Chapter 4

Road Network and Intersection Issues

4.1 Present Road Network Configuration

This chapter discusses the road network system in Chiang Mai city and the traffic situation at the time of this Study. Traffic volumes on the existing road network have been reported in Chapter 2. This chapter however highlights the deficiency of the road network, traffic congestion prone road sections and intersections in the city. General issues on the network and intersections are then summarized.

(1) Radial and Ring System

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. From the four major cardinal points are ancient gates that give rise to the major radial roads (see Figures 4-1 and 4-2).

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. This is an area with a radius of about 2.5 km to 4 km from the old city center.

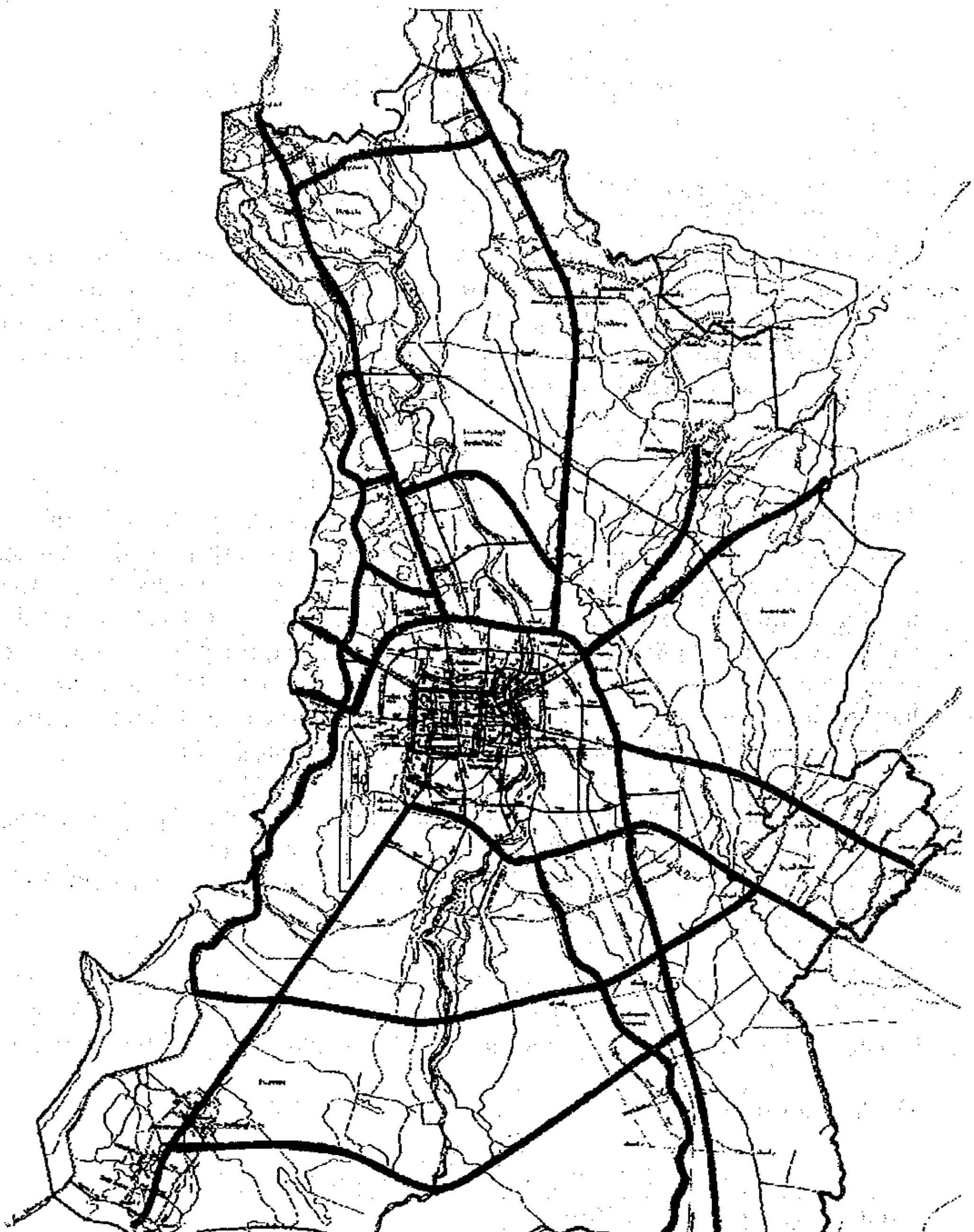
The Outer Ring, which is nearing completion (expected by 2002), is much further out at about 8 to 10 km from the city center, and demarcates the main city planning area of Chiang Mai. Between this Outer Ring and Super Highway is the Middle Ring Road.

The 8 major radial roads in Chiang Mai are shown in Table 4-1.

Table 4-1 Major Radial Roads in Chiang Mai

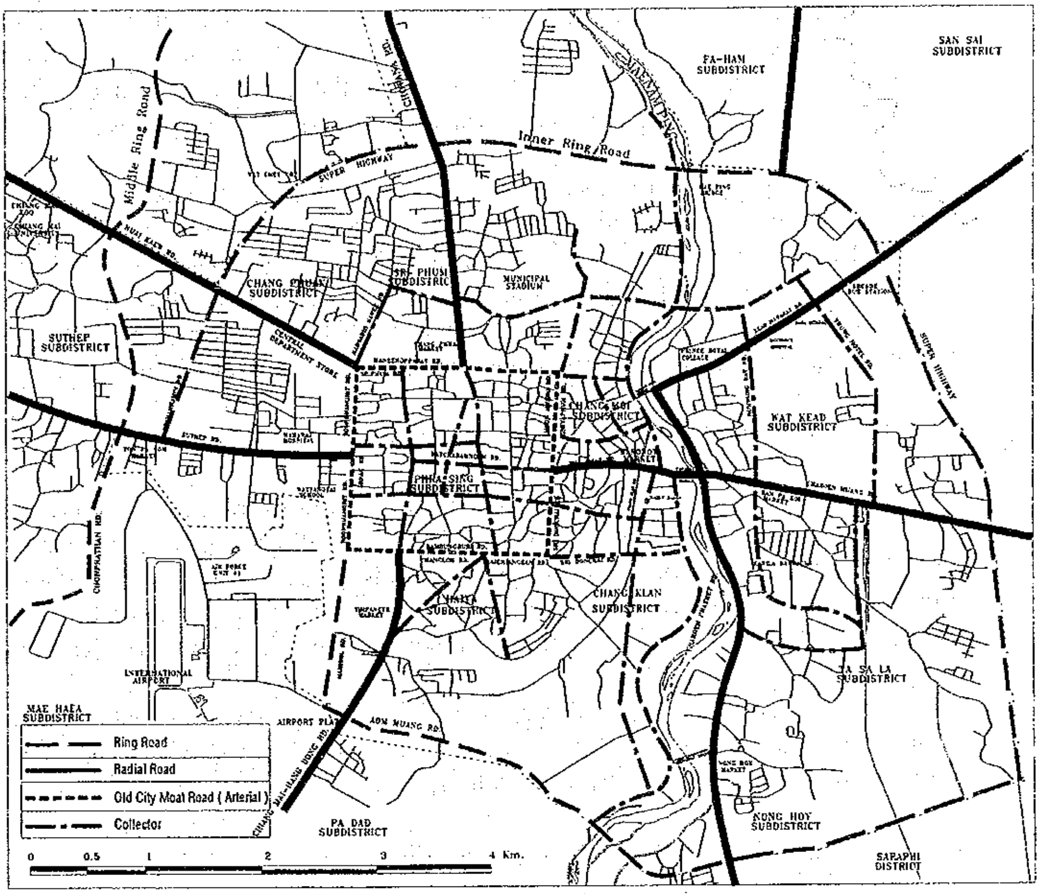
Area of the City	Radial Road
North	Chotana Road which continues as Route No.107
	Mae Jo Highway (Route No. 1001)
East	Charoen Muang Road, which continues as Route No.1008 to San Kamphaeng District
	Kaew Nawarat Road
South	Hang Dong Road, which continues as Route No.108
	Lamphun Road, which continues as Route No.106
West	Huay Kaew Road
	Suthep Road

Source: This study



Source: This study

Figure 4-1 Existing Road Network in Chiang Mai Region



Source: This study

Figure 4-2 Existing Road System in City Area

(2) Collector and Access Roads

These ring and radial roads carry most of the city traffic and are the arterial or primary roads. The old city moat roads are a pair of one-way streets on both sides of the moat, functioning as an important arterial road. Structurally, it is a divided 6 lane primary road with right turn only connections between the two roadways. This road carries high traffic throughout the day as traffic tends to converge from the radial roads and then distribute via this road.

The Super Highway is a high-grade 6 lane divided road with both grade separated and signalized access controls. The radials are mostly 4-6 lane divided roads. While the rings and radials are major traffic thoroughfares, the next category, the collectors, is important for distributing traffic into the smaller access roads.

In Chiang Mai, this group of collector roads is conspicuously inadequate (see Figure 4-2). The result is that many smaller access roads connect directly to the major thoroughfares without first linking to the collectors. Chotana Road is a good example of a major arterial that has many access points from minor access roads on both sides.

Traffic to and from these numerous access roads disrupts the otherwise smooth flow of the main traffic on Chotana Road. Bumruang Rat Road and Thung Hotel Road, are good examples of the type of collector roads that are required to distribute the high traffic volume from the major road to the access roads.

Due to this inadequacy of collector roads, many minor access roads, which are narrow and winding, are in fact functioning as collectors. A series of access roads, for example, Haiya Road, Sripingmuang Road, S4 Road, Pracha Samphan Road, between Mahidol Road and Chang Klang Road, functions as a collector on the east-west axis. It is considered that the city must extensively expand the number of collector roads within the network in order to better distribute traffic and improve its flow.

(3) Effects of 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.

Presently, there are 8 bridge linkages over the Mae Ping River, as listed below, of which 6 are solely for vehicular traffic, one is for limited types of traffic as well as one footpath for exclusive pedestrian/bicycle usage.

- Super Highway North Bridge – 6 lanes divided
- Phakiat Rama IX bridge – 4 lanes
- Nakhon Phing Bridge – 4 lanes
- Ton Lamyai Market Footbridge (pedestrian/bicycle only)
- Nawarat Bridge – 4 lanes
- New Bridge -- 2 lanes (truck prohibited and one way west to east only)
- Mengrai Bridge – 2 lanes
- Super Highway South Bridge – 4 lanes divided.

Of the above linkages, traffic bottlenecks are most obvious on Nakhon Phing Bridge and Nawarat Bridge and to a lesser extent, on Mengrai Bridge and Rama IX Bridge. The former two bridges are close to the city's CBD and commercial (Warorot Market) area and thus carry large commuter and business trip traffic throughout the day. Nakhon Phing Bridge is also narrow and thus creates a bottleneck.

Based on the traffic survey results, it is estimated that the major 6 bridges (except the footbridge and one way new bridge) carry about 360,000 vehicles a day in both directions.

4.2 Congestion Prone Road Sections and Intersections

Due to the peculiarity of the traffic demand pattern, flow and road network, some road sections are more congested than others. This section identifies some of the more congestion-prone road sections according to certain times of the day (see Figure 4-2).

During morning/evening peak hours, the following roads are congestion-prone:

- Charoen Muang Road including Nawarat Bridge from Bumrung Rat Road
- Taphae Road
- Keow Nawarat Road, especially Nakhon Phing Bridge and section between Super Highway and Thung Hotel Road,
- Warorot Market New Road/Wichayanon Road
- Boonruang Rit Road / Arak Road especially near intersection with Suthep Road
- Chiang Mai-Lamphun Road
- Wua Lai Road
- Hong Dong Road

Morning and evening school traffic also causes congestion along the following road sections:

- Chang Klang Road
- Charoen Prathet Road
- Rakaeng Road
- Keow Nawarat Road

Morning school traffic congestion occurs earlier than the normal commuter traffic, commencing from 6.30am to 8.30 am and then in the afternoon from 3.30 to 5.30 pm. Congestion due to school traffic is short-lived and is more severe or concentrated in the morning compared to the evening. The general public is very aware of such routine congestion at these school areas, and consciously avoids such road sections during those hours.

It follows that intersections of the above congestion prone road sections also face large traffic demand and hence congestion. Intersections that face some delays especially during peak hours due to sudden very large traffic demands are:

- Charoen Muang Road with Charoen Raj Road
- Super Highway with Charoen Muang
- Kaew Nawarat Road with Charoen Raj Road
- Huay Kaew Road with Boonruang Rit Road
- Chang Klang Road with Sri Donchai Road
- Lamphun Road with Super Highway

The above observations are further substantiated or reflected by the estimated total daily traffic volumes at some 26 locations throughout the city.

(1) Estimated Daily Traffic Volume on Selected Road Sections

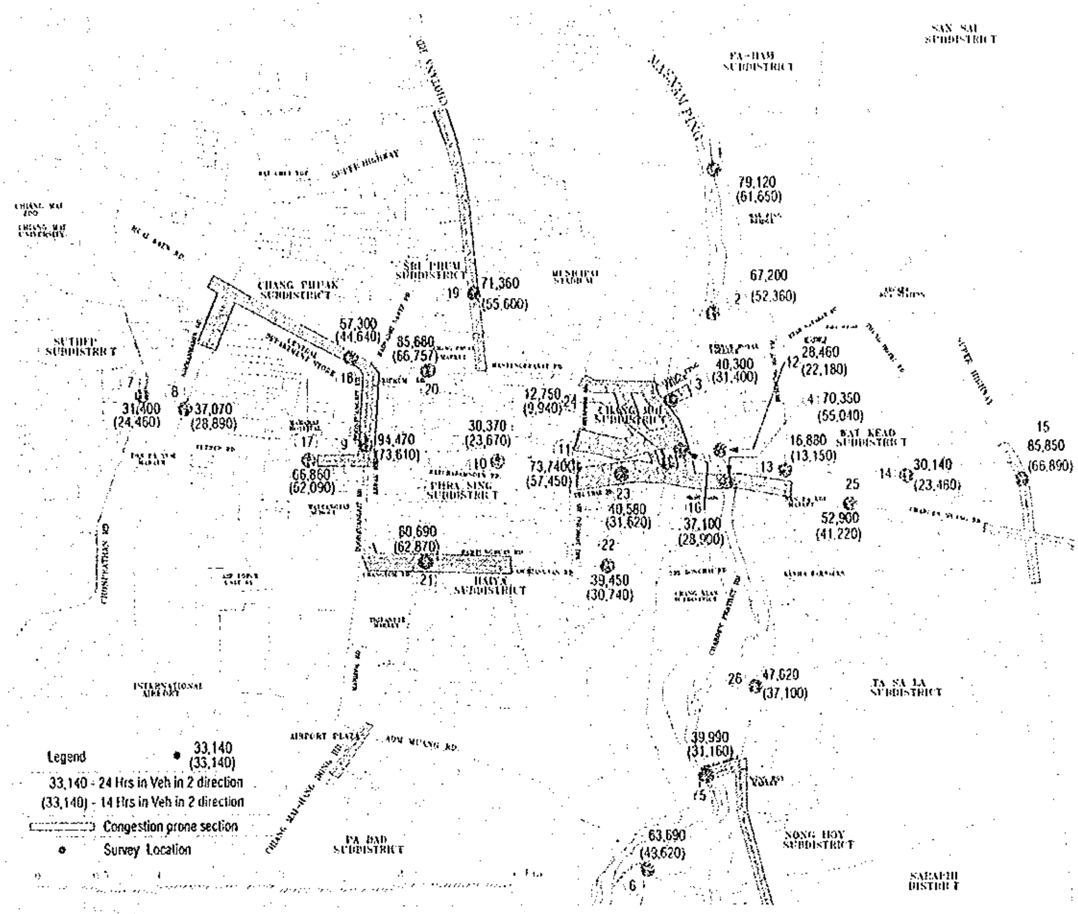
A classified cross sectional traffic survey was conducted at 26 locations as described in Chapter 2. One location was surveyed for 24 hours (TC4), five locations for 14 hours (TC3, 9, 11, 12, and 15) and the others for 8 hours only (morning and evening peak hours). For the latter group, the traffic volume for 14 hours is first estimated using the average ratio of the peak hour traffic to the 14 hour traffic for the 6 locations in the other groups. Then using the ratio of 24/14 hours traffic for TC 4, the 14 hours traffic volumes are further expanded into 24 hours daily traffic volumes. The average 8 hour peak traffic was found to be about 62% of the total 14 hour traffic volume; while the 14 hour traffic is 78% of the total daily traffic volume.

Based on the estimated traffic volumes, the total east-west movement traffic across the Mae Ping River Screen Line within the ring road was found to be about 360,650 veh/day. Of the 6 major bridges over the Ping River, the largest volume is found on Super Highway North Bridge at 79,120 veh/day, followed by Nawarat Bridge at 70,350 veh/day, Rama IX bridge at 67,200 veh/day, and Super Highway south bridge at 63,690 veh/day. Although Nakhon Phing and Mengrai Bridge both have only about 40,000 veh/day, they are congested due to the narrow structure. Due to differences in design capacity, traffic congestion and delays are particularly conspicuous on Nakhon Ping and Nawarat Bridge during the peak hours.

The total North-South traffic movement across the major roads in the city at an east-west screen line was found to be about 465,480 veh/day. High traffic volumes are found on the eastern and western sections of one way roads flanking the old city moat, Chotana Road, Hang Dong Road and the eastern section of Super Highway. Similarly, due to design capacity, congestion is more conspicuous on Chotana Road and the old city moat roads.

The old city moat ring road carries a very high traffic volume throughout the day. It ranges from 73,700 veh/day in both directions on the eastern section to 94,500 veh/day on the western section (see Figure 4-3). Super Highway carries similarly high traffic ranging from 55,000 veh/day in both directions near Wat Chet Yod area to 85,900 veh/day near Chareon Muang Juction. Among the radial roads, Chotana Road carries the highest volume per day of more than 71,000 vehicles in two directions, followed closely by Chareon Muang Road and Suthep Road.

Table 4-2 shows the traffic volumes observed at the 26 survey locations.



Source: This study

Figure 4-3 Daily Traffic Flow

Table 4-2 Estimated Daily Traffic Volumes at Road Sections

Survey Location	Name of Road	Peak 8-Hour	14-Hour Traffic	24-Hour Traffic	Remarks
TC-1	Super Highway (North Bridge)	38,026	*61,650*	*79,120*	
TC-2	Rattanakosin Road (Rama IX Bridge)	32,297	*52,362*	*67,200*	
TC-3	Keao Nawarat Road (Nakhon Ping Bridge)	19,636	31,403	*40,300*	
TC-4	Charoen Muang Road (Nawarat Bridge)	34,391	55,042	70,351	
TC-5	Mengrai Bridge	19,221	*31,162*	*39,990*	
TC-6	Super Highway (South Bridge)	30,608	*49,623*	*63,690*	
TC-7	Canal Road	15,089	*24,463*	*31,400*	
TC-8	Ninmanhemin Road	17,817	*28,886*	*37,070*	
TC-9	Bunruangrit/Arak Road	44,837	73,608	*94,470*	
TC-10	Phra Pokklao Road	14,598	*23,667*	*30,370*	
TC-11	Moonmuang/ Chayaphum Road	35,139	57,454	*73,740*	
TC-12	Charoen Raj Road	13,741	22,178	*28,460*	
TC-13	Bumrung Rat Road	8,111	*13,150*	*16,880*	
TC-14	Thung Hotel Road	14,484	*23,482*	*30,140*	
TC-15	Super Highway (near Makro)	41,070	66,894	*85,850*	
TC-16	Praisanee Road	17,828	*28,904*	*37,100*	One way
TC-17	Suthep Road	32,132	*52,094*	*66,860*	
TC-18	Huay Kaew Road	27,537	*44,644*	*57,300*	
TC-19	Chotana Road	34,294	*55,600*	*71,360*	
TC-20	Maneenoparat/Sriphum Road	41,176	*66,757*	*85,680*	
TC-21	Bamrungburi/Changloh Road	38,779	*62,870*	*80,690*	
TC-22	Sri Donchai Road	18,959	*30,737*	*39,450*	
TC-23	Taphae Road	19,505	*31,623*	*40,580*	One way
TC-24	Witchayanon Road	6,128	*9,935*	*12,750*	One way
TC-25	Charoen Muang Road	25,424	*41,220*	*52,900*	
TC-26	CM-Lamphun Road	22,884	*37,100*	*47,620*	

Notes: 8 hrs: (6-10 am,4-8 pm), 14 hrs: (6 am – 8 pm).
Figures in *italics* are estimated volumes, others are actual counts.
Source: This study

(2) Super Highway

Super Highway plays an important role in bypassing most of the regional traffic as well as distributing most cross-city trips. This Super Highway is peculiar in its functions as well as design.

Super Highway was constructed and managed by the Department of Highway (DOH) and actually consists of two separate roads, the northern and eastern sections being Route No.11 (10.6 km) and the south section, locally called Aom Muang Road (meaning bypass) and Mahidol Road, is Route No.1141 (7.4 km). Both of these roads intersect at a large interchange called the Lampang Interchange at the south-east corner. Route No.11 continues down towards the south to Lampang Province. The Super

Highway is therefore 18 km long but does not actually constitute a complete ring due to the location of the International Airport to the west.

Super Highway is basically designed as a high grade 6 lane divided road on raised foundations with wide shoulders and open drainage on both sides. For the northeast section, service roads on both sides of the highway are also constructed. Grade separations are provided at the Lampang I/C, over the railway tracks, over Chiang Mai-Lamphun Road (Route 106), over the Ping River (2 bridges in the north and south), and over Hang Dong Road (Route 108). Intersections with other major radial roads are signal controlled.

Although this road is of vital importance to Chiang Mai, it has several conspicuous faults that require attention:

Access Control

For a major road designed to facilitate relatively high speed travel (design speed 90 kph), access on to this road must be better controlled. Vehicle speeds on Super Highway far exceed the limit and speeds of 120 to 150 kph are not uncommon. Despite such high speed traffic, there is direct access to some buildings or other areas lacking proper controls. This makes the highway a very dangerous and accident-prone road. Direct accesses to building or lands should not be allowed, and instead achieved via a controlled service road.

Two intersections along Super Highway are among the 20 intersections that are being investigated in this Study. J-2: Wat Chet Yod and J-7: Chiang Mai Land Road are two of the most dangerous access points along Super Highway with frequent accident occurrences (see Chapter 2 and Chapter 5 for locations). Besides these two intersections, there are several others that deserve further study and examination.

U-turns

Grade separated u-turns are provided wherever possible at bridges or flyovers. Along this highway, however, there are still several breaks at the median that allow for u-turns at grade. Where specific space and lanes are provided for such purpose, the danger of u-turn vehicles facing fast on-coming vehicles may be abated to some degree. However, locations remain where no specific space is provided. An example is the entrance to the Chiang Mai Land Road (J-7). This opening is obviously not a designed break and although u-turn prohibition signs are erected, violators in addition to right turning vehicles render this location a rather dangerous one. Ideally, all at-grade U-turns should be prohibited to ensure adequate traffic safety. Where such a facility is deemed absolutely necessary, signalization or ample traffic safety facilities must be provided to warn on-coming drivers.

Incomplete Ring

Super Highway as a ring road is physically incomplete. It stops short at Huay Keaw Road as a DOH managed highway and continues to Suthep Road as Nimmanhamin

Road, a Municipality road. At the other end, it stops short at Hang Dong Road and continues as Mahidol Road to join the old city moat ring road.

The incomplete ring formation is physically constrained due to the presence of the Chiang Mai International Airport in the south western corner of the city. Due to this discontinuity, traffic from the ring road tends to continue along Huay Kaew road, Boonruangrit Road, thus contributing to city center congestion to some extent.

Under-Capacity Section

Due to the incompatible design capacity of Super Highway and Nimmanhamin Road, the intersection at Super Highway with Huay Kaew Road is a traffic bottleneck. While the approach from Super Highway at this intersection is eight lanes (including the exclusive left turn lanes), those on Nimmanhamin are only 4 lanes. This inconsistency in the road capacity of the ring road thus hampers traffic flow and creates congestion.

4.3 Intersection Problems

Twenty intersections are selected for further investigation in this study. These locations were selected based on the results of a site survey on most of the major intersections in the city. 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.

(1) Intersection Studies

The detailed intersection studies consist of a set of 20 intersections, generally chosen based on their: (i) traffic volume data; (ii) congestion and queue pattern; (iii) proximity to major activity centers (such as the Night Bazaar or a school); (iv) high incidence of reported accidents; and (v) perception as being problematic or flawed based on visual observations.[1] This wide set of intersections covers representative problems and issues found at many Chiang Mai intersections throughout the Municipality. In addition, the intersections vary in classification, size, traffic volume, and service level. Table 4-3lists the selected intersections as well as their primary reasons for selection.

For the actual study, intersection schematics were drawn showing intersections and approach layouts including right-of-ways, medians, traffic islands, sidewalks, pavement markings, traffic signs, traffic obstacles such as utility poles and trees, as well as other related facilities for vehicular and pedestrian traffic. Turning movement counts and queue length surveys were conducted at all of these selected intersections, while pedestrian count surveys were conducted at some of these intersections.

[1] The twenty intersections are chosen by the Traffic Police and the Study Team as they are representative of intersections as a whole throughout the Municipality at which high accident rates, traffic volumes and congestion are observed historically. Furthermore, this set of 20 intersections includes a subset of 4 intersections controlled by ATC signals.

(2) Traffic Management Problems at Intersections

Based on the data collected and observation of traffic conditions at the site, particular problems and issues have been identified and summarized in Table 4-4. Some of the major findings are discussed below.

- 13 of the 20 intersections have geometric deficiencies. For instance approaches connect obliquely to intersections and are not at right angles to each other, while roadway widths change after intersections. One prime example of a intersection with geometric deficiencies is Intersection No. 14 (Ratchawithi Road-Ratchaphakhinai Road) in the old city, which despite having a small intersection with light traffic, is accident-prone due to its strange configuration.

- Some intersections have signal and warning flasher problem that includes either the malfunctioning or non-existence of such infrastructure, rendering such intersections extremely hazardous due to conflicting movements and priority uncertainty, which also affects the efficiency of the intersection to handle traffic.

- Pavement marking problems are present in all but one intersection. The quality of marking materials is generally sub-standard and some intersections lack pavement markings or have inadequate layouts. The color of markings appears faded from insufficient usage of pigment, while reflection of markings is inadequate due to insufficient usage of glass beads. Pavement marking materials should meet Thai Standard 542-2530 for thermoplastic road marking materials. The standard sets forth, among others, the minimum or maximum amount of components to be mixed. It is quite obvious from visual observations however, existing materials for pavement markings fail to satisfy these standards.

- Traffic signs are adequately installed. But there are some intersections where necessary signs, particularly stop sign are not installed.

- Most of the intersections lack pedestrian facilities such as sidewalks, pedestrian crossing markings and pedestrian signals. Sidewalks, if provided, are narrow and discontiguous at many locations. It is apparent that pedestrians perceive a real danger when crossing the streets. In short, roads are not pedestrian-friendly.

- Enforcement of traffic regulations is poor. For example, at Intersection No. 5, right-turns are prohibited from the minor road (Haiya Road), however site observation and traffic count data show that many drivers simply ignore the restriction. Furthermore near Intersection No. 15, parking is prohibited along the east side of Phra Pokklao Road, yet many parked cars may be found there.

- Several intersections are saturated. Traffic volumes at Intersection No. 1 Super Highway-Huay Kaew, No. 12 Huay Kaew-Hadsadhi Sawee Road, and No. 18 Super Highway-Charoen Muang exceed intersection capacity thus causing congestion. At Intersection No. 20 Rot Fai Road-San Na Lung Road, queues form at the railroad crossing, especially when the crossing is closed for prolonged periods of time particularly when train switching operations occur in the yard.

In short, many of the intersections in the city of Chiang Mai have the following problems.[2]

- 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)

While some of these intersections require immediate attention due to their danger to traffic operations (J-2 Wat Chet Yod intersection, J-7 Chiang Mai Land Road intersection, J-5 Mahidol Road intersection), others require improvements in the short term.

Overall, basic geometric design, signage, and markings are inconsistent or conspicuously lacking. This suggests non-conformity with proper design standards or inconsistency by following several standards. To prevent the future occurrence of poorly designed intersections, this important issue must be addressed.

Recommended improvements to intersections are further given in Chapter 9 and Appendix F.

[2] Table E-1 in Appendix E summarizes the various problems faced by the selected 20 intersections.

Table 4-3 List of Intersections Studied in Detail

No.	Intersection	Reasons for Selection[A]				
		High Traffic Volumes	High Level of Congestion	High Number of Accident	Presence of ATC Signals	Others
1*[B]	Huay Kaew Road-Super Highway	O	O		O	
2	Super Highway-Soi Wat Chet Yod	O		O		
3	Klong Chonpratan Road - Soi Chet Yod Khian			O		
4	Hadsadhi Sawee Road-Chang Phuak Soi 4			O		
5	Mahidol Road - Haiya Road	O				
6	Thipanet Road - Wua Lai Road	O	O			
7	Chiang Mai Land Road-Aom Muang Road	O	O	O		
8	Chiang Mai Land Road/Soi 15-Chang Klan Road		O			School Area
9	Rakhang Road - Kamphang Din Road			O		
10	Rattanakosin Road - Trat Wong Road		O			
11	Rattanakosin Road - Bumrung Rat Road		O			School Area
12*	Huay Kaew Road - Hadsadisawee Road	O	O		O	
13*	Charoen Muang Road - Charoen Rat Road	O	O		O	
14+	Ratchawithi Road-Ratchaphakhinai Road			O		
15+	Ratchawithi Road - Phra Pokklao Road		O			
16+	Inthawororot Road - Singharat Road			O		
17+	Phra Sing Road - Phra Pokklao Road		O	O		
18+	Super Highway - Charoen Muang Road	O	O		O	
19	Chang Khlan Road - Loi Kroh Road					Night Bazaar
20	Rot Fai Road - San Na Lung Road		O			Railway Crossing

Source: This study

Notes: A) Selection Criteria: (i) Volume: Traffic Volume > 30,000 PCU for 14 hours; (ii) Congestion: Queue > 100 meters.; (iii) Accidents: 10 most accident-prone sites in 1999 and from consultations with Municipality and Traffic Police; and (iv) ATC Signal: ATC signal location.

B) "*" symbol denotes denotes ATC signal, while "+" symbol denotes isolated signal.

Table 4-4 Problems Identified at 20 Selected Intersections

No.	Intersection	Problems Identified					
		Geometry	Signal/ Flasher	Marking/ Sign	Pedestrian Facility	Enforcement	Others
1*	Huay Kaew Road-Super Highway	X			X		Saturated
2	Super Highway-Soi Wat Chet Yod	X	X	X	X		
3	Klong Chonpratan Road - Soi Chet Yod Khian…	X	X	X	X	X	Parking
4	Hadsadhi Sawee Road-Chang Phuak Soi 4	X	X	X	X		
5	Mahidol Road - Haiya Road		X	X		X	
6	Thipanet Road - Wua Lai Road	X		X	X		
7	Chiang Mai Land Road-Aom Muang Road	X	X	X		X	
8	Chiang Mai Land Road/Soi 15-Chang Klan Road			X	X		
9	Rakhang Road - Kamphang Din Road	X		X			
10	Rattanakosin Road – Trat Wong Road	X	X	X	X		
11	Rattanakosin Road - Bumrung Rat Road		X	X	X		
12*	Huay Kaew Road - Hadsadisawee Road	X		X	X		Saturated
13*	Charoen Muang Road - Charoen Rat Road			X	X		
14+	Ratchawithi Road-Ratchaphakhinai Road	X		X			
15+	Ratchawithi Road - Phra Pokklao Road	X		X	X	X	Parking
16+	Inthawororot Road - Singharat Road	X		X	- X		
17+	Phra Sing Road - Phra Pokklao Road			X			
18+	Super Highway - Charoen Muang Road			X	X		Saturated
19	Chang Khlan Road - Loi Kroh Road			X	X		
20	Rot Fai Road - San Na Lung Road	X		X	X		Closure of railroad crossing

Source: This study

Notes: "*" symbol denotes ATC signal, while "+" denotes isolated signal.

4.4 Road Administration

Road administration is handled by three different entities.

(1) Department of Highways (DOH)

The Department of Highways (DOH), Chiang Mai Office is one of 26 such similar bureaus throughout the country. It is responsible for three different types of roads: (i) special highways; (ii) national highways; and (iii) concessionary highways. Of importance to Chiang Mai, the DOH manages the Super Highway. The DOH is currently completing the final stages of the Outer Ring Road. Table 4-5 shows the highways (or sections of highways) that are under the administration of the Chiang Mai DOH Office.

Table 4-5 Highways under Management of Chiang Mai DOH Office

Highway	Designation	Length (km)
Super Highway (NE Segment)	Route 11	10.6
Super Highway (SW Segment)	Route 1141	7.4
Chiang Mai – Mae Jo Highway	Route 1001	9.4
Chiang Mai – New Mae Jo Highway	Route 1001	21.4
Chiang Mai – Lampang Highway	Route 11	3.6
Chiang Mai Outer Ring Road	Route 121	30.6

Source: Study Team Survey Questionnaire, October 2001.

Responsibilities of DOH include surveying and detailed design work, construction, rehabilitation, widening and maintenance of highways for economic, social, political and military objectives. DOH is also responsible for enforcing rules and regulations on these thoroughfares through the Highway Police Division, which is actually under the jurisdiction of the National Police Department, but receives its annual budget and enforcement directives from the Department of Highways.

(2) Chiang Mai Public Works Department (PWD)

The Chiang Mai Public Works Department also constructs and manages roadways in the Municipality. In particular, the PWD is responsible for the Middle Ring Road (which should be functional by the end of 2001) and Canal Road. The PWD is chiefly responsible for the design and construction of bridges over Mae Ping River.

Overall, the PWD has four primary duties as listed below:

- Planning, surveying, design, construction, preservation and maintenance of roads bridges, buildings, dams, banks, piers, and related facilities necessary for water supply, electricity, waste water treatment, flood prevention, garbage disposal, and potable (clean) water systems;
- Enforcement of regulations governing oil and gas storage, including handling, operation, accident prevention etc.;
- Provision of consulting advice/services for construction and other related projects

for other divisions; and

- Enforcement and regulation of other works/projects according to specified laws, ministerial regulations, or government edicts.

(3) Chiang Mai Municipality – Traffic Engineering Division

The Municipality of Chiang Mai, under the Traffic Engineering Division of the Engineering Office, administers all roads within the Municipality except those under jurisdiction of the Department of Highways (DOH) and the Public Works Department. These include all roads within the Super Highway, except Mahidol Road (which is part of Route #1141 under DOH) and Chang Phuek Road (part of Route #107, under DOH). All other roads however, particularly those within the old city and the Chang Klan Business District are under the Municipality. The Municipality is responsible for maintaining and constructing these roads (as well as bridges and pathways), and placing road and traffic signs in these areas.

The Engineering Office is also responsible for data collection, data analysis, planning, and the design and development of the road network and traffic/transportation systems. Lastly, it is responsible for the promotion of safety and convenience throughout the Municipality.

4.5 On-Going and Planned Road Projects

(1) Road Projects under the Municipality

The Municipality currently has 8 road projects planned to improve the network. As shown in Figure 4-4, these are secondary or collector roads aimed at improving the inadequacy of this class of road. Upon completion of these collectors, traffic can be dispersed away from the city center and the southern segment will be opened up for further development.

The extension of Assadathon Road to link up with Super Highway in the north, and the linkage to connect Sri Mongkol Road with Rattanakosin Road with a new bridge over the Mae Ping River near Wat Faham will be constructed by next year. This will help to provide a more direct link for buses from the Arcade Bus Terminal on Keow Nawarat Road to the northern segment of the city.

Table 4-6 identifies some planned roadway projects under the Municipality.

Table 4-6 Planned Road Projects under the Municipality

Road Links	Type of Development
(1) Extension of Assadathon Road	New Road Construction
(2) Linkage between Rattanakosin Road And Sri Mongkol Road (and bridge over Ping River Near Wat Faham*)	New Road Construction
(3) Improvement of Sri Mongkol Road	Road Improvement
(4) Chotana-Huay Kaew Road Link	New Road + Upgrading

(5) Bumrung Rat Road and Super Highway Link	New Road Construction
(6) Extension of Thung Hotel Road to Aom Muang	
(7) Super Highway to Thipanet Road (and bridge over Mai Ping River above Mengrai Bridge)[A]	New Road + Upgrading
(8) Extension of Suriyawongse Road to Aom Muang	New Road Construction

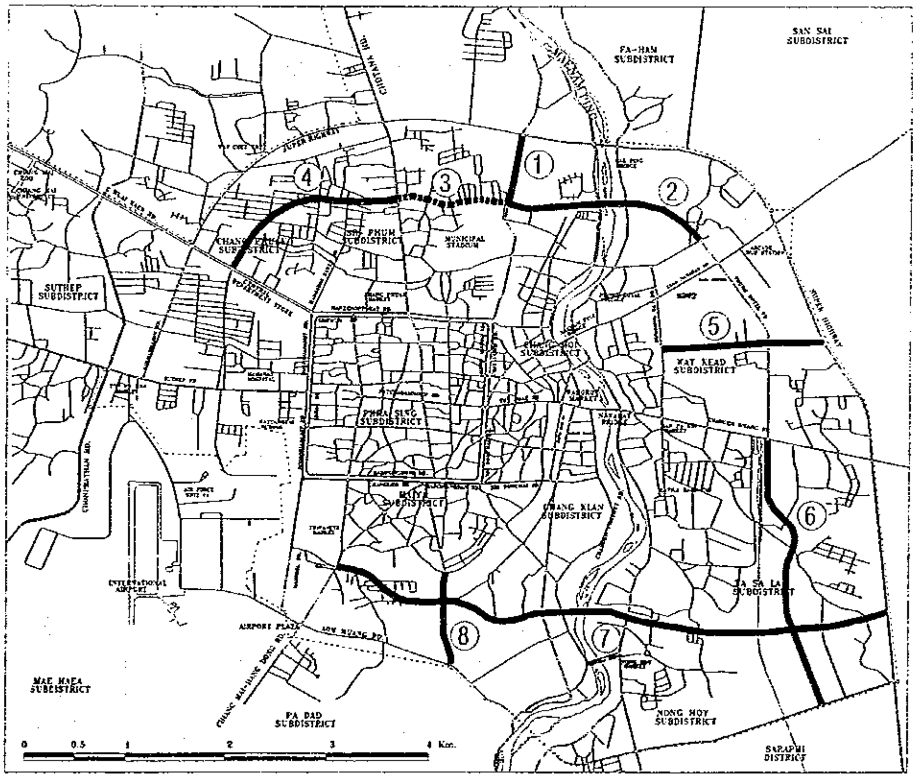
Notes: [A] Bridges are under the jurisdiction of the PWD.
Source: This study

Priority is given to (6), which will serve the needs of two large schools located in the south eastern Ta Sala sub-district.

New bridges over the Mae Ping River as part of projects (2) and (7) would also help to relieve pressures on the existing bridges, especially the Nakhon Ping and Mengrai Bridges. The northern ((2)+(3)+(4)) and southern (7) collector roads would provide a much needed alternative and dispersal routes from the existing radial roads, especially on Chareon Muang Road, Keow Nawarat and Huay Kaew Road, and the old city moat roads which already have heavy traffic.

(2) Other Road Projects

Other notable road projects in the study area include on-going road projects for the Middle Ring Road (under the PWD) and the Outer Ring Roads (under the DOH). These two major highways are expected to be completed and open to traffic by 2002.



Source: This study

Figure 4-4 Planned Road Projects

4.6 Summary of Issues

(1) Road Network and Hierarchy Improvement

In so far as road network functions, Super Highway is effective in dispersing or diverting traffic away from the city center. The radials are well allocated in four directions thus sharing the total load of city bound traffic.

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 (including Ta Sala, Noi Hoy, Haiya or residential sub-districts such as Chang Phuak and Sri Phum).

The Municipality of Chiang Mai recognizes this deficiency and as discussed in the previous section, plans to construct 8 road sections comprising both new construction and the upgrading of existing roads.

This collector class of road should be further developed in the future, by upgrading some of the small access roads that connect to the arterials, while at the same time, reducing the number of access points of small access roads to the arterials, especially to Super Highway and radial roads. In this manner, an improved road network with a clear hierarchy can be achieved. Traffic from access roads should be first channeled into collectors first, and then on to arterials. Direct connections of access roads or buildings to arterials should be avoided in road network development.

(2) Design and Installation Standards for On-Street Facilities

Design of roads in Chiang Mai by the DOH and Municipality basically follows that of AASHTO, but some inconsistency still exists. Road marking for instance, is rather inconsistent and stop lines with stop signs are often not installed at intersections.

In addition, the installation of urban facilities such as lamp posts, wayside trees, refuse bins, signals, and traffic signs requires more consistent specifications and requirements. Many of these facilities are of varied specifications. Wayside trees, refuse bins and lamp-posts for instance are poorly located on sidewalks and obstruct the safe and comfortable flow of pedestrian traffic. It is recommended that the Municipality develop good design and installation standards for the various urban facilities, road markings and traffic signs.

Considering that motorcycles constitute about 50% of all vehicles in Chiang Mai, it is advisable to examine the possibility of providing exclusive motorcycle lanes along major roads to improve safety. Traffic accident records show a very high level of accident casualties involving motorcyclists. To this end, road design standards incorporating special motorcycle lanes should be carefully studied, proposed and implemented wherever possible by the city government. Such a facility may be impractical to “add” onto existing highway, but may be incorporated into new roadway designs.

(3) Pedestrian Walkway Network

While pedestrian crossing facilities are satisfactorily provided at intersections and mid blocks, there is still sufficient room for improvement. Pedestrian signals at large and heavily trafficked intersections are not installed. At such intersections, due to the large volume and high speed of vehicular traffic, it is very dangerous for pedestrians to attempt crossing the road.

It has been observed that drivers often do not yield to pedestrians at intersections. Driver education and licensing exams should emphasize the importance of yielding to pedestrians at intersections. Pedestrian sidewalks are often too narrow, or obstructed by various improperly located objects like lamp posts, trees, refuse bins, telephone booths, sign posts, etc. If the city government intends to encourage more walking and less driving, pedestrian sidewalks need to be systematically upgraded in such a way as to form a contiguous and safe pedestrian network in the city.

Along one-way operation streets, crossing at mid block is again very difficult and dangerous due to the continuous flow of traffic. At such locations, pedestrian signals of the push button type should be installed. This issue is further addressed in Chapter 5.

(4) 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.

The intersection of Huay Kaew Road with Super Highway and Ninmanhemin Road, for example, requires investigation into the possibility of widening, at least, the approach section of Ninmanhemin Road. The difference in the approach lane number between Ninmanhemin (4 lanes) and Super Highway (8 lanes) creates a bottle neck at this intersection.

The other notable traffic bottlenecks are at Nawarat Bridge, Nakhon Ping Bridge, intersection at Chang Moi Road with Prisanee Road (Warorot Market), Mengrai Bridge, intersection of Huay Kaew Road with Hasadhi Sawee Road and Tapae Gate Intersection.

Chapter 5

Traffic Signal Systems

5.1 Introduction

ATC system in Chiang Mai was originally designed by DOH in 1994 and an installation contract was drawn up between the Public Works Department in Bangkok and Peek Traffic Ltd. of Thailand. The scheduled period of construction was 18 months, but actually took for 24 months due to the instability of public telephone lines between the ATC Center and local controllers. The system partially commenced operation in 1996 at intersections where adjustments had been completed and no kick-off ceremony or event was held.

According to the original plan, the ATC system was installed at 40 intersections. Since then, 2 controllers were removed due to grade separation of the main road, thus removing the need for traffic signals. Presently, 38 intersections are operating under the ATC system and of these, the computer controls 35 controllers and only monitors 3 controllers. Of these 3 controllers, 2 are isolated from computer control due to on-going construction of the intersection, and one controller is isolated because the main road was grade separated and reduced the need to be included in the system. Isolated pre-timed signal controllers are also installed at 12 intersections and independent pedestrian push button signal controllers are installed at 6 intersections and pedestrian crossings.

On completion of installing the system, its management moved to Chiang Mai Municipality in February 2000. Since this time, maintenance of the system has been undertaken by Traffic Engineering Division of Chiang Mai Municipality.

5.2 System Configuration

Intersections controlled by the ATC system are listed in Table 5-1, which includes those that have been removed, as described above, and are now operating at a pre-timed pattern while being monitored by the system. These intersections are shown in Figure 5-1. Sub areas with closed loop lines are also indicated on the map. A sub area is a group of intersections that have the same cycle length. There are 11 sub areas, including areas with a single intersection, noted in this study. While Peek Ltd. states that 18 sub areas exist, no more than 11 could be found from the system console at ATC center.

Pre-timed signal controllers and pedestrian push button signal controllers are also shown on the map, though they are not monitored by the ATC system. There are 12 pre-timed (isolated) signals and 6 pedestrian signals.

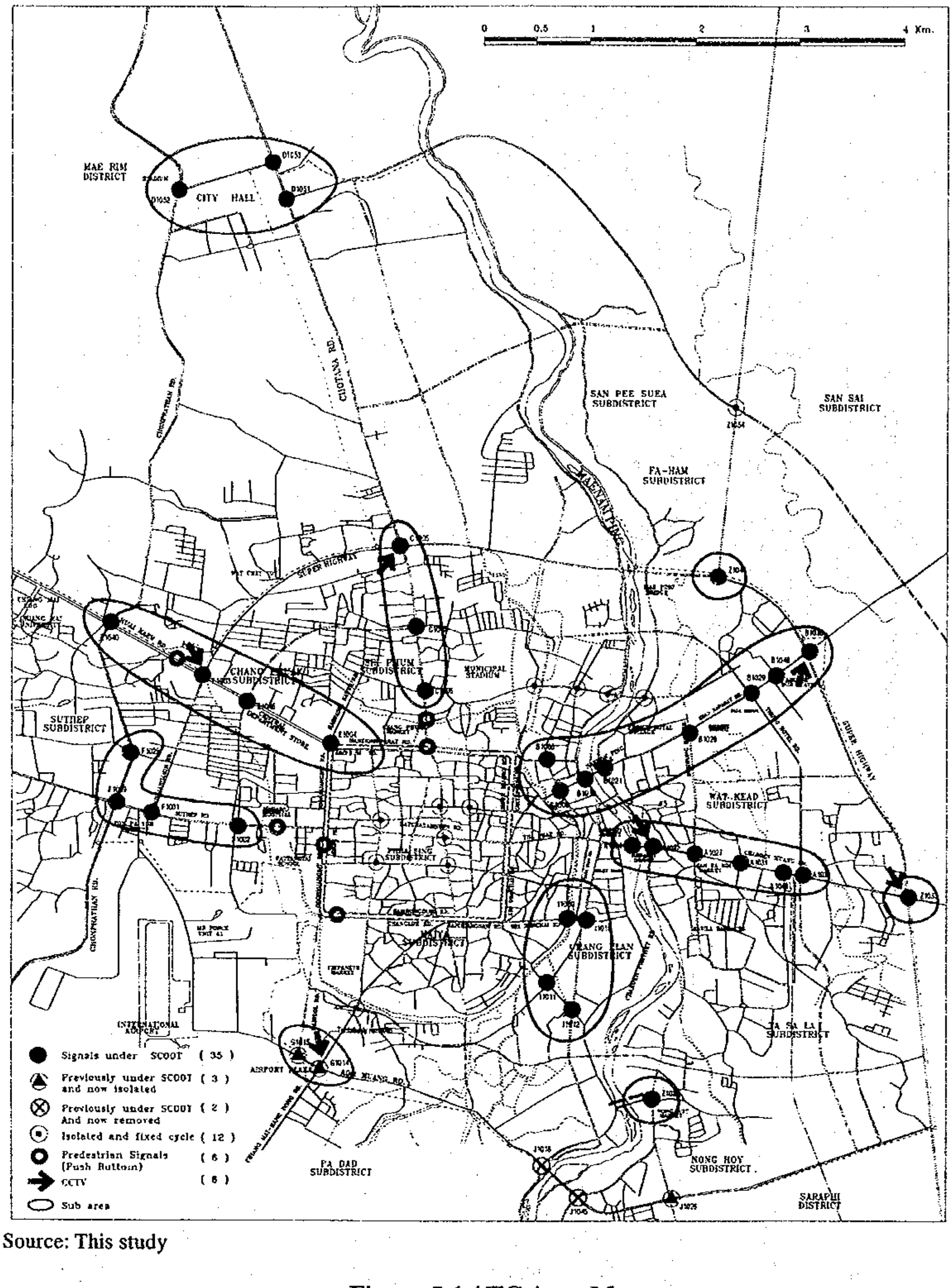
Table 5-1 List of Intersections under ATC

Intersection #	Intersection Name	Main Road	Sub Road	Shape of Intersection	Sub Area & Control #	On/Off line	Phase	No. of Det's	CCTV	Remarks
1	Nimmanhemin	Suthep Rd.	Nimmanhemin Rd.	T	F1001	On	III	4		Traffic volume survey
2	Sirimangkhlachan	Suthep Rd.	Sirimangkhlachan Rd.	Def +	F1002	On	IV	4		
3	Rinkum	Huaw Kaew Rd.	Super Highway	+	E1003	On	IV	4	CCTV	Traffic volume survey
4	Janghuarin	Huaw Kaew Rd.	Boonruangrt Rd.	+	E1004	On	III	5		Traffic volume survey
5	Kuensingha	Super Highway	Chatan Rd.	+	C1005	On	IV	6	CCTV	
6	Chang Phuak	Chang Phuak Soi 4	Chang Phuak Rd.	+	C1006	On	II	3		
8	Mung Samut	Ratchayanon Rd.	Mung Samut Rd.	+	B1008	On	II	4		
9	Ratchawong	Taiwan Rd.	Ratchawong Rd.	+	B1009	On	II	6		
10	Nakorn Ping Br.(west)	Kaew Nawarat Rd.	Wchayanon Rd.	+	B1010	On	III	3		
11	Prachasumphan	Prachasumphan Rd.	Rakaeng Rd.	+	I1011	On	II	3		
12	Rakaeng	Chnag Khlan Rd.	Rakaeng Rd.	+	I1012	On	II	5		
14	Chian Mai - Hangdon	Chian Mai-Hangdon Rd.	Om Muang Rd.	+	G1014	Off	IV	3	(CCTV)	Under Construction, CCTV removed
15	Ring Rd.	Mahidol Rd.	Om Muang Rd.	T	G1015	Off	IV	5		Under Construction
16		Chang Khlan Rd.	Om Muang Rd.	+	J1016	Off				Under Construction, removed
18	Saengtawan	Chang Khlan Rd.	Sri Donchai Rd.	+	I1018	On	IV	6		
19	Nawarat Br. (West)	Charoen Muang Rd.	Charoen Prathet Rd.	+	A1019	On	II	3		
21	Nakorn Ping Br.(East)	Kaew Nawarat Rd.	Charoen Radj Rd.	+	B1021	On	III	4		
22	Nawarat Br. (East)	Charoen Muang Rd.	CM Lanmphun Rd.	+	A1022	On	III	7	CCTV	
23	Land Transport Dept.	CM Lanmphun Rd.	Meng Rai Br.	T	Z1023	On	III	4		
25	CMU-Chonpratan	Chonpratan Rd.	2 Chiang Rai Rd.	+	F1025	On	IV	5		
26	Nongchoi	CM Lanmphun Rd.	Om Muang Rd.	+	J1026	Off	IV	4		Isolated (Overpath)
27	San Pakhoi	Charoen Muang Rd.	Bamrung Rat Rd.	+	A1027	On	II	8		
28	Prince Royal School	Kaew Nawarat Rd.	Bamrung Rat Rd.	+	B1028	On	II	6		

Table 5-1 List of Intersections under ATC (Continued)

Intersection #	Intersection Name	Main Road	Sub Road	Shape of Intersection	Sub Area & Control #	On/Off line	Phase	No. of Det's	CCTV	Remarks
29	Thung Hotel (North)	Kaew Nawarat Rd.	Thung Hotel Rd.	+	B1029	On	II	6		
30	San Dek	Kaew Nawarat Rd.	Super Highway	+	B1030	On	IV	6	CCTV	
31	Chintusssanee	Charoen Muang Rd.	Thebutit Rd.	+	A1031	On	II	6		
32	Thung Hotel (South)	Charoen Muang Rd.	Thung Hotel Rd.	T	A1032	On	III	4		
33	Sankampheng	Charoen Muang Rd.	Super Highway	+	Z1033	On	V	7	CCTV	Traffic volume survey
39	Tonpayom Market	Suthep Rd.	Khlong Chonprathan Rd.	+	F1039	On	IV	4		
40	Ladda Land	Huaw Kaew Rd.	Khlong Chonprathan Rd.	+	E1040	On	IV	4		
41	Mae Jo	Mae Cho	Super Highway	T	Z1041	On	III	4		
45		Ko Klan Rd.	Om Muang Rd.	+	J1045	Off				Under Construction, removed
46	Phathanee	Huaw Kaew Rd.	Sirimangkhlachan Rd.	T	E1046	On	III	4		
47	Chotana-Ratchapat	Chotana Rd.	Phattana Chang Phuak Rd.	+	C1047	On	III	4		
48	Arcade	Kaew Nawarat Rd.	Arcade Bus Stop	T	B1048	On	III	3		
49	Railway Station	Charoen Muang Rd.	Bot Fai Rd.	T	A1049	On	II	3		
50	Kampaneng Din	Sridonchai Rd.	Kampaneng Din Rd.	+	I1050	On	III	4		
51	In Front of City Hall	Chotana Rd.	Ring Rd.	+	D1051	On	III	5		
52	Chonpratan-Salaklang	Khlong Chonrratan Rd.		+	D1052	On	III	4		
53	Maerim-Slaklang	Chotana Rd.		T	D1053	On	III	5		
Current Installation		38						175	5	
Original Installation		40							6	

Source: This study



Source: This study

Figure 5-1 ATC Area Map

Figure 5-2 shows the block diagram of the systems. The ATC Center is located at Chiang Mai Provincial Police Office along Super Highway near San Kampaeng Intersection. From the Center to the TOT (Telephone Organization of Thailand) relay station, data is multiplexed and transmitted by optical fibers. An individual telephone (analog) cable connects the TOT station to each local controller at the intersection. A CCTV system is also installed but it is independent system from the traffic signal control system and omitted from the block diagram.

System capacity, the maximum number of local signal controllers, detectors or sub areas which can be increased without replacing the basic configuration of the CPU, is shown in Table 5-2.

Table 5-2 System Capacity

Item	Present system	System capacity
Numbers of local controllers	35*	1,000
Numbers of vehicle detectors	150	5,000
Numbers of Sub Areas	18	99

* At present, 3 controllers are isolated because of construction.
Source : Peek Traffic (Thailand).

However, some reinforcement of the system may be necessary, such as increased memory, to achieve the numbers in the table.

5.3 System Equipment

System specifications are explained below:

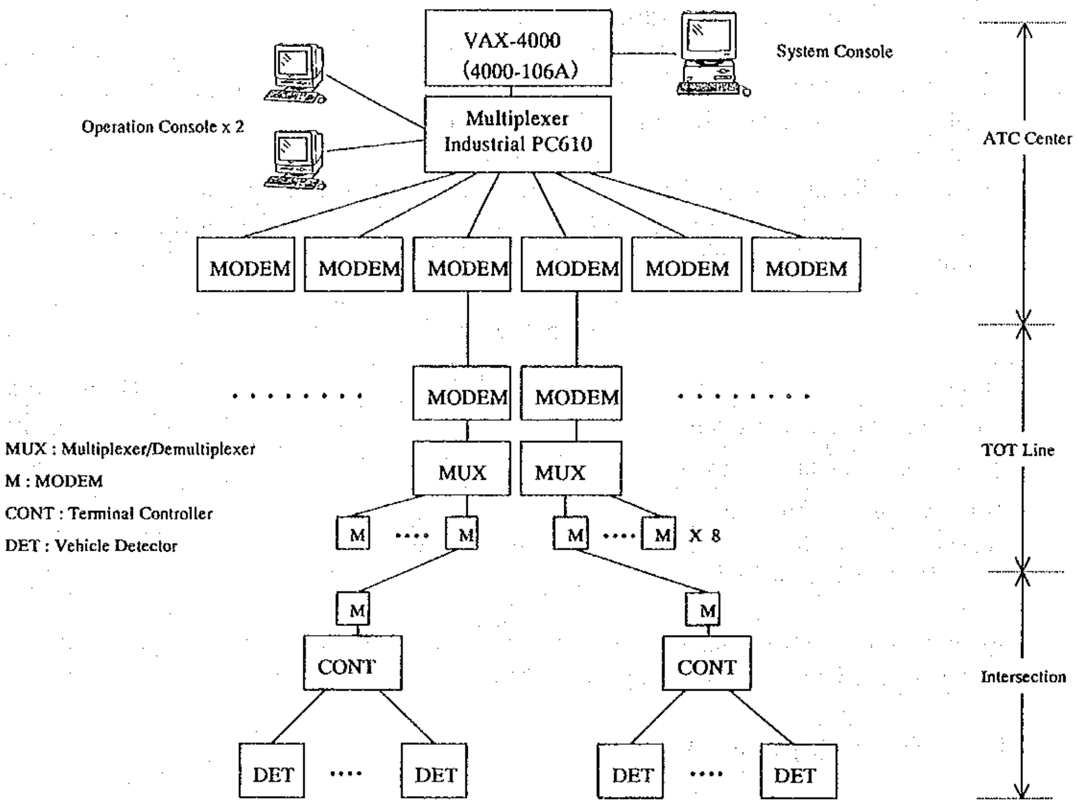
Table 5-3 CPU Specification

Item	VAX-4000-106A	PC-Bus Industrial PC-610
Use of the CPU	Processing	Multiplexer/Demultiplexer
Size of main memory	64MB	16MB
Auxiliary disk capacity	0.56GB	0.5GB
OS	OPEN VMS	DOS 6.2
Supporting language	PASCAL	C+

Source: Peek Traffic (Thailand).

- CPU
- Local controller:
  Data transmission speed : 1200 baud
- Vehicle detector:
  Loop detector
- CCTV camera:
  Posture of cameras can be controlled from the ATC Center.
- CCTV monitor:

Display monitors: 6 (ATC Center)
- Radio communication desk (ATC Center)



Source: This study.

Figure 5-2 System Configuration of ATC in Chiang Mai City

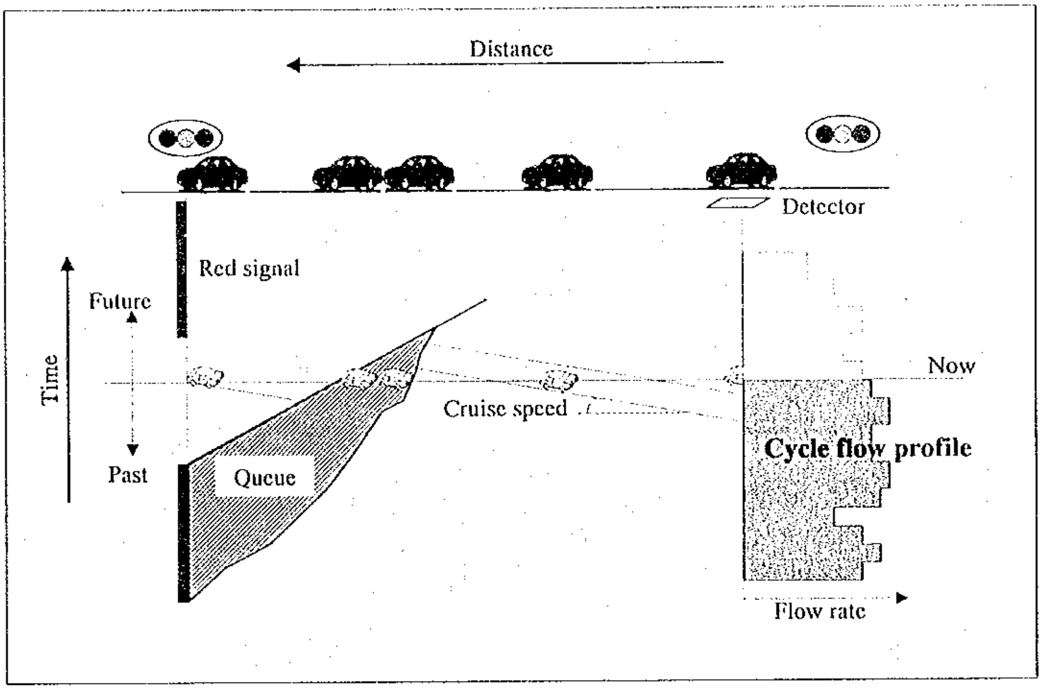
5.4 System Functions

The ATC System in Chiang Mai utilizes the Split, Cycle and Offset Optimization Technique (SCOOT) as a control algorithm. This system was developed in the UK and its objective is to minimize delay time and maximize traffic volume. Each approach to the intersection has a vehicle detector set back 100-150m from the stop line of the intersection. The traffic volume, split, cycle and offset are calculated from the data derived by these vehicle detectors.

(1) Index Parameters

Two indexes are used to calculate split, cycle and offset parameters. These are "cyclic profile" and "degree of saturation."

The Cyclic Flow Profile: Through the detector located at 100-150 meters before the stop line, the vehicle arriving pattern (Cyclic Flow Profile) is estimated by the SCOOT computer. From this pattern, the queue length at the downstream intersection and waiting time are estimated. The sum of the waiting time and delay time is called the performance index (PI) and SCOOT controls the offset to minimize PI. The model is shown in Figure 5-3.



Source: This study.

Figure 5-3 Cyclic Flow Profile (Vehicle Arrival Pattern)

Degree of Saturation: The other index is "degree of saturation" at the intersection and is the ratio of the traffic demand (q) to the traffic capacity of the intersection (s*g). It is calculated by the following equation:

$$x = q / (s^*g)$$

where:
x:degree of saturation
q:flow rate (car/sec)
s:saturation flow rate (car/sec)
g:ratio of effective green time

When the value of x is over 100%, the traffic condition is congested and a queue will appear. It is recommended that the index is to be kept below 90% to ensure smooth traffic. This index is used to calculate the cycle and split.

(2) Calculation of Control Parameters

The control parameters (split, cycle and offset) are optimized by the following measures.

Green split optimizer: A few seconds before the green split change is scheduled to occur, the green split optimizer estimates whether it is better to make a change as scheduled or later. In the optimizing process, the split for the most saturated approaching lane(s) is adjusted so that every lane has the same degree of saturation. The calculation of split is independently processed at each stage for each intersection.

Offset optimizer: The offset is calculated for each cycle; the incremental length is several seconds. The offset optimization process utilizes the cyclic profile for lanes approaching and leaving the intersection. A decision is then made as to whether the offset should be shortened or extended from the scheduled value.

Cycle optimizer: The same cycle is used for all intersections in a sub area. Pedestrian crossing signals can be controlled by the half cycle (the so-called double cycle operation) and it is possible to switch automatically between single and double cycle operation according to traffic conditions. The optimizing process is performed at an interval of less than 2.5min and the cycle length is adjusted by increments of several seconds. There are upper and lower limits for cycle length and the engineer pre-determines the limits by considering length of time for pedestrians to cross the road, as well as traffic volume etc. Cycle length is determined so that the degree of saturation becomes 90% for the most congested intersection in the sub area.

Detectors: Traffic conditions are measured by loop detectors. Placement of the detectors is at the inlet of the link, i.e. the far end of the link from the target intersection. However, if the link is long, the detector is installed at 100-150m from the target intersection. Furthermore, if the traffic conditions change frequently due to the effect of large retail stores, a bus stop or a non-signalized intersection, the detectors are installed at a point nearer the intersection.

5.5 Comparison of Different Technologies

SCOOT determines the offset from the Performance Index (PI), which is the total delay time at the intersection. The cycle and splits are determined from the degree of saturation (DS). However, during saturated conditions, once a queue appears, detectors are unable to detect it and it takes some time before the queue dissipates.

The MODERATO System[1] uses a single index from non-saturated to saturated traffic conditions and is capable of reducing queue length earlier than SCOOT. In MODERATO, the offset is determined by the ratio of the traffic volume in both up and down directions. The cycle is determined by the load ratio (LR) and clearance time, and the split is determined by the LR of intersecting roads. These calculations of the cycle are performed every 2.5 minutes and the response is slower than SCOOT.

The SCATS System[2] also determines the offset in accordance with the ratio of traffic volume in both up and down directions. The cycle and split are determined by degrees of saturation (DS) in similar manner to SCOOT. The detectors are installed near the stop lines and cannot detect queue length. In the non-saturated situation, congestion is shared in both directions, however, in saturated conditions, congestion cannot be solved.

The detailed comparison of different technologies is shown in Table 5-4.

---

[1] "MODERATO" is an abbreviation of "**M**anagement by **O**rigin-**DE**stination **R**elated **A**daptation for **T**raffic **O**ptimization" and developed in Japan and used many cities in Japan.

[2] "SCATS" is an abbreviation of "Sydney Coordinated Adaptive Traffic System" and as it is easy to guess, it was developed in Australia. This also has many examples in the world.

Table 5-4 Comparison of Different Technologies

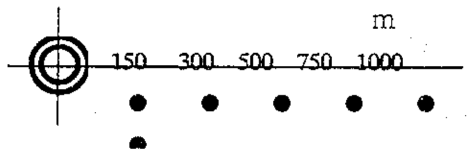
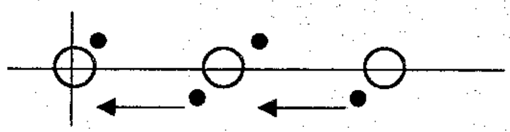
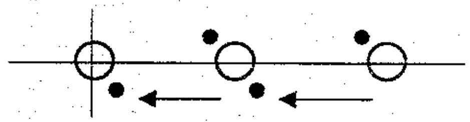
Items		MODERATO	SCOOT	SCATS
Detector allocation		Regarding the critical intersection as a center, a detector to count traffic volume is set at the stop line or 150m and detectors are set at 300m, 500m and every 250m from that after. At right turn lane, a detector is set to detect a car to make right turn.	A detector is set at the inlet of each link. At the boarder of sub area, a detector is set at 100 – 150 m before the stop line. One detector covers two lanes.	Detectors are set just before the stop line of all approaching lane.
				
Traffic Indexes	To determine cycle length and split	Load ratio (LR) $LR=(q+k*E)/s$ where q: Traffic volume (veh/2.5min) k: Use ratio of E (0 – 1) E: Vehicles in queue s: Saturation flow (veh/2.5min) (Concept) Regarding the sum of traffic volume and vehicles in queue as a demand, the ratio of the demand and s is used as an index. When saturated, LR>or=1.	Degree of saturation (DS) : $DS=q/(s*g)$ where q : Traffic volume (veh/sec) s : Saturation flow (veh/sec) g : Ratio of effective green time (0 – 1) (Concept) The ratio of traffic volume and the volume which can pass the intersection in green time is the index. When over saturated, DS=1 and the index can not represent the congestion.	Degree of saturation (DS) : $DS=g_s/g$ where g_s : Saturated portion of green period (sec) g : Effective green time (sec) (Concept) The index is the ratio of the time which the vehicles run at saturated flow and green time. When over saturated, DS=1 as same with SCOOT.
	To determine offset	Non saturated : degree of saturation for up and down stream (q/s) Over saturated : queue length of up and down stream	Delay of the link and stopping.	Traffic volume for both up and down stream.

Table 5-4 Comparison of Different Technologies (Continued)

Items		MODERATO	SCOOT	SCATS
Cycle length	Period to change	15 min. or 5 min.	Less than 2.5 min.	Every cycle
	Measures to change	Cycle length is calculated from Σ LRi of criticai intersection by the following equation. C=(a1*L+a2)/(1-a3* Σ LRi) Σ LRi : Load ratio of intersection L : Loss time a1=1.5, a2=0, a3=1	For the link with maximum DS with in a sub area, cycle length is adjusted so that DS becomes 0.9 incrementing or decrementing by 8 sec.	Cycle length is adjusted by several seconds using DS. (Algorithm is not available)
Split	Period to change	2.5 min.	Every phase	Every cycle
	Measures to change	(For critical intersection) Split gi is calculated by the ratio of load ratio for crossing roads. SPgi=LRi/ Σ LRi i : stage number SP=split (For non critical intersection) Pattern selection in accordance with cycle length.	(For all intersections) At every stage, several seconds before the green time ends, the extension or reduction of green time is decided. Green time of the stage which DSi is maximum is incremented ± Δ G sec (4 sec.) and adjusted so that every phase has same DSi.	Maximum DS is calculated for 4 predetermined plans and choose the plan which DS becomes minimum. Within consecutive 3 cycles, if the same pattern was selected more than 2 times, the split changes to the pattern.
Offset	Period to change	15 min.		
	Measures to change	Pattern selection Non saturated : 7 patterns or automatic calculation Over saturated : 3 patterns When non saturated, the offset which minimize the delay is calculated automatically by ROC (Real time offset control) function.	(Non saturated) Offset for two intersections are adjusted by Δ C sec. (4 sec.) to reduce total delay and stops of the link. (Over saturated) For every link, offset is selected from predetermined pattern.	Most suitable pattern is selected from predetermined 5 plans in accordance with up and down traffic volume and cycle length. For 5 consecutive cycle, if the same plan was selected 4 times, change to that plan.

Source: This study.

5.6 Evaluation of Cycle Length, Split and Offset

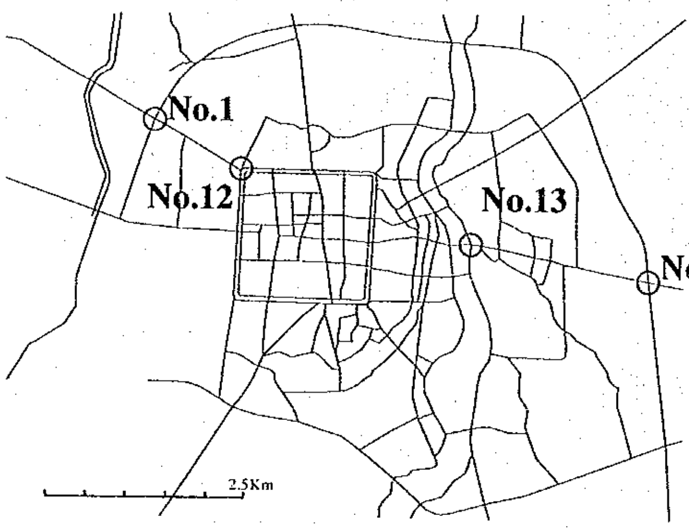
(1) Performance of SCOOT Operation

Evaluation of the system was performed at 4 intersections. These intersections are listed in Table 5-5 and their locations are shown in Figure 5-4.

Table 5-5 SCOOT System Evaluated Intersections

Intersection No.	Name	SCOOT No.
1	Rinkum	E1003
12	Junghuarin	E1004
13	Nawarat Br. (East)	A1022
18	Samkamphcng	Z1033

Source: This study



Source: This study

Figure 5-4 Location of Surveyed Intersections

The following items were evaluated:

Waste green time: Waste green time is the green period when vehicles approach sparsely after the main group of vehicles has passed the intersection. The green period maintained for pedestrian crossing is excluded. Waste green time increases the delay time for the other split and at peak hours causes an early start of saturated congestion, thus increasing the total delay time of the intersection. At periods of near saturated and saturated congestion, waste green time was observed.

Traffic volume and split: At the near saturated congestion period, the split was observed to assess whether it was adequately calculated.

Queue length balance for intersecting road when intersection is congested: During the saturated congestion period, it is desirable to distribute the queue length for both the main and intersecting roads. That is, the waiting time for the main road and intersecting road should be equal although a trunk road, such as Super Highway should take priority. Also, if congestion is observed to be uneven and mainly in one direction, motorists lose trust in the traffic control system. Therefore, the balance of the queue length is checked.

The following data was collected:

Parameters for the SCOOT system:

- Minimum and maximum cycle length
- Minimum and maximum green length for each phase stage
- Inter-green length (green flashing, amber and all red)

These parameters are shown in Table 5-6.

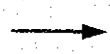
Table 5-6 Predetermined Parameters

Intersection #1 (E1003)

Cycle (sec.)		Min : 32 - Max : 144			
Green Time (sec.)					
	Max	41	76	45	50
	Min	17	17	21	17

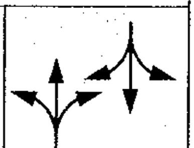
Inter-green time (sec.) GF:3, Y:3, AR:1

Intersection #12 (E1004)

Cycle (sec.)		Min : 48 - Max : 120		
Green time (sec.)				
	Max	30	19	32
	Min	16	16	20

Inter-green time (sec.) GF:3, Y:3, AR:0

Intersection #13 (A1022)

Cycle (sec.)		Min : 32 - Max : 112			
Green time (sec.)					
	Max	100	52	6 (fixed)	52
	Min	20	16		20

Inter-green time (sec.) GF:3, Y:3, AR:0

Intersection #18 (Z1033)

Cycle (Sec.)		Min : 64 - Max 176				
Green time (Sec.)						
	Max	40	50	21	40	45
	Min	22	21	13	21	21

Inter-green time (sec.) GF:3, Y:3, AR:2

Source: This study

The survey period for measuring traffic volume and queue length is shown in Table 5-7.

Table 5-7 Survey Period

Intersection	Date	Traffic Volume Survey	Queue Length Survey
1	August 20, 2001	6:00-20:00	Morning 06:30 – 09:30 Noon 13:00 – 14:00 Evening 16:30 – 19:30
2	August 22, 2001		
13	August 22, 2001		
18	August 21, 2001		

Source: This study.

Fifteen minute traffic volume is measured in accordance with vehicle types and directions. The conversion factor used to normalize the data was shown in Table 5-8.

Table 5-8 PCU Factors

Vehicle Classification	PCU
Car, Pickups & 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.

On the same day when traffic volume and queue length are measured, the cycle length and split data were collected at ATC center. The data were collected using console desk that is used for the policeman to intervene in the system. The data for intersection #12 was omitted because the survey date was on the same day as #13 and the data of only one intersection can be monitored at the console. The time zones which the green length were recorded are shown in Table 5-9.

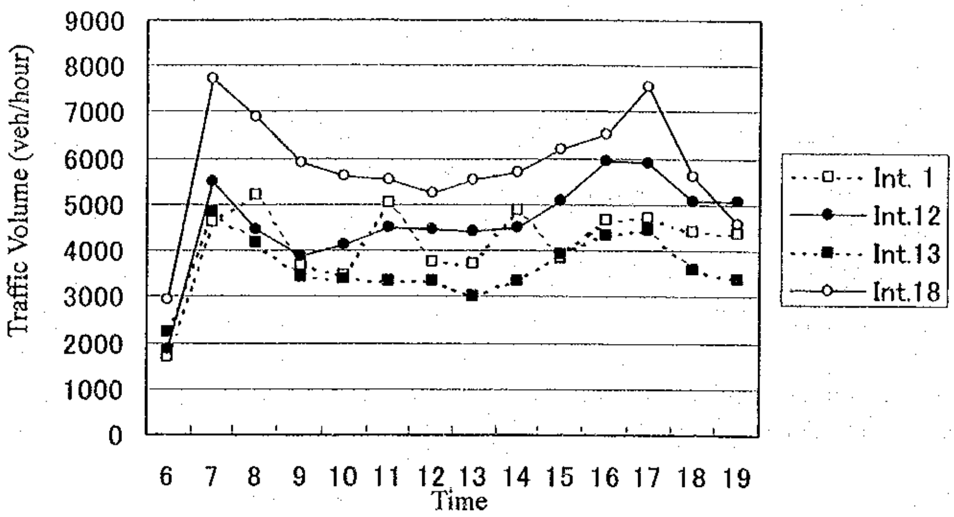
Table 5-9 Time Zone of the Green Length Survey

Intersection	Date	Noon	Evening
1	August 20, 2001	13:00-14:00	16:30-17:45
3	August 22, 2001	13:00-13:45	Suspend
18	August 21, 2001	13:00-14:00	Pre-timed Control

Source: This study

(2) Fluctuation of Traffic Volume

Hourly fluctuation of the traffic volume are shown in Figure 5-5. The morning peak is between 7 and 8am and the evening peak is between 4 and 5pm. In the day time, the traffic between 12 and 1pm is at its lowest.



Source: This study.

Figure 5-5 Fluctuation of the Traffic Volume

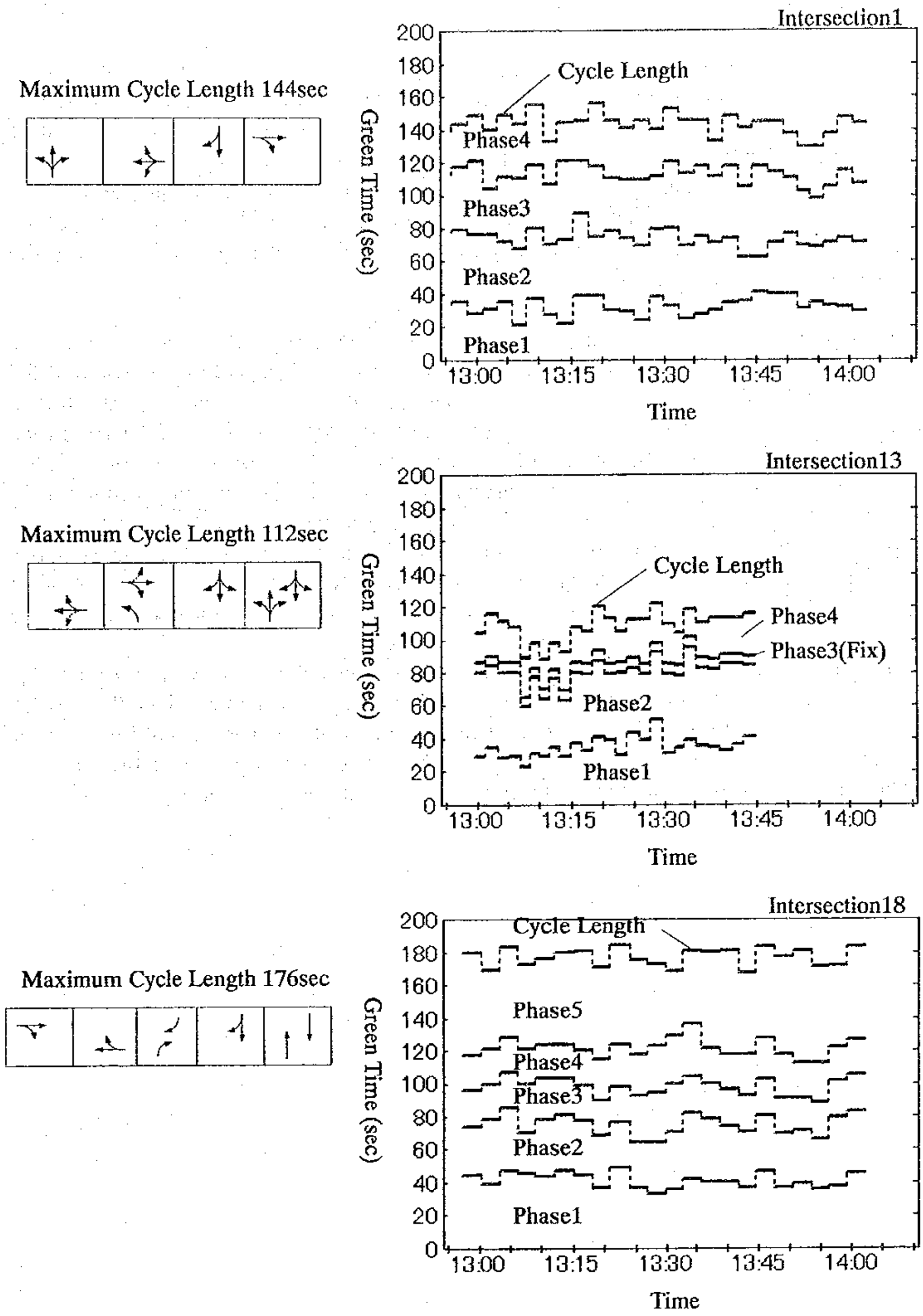
(3) Signal Controls during Period of Non-congestion

The relationship between traffic volume and green length (split) was analyzed for intersections #1, #13 and #18. The time period between 13:00 and 14:00 was selected as it is the low traffic time.

Fluctuation of green length and cycle length for each stage

Fluctuations of green length (including inter-green period) are shown in Figure 5-6. The green length is shown accumulatively, so that the total green time indicates the cycle time. Even in the low traffic period during daytime, the cycle length was close to the pre-determined maximum length. It can be concluded that the cycle length is at its maximum length during the daytime when it is controlled by SCOOT. Usually the cycle length is calculated so that the "degree of saturation" for the most congested link in the sub area becomes 90% and in general, under rather congested traffic conditions, the cycle length is controlled at the maximum length. It is necessary, however, to check if the maximum and minimum value of the cycle length is adequate in relation to the traffic conditions, the size of the intersection, and the geometric shape of the intersection. This is not a problem of the SCOOT system itself, but the subject of its parameter settings. According to the traffic data, it can be said that the cycle length appears adequate during the survey.

The green length (split) varies for each cycle and in the next section, the fluctuation of the split is evaluated as to whether it is related to traffic volume.



Source: This study.

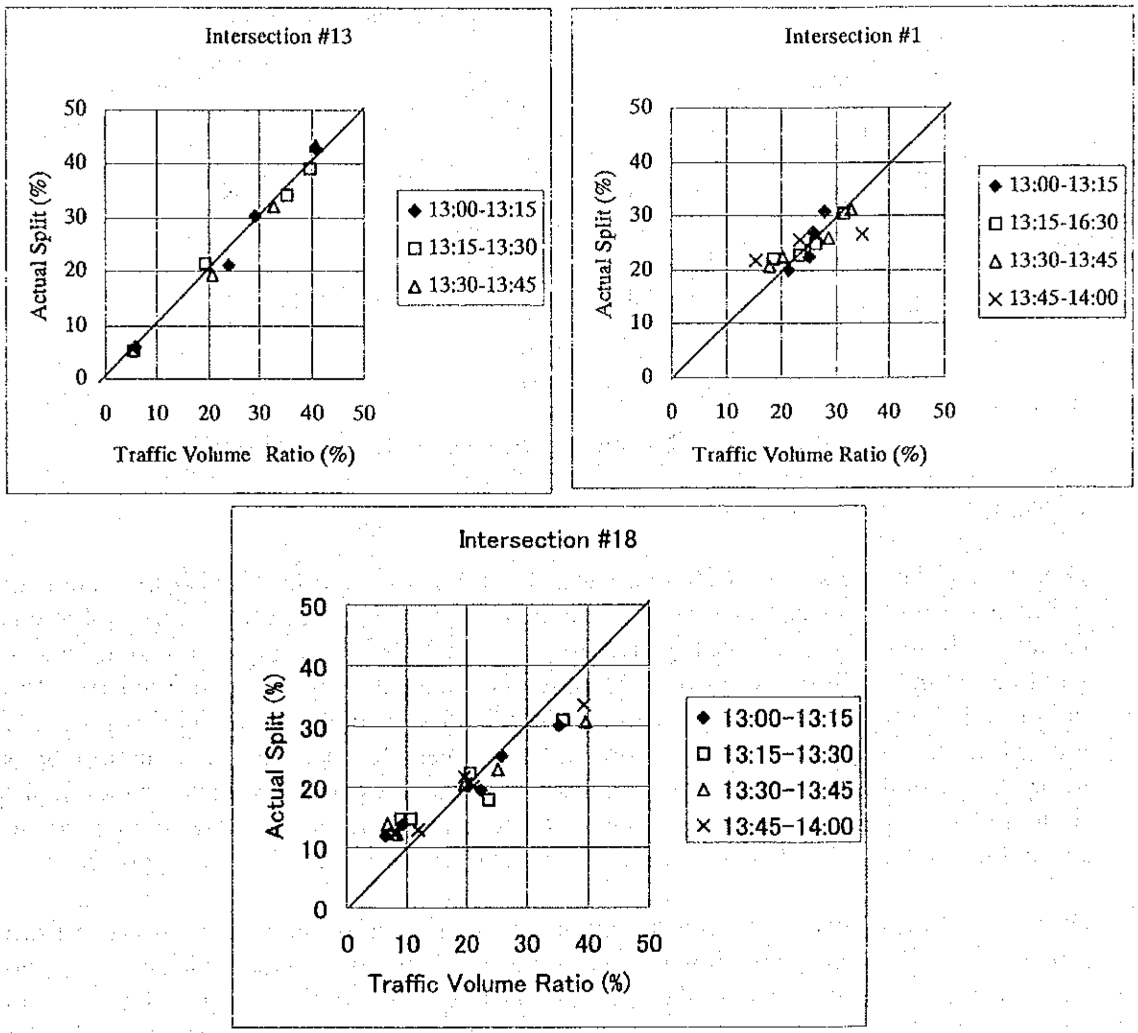
Figure 5-6 Fluctuation of Green Length

Validity of the green length (split)

In the SCOOT system, the green length (split) is calculated so that the "degree of saturation (x)" becomes equal for every stage. Increased split is given to the stage that has the largest x value. The aim of the control is to get the same ratio of traffic volume for unit lane and ratio of the green length (split). The actual splits and the ratios of the traffic volume are compared. The actual splits are recorded from the monitor of the ATC Center and the ratios of the traffic volume are calculated from the traffic survey data. Figure 5-7 shows a comparison between actual green split ratio (%) and the ratio of the traffic volume for green split direction (%).

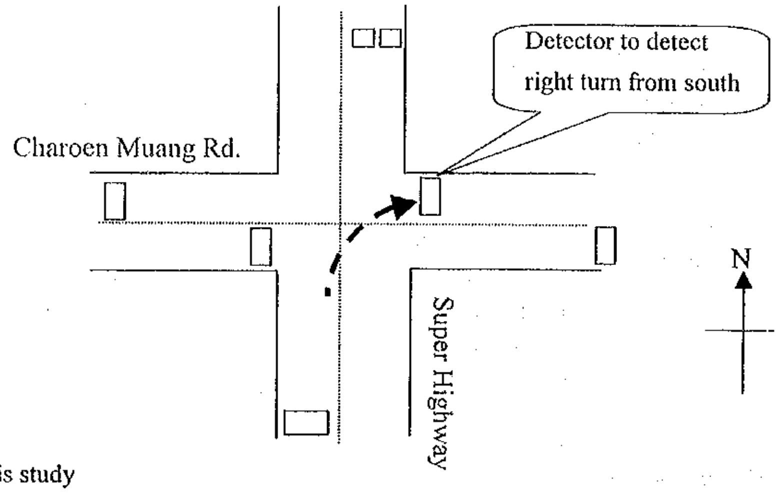
Vertical axis is the actual green split ratio and horizontal axis is the ratio of the traffic volume for green split direction. Actual split and ratio of traffic volume are plotted for each stage and different time zones. If the actual splits and the ratios of the traffic volume matches, the plotted points are on the line of 45 degree slope. For intersections #1 and #13, the slopes are almost 45 degrees, on the other hand for intersection #18, the slope is declined and it shows that for short splits, the actual splits are longer than traffic demand, and for long splits, the actual splits are shorter than traffic demand. At intersection #18, short split is for right turn and long split is main road that is Super Highway. That is there are waste green for right turn and the split for the main road is short for the traffic demand. As a result, the queue occurred for the northbound highway.

It is considered that the detector to detect the right turn vehicles is not working properly. In this intersection, the right turn vehicle is detected by the detector installed at the outlet of the intersecting eastbound lane. The placement of the detectors at intersection #18 is shown Figure 5-8. To detect the right turn vehicle correctly, some adjustment or addition of the right turn detector on the right turn lane might be necessary.



Source: This study

Figure 5-7 Comparison of Actual Split and Traffic Volume



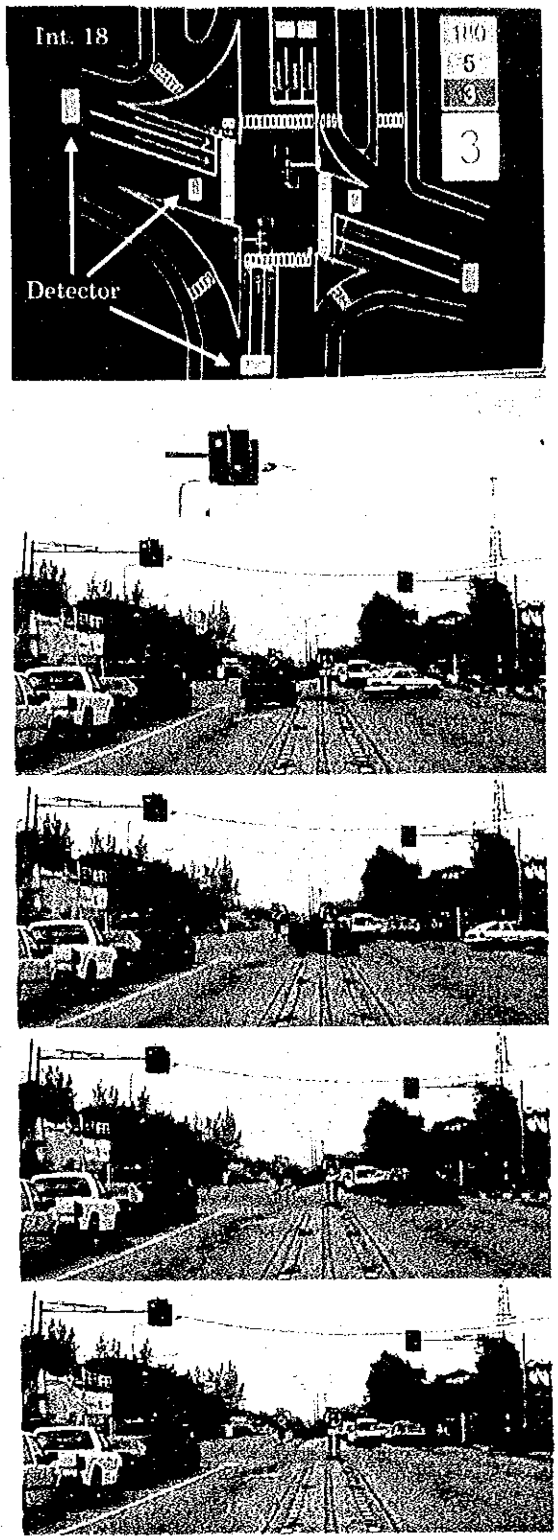
Source: This study

Figure 5-8 Detector Allocation at Intersection #18

Management of right turn

Detectors at the intersection #18 are installed at each approach lane and at the outlets of the intersection to detect the right turn vehicle (Figure 5-8). Right turn traffic volume is calculated based on the right turn detectors and signal phases. In SCOOT system, queue length is estimated from the traffic data which is collected by detectors located 100 -150 m before the intersection. However the detector to detect right turn vehicles is presently located at the outlet of the intersection after the vehicle has made a right turn. It is necessary to make distinguish the vehicles which go straight and vehicles which make right turns. The accuracy to detect right turn vehicles is low compared to straightforward vehicles because it uses data one cycle before the current right turn.

During the traffic survey, waste green time for the right turn stage was observed from time to time. The scenes are shown in Figure 5-9. After a track had made right turn, no cars are making right turn while the right turn signal remains green. There is no dedicated right turn detector and the volume of the right turn vehicle is calculated by the data of pervious cycle. Thus, the number of the right turn vehicles does not match the present condition. It is necessary to install the detector on the right turn lane and adjust the timing so that the right turn stage matches the demand of the right turn traffic.



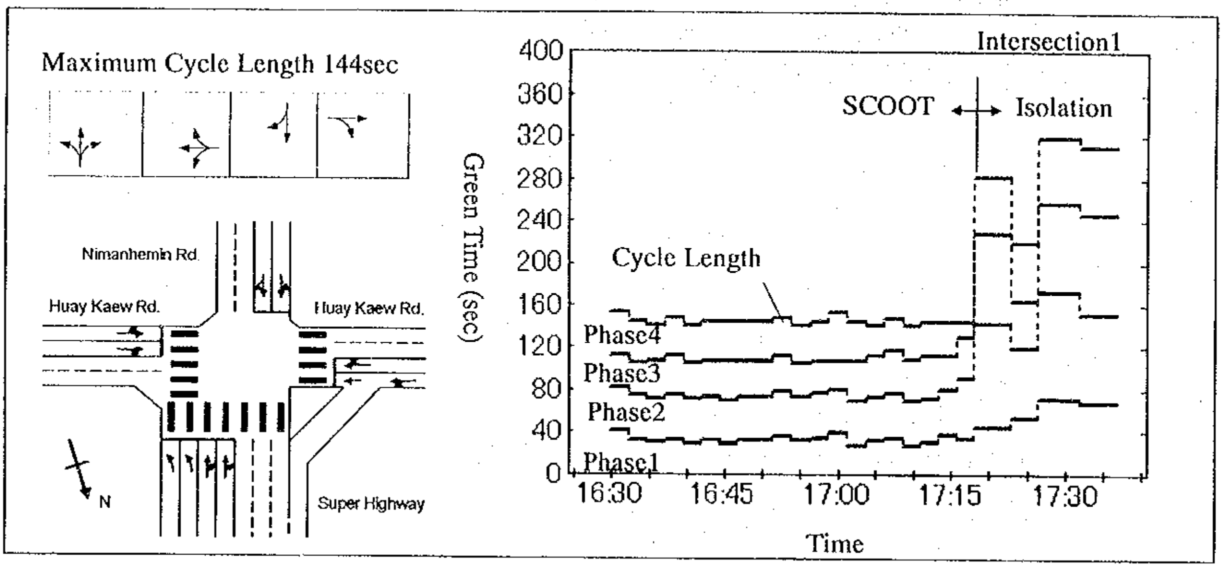
The bottom picture shows the green arrow without right-turn traffic

Source: This study

Figure 5-9 Waste Time at Intersection #18

5.7 Signal Performance at Congested Intersection

Figure 5-10 shows the change of cycle length during evening peak hour (16:30 – 17:30) on the day of survey at intersection #1. At this intersection, the signal control switched from SCOOT to isolated manual control. Analysis of the traffic condition before and after switching from automatic to isolated, determines what kind of problem existed and what kind of problem the policeman tried to solve.



Source: This study

Figure 5-10 Cycle Change at Intersection #1

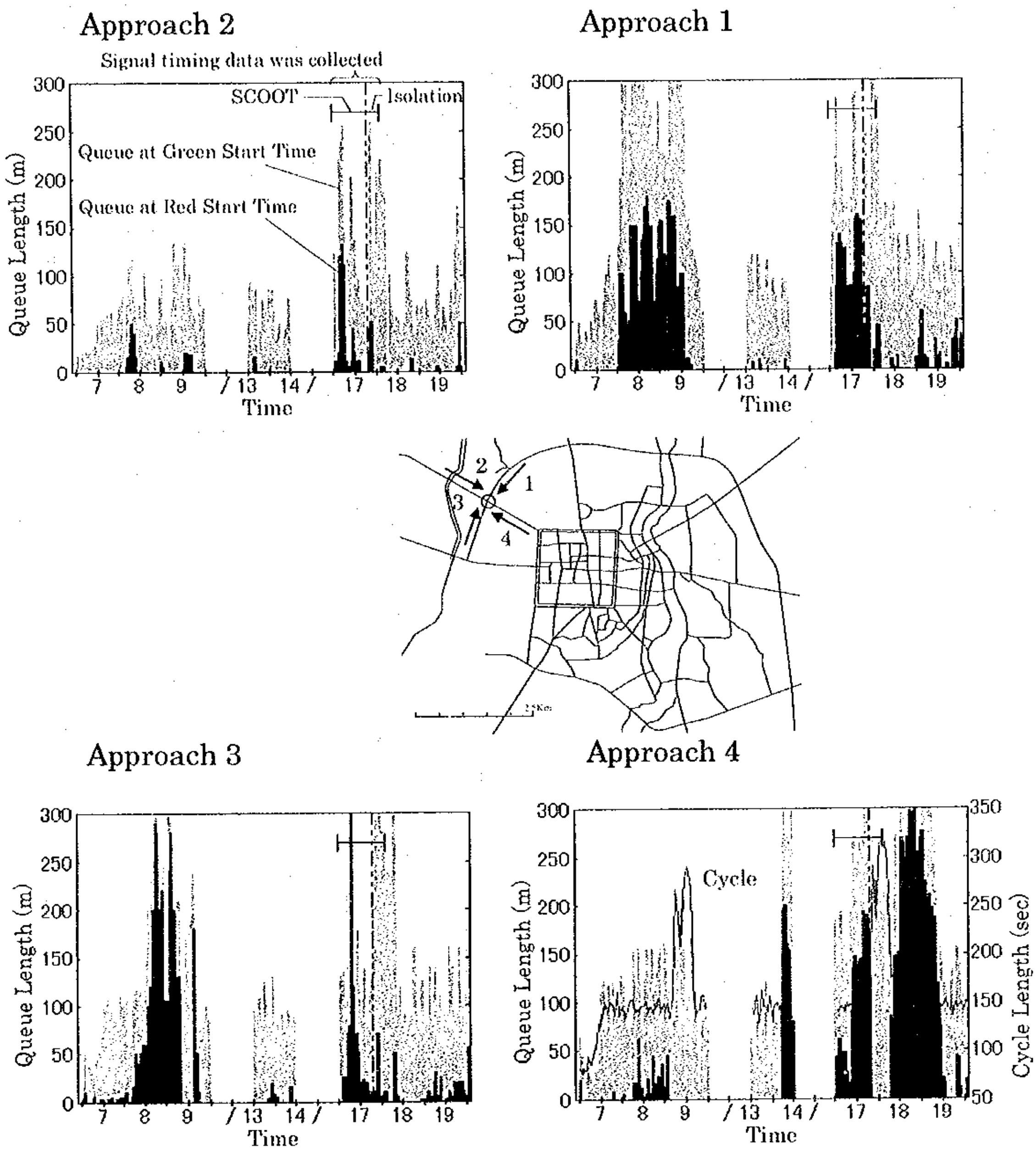
Figure 5-11 shows the queue length versus time at intersection #1. The gray area shows the queue length at the beginning of green signal split and the black area shows the queue at the beginning of red split. Congested queue is defined as the condition when cars are left at the stop line at the beginning of red split. If there are no queues in any directions, it is a non-saturated condition and if there is a queue on at least in one of the approaches, it is a saturated condition.

The congested queue occurs when the traffic demand is over the capacity of the intersection or when the traffic signal control is not functioning adequately. In the former case, it is necessary to make a balance of the queue length for each approach by adjusting the signal control parameters and in latter case, it is necessary to dissolve the queue by adjusting the signal control parameters.

During the period were between 16:30 and 17:30 on the day that the traffic survey was conducted, the green split times were collected at the ATC Center and are shown in the Figure 5-10. On that day, at around 17:15 the control of the intersection #1 was switched from SCOOT control to manual operation by the policeman at the site. Comparing the traffic condition before and after this timing, the reason why the policeman switched the control can be assessed.

Condition in the morning

On approaches 1 and 3 a queue occurred but there were no queues in approaches 2 and 4. This intersection is controlled by independent stage for each approach. The queues on approaches 1 and 3 should be dissolved by giving more splits to these approaches from the splits of approaches 2 and 4.



Source: This study

Figure 5-11 Queue length change at the intersection #1

Condition in the evening

While the signal is controlled by SCOOT, the queue appears in approaches 1 and 4, but disappears when control is performed manually or isolated from the SCOOT system. This shows that the traffic demand was less than the capacity of the intersection and the policeman at the site decided to switch from SCOOT to manual aiming to dissolve the queue by moving the waste green split to the congested approaches. This is the worst case in that the congested queue occurred even though the traffic demand did not exceed the capacity of the intersection. In spite of efforts to leave the control to the computer, policemen sometimes isolate the control from SCOOT to manual. Traffic Police know that SCOOT is not working efficiently although they cannot provide perfect control for all intersections in the sub area[3]. It is speculated, however, that the control was switched to manual at around 8:45 in the morning. Also the queue started to grow from 17:45 when the policeman might have stopped the manual operation. This can be interpreted from the change of the cycle length, which is shown in the graph of approach 4 in Figure 5-11.

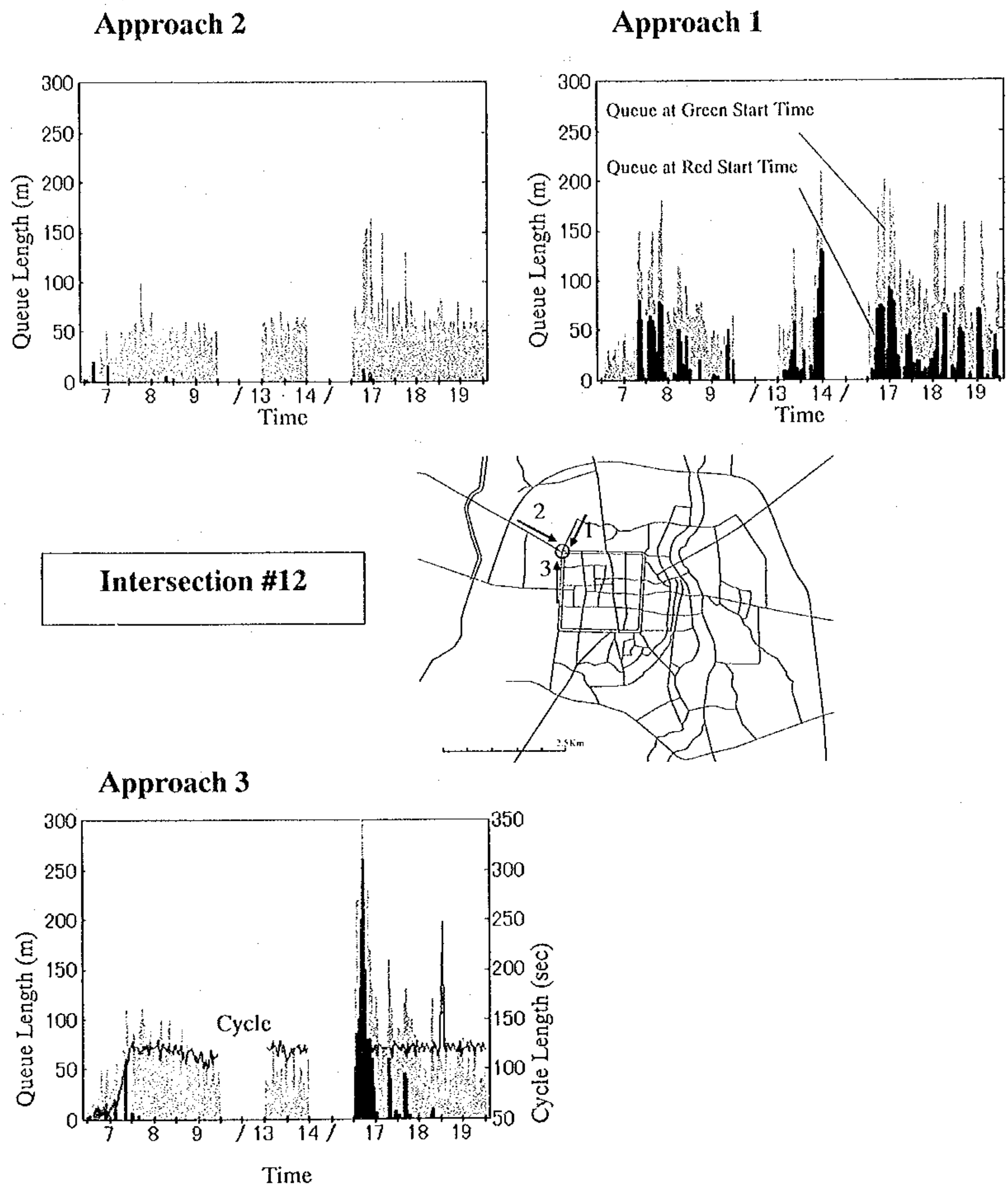
The reason why this kind of phenomenon occurred is that once the queue is beyond the detector which is installed at the 100 - 150 m from the stop line, the system cannot detect the length of the queue, and try to minimize the PI in other approaches. In other words, the system tries to give enough splits for those non-saturated approaches and the queue in saturated approach becomes longer and longer. It should be carefully evaluated, however, whether or not this phenomena is essential for SCOOT. The situation may be improved if more detectors are installed and utilize more traffic data. Although there is some wasted green time for the non saturated approaching link, the flow rate at the end of the green time is low. Thus at saturated condition, the total efficiency of the intersection can be improved if the queue can be balanced for every link. That is, the total delay time can be reduced.

The data for the other 3 intersections are shown in Figure 5-12 (1/3 – 3/3). Looking at these figures, it can be said that the queue often happens only in one approach. That means some waste green occurred in the non-saturated approaches. Particularly intersection #18 is obvious and there is room for improvement. As mentioned above, the delay time for each approach should be balanced. According to the survey data (See Figure 5-12 3/3) there were some periods when the cycle length exceeded 350 seconds. The record at the ATC Center shows that the control during this period is determined by the time of day and it is difficult to estimate when the control is isolated. The reason is not clear.

In any case, the system parameters such as maximum and minimum values of split,

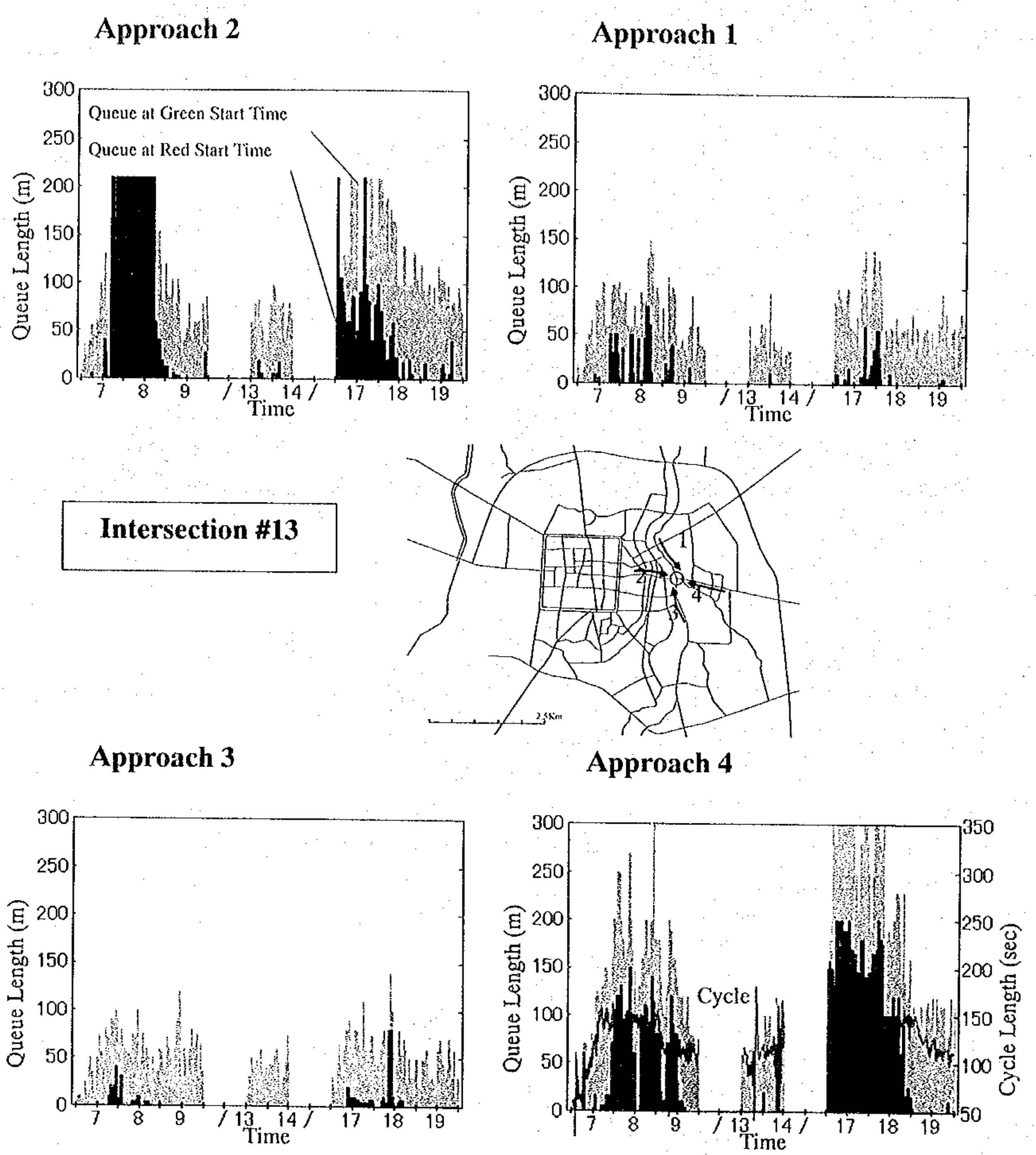
[3] In general, manual control is not advisable except under unusual conditions such as a traffic accident. The way policemen control the signal is to maintain the green signal for an approach until the queue is cleared. Then the green is shifted to the next approach. This is a very dangerous operation, as it works only when the total demand is below intersection capacity but split is not properly assigned to each approach. If the total demand exceeds the capacity, this method leads to the situation in which the green time gets longer and longer every cycle as more time is needed to clear the queue.

cycle and offset and the incremental values of these parameters should be reviewed and adjusted. If there is still inappropriate control, the control software or the allocation of detectors should also be reviewed.



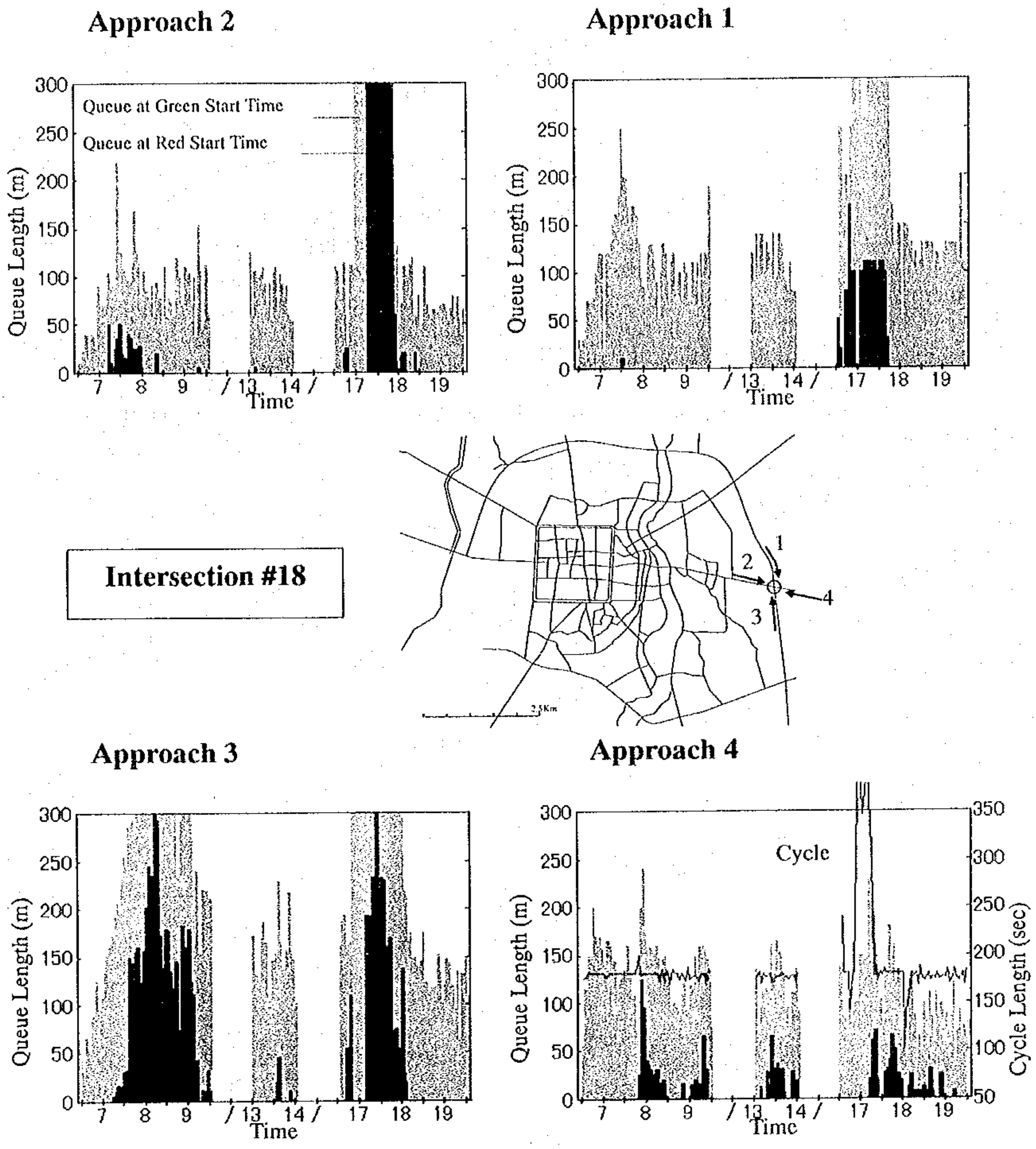
Source: This study.

Figure 5-12 (1/3) Result of Queue Length Survey at Intersection #12



Source: This study.

Figure 5-12 (2/3) Result of Queue Length Survey at Intersection #13



Source: This study.

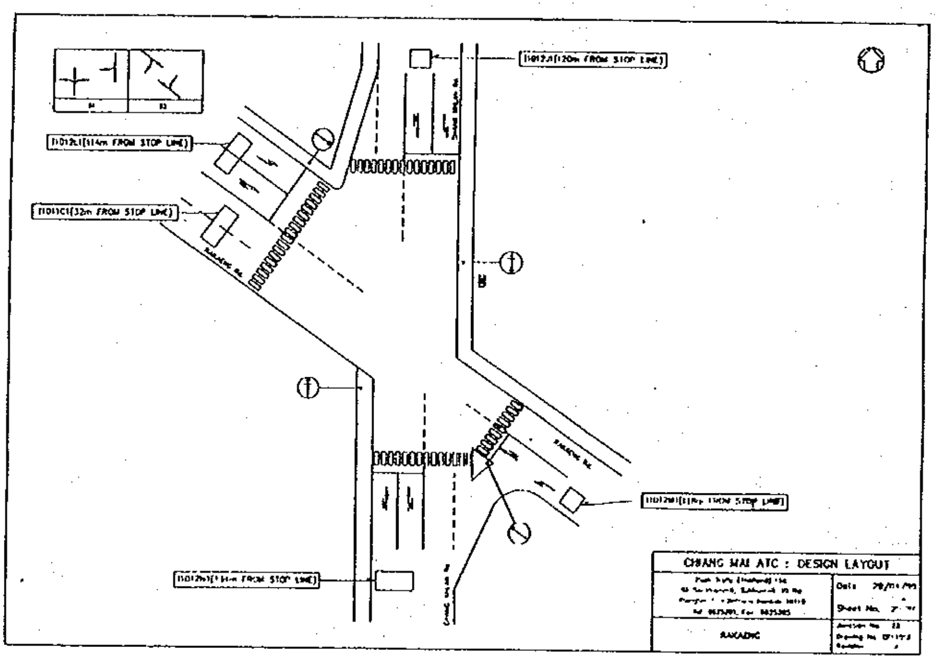
Figure 5-12 (3/3) Result of Queue Length Survey at Intersection #18

5.8 Issues on Phase Plans and Signs

While observing the actual traffic conditions in the field, it was noted that some intersections have phase patterns with certain conflicts. This survey was not done for all of the intersections, but some examples should be pointed out.

Rakaeng (SCOOT #I1012)

The intersection drawing and phase plan are shown in Fig. 5-13. According to the phase plan, while the main street (Chiang Khlan Rd.) is green, the right turn arrow signs are also illuminated for both directions. For the right turn driver, this situation is very dangerous because when the driver sees the arrow sign, he assumes the way is clear and he can proceed without paying attention to the vehicles from the opposite straight direction. To solve this situation, the stages should be separated or the right turn arrow signal should be removed. The ATC center has already noted this conflict, and said in August 2001 that it will be improved soon. Finally one year later, in August 2002, the system was improved eliminating the light green allow sign at that intersection. The same conflicting green indication is also found at the signal located at the intersection of Route 1269 and Chonprathan Road.

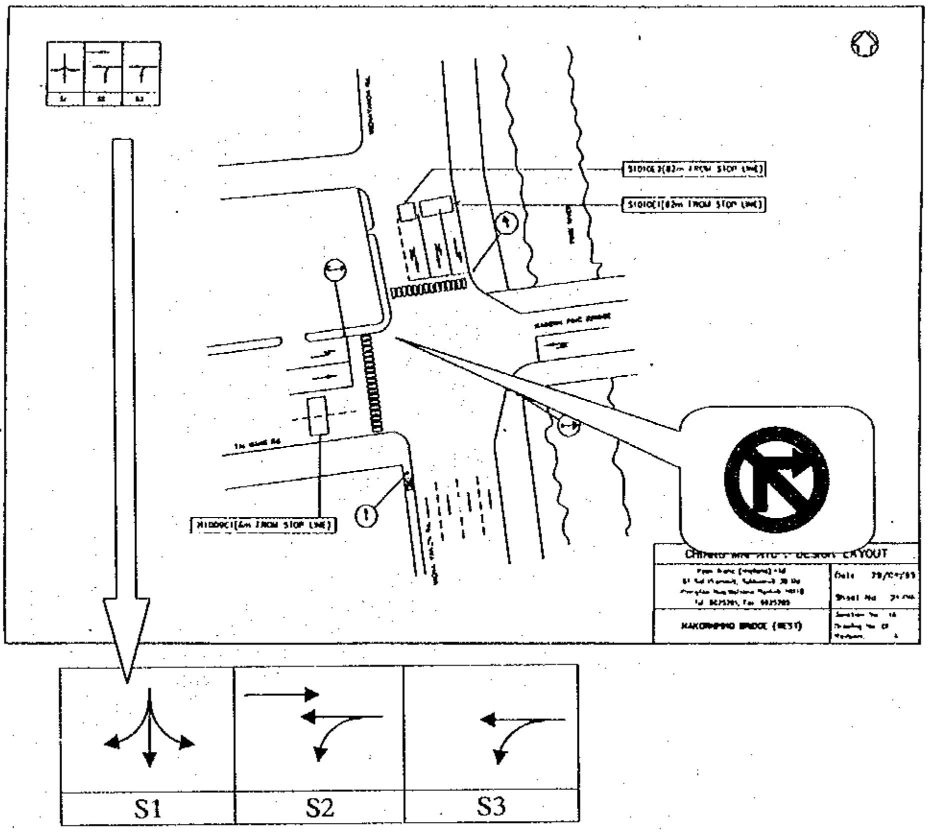


Source: Peck Traffic (Thailand).

Figure 5-13 Rakaeng Intersection (#I1012)

Nakom Ping Br. (West) (SCOOT #B1010)

The right turn from the east is prohibited at this intersection. Nevertheless, there is a stage where the east bound straight signal is delayed from the west bound straight signal. The phase diagram is shown in Figure 5-14.



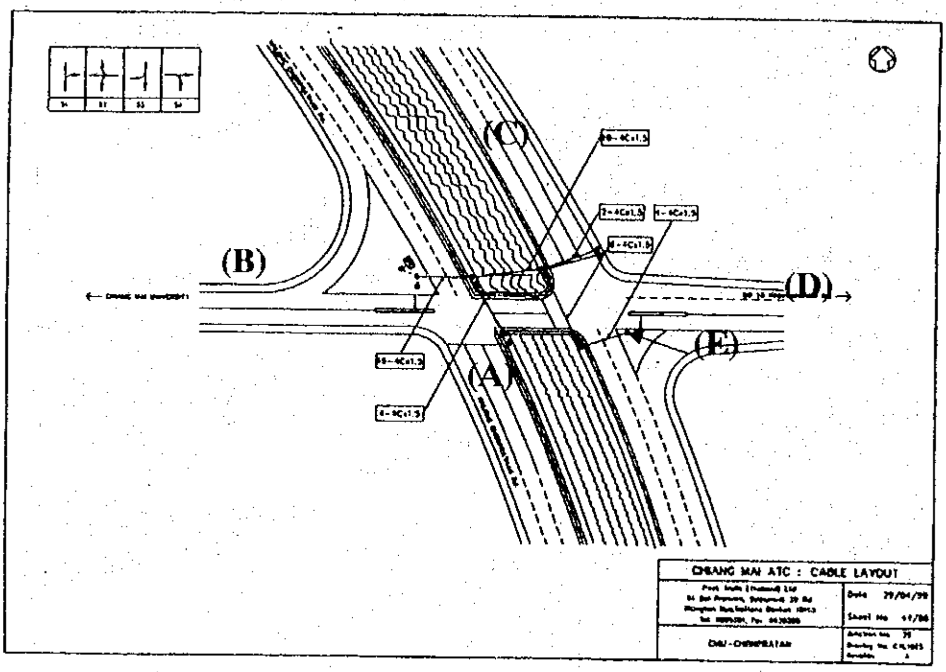
Source: Peek Traffic (Thailand) and This study.

Figure 5-14 Nakon Ping Br. (West) (#B1010)

At stage 3, east bound is blocked and some vehicles take this opportunity to make a right turn. However, the right turn is prohibited as indicated by a sign "No Right Turn" at the north west corner. This problem should be resolved immediately.

CMU-Chonpratan (SCOOT #F1025)

This intersection is controlled as a 4 stage plan. At stage 1 the vehicle from (A) to (D) has to stop at the stop line on the bridge according to the signal which is installed at (E). However no vehicles are coming from the (C) direction so most of the vehicles go without stopping the at the stop line. The same situation happens from (C) to (B).



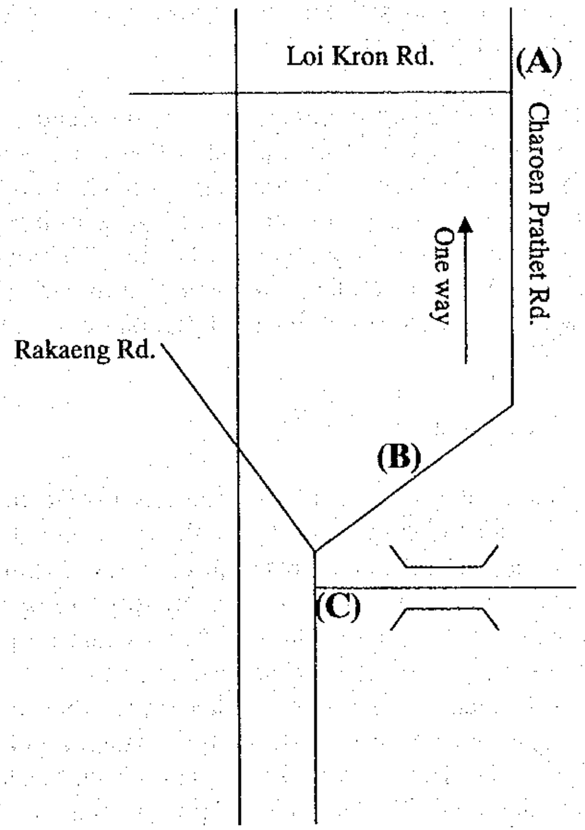
Source: Peck Traffic (Thailand) and this study.

Figure 5-15 CMU-Chonpratan (#F1025)

To solve this situation, one method is to combine stages 1 and 3. Another way is to change the red signal during stage 1 to green. If the situation is left as now, drivers tend to think they can ignore the signals and this mentality can expand to other situations. From the viewpoint of traffic safety, the phase plan should be re-considered.

Traffic Signs

On Charoen Prathet Rd. the north bound one-way traffic regulation is held every school day according to the time of the day. However the sign at Loi Kron Rd. (A) says that the regulation hour is 6:30 – 8:30 and the sign at Rakaeng Rd. (B) says that the regulation hour is 6:00 – 9:00. These regulations should at least start at the same time and cover the same period of time otherwise some conflicts may occur. Also, if possible the regulation at Loi Kron Rd. should start earlier than that of at Rakaeng Rd.



Source: This study.

Figure 5-16 Conflict of Traffic Sign

The sign at the corner of Charoen Prathet Rd. and Mengrai Br. (C) prohibits the right turn from south to east from 6:00 to 8:00. However, until a physical barricade is placed at around 6:30, many cars make right turns from the south here. It is important for the traffic signs to be out of conflict other wise no body believe the signs and traffic signals. One way of solving this problem is to install variable traffic signs which change the sign automatically by the time of day.

5.9 Maintenance Management

(1) Maintenance Contract

One-year maintenance contract was signed on November 29, 2000 between Chiang Mai Municipality and Peek Traffic (Thailand) in Bangkok and became effective from December 1, 2000. Peek Traffic then made a sub-contract with Anan Electric in Chiang Mai. The contract amount is 1,979,000 bahts. Before this contract, maintenance was undertaken on an on-call basis and the work was carried out by Kantawichit Engineering Co. Ltd. of Chiang Mai.

Data on maintenance before the contract was not provided to the Study Team, but a preliminary survey from August, 2000 indicated that many vehicle detectors were not working. The status of the vehicle detectors on the operation monitor at ATC Center were checked during the survey period and most are working properly. This suggests that a significant improvement in maintenance has been achieved. Also, observing the movements of vehicles at intersections, it appears that the vehicle detectors are working properly, so that when a vehicle is not detected, the phase goes to the next stage without delay.

(2) Maintenance Management

The ATC center is operated as one of the sections of Traffic Division, Chiang Mai Provincial Office. Under the supervisor, 9 people are assigned to radio communication between the Center and the traffic policemen at the sites. From 7:00 to 18:00, 2 people are on duty and from 18:00 to 07:00 1 person is on duty. To operate the SCOOT system, 2 people are assigned and from 07:00 to 18:00 and while no person is on duty during night time, a radio operator can monitor the system and call Peek Traffic in Bangkok if some significant faults occurs. During the day time, when a fault is reported to the Center, the system operator confirms it through the system and calls Anan Electric, the sub-contractor of Peek Traffic, to go to the site and check. After Anan Electric repairs the fault, they call the ATC Center and a report is sent to the Traffic Engineering Subdivision of Chiang Mai Municipality with a copy sent to Peek Traffic.

Equipment Failures and MTBF

At the Traffic Engineering Subdivision of the Municipality, a report on maintenance statistics is made every 2 months from the repair reports. This has been the procedure since the current maintenance contract became active. Table 5-10 is the summary data of maintenance from December, 2000 to July, 2001.

Table 5-10 Summary Maintenance Record

From Dec. 1, 2000 To July 31, 2001

No.	Intersection Name	#	No. of Repairs	A	B	C	D	E	F	G	H	I	J
1	Thung Hotel (South)	A 1032	16	0	6	1	0	4	0	0	1	0	4
2	Railway Station	A 1049	14	8	3	1	0	1	0	0	0	0	1
3	Chintusssanee	A 1031	23	10	6	1	0	1	0	1	2	0	2
4	San Pakhoi	A 1027	7	3	1	0	0	0	0	0	2	0	1
5	Nawarat Br. (East)	A 1022	25	3	5	3	3	0	0	0	2	0	9
6	Nawarat Br. (West)	A 1019	14	2	9	0	0	0	0	0	2	0	1
7	San Dek	B 1030	41	12	1	2	3	2	0	1	5	0	15
8	Arcade	B 1048	31	6	18	0	0	4	0	0	0	0	3
9	Thung Hotel (North)	B 1029	13	3	1	1	0	1	0	1	3	0	3
10	Prince Royal School	B 1028	15	4	2	2	0	3	0	0	1	0	3
11	Nakorn Ping Br.(East)	B 1021	21	10	4	0	0	0	0	0	3	0	4
12	Nakorn Ping Br.(west)	B 1010	17	3	8	0	0	2	0	0	1	0	3
13	Ratchawong	B 1009	19	4	6	0	0	4	0	0	2	0	3
14	Mung Samut	B 1008	32	15	7	3	0	1	0	0	2	0	4
15	Kuensingha	C 1005	36	7	10	5	2	5	0	2	2	0	3
16	Chotana-Ratchapat	C 1047	37	19	10	0	1	1	0	0	2	0	4
17	Chang Phuak	C 1006	29	12	5	2	0	2	0	0	2	0	6
18	*Chotana-Ring Rd.*	D 1051	25	9	4	0	0	4	0	2	1	0	5
19	Chonpratan-Salaklang	D 1052	24	10	3	5	0	1	0	1	1	0	3
20	Maerim-Slaklang	D 1053	20	6	2	7	0	1	0	0	1	0	3
21	Ladda Land	E 1040	57	23	17	2	0	1	1	0	2	0	11
22	Rinkum	E 1003	38	14	7	0	3	4	0	0	5	0	5
23	Phathanee	E 1046	14	4	3	1	0	2	0	0	1	0	3
24	Janghuarin	E 1004	29	9	9	1	0	2	0	0	1	0	7
25	Tonpayom Market	F 1039	47	18	17	2	0	2	1	0	1	1	5
26	CMU-Chonpratan	F 1025	41	16	4	6	0	1	0	0	4	0	10
27	Nimmanhemin	F 1001	31	5	6	0	1	11	0	0	1	0	7
28	Sirimangkhlachan	F 1002	37	7	20	1	0	4	0	0	2	0	3
29	Chian Mai - Hangdon	G 1014	9	1	4	0	0	0	0	0	1	0	3
30	Ring Rd.	G 1015	13	4	3	0	0	0	0	0	1	0	5
31	Prachasumphan	I 1011	36	17	8	3	0	2	0	0	3	0	3
32	Rakaeng	I 1012	42	18	10	3	0	6	0	0	2	0	3
33	Saengtawan	I 1018	31	10	12	0	0	3	0	0	1	0	5
34	Kampaneng Din	I 1050	32	12	8	0	0	0	0	1	0	0	11
35	Nongchoi	J 1026	11	3	3	0	0	1	0	0	1	0	3
36	Mae Jo	Z 1041	23	2	12	3	0	1	0	0	0	0	5
37	Sankampheng	Z 1033	32	11	3	0	3	3	0	2	4	0	6
38	Land Transport Dept.	Z 1023	41	9	10	1	0	8	0	0	4	0	9
	Total		1023	329	267	56	16	88	2	11	69	1	184

Notes
A. Bulb failed
B. Controller failed
C. Detector failed
D. CCTV camera failed
E. TOT failed
F. PEA(Electric power Co.) failed
G. Underground cable chopped
H. Periodic maintenance
I. Instation equipment failed
J. Other

Source: The Traffic Engineering Subdivision of Chiang Mai Municipality

From this data, the MTBF (Mean Time Between Failures) is calculated for controllers, vehicle detectors and other system equipment, and shown in Table 5-11. MTBF of the controller is 830 hours and MTBF of the detectors is 18,225 hours.

Table 5-11 Mean Time Between Failure of the Equipment

Item		MTBF			Remarks
		Hour	Day	unit	
A	Bulb	18	0.74	intersection	
B	Controller	830	35	controller	
C	Detector	18,225	759	detector	
D	CCTV camera	1,823	76	camera	
E	Communication line	2,518	105		
F	Electric power	110,808	4,617	intersection	
G	Underground cable	20,147	839	Intersection	
H	Periodic maintenance	-	-	-	Excluded(69 times)
I	Instation equipment	5,832	243	Center	
J	Others	221,616	9,234	intersection	
Total		232	10	intersection	

Source: This study.

The MTBF of a signal controller is 830 hours or 35 days. That is, each signal controller fails almost every month. This MTBF is quite low when compared to Japanese equipment. According to the National Police Agency there is no official data in Japan recently, but the MTBF of a Japanese controller is over 10 years. Data from Manila, Philippines shows 3,217 hours or 134 days for the controller and 9,281 hours or 387 days for detectors. Detectors in Chiang Mai are becoming stable but the communication line requires improvement. The low MTBF causes lost reliability and faith in the system from motorists and policemen. The MTBF therefore needs to be improved. The life of bulbs is also quite low. The above MTBF is not for the bulb itself, but assuming 30 bulbs per intersection, the MTBF is 540 hours or 22 days. The quality of bulbs should therefore be considered. Although it is expensive at the moment, the LED lantern should be considered.

When the signal controller fails to be controlled by the computer, it operates using its own timer and stored pattern maintaining the same split, cycle and offset before the failure occurred. In this way, a failure does not cause traffic congestion immediately, although it cannot respond to a sudden change in traffic conditions.

Detectors are important units of the system and attempts should be made to maximize their reliability. SCOOT has the software to check the status of the detectors and it should be utilized periodically. To further improve this situation, it is recommended that more details of repair work are obtained. For example, within the failures of the signal controllers, units or parts causing most frequent failures should be identified. Using this data, the units or parts that have weak points can be analyzed to find the actual cause of failure. Sometimes there is a possibility of design failures or the lot of the parts may have flaws.

(3) Maintenance Parts Management

The subcontractor (Anan Electric) stocks only the function units such as printed circuit boards, which are supplied by Peek Traffic (Thailand). At the site, technicians only replace the function unit. After replacing the unit, they send the unit to Peek Traffic (Thailand) to get it repaired.

5.10 Summary of Issues

In general, the overall ATC system seems to work properly. However, as mentioned in the above sections, there are several issues.

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. The behavior of the queue length at intersection #1 reveals a lack of balance. A queue appears in only one direction and some waste green time occurs for approaches without queues. From the standpoint of the motorist, the delay for all approaches should be balanced so that the situation can be understood. Thus the balance of the queues is important.

Waste green time in the right turn lane

As observed at intersection #18, the right turn stage has some waste green. It is estimated 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.

Conflicts in the phase plan and sign

From observation of sample intersections, there are some conflicting phase plans, as mentioned in 5.8. These conflicts may lead to traffic accidents. Also, there is some conflict in the traffic regulation signposts. Usually the time of the period when the sign becomes effective is conflicting. Such conflicts may cause motorists behave in a way that ignores traffic regulations.

Maintenance

The MTBF 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.