained at the same level with slight seasonal fluctuations.

The results of the other four surveys are briefly summarized in Table 4-4. Although, the average loss time at the intersection increased, there is a significant reduction in conflicts. As to queue length, the maximum queue length became longer but discharge time remains at the same level. These data imply that the traffic flow at Wat Ched Yod became more consistent and stable. Thus, a reduction in accidents can be expected. Such expectation is supported by the results of the interview survey. Before the project, drivers felt that the intersection was dangerous. After the project, however, more than 95% of drivers feel safer at the intersection and can make a turn more easily.

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

Table 4-3 Summary of Survey Results

Survey	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

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

Measures implemented are extremely effective for traffic safety

One of the reasons for the success is the well-prepared design. The Consultant spent time and exerted effort in the design of the measures taken in the Pilot Project. Base drawing was prepared by site survey and traffic volume was counted by traffic survey. Based on the intersection drawing and traffic volume data, the intersection geometry and signal were carefully designed. For future projects, it is hoped that similar efforts are exerted to achieve the intended objectives.

Drivers' behavior becomes more disciplined if intersection and signal are well designed

Before the project, the traffic condition at Wat Ched Yod intersection was chaotic. Drivers drove any path, even on the wrong side of facing traffic, and took risks to cross. The situation became orderly after the Project. It suggests that an unruly situation is sometimes created by a lack of or inadequate traffic and road facilities. Such conditions can be improved by well-designed traffic management measures.

On the other hand, there were also lessons on what could be improved.

Construction took much longer time than expected

The civil and signal works were expected to take two months to finish. In reality, however, it took more than four months, although there was one-month break due to contract renewal of the

Consultant. The main reason for such delay was inefficient arrangement by the inexperienced and poorly equipped contractor and sub-contractor. It is suggested that the qualifications of contractor including sub-contractors must be checked closely before the works are contracted out.

Quality of work was not satisfactory

Several sub-standard works were found during the Project, particularly in civil works such as curb and gutter, and pavement marking materials. Although these defects were eventually corrected, the Consultant had to spent more time at the site to supervise the work. It was also felt that quality was not regarded important among the contractor's staff and workers. More concern must be given to the quality of work.

The Consultant had regular weekly meetings with the counterpart agency staff during the Study to discuss various topics related to traffic management. The process of geometric and signal design at Wat Ched Yod was also explained and discussed in detail as the work progress.

Many staff from Provincial Police and Municipality eagerly attended the workshops held at the office and the site for operation and maintenance of the signal. They were generally very much interested in the signal, as it is different from those found at other intersections.

It is still not clear how much technology has been transferred to the counterpart and how much contribution has been made to enhance the traffic management skill of the counterpart agencies through these activities. It is sure, however, that the Pilot Project will play the role of a symbol for good traffic management. In conclusion, it can be said that the Pilot Project was a success.

5. Economic Evaluation of Selected Projects

5.1 WCY Intersection Improvement

Economic analysis shows that the intersection improvement work at Wat Chet Yod intersection, which includes modification of intersection geometry and the installation of a signal system, is expected to produce large benefits to the road users. By just estimating the monetary benefits that can be computed from the savings in delays by drivers, this benefit alone when compared to the cost of the project, is enough to produce favorable indicators such as B/C ratio, IRR and NPV; indicating that the project is highly economically viable.

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.

If other benefits, as discussed in this section, such as savings in damages to properties and lives from reduced accidents, improved levels of air and noise pollutions; are taken into account, the amount of benefits will be even much higher as those computed above and will produce even higher evaluation results.

5.2 Other Five Intersection Improvements

(1) Proposed Improvements to Five Intersections

Among the 20 intersections studied and analyzed in this Study, improvements for six intersections (Nos. 1, 2, 5, 7, 13, and 18) were deemed urgent. The intersection at Wat Chet Yod was selected as the Pilot Project. Two of the other five intersections are high accident prone intersections (Intersection Nos.5 and 7) while the other three have high traffic demand and their efficiency can be improved by reviewing their signal timing plans or adoption of geometric improvement or traffic regulation measures.

Improvements to Intersections No.1, 5, 7 and 18.

Four of the five high priority intersections identified for priority improvements are under the DOH management as they are located along Super Highway. These are:

Table 5-1 Four Intersections for Improvement Under DOH Management

Inter-section No	Name of Roads	Present Control	Major Problems	Proposed Improvements
1	Huay Kaew Road with Super Highway	Signal control under ATC	Incompatible number of exit and entry lanes.	Shifting of median to increase one right-turn lane on Super Highway, and adjust signal timing
5	Mahidol road with Haiya Road	No signal	High potential accident point, high speed on Mahidol	Signalization, and improvement of geometry on minor road
7	Chiang Mai Land road with Super Highway	No signal	High potential accident point with high speed traffic on Super Highway	Signalization, improvement with right-turn lane on Super Highway, removal of gate
18	Charoen Muang Rd with Super Highway	Signalized under ATC control	Very heavy traffic during peak hours	Widening of approach on Super Highway, and signal timing and phasing improvements

Notes:
1) The study team submitted the proposed improvement measures to the DOH of Chiang Mai District 2 and received the following comments.
- DOH is in agreement with the proposed improvement measures at the above four intersections.
- However, DOH wishes to amend the length of the right turn lane on Super Highway to Chiang Mai Land from the recommended 70m to at least 100 m, on account of the long queue on Super Highway during peak hours.

2) DOH placed median barrier and closed intersection No. 7 in May 2002.
Source: This study

Improvement Measures at Intersection No.13

Besides the above four intersections, the other intersection that warrants short term improvement is No.13, which is under the management of the Municipal Council of Chiang Mai.

Table 5-2 Intersection No.13 Improvement Under CMM Management

Inter-section No	Name of Roads	Present Control	Major Problems	Proposed Improvements
13	Charoen Muang Road with Charoen Raj Road	Signal control under ATC	Space constraint but intersection and signal efficiency may be improved by removing minor movements.	Prohibit right turn traffic from east approach. Signal phasing and timing modification.

Source: This study

For the improvement and/or signalization of the proposed five intersections, the total project cost is estimated at Baht 25.4 million. This cost is comprised of intersection geometric improvement cost, signal equipment and installation cost or improvement cost; maintenance and operation costs for 10 years.

Maintenance cost for the proposed project is assumed to be 5% of the total equipment costs. This cost item is the cost of spare parts and repairs. Operation cost of the improved intersection is taken to be the cost of utilities and is assumed to be 2% of the equipment cost.

Comparing the estimated benefits from savings in VOC and person time cost above, with the estimated costs for improvements at each of the five intersections, the simple B/C ratios are computed as shown in the table below. Assuming a discount rate of 12 percent, the IRR and NPV are also computed.

Table 5-3 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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