Analysis Of Corridor Delay Under SCATS Control

FAST-TRAC Phase III Deliverable

#10 Final Report On analysis Of Corridor Delay Under SCATS Adaptive Control System (Orchard Lake Road Corridor)
EECS-ITS LAB-FT-083

William C. Taylor Ph.D.
Ahmed S. Abdel-Rahim

FAST-TRAC Evaluation
Technology Planning and Evaluation Group (TPEG)
Intelligent Transportation Systems Laboratory
University of Michigan
Ann Arbor, MI 48109

Steve Underwood, Ph D. Principal Investigator
Zakia R. Shaikh M.E. Project Manager

Program Offices Telephone
(313) 764 4333

Program Offices Facsimile
(313) 763 4764

Final Report

On

ANALYSIS OF CORRIDOR DELAY UNDER SCATS CONTROL

(ORCHARD LAKE ROAD CORRIDOR)

Prepared by

William C. Taylor, Ph.D.,

and

Ahmed S. Abdel-Rahim

Department of Civil and Environmental Engineering
Michigan State University
East Lansing, MI 48824

April 1998

ACKNOWLEDGMENT

The authors would like to thank the Oakland county road commission (OCRC), the Michigan department of transportation (MDOT), and the federal highway administration (FHWA) for funding this study. We extend our thanks to all OCRC staff members for their continuous cooperation during all phases of this study.

ABSTRACT

This study was designed to determine the change in travel time following the implementation of the Sydney Coordinated Adaptive Traffic System (SCATS) in Oakland County, Michigan. A before/after comparison was used to examine the change in travel time on a specific corridor (Orchard Lake Road). The results of the study showed that corridor travel-time and intersection delay for the main street through traffic improved as a result of SCATS implementation. The corridor travel-time improved for both directions for both the peak and the non-peak periods. The reduction in corridor travel time ranged from 6.56% to 31.80%, with savings in travel time being higher during the non-peak periods.

Before/after intersection delay studies showed that both stopped and approach delay decreased for the main street through traffic at the intersections as a result of SCATS implementation. The reduction in delay and travel time is attributable to the increase in green time for the main street traffic under SCATS control. SCATS extended the green time for the main street through traffic, reducing the average degree of saturation from 1.02 to 0.87 during the peak periods and from 0.73 to 0.56 during the non-peak periods. SCATS reduced the green time for other approaches increasing the degree of saturation on the minor street through traffic from 0.86 to 0.95 during the peak periods and from 0.42 to 0.51 during the non-peak periods.

SCATS allocated the green time effectively, especially during the non-peak periods. The system utilized the excessive green allocated for the minor street by reassigning it to the main street traffic. Extending the green time contributed to the reduction in delay in many ways. It reduced the degree of saturation, reduced the red time for the main traffic, and provided a wider through bandwidth for the main traffic along the corridor. In oversaturation cases, extending the green time often eliminated the number of vehicles that had to stop for more than one cycle.

A Before/after offset study showed that the through bandwidth increased during all time periods for both directions, mainly as a result of extending the green time for the main street traffic.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

In 1991, the Road Commission for Oakland County (Michigan) began implementation of the FAST-TRAC (Faster and Safer Travel - Traffic Routing and Advanced Controls) project, a national demonstration project involving both suburban Advanced Traffic Management System (ATMS) and Advanced Traveler Information Systems (ATIS) technologies. As part of the project, the county has converted much of its signalized traffic network from optimized fixed-time to SCATS (Sydney Coordinated Adaptive Traffic System) control. SCATS is a computer based area traffic control system that uses adaptive techniques to increase the efficiency of the road network. SCATS is one of several adaptive traffic control systems which have the ability to change the phasing and timing strategies and the signal coordination within a network to meet the changes in demand. The principal purpose of SCATS is to minimize overall stops and delay, maximize the throughput, and minimize the possibility of “traffic jams” by controlling queue formation.

The efficiency of any traffic signal control system can be measured in terms of the difference in total time taken by a vehicle to complete a designated trip from a specific origin to a specific destination. Travel time characteristics within a network are useful indicators of overall system performance. In this study, a before/after comparison was used to determine the changes in travel time on a specific corridor as a result of SCATS implementation. The sole variant in the study location was the change from optimized pre-timed signals to SCATS signal control. Thus, any recorded changes in the travel time characteristics are considered to be the result of the implementation of SCATS.

In addition to the travel time analysis, before/after intersection delay analyses were conducted for three major intersections along the corridor to examine the changes in intersection delay. The intersection delay study is important to understanding the impacts of SCATS on the minor street traffic along the corridor. Having examined changes in travel time and intersection delay, the results were analyzed to determine which characteristics of the adaptive control system caused these changes. Before/after green time and offset analyses were conducted to examine how the dynamic green time allocation and the dynamic progression algorithm contributed to the changes in corridor travel time and intersection delay. The study was the last phase in a five years project to assess the long-term and short-term impacts of SCATS implementation in Oakland county.

2 Study Objectives

As part of a national demonstration project, it is important to fully understand the impacts of SCATS implementation on different traffic parameters throughout the network. It is also important to understand how different components of SCATS adaptive control contributed to these impacts. Bearing this is mind, the following three objectives were identified as primary for the study:

1) determine corridor travel time savings attributed to the installation of SCATS;
2) determine changes in intersection delay for all approaches as a result of SCATS implementation; and

3) determine which characteristics of the adaptive signal control contributed to the changes in travel time and delay

3 Study Location

Oakland County is located in the southeastern part of Michigan, immediately to the north of the city of Detroit. Throughout the past 15 to 20 years, Oakland County has experienced rapid growth in both commercial and residential development, accompanied by an equally significant increase in traffic. In 1991, the Road Commission for Oakland County embarked on a national demonstration project for suburban Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS). As part of the project, the county has converted many of its 300 signalized intersections from fixed time signal control to SCATS (Sydney Coordinated Adaptive Signal System).

For this corridor travel time study, a 3.1 mile section of Orchard Lake Road, Figure 3.1, a major corridor in the city of Farmington Hills, was chosen as the study location. The corridor is urban in nature, with many commercial establishments along the route. The corridor connects residential areas to the north (near Orchard Lake) with Interstate 696 to the south. During the morning peak, the traffic flows from the residential areas in the north to the freeway in the south (southbound traffic). In the afternoon, the peak traffic is northbound.

The beginning and ending points for the selected analysis unit were chosen to be mid block locations between intersections. There are three major signalized intersections in

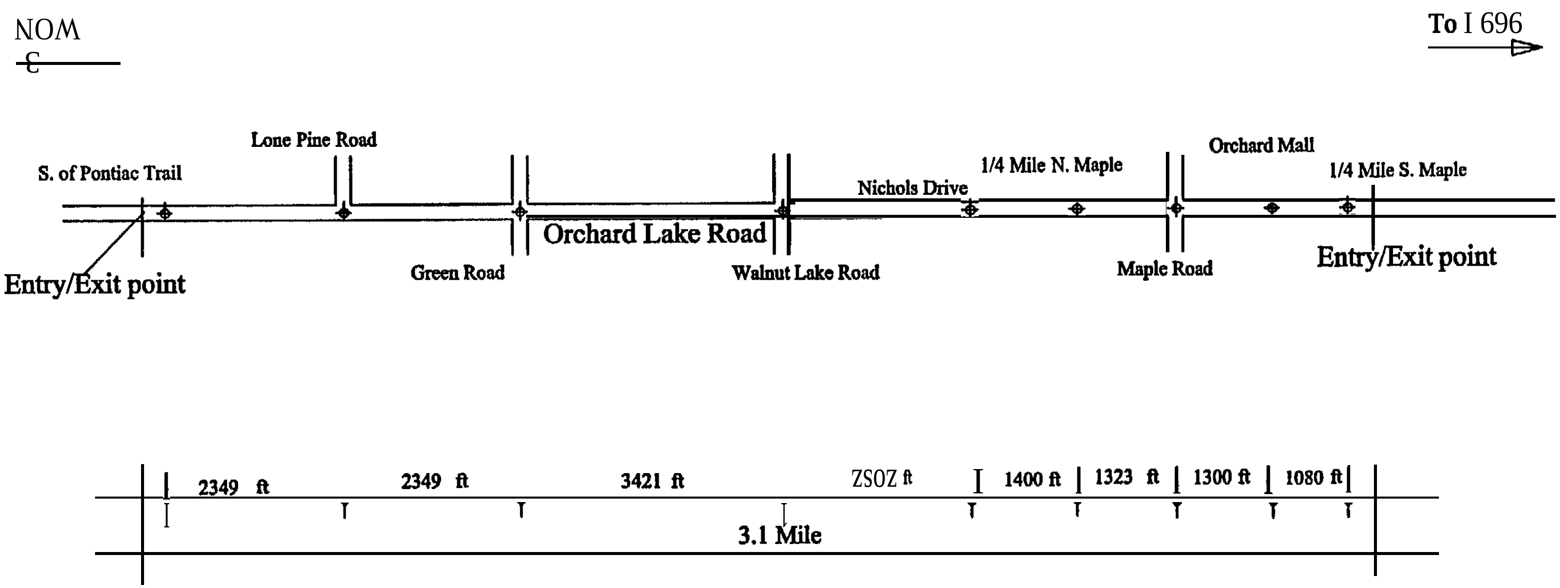


Figure 3.1 Corridor Travel Time ßɛxʎou

this section (Maple Rd., Walnut Lake Rd., and Lone Pine Rd.) as shown in Figure 3.1. In addition, there are five other shopping malls and driveway signals. The before/after intersection delay study was conducted for the three major intersections

4 Before and After Traffic Control

4.1 The Before Traffic Control - Optimized Fixed Time Signals

Before the implementation of SCATS at the study location in spring 1997, the intersections along the corridor were operating under PASSERII optimized fixed time signals. The signals were operating under three different dials. Dial 1 for the non-peak period, from 7:00 PM to 6:00 AM and from 9:00 AM to 3:00 PM. Dial 2 for the morning peak period operating from 6:00 AM to 9:00 AM, and dial 3 for the evening peak period operating from 3:00 PM to 7:00 PM. Similarly, the intersections had different offset plans for each of the three time periods. Table 4.1 lists the cycle length and the-offset plans and Table 4.2 lists the phase plan for each of the signals in the study location.

Table 4-l Cycle length and Offset Plans (Fixed Time Signal)

Intersection	Dial 1		Dial 2		Dial 3	
	Cycle Length	Offset	Cycle Length	Offset	Cycle Length	Offset
1/4 Mile South of Maple	80	18	120	97	120	25
Boardwalk Drive*	80	32	120	109	120	36
Maple Road	80	66	120	113	120	12
Orchard Mall*	80	58	120	104	120	113
Nicholas Drive*	80	18	120	70	120	29
Walnut Lake Road	80	67	120	44	120	83
Green Road	80	21	120	91	120	91
Lone Pine Road	80	43	120	67	120	51
South of Pontiac Trail	80	18	120	24	120	39

Dial 1: Non-Peak Period (9:00 AM to #:00PM & 7:00 PM t 6:00AM)
Dial 2: AM Peak Period (6:00 AM to 9:00 AM)
Dial 3: PM Peak Period (3:00 PM to 7:00 PM)
N(LDg 12.D Operate on flashing mode 7:00 PM to 7:00 AM

Table 4-2 Phase Plan (Fixed time Signal)

1/4 Mile South of Maple

	Orchard Lk. Rd.	A	Driveway	A
Dial 1	51	5	19	5
Dial 2	91	5	19	5
Dial 3	91	5	19	5

Boardwalk Drive

	Orchard Lk. Rd.	A	Driveway	A
Dial 1	49	5	21	5
Dial 2	89	5	21	5
Dial 3	89	5	21	5

Maple Road

	Orchard Lk. Rd.	A	LT Orchmi lK Rd.	A	Maple Rd.	A	LT Maple Rd	A
Dial 1	27	5	8	5	19	5	6	5
Dial 2	49	5	9	5	31	5	11	5
Dial 3	51	5	19	5	20	5	10	5

Orchard Mall

	Orchard Lk. Rd.	A	Drivewav	A
Dial 1	50	5	20 .	5
Dial 2	84	5	26	5
Dial 3	84	5	26	5

Nicholas Drive

	Orchard Lk. Rd.	A	Driveway	A
Dial 1	50	5	20	5
Dial 2	90	5	20	5
Dial 3	90	5	20	5

Walnut Lake Rd.

	Orchard Lk. Rd.	A	LT Orchard Lk Rd.	A	Walnut Rd.	A	LT Walnut Rd	A
Dial 1	33	5	5	5	19	5	6	5
Dial 2	50	5	9	5	33	5	9	5
Dial 3	50	5	9	5	34	5	12	5

Green Rd.

	Orchard Lk. Rd.	A	Green Rd	A	School Drive	A
Dial 1	45	5	10	5	10	5
Dial 2	75	5	15	5	15	5
Dial 3	70	5	15	5	20	5

Lone Pine Rd

	Orchard Lk. Rd.	A	Lone Pine	A
Dial 1	45	5	25	5
Dial 2	84	5	26	5
Dial 3	84	5	26	5

South of Pontiac Trail

	Orchard Lk. Rd.	A	Driveway	A
Dial 1	50	5	20	5
Dial 2	84	5	26	5
Dial 3	84	5	26	5

4.2 The After Traffic Control – SCATS Adaptive Signal Control

4.2.1 SCATS Development and Control Logic

The SCATS system was developed in the 1970's by the Road and Traffic Authority of New South Wales, Australia. SCATS is a computer based real-time adaptive control system. SCATS is one of several forms of adaptive control that has the ability to change the phasing and timing strategies and the signal coordination within a network to meet changes in demand.

In the system employed in Oakland County, input data for SCATS is collected via a system of Autoscope@ video image devices mounted overhead on the signal strain poles or attached to mast arms. Traffic data collected in the field includes the discharge characteristics (i.e. flow and occupancy during the green phase) on each approach to the intersections. These data are then transmitted to a regional control center where the SCATS control program attempts to optimize the degree of saturation on different approaches to the intersections. Signal phases can be set to equalize the degree of saturation on all approaches or they can be arranged to give priority to a particular direction of travel.

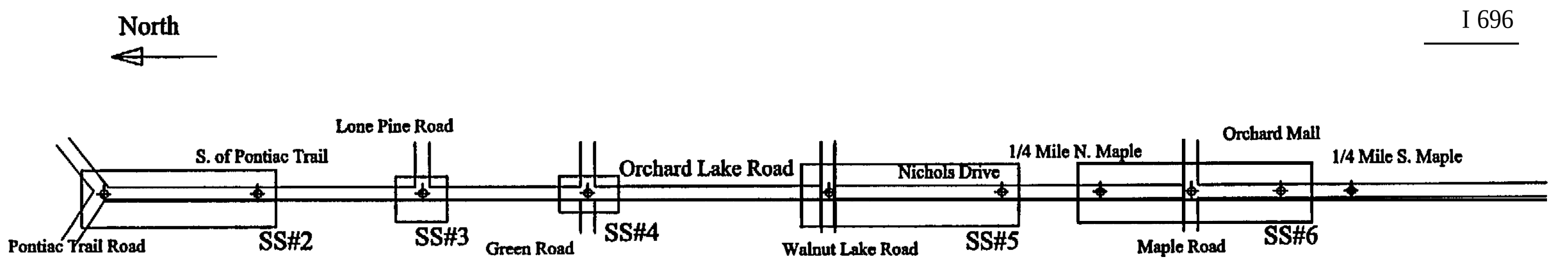
SCATS divides the network into subsystems. Each subsystem contains a single “critical” intersection, usually where two high volume roads intersect. SCATS control logic incorporates a dynamic process whereby intersection signal phasing is coordinated. This process is known as “marriage’ or “divorce”. Married intersections coordinate timings to allow platoons of traffic to pass through the intersections on green. A divorce occurs when two intersections no longer require coordination, typically during low traffic volume periods. Figure 4.1 presents the sub-system configurations for the study area.

SCATS has two levels of control; strategic and tactical. The strategic control is done by a regional computer and controls the cycle length, the phases, the offsets, and the marriage between subsystems. The tactical control is done by a local controller for each sub-system. It terminates, prolongs or skips phases according to the local traffic.

4.2.2 Cycle Length Control

In SCATS control, there are three ranges for the cycle length,

1. Short cycle length, when the traffic flow is low (MinCL to STOPPER- 1)
2. Medium cycle length, when the traffic flow is moderate (STOPPER- to STOPPER-2)
3. Long cycle length. when the traffic flow is near or over saturation (STOPPER-2 to MaxCL)


North
I 696
Lone Pine Road
S. of Pontiac Trail
Orchard Lake Road
Nichols Drive
1/4 Mile N. Maple
Orchard Mall
1/4 Mile S. Maple
Pontiac Trail Road
SS#2
SS#3
Green Road
SS#4
Walnut Lake Road
SS#5
Maple Road
SS#6

When the flow rate is lower than a pre-defined value (Fl), the cycle length is set to the minimum cycle length (MinCL). When the traffic flow rates fall between Fl and F3, the cycle length is set to the value obtained from the equation:

$$CL(new) = CL(old) + 60 \times (DS - F3)$$

Where F3 is a function of the cycle length and ranges between 0.5 for a short cycle and 0.9 for a long cycle. If the cycle length is longer than STOPPER-2 (or STOPPER-l if STOPPER-2 is not specified), the increase in cycle length is added to the green time of a predefined “stretch phase”, usually the green phase for the highest volume approach. With this cycle length range, the degree of saturation from the stretch approach only is used in the cycle length calculation. If the subsystems are married, they are forced to have the same cycle length, calculated from the approach that had the highest value of degree of saturation among the strategic approaches of all married subsystems. However, the calculated cycle length might be forced up or down to fit in the offset plan of each subsystem.

4.2.3 SCATS Green Split Allocation

One, four or eight different green split plans can be assigned to each subsystem. For each plan, one phase is defined as a stretch phase, typically the through traffic in the main road. The phases are specified either as a percentage of the cycle length or in seconds, except the stretch phase which must be defined by a percentage. Each phase is specified if it can be skipped or shortened. The increase in cycle length gives additional green time to the phases that are specified by percentage of the cycle, whereas, the phases that are specified in seconds remain constant. After the cycle length reaches a pre-defined value

(STOPPER-l or STOPPER-2), any increase in cycle length is added to the stretch phase only.

The selection of the appropriate phase plan is done through a voting algorithm during each cycle. The algorithm attempts to choose the plan that equalizes the degree of saturation for different strategic approaches and maintains them at a level near the optimal degree of saturation (typically 0.9). The phase plan will be selected when the same plan is voted for twice in three consecutive cycles.

42.4 SCATS Offset Plan

Each subsystem has four different offset plans. Two plans are set for the optimal offset when the flow is highly directional, such as morning and afternoon peak hours. The other two are set for the non peak periods. For each offset plan, the following factors are identified:

1 -Low cycle length and high cycle length (Clmin and Clmax)

2-Low cycle length offset and high cycle length offset (PPl and PP2)

3-The phase to be coordinated, and the phase and intersection to whom this phase is coordinated with.

For each plan, if the cycle length is lower than or equal to Clmin, the offset value is set to PPl. Similarly, if the cycle length is greater than Clmax, the offset is set to PP2. If the cycle length lies between Clmin and Clmax, the system will choose an offset value linearly between PPl and PP2 based on the value of the cycle length

5 Research Methodology and Approach

It has been hypothesized that the use of advanced traffic management system technologies, like SCATS, would result in significant improvements in traffic flow performance within the controlled network. Prior studies, (1,2,3) have demonstrated that SCATS can exhibit some improvements over a conventional fixed time signal system by reducing route travel time and intersection stopped delay.

This study was designed to advance the understanding of some of the ramifications of implementing the SCATS adaptive signal control system in the Oakland County traffic network. The results of this study provide evidence that supports the hypothesis that traffic improvements can be expected from SCATS implementation. Since the study was part of a national demonstration project, it was important not only to determine whether the implementation of SCATS had a significant impact on traffic flow, but also to identify what characteristics of the adaptive control contributed to these changes. Figure 5.1 presents a diagram of the methodology and approach to different parts of the evaluation study. The study incorporated four main parts:

1. Before/After corridor travel time study, to determine the impact of SCATS on corridor travel time.
2. Before/After intersection delay study, to determine the impacts of SCATS on intersection approach and stop delay for main and minor road traffic.
3. Before/After green time study, to determine how the dynamic green time allocation in SCATS contributed to the changes in intersection delay and corridor travel time

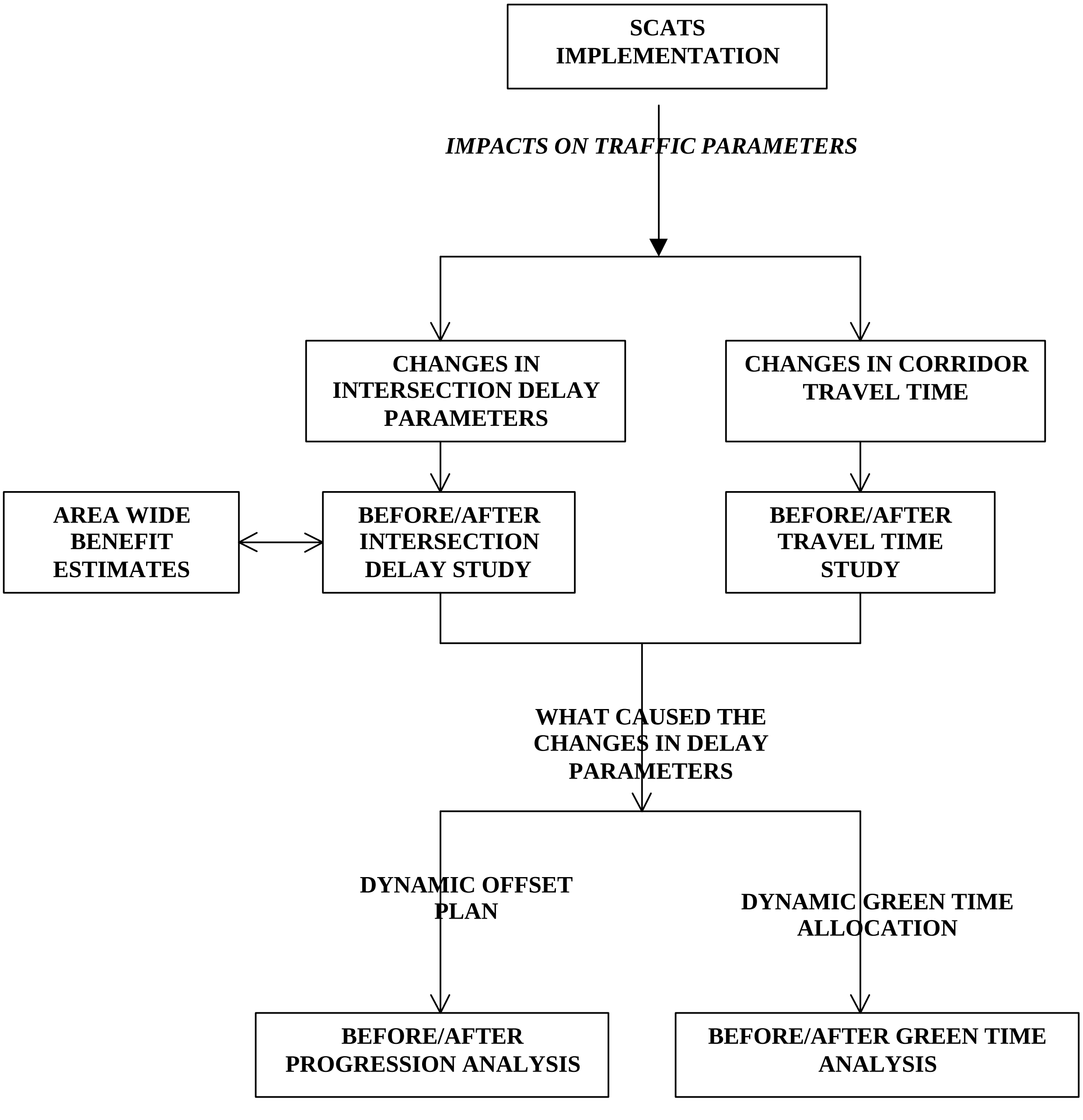


Figure 5.1 Study Objectives and Methodology

4. Before/After progression study, to determine how the dynamic offset allocation in SCATS contributed to the changes in intersection delay and corridor travel time.

The methodology, the analysis and the results of each part of the study are presented in the following sections.

6 Corridor Travel Time Study

N (LDg 12.3 Corridor Travel Time Study Objectives And Approach

The efficiency of any traffic signal control system can be measured in terms of the total time taken for all vehicles to complete their designated trip. Travel time studies are commonly used to measure arterial levels of service, evaluate road improvements, and identify problem areas within a network. The travel time characteristics within a traffic network are very useful as an indicator of overall system performance. Travel time is an indication of delay on a broader scale than intersection delay which only measures the delay on a single intersection or specific approach.

Many studies have been carried out to evaluate the performance of SCATS by the Australian Road Research Board (ARRB) and the Department of Main Roads in New South Wales. Their comparison of SCATS and TRANSYT optimized fixed time signals showed that SCATS can improve the travel time and number of stops from 3% to 18%, depending on the network, (3).

In this study, a before/after travel time comparison was used to determine the change in travel time on the study corridor after the implementation of SCATS. The sole variant in the study location was the change from TRANSYT optimized pre-timed signals to SCATS signal control. There were no geometric changes in the corridor and the before and after data were collected within a short time period, with no significant changes in traffic characteristics. The analysis assumes that the data collected during the “before” and "after" periods comes from two separate, but essentially equal samples. Thus, all recorded changes are assumed to be the result of the change to SCATS signal control.

6.1 Study Location

As described in section 3 of this report, the selected study is a corridor (Orchard Lake Rd) in an urban district in Oakland County, Michigan. The entry and exit points to and from the study segment were chosen to be in mid block locations between signalized intersections. There are three major signalized intersections and five minor shopping mall signals along the corridor.

6.2 Data Collection

Data collection for travel time studies is usually accomplished by the use of one of two basic methods. The first method of data collection involves a "moving observer", or the floating car" method. In this procedure a test vehicle travels with the existing traffic stream and makes time measurements based on the flow of normal traffic. The vehicle moves with the traffic along the corridor, so that the recorded travel time represents the average travel time during this time period. The disadvantage of the floating car method is that the number of data point collected may not be sufficient to construct a distribution of vehicle travel time or to conduct statistical analyses.

The other method of travel time data collection is the "stationary observer" method. This method is basically done by time-logging specific vehicles at both ends of the corridor. For this study, the stationary observer method was adopted as the main data collection method, with some travel time data collected through the floating car method to verify the data points obtained from the stationary observer method.

Several attempts and pilot studies were conducted in the early stages of this study to determine which technique would be used to obtain the data. The first attempt was to use computer-based image processing and matching technique. In this procedure two cameras sensed images of vehicles at the entry and exit points of the corridor. The color images were then digitized and analyzed to extract moving vehicles and to segment the vehicles into identifiable parts such as the roof, the hood, the trunk, the sides, and the wheels. These parts and their shape and color attributes were then used to match the vehicles observed at the two stations. A good match implies that the same vehicle has been sensed by both cameras. It was concluded that this technique was not suitable for data collection in this study because of the limitations on cameras position and light requirements, (5).

Another attempt was made to use the license plate matching method to determine corridor travel time. In this method, the first three digits of the license plate of vehicles were manually recorded at both ends of the corridor for each vehicle. These numbers were then matched to determine the corridor travel time. This method was not reliable, as many vehicles shared the first three digits. Adding the other three digits would have reduced the error rate, but it was not possible to manually collect the full license plate number for vehicles traveling with an average speed ranging from 35 to 50 mph.

The third attempt was to use video taping and time-logging specific vehicles at both ends of the corridor. The video tapes are manually reviewed for matches of vehicles between the entrance and exit tapes, and the entry and exit time were recorded. Although time consuming, this method proved to be a reasonable method to obtain a sufficient sample size for the corridor travel time study, and was chosen to be the main data collection method. In addition to the data collected using this method, some data were also collected using the "floating car" method to verify the data collected from the videotapes.

Travel time data were collected for both northbound and southbound traffic during three representative time periods: 7:00 – 9:00 AM (morning rush hours), 4:00 – 6:00 PM (evening rush hours), and 1:00 – 3:00 PM (non-peak hours). Travel time data were collected on two different weekdays during the before period, and on three weekdays after SCATS was installed.

To examine the stability of the travel time data collected on different days, average travel times were compared. The average travel time for each day of data collection are presented in Table 6.1. The results indicate that the within group difference was not significant when the before and after sets of data were compared.

6.3 Results and Discussion

The traffic volumes during the before and after periods were compared to make sure that there was no significant change in traffic conditions between the two time periods. During the before period, the northbound and southbound PM peak hour volumes were

1410 and 1965 vph, respectively. During the after period these values increased to 1500 and 2050 vph, respectively, for an average volume increase of 6% during the after period.

Results from the before/after travel time comparison are presented in Figure 6.1 for both northbound and southbound traffic for the three time periods. A sumrnary of the results is presented in Table 6.2. As can be seen from the results, the link travel time improved for both northbound and southbound traffic for all time periods. The reduction in travel time ranged form 6.6% to 3 1.8%.

During the morning peak period, the southbound travel time (peak direction) improved 7.9% (the average speed increased from 29.4 mph to 32.0 mph), while the reduction in travel time for the northbound traffic (non-peak direction) was 20.3%. The northbound non-peak traffic had the largest reduction in travel time, 3 1.8%. For the same period, southbound traffic travel time improved by 15.2%. During the evening peak hour, the northbound traffic travel time (peak direction) improved by 7.8% (the average speed increased from 25.3 mph to 27.3 mph). The southbound evening travel time improved by 7.2%.

Table 6.1 Average Travel Time and Sample Size For Corridor Travel Time Study

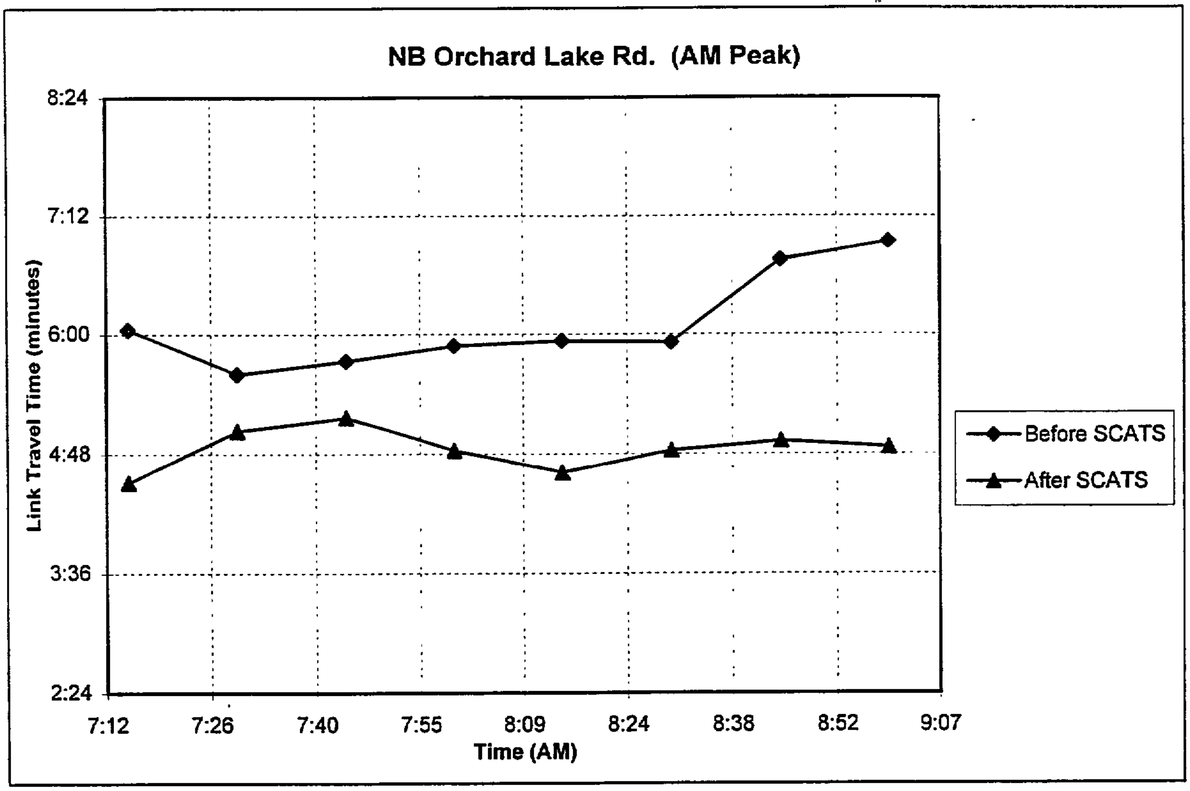
	Before						After					
	Northbound			Southbound			Northbound			Southbound		
	Day	Sample *	Travel Time**	Day	Sample	Travel Time	Day	Sample	Travel Time	Day	Sample	Travel Time
AM Peak (7:00-9:00)	4-Jun-96	110	6:16	4-Jun-96	102	6:29	2-Mar-97	69	5:06	27-Mar-97	54	5:50
	6-Jun-96	96	6:24	6-Jun-96	96	6:14	16-Apr-97	112	4:56	16-Apr-97	69	5:44
							14-May-97	81	4:52	14-May-97	109	5:56
Non-Peak Noon (1:00-3:00)	4-Jun-96	87	7:16	4-Jun-96	124	6:12	27-Mar-97	101	5:11	27-Mar-97	87	5:28
	13-Jun-96	114	7:10	13-Jun-96	86	6:21	23-Apr-97	99	4:52	23-Apr-97	69	5:20
							14-May-97	96	5:00	14-May-97	64	5:14
PM Peak (4:00-6:00)	4-Jun-96	78	7:23	4-Jun-96	66	6:24	27-Mar-97	81	6:41	27-Mar-97	101	5:52
	13-Jun-96	95	7:19	13-Jun-96	98	6:16	23-Apr-97	103	6:48	23-Apr-97	68	6:01
							14-May-97	102	6:51	14-May-97	83	5:49

* Number of matched vehicles

** Travel Time in Minutes

Table 6.2 Travel Time and Speed Results For Orchard Lake Road Through Traffic

		Northbound			Southbound		
		Before	After	% Change	Before	After	% Change
Travel Time (minutes)	AM Peak	6:19	5:02	-203.	6.:22	5:49	-8.6
	Non-Peak	7:14	4:56	-31.8	6:16	5:19	-15.2
	PM Peak	7:21	6:49	-7.3	6:21	5:56	-6.6
Speed (mph)	AM Peak	29.4	37.0	25.5	29.3	32.0	9.3
	Non-Peak	25.7	37.7	46.6	29.7	35.0	17.9
	PM Peak	25.3	27.3	7.8	29.3	31.3	7.0



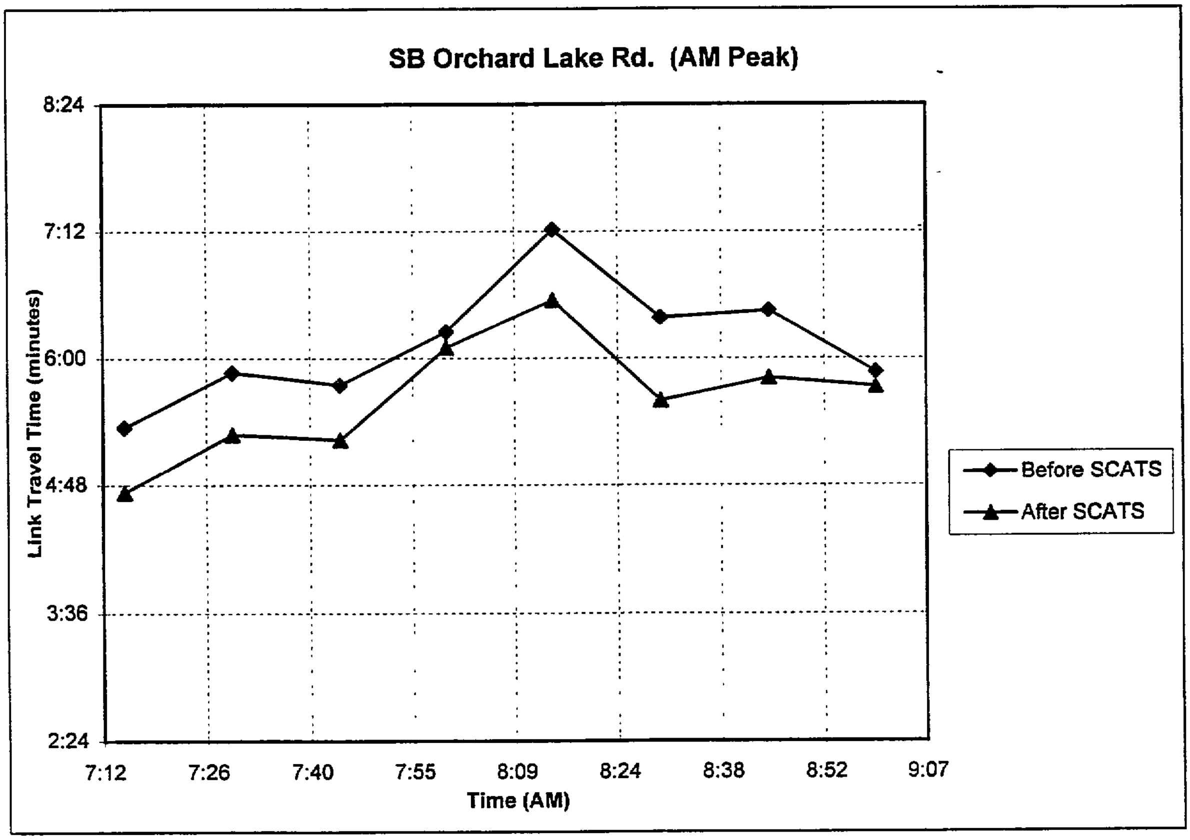
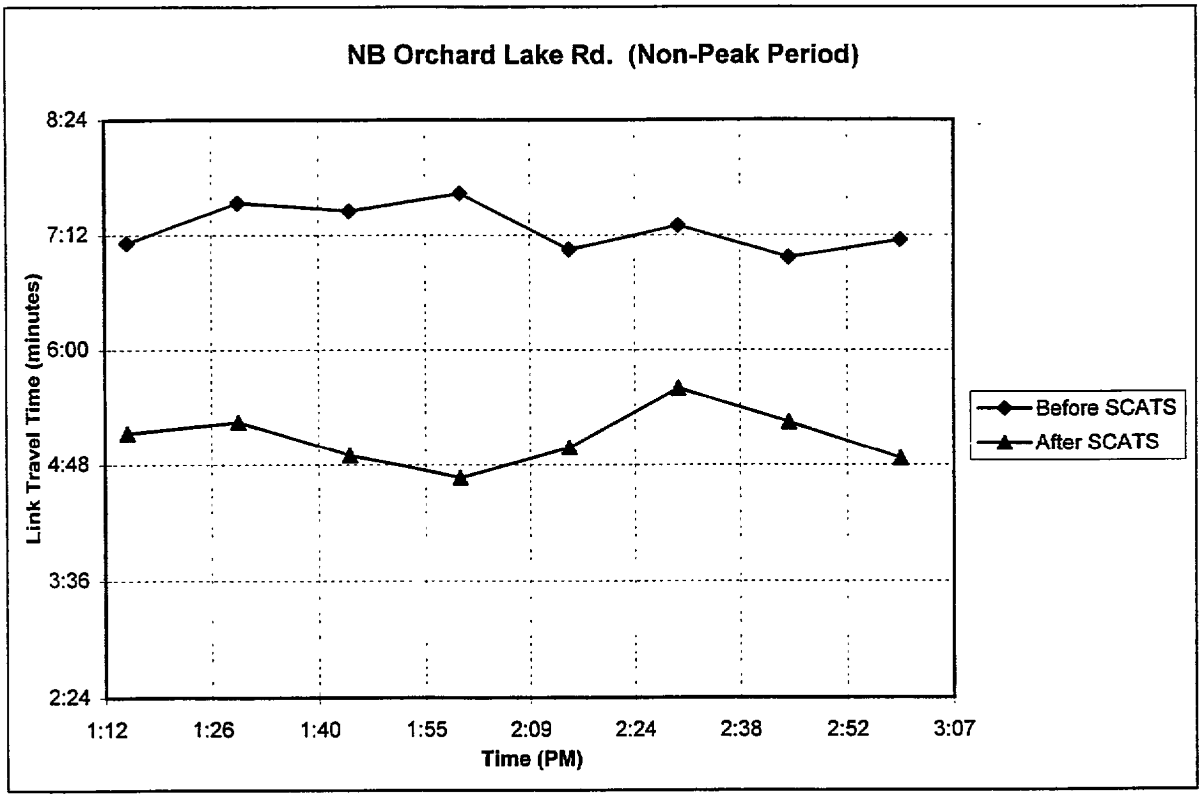


Figure 6.1 Before/After Average Travel Time Averaged over 15 Minute Time Increments



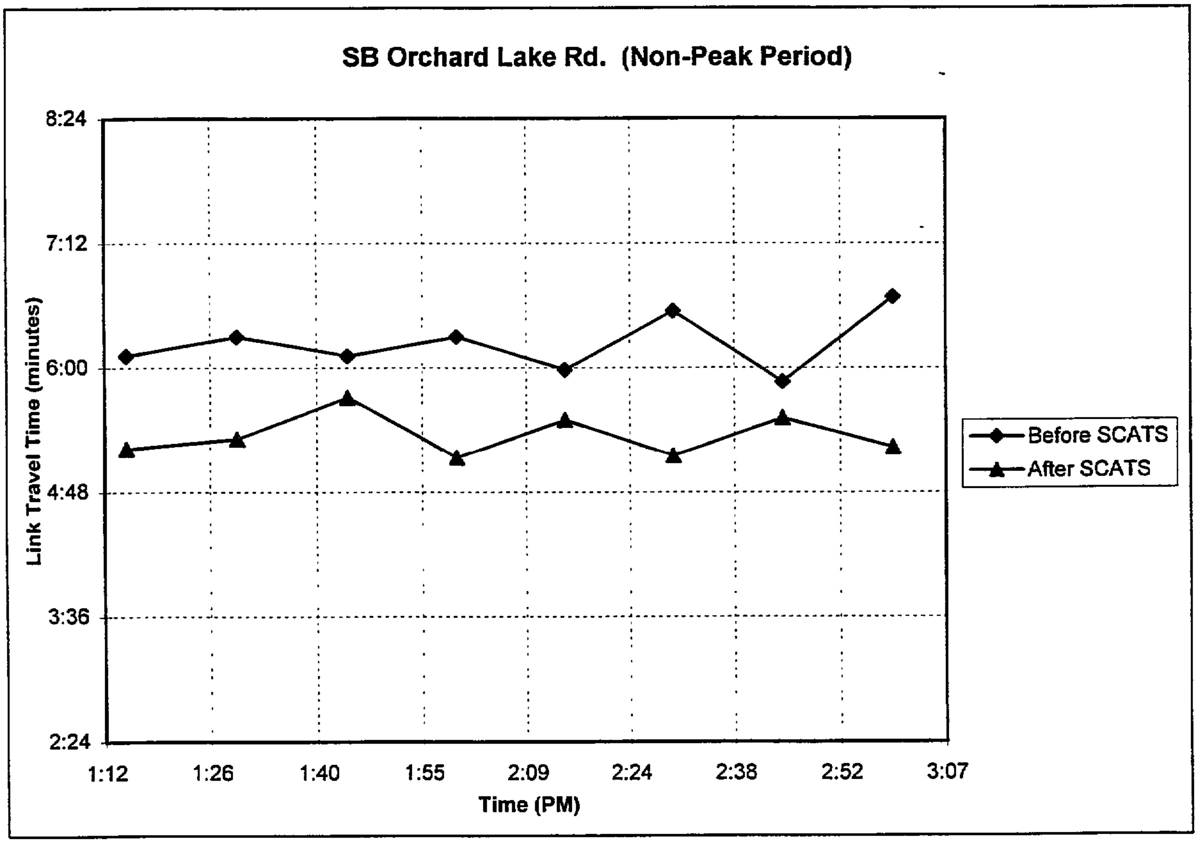
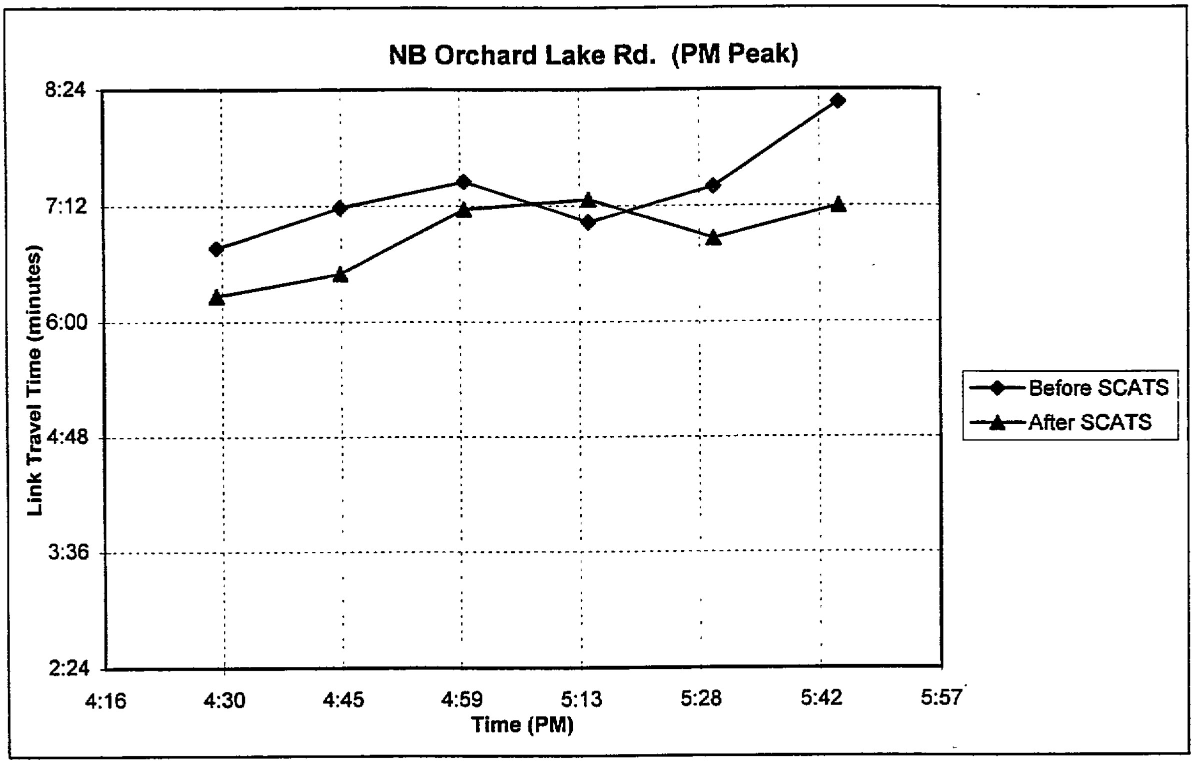


Figure 6.1 (Cont.) Before/After Average Travel Time Averaged Over 15 Minute Time Increments



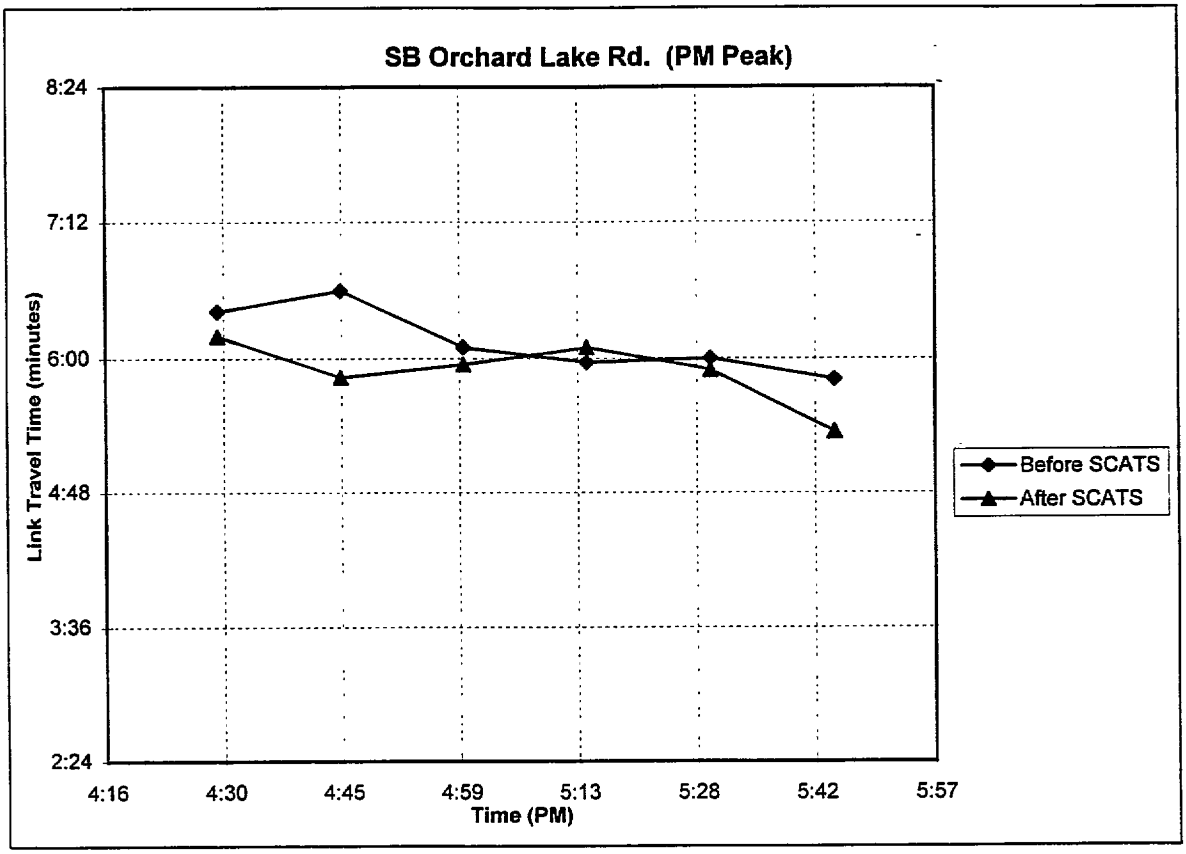


Figure 6.1 (Cont.) Before/After Average Travel Time Averaged Over 15 Minute Time Increments

7 Intersection Delay Study

7.1 Objectives and Approach

An intersection delay study was conducted to examine the changes in intersection delay for all approaches as a result of SCATS implementation. This study compared intersection delay parameters obtained from field data collected before and after SCATS implementation in the Orchard Lake Corridor. Prior to SCATS adaptive control, which was deployed in the network during spring 1997, the intersections along the corridor were controlled by fixed time signals. To compare the two control strategies, the following measures of performance were examined in the study:

l-__Average Approach Delay:__ the term approach delay, as used in this study, is defined as the length of the time that vehicles approaching the intersection from a particular direction are delayed due to a red signal and/or stopped queue which prohibits their free flow travel through the intersection. Average approach delay is the sum of the approach delay for all vehicles divided by the total number of vehicles.

2-__Average Stopped Delay:__ stopped delay is the amount of time that a vehicle spends in a queue plus the time it takes to travel from its position in the queue to the approach stop line. This is the measure used in the Highway Capacity Manual to assign a Level of Service (LOS) rating to signal controlled intersections. Average stopped delay is the sum of stopped delay divided by the total number of vehicles.

3-Average In-Queue Time: In-queue time is the amount of time that a stopped vehicle spends in a queue plus the time it takes to travel from its position in the queue to the approach stop line. Average in-queue time is the sum of in-queue time divided by the number of stopped vehicles.

4-Percentage of stopped/non-stopped vehicles: Since one of the objectives of SCATS is to minimize overall stops and queue formation in the network, these factors were included in the comparative analysis.

Figure 7.1 shows how each of the delay parameters were obtained from the field data. An approach section was first defined for each intersection. For each approach an entry point (upstream from the intersection), and an exit point (near the stop bar of the intersection) were selected. For each vehicle, three different times were recorded; the time it crossed the entry point (In -time), the time it crossed the exit point (Out-time), and the time the vehicle came to a stop, if it did, (Stop-time). Delay parameters were computed as follow:

Average Stopped delay = 3 [(Out-time) - (Stop-time)// total number of vehicles

Average Approach delay = 3 [[(Out-time) - (In-time)] - (Free flow travel time)]] / Total number of vehicles

Average In-Queue Time = 3 [(Out-time) - (Stop-time) / /number of stopped vehicles

Free flow travel time represents the time the vehicle takes to travel through the intersection approach section using the average speed of vehicle on the approach.

Stopped Delay=(Out_time)-(Stop_time)

Approach Delay=(Out_time)-(In_time)-(Free Flow Travel Time)

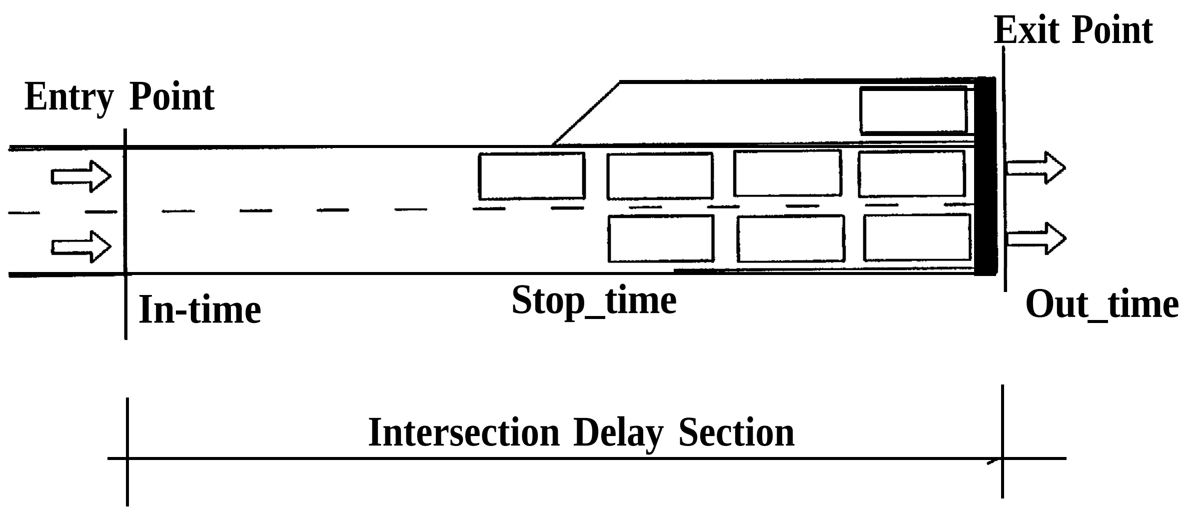


Figure 7.1 Approach Delay Section

Before SCATS was employed, the signals were operating in a fixed time mode with the plan pre-determined according to the time of the day and the day of the week. For the weekdays, three different plans were used, morning rush (6:00 – 9:00 AM), evening rush (3:00 – 7:00 PM) and non-rush periods (9:00 AM – 3:00 PM) and (7:00 PM – 6:00 AM). The cycle length, green split and offset remained constant during each of these plans, and the data were obtained from the timing plans. After SCATS was implemented, the system monitoring files provided cycle-by-cycle signal and traffic data for all major intersections along the corridor. The data included green time for each approach, volume for each lane, degree of saturation for each lane, and phase and offset plans.

7.2 Study Locations

There are three major signalized intersections and five minor shopping mall or driveway signals along the Orchard Lake corridor (Figure 3.1). Before/After intersection delay analyses were conducted for the three major intersections along the corridor. The three intersections are Maple Road, Walnut Lake Road, and Lone Pine Road. The geometric configuration, as well as the phasing diagrams, for these intersections are presented in Figure 7.2.

7.3 Data Collection and Reduction

For the Lone Pine Road and Walnut Lake Road intersections, data were collected using Autoscope@ Cameras mounted overhead and pointed to the section approaching the intersection (Figure 7.3) for both the before and after phases. The before data were

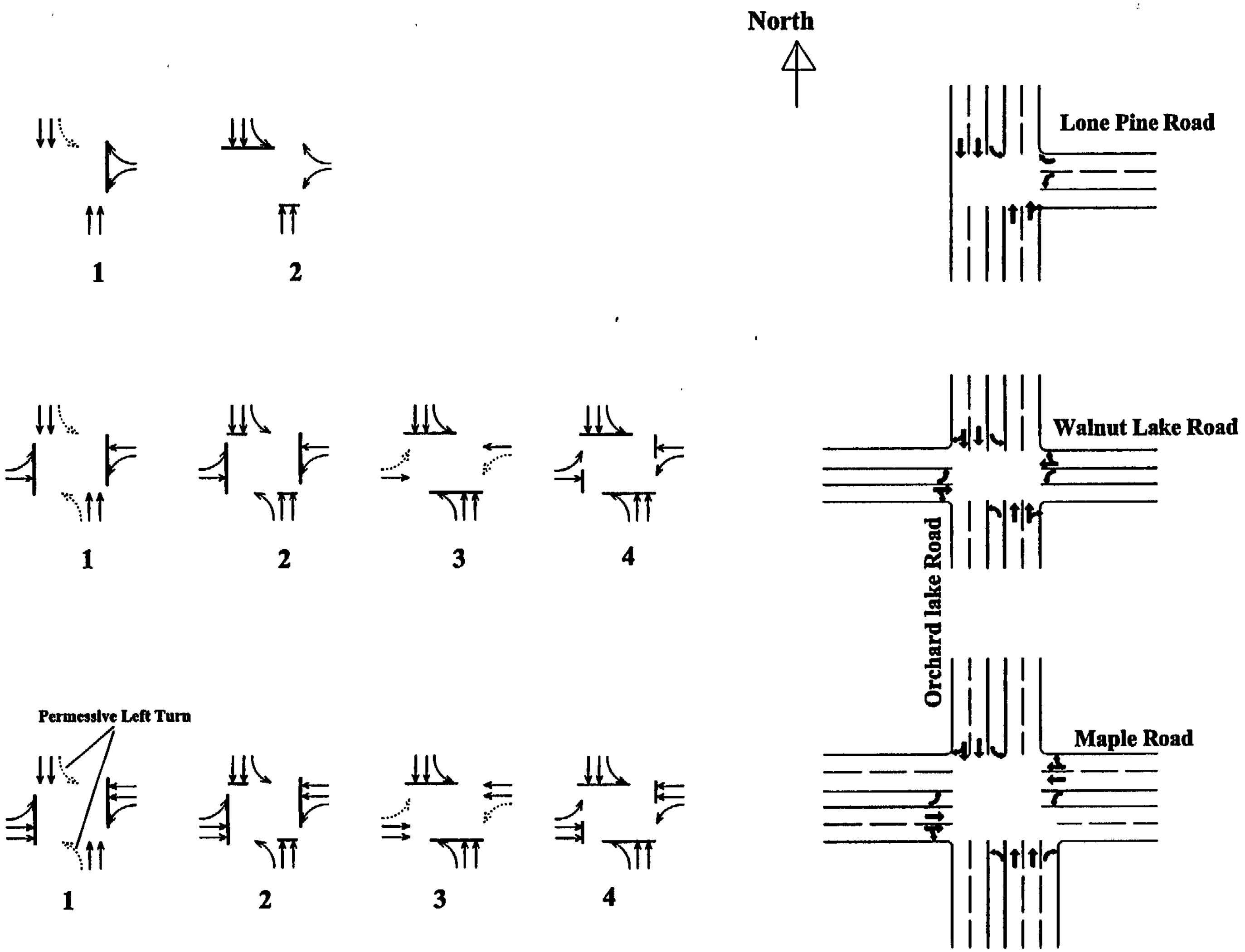


Figure 7.2 Lane Configuration and Phase Plan for Maple Rd., Walnut Lake Rd., and Lone Pine Rd. Intersections

Figure 7.3 View from Autoscope Camera (Northbound-Traffic – Orchard Lake Road & Maple Road Intersection)

collected during January 1997, when Autoscope@ cameras were mounted in the intersection but the signals were still running under fixed time control.

For Maple Road, the Autoscope cameras were not mounted until just before changing to SCATS control and there was no time to collect fixed-time data. The before data at this intersection were collected using two video cameras for each approach; one pointed upstream and the other pointed at the stop bar. The after data, however, were collected using Autoscope cameras similar to the other two intersections. For all intersections, data were collected for two approaches, northbound and westbound. Data were collected for three time periods; from 11:30 AM to 1:00 PM, from 1:00 PM to 3:00 PM, and in the afternoon peak from 4:00 PM to 6:OOPM.

Data collected through Autoscope@ cameras were processed and analyzed using the Mobilizer@ Advanced Image Sensor System. The system uses an image sensing algorithm to detect the presence of vehicles when they cross the entry point, tag them and track their movement throughout the intersection approach section. The system reports the time the vehicles entered the approach, and the time they departed from the approach section. If the vehicle had to stop, the system reports the stopped time as well.

To determine the accuracy of the data obtained from the Mobilizer@ image processing system, the data reported by the system were compared with the ground truth data obtained through manual reduction for three 10 minutes periods for three different tapes. The comparison showed that the system failed to detect some of the vehicles approaching the intersection. The percentage of undetected vehicles ranged from 6.4% to 18.8%. The percentage error seems to increase as the volume approaching the intersection increases. The poor picture quality and the non-optimal vision angle contributed to this error.

The error in the average approach delay aggregated over 5 minute period ranged from 1.4 to 5.8 seconds with an average of 2.6 seconds (9.56%). Again, the error seems to increase when the volume approaching the intersection increases. The magnitude of the error was considered acceptable, and this data reduction technique was used as the primary method to reduce the data for two of the three intersections included in the study, (Orchard Lake Road – Maple Road and Orchard Lake Road – Lone Pine Road). To verify the results, on average 20% of the data in each tape for these two intersections were reduced manually. For the third intersection, (Orchard Lake Road – Walnut Lake Road), the data were reduced manually. The length of the queue as reported by the system was not reliable. Therefore, the number of vehicles in the queue, as well as the number of stopped/and non-stopped vehicles, were reduced manually to ensure accuracy of the output.

7.4 Results And Discussion

7.4.1 Orchard Lake Road -Walnut Lake Road Intersection

Walnut Lake Road is a major intersection along the Orchard Lake Corridor study area. Walnut Lake Road runs East-West with most of the morning traffic heading east, and the afternoon traffic heading west. Data were collected for two days during the before period (January 16 and January 23,1997) and for two days during the after period (March 20 and March 26, 1997). The data were collected for Orchard Lake Road northbound traffic and Walnut Lake Road westbound traffic The data were collected form 12:OO PM to 6:00 PM.

The field data were reduced manually using the following method. First, the number of stopped and non-stopped vehicles for each cycle were recorded. The first, the last and the median vehicles in the queue were identified. For these three vehicles, the time the vehicle crossed the entry line of the intersection approach (in-time), the time it stopped (stop-time), and the time it crossed the exit line (out-time) were recorded. The in-queue time for these vehicles was obtained. The average of the in-queue time for these three vehicles was considered to be the average in-queue time for the vehicles stopped during the cycle. The average stopped delay was obtained for each cycle as follows:

average stopped delay = average in-queue time x number of stopped vehicle /total number of vehicle

The traffic volume was higher during the after period for both northbound and westbound traffic. During the non-rush period, the after traffic was higher by an average of 6.1%. The increase in traffic during the rush period (4:00 PM to 6:00 PM) averaged 9.0%.

Results from the before/after delay comparisons for Orchard Lake Road northbound through traffic are presented in Figure 7.4. As expected from the reduction in corridor travel time, the results showed a reduction in average stopped delay after SCATS implementation even though the traffic volumes were higher during the after period. During the non-rush period (1:00 PM to 4:00 PM), the average stopped delay decreased from 18.35 seconds/vehicle to 16.00 seconds/vehicle (14.7%). The reduction in delay seems to decrease as traffic volumes increase.

During the rush period (4:00 PM to 6:00 PM), the average stopped delay decreased from 21.72 seconds/vehicle to 20.75 seconds/vehicle (4.6%). Again, the reduction in delay seems to decrease as traffic volumes increase. After 5:00 PM, stopped delay was slightly higher after SCATS implementation. This might be a result of the increased traffic volume during the after period.

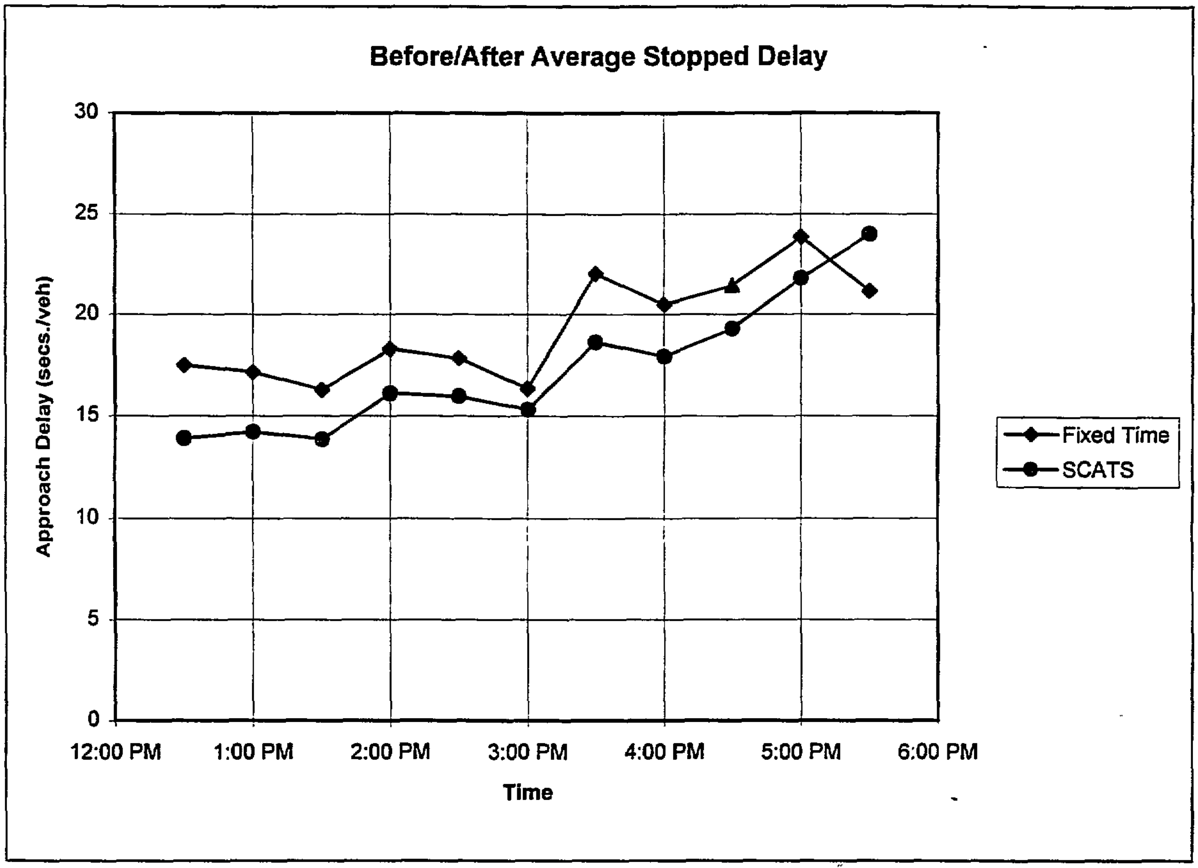
The percentage of non-stopped vehicles increased from 5 1.6% during the before period to 56.1% during the after period. This reduction was associated with reduction in in-queue time for both peak and non-peak periods. During the non-peak period, the average in-queue time decreased from 31.87 seconds/vehicle to 28.01 seconds/vehicle (13.8%). During the peak period, the in-queue time also decreased from 40.58 seconds/vehicle to 40.30 seconds/vehicle (0.5%)

Figure 7.5 shows the before/after delay comparisons for northbound left-turn traffic. During the before period, 71.4% of the vehicles that were turning left had to stop with an average stop time of 40.36 seconds/vehicle. This percentage decreased to 67.7% during the after period. However, the average stop time was increased to 44.27 seconds/vehicle (9.1%). The average stopped delay was 29.9 seconds/vehicle during the before period, and remained almost the same during the after period (29.8 seconds/vehicle).

Figure 7.6 shows the before/after delay comparisons for Walnut Lake Road westbound through traffic. Generally, both the stopped delay and in-queue time were higher after SCATS implementation. During the non-peak period, the stopped delay increased from an average of 18.40 seconds/vehicle to 19.99 seconds/vehicle (8.0%). The time-in-queue delay during the same period decreased from 28.91 seconds/vehicle to 28.20 seconds/vehicle (2.5%) after SCATS implementation. During the rush-period, the average stopped delay increased from 29.04 seconds/vehicle to 32.85 seconds/vehicle (11.9%). The in-queue time also increased from 42.95 seconds/vehicle to 46.03 seconds/vehicle (6.7%). The percentage of non-stopped vehicle also decreased from 42.8% to 36.4% after SCATS implementation

The average intersection delay, (computed from northbound and westbound traffic) decreased from 24.04 seconds/vehicle to 23.45 seconds/vehicle (2.6%) during the rush-period, and from 18.36 seconds/vehicle to 17.06 seconds/vehicle (7.6%) during the non-rush period.

Figure 7.4 Before/After Delay Comparison for Orchard Lake Road Northbound Through Traffic (Orchard Lake Road & Walnut Lake Road Intersection)



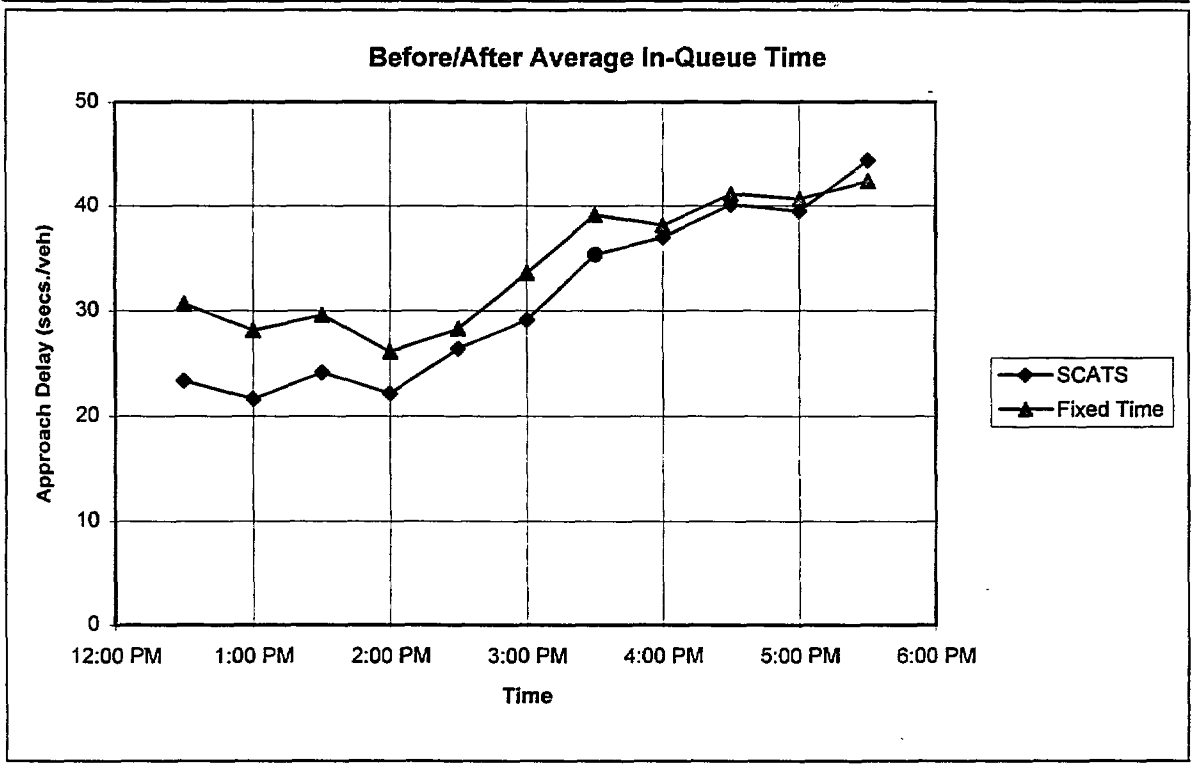
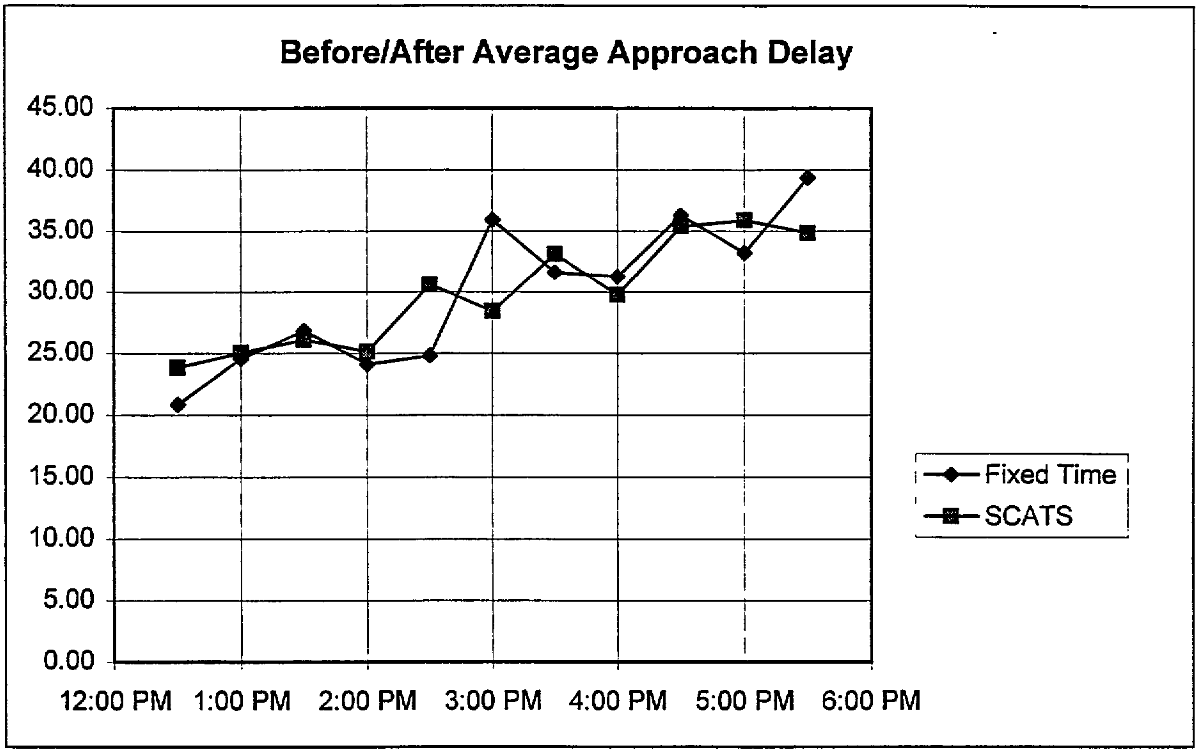


Figure 7.5 Before/After Delay Comparison for Orchard Lake Road Northbound LT Traffic (Orchard Lake Road & Walnut Lake Road Intersection)



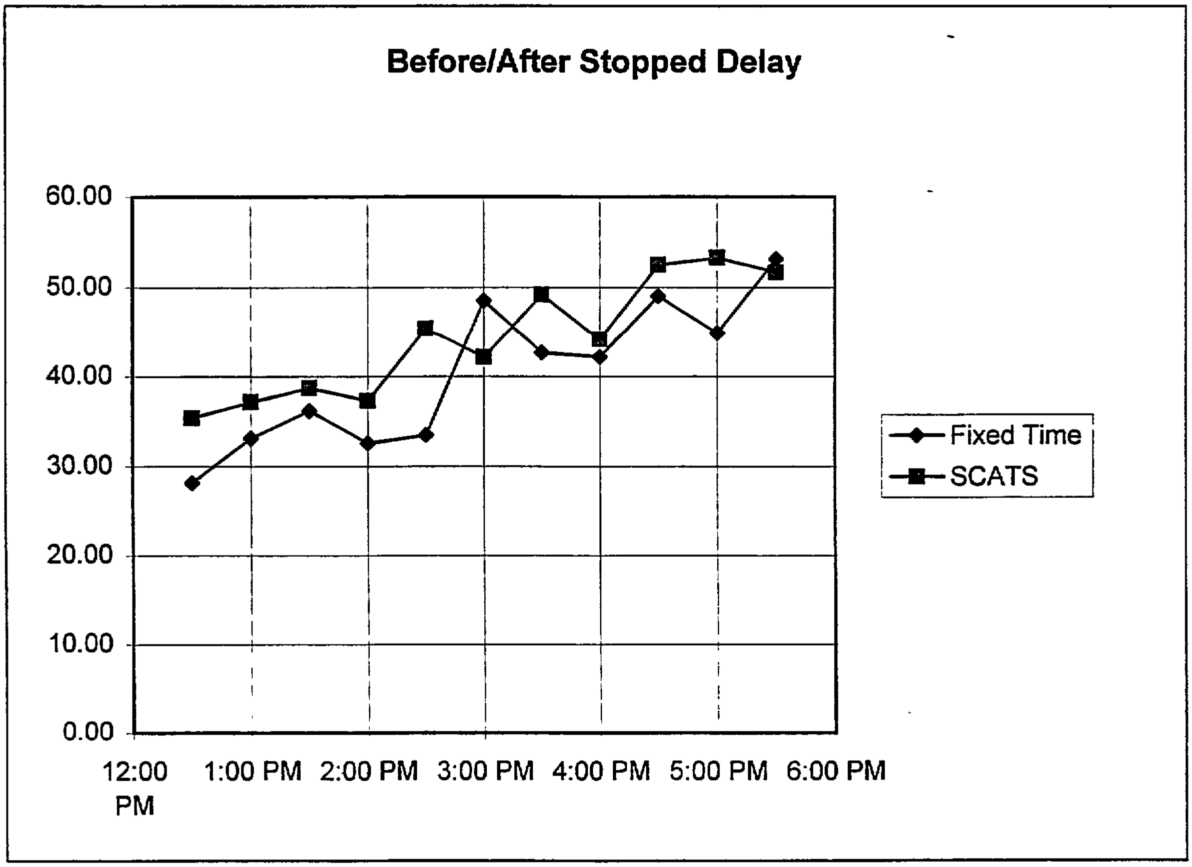
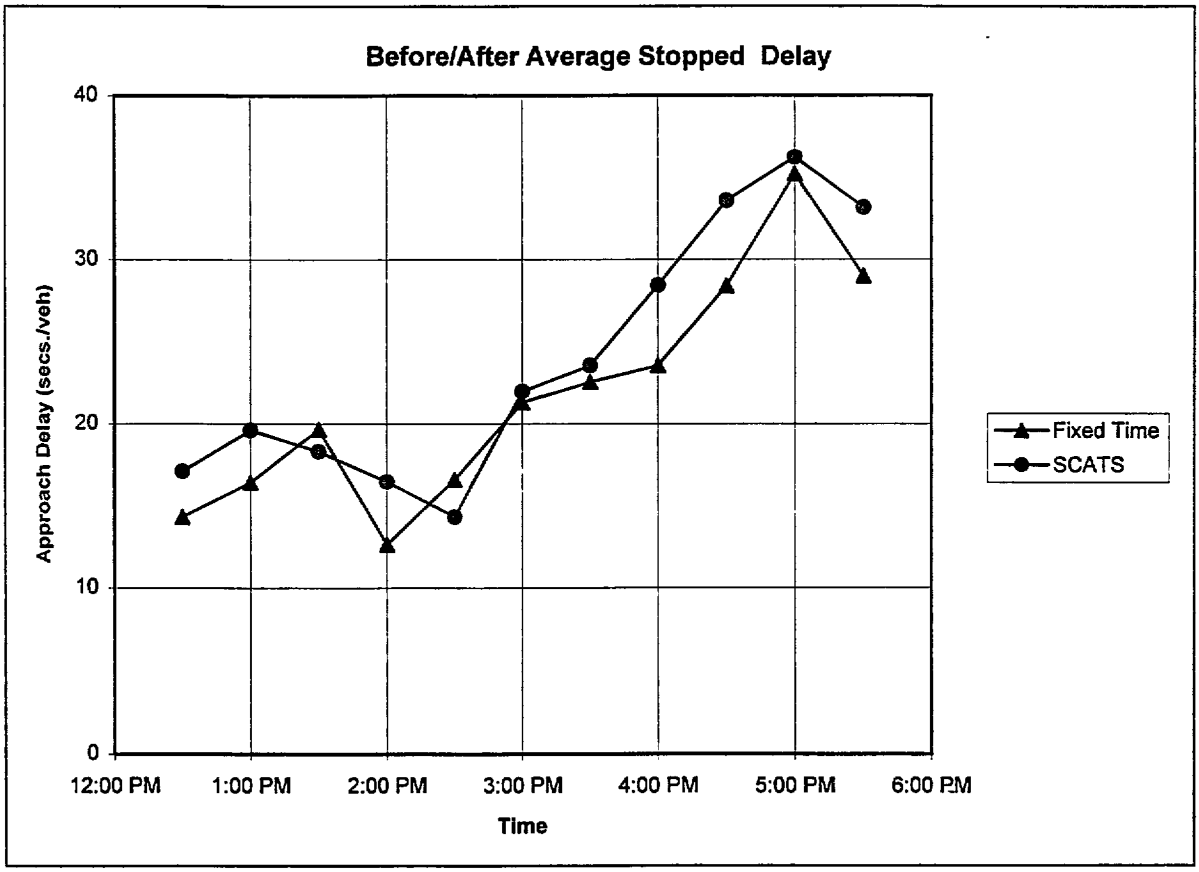
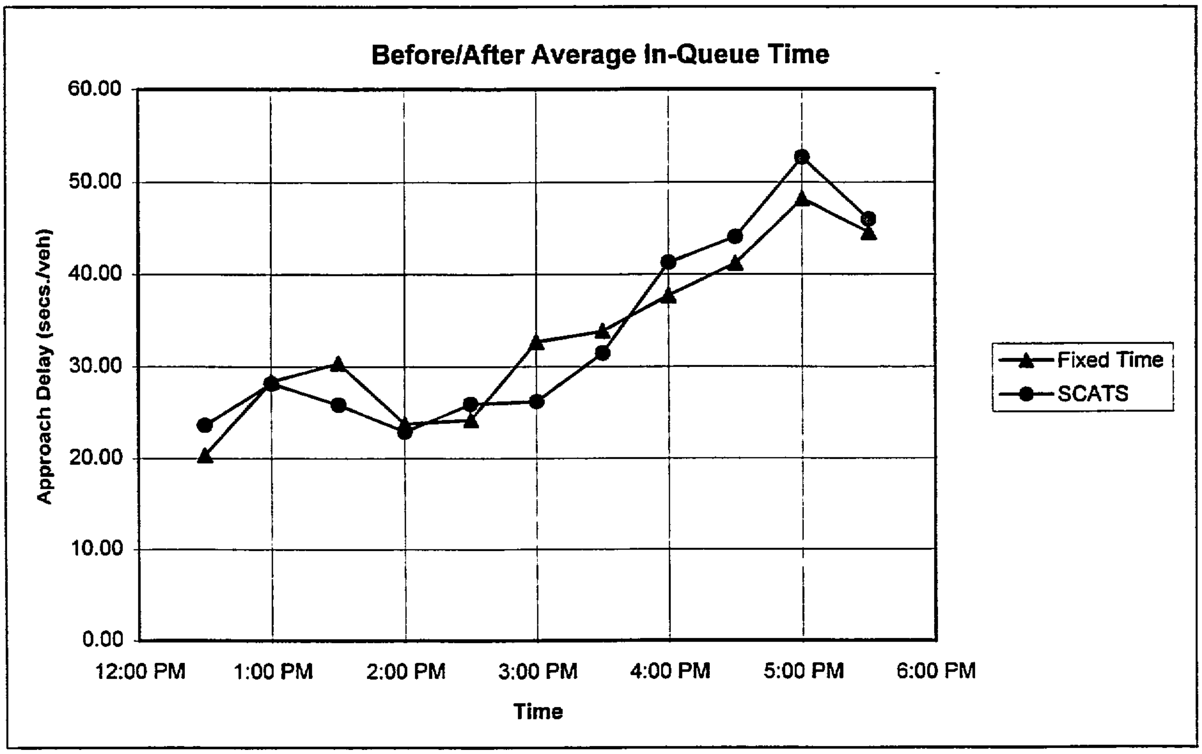


Figure 7.6 Before/After Delay Comparison for Walnut Lake Road Westbound Through Traffic (Orchard Lake Road & Walnut Lake Road Intersection)





7.4.2 Orchard Lake Road – Lone Pine Road Intersection

Results from the before/after intersection delay for the Orchard Lake Road-Lone Pine Road intersection are presented in Figures 7.7 and 7.8 for northbound and westbound traffic, respectively. Similar to the output from the Walnut Lake Road intersection, and as expected from the reduction in corridor travel time, average approach delay for northbound through traffic decreased for both the peak and non-peak periods. The average delay for this approach decreased by 29%. The percentage of vehicles traveling northbound that had to stop at the intersection dropped from 53.2% to 48.4%.

Westbound traffic, however, experienced an increase in average delay as a result of SCATS implementation. The approach delay increased by an average of 16.7% during non-rush hours and by an average of 49.8% during rush hours. This was expected as SCATS gives more priority to the main street traffic (northbound and southbound traffic). During peak periods, the percentage of vehicles that had to stop increased from 68% to 72%, with an increase in average number of vehicle in the queue from 4;2 to 5.6 vehicles.

The average intersection delay, computed from northbound and westbound traffic only, decreased from 18.75 seconds/vehicle to 13.8 1 seconds/ vehicle (26.3%) during the non-peak period, and from 18.25 seconds/vehicle to 15.16 seconds/vehicle (16.9%) during the peak period.

Figure 7.7 Before/After Delay For Orchard Lake Road Northbound Through Traffic (Orchard Lk. Road & Lone Pine Road Intersection)

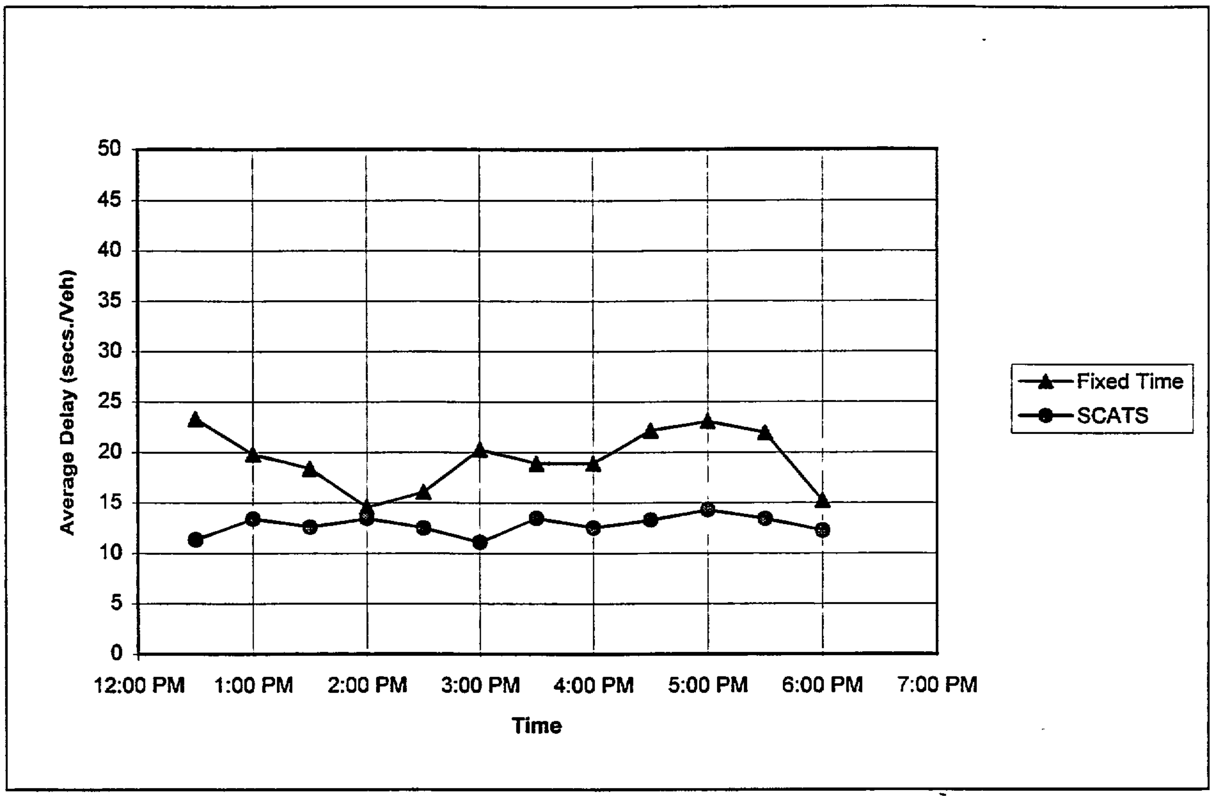
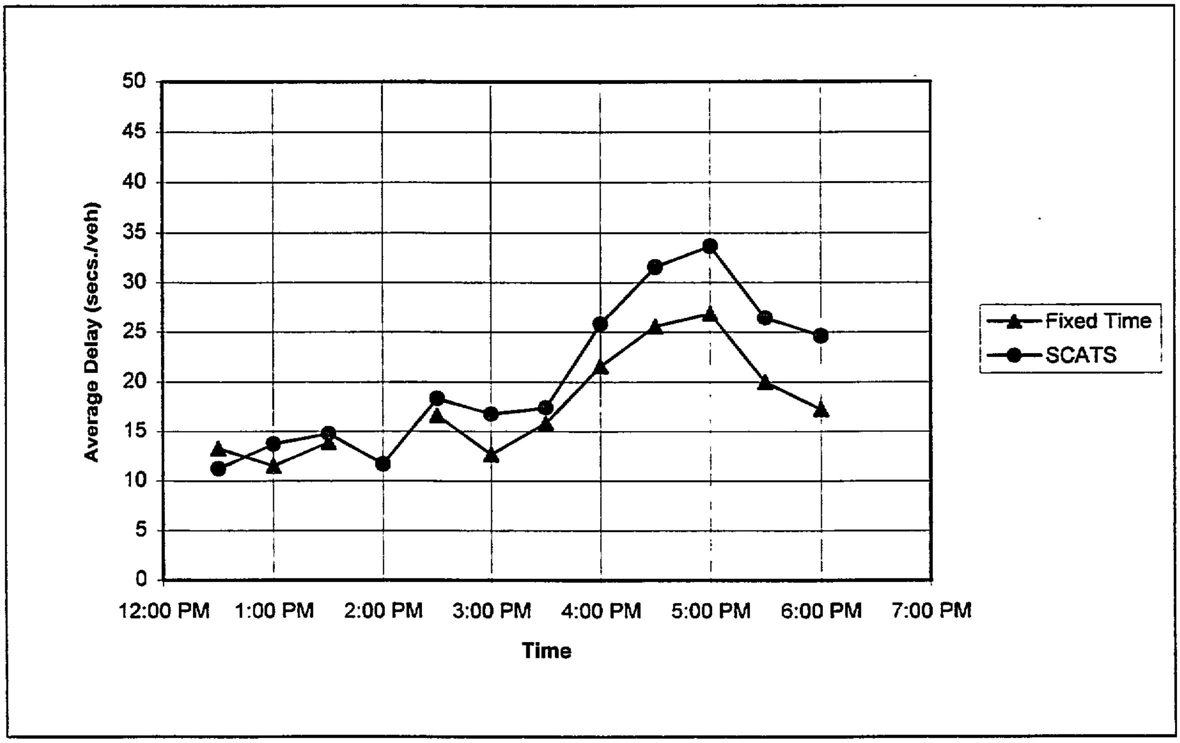


Figure 7.8 Before/After Delay For Lone Pine Road Westbound Traffic (Orchard Lk. Road & Lone Pine Road Intersection)



7.4.3 Orchard Lake Road – Maple Road Intersection

Maple Road is the major cross road in the Orchard Lake corridor study area. Figures 7.9 and 7.10 show the before/after average approach delay for northbound and westbound traffic, respectively. Similar to the results from the Walnut Lake Road and the Lone Pine Road intersections, the delay for Orchard Lake Road northbound traffic decreased after SCATS implementation, whereas, the westbound through traffic experienced an increase in delay.

The northbound through traffic average delay decreased from 34.65 seconds/vehicle to 30.26 seconds/vehicle (14.7%). The westbound through traffic average delay was increased from 34.53 seconds/vehicle to 37.65 seconds/vehicle (8.2%). The average intersection delay, obtained from northbound and westbound through traffic only, was decreased from 34.6 1 seconds/vehicle to 3 1.75 seconds/vehicle (9.0%).

Figure 7.9 Before/After Delay For Orchard Lake Road Northbound Through Traffic (Orchard Lk. Road & Maple Road Intersection)

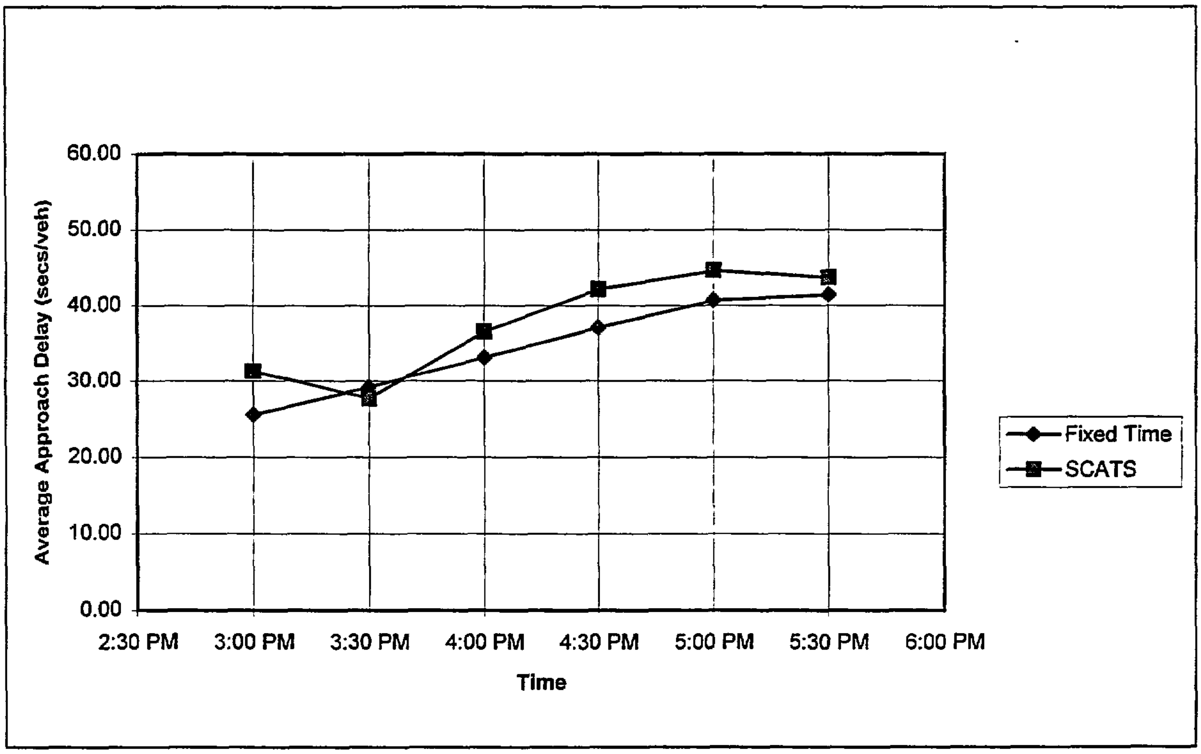
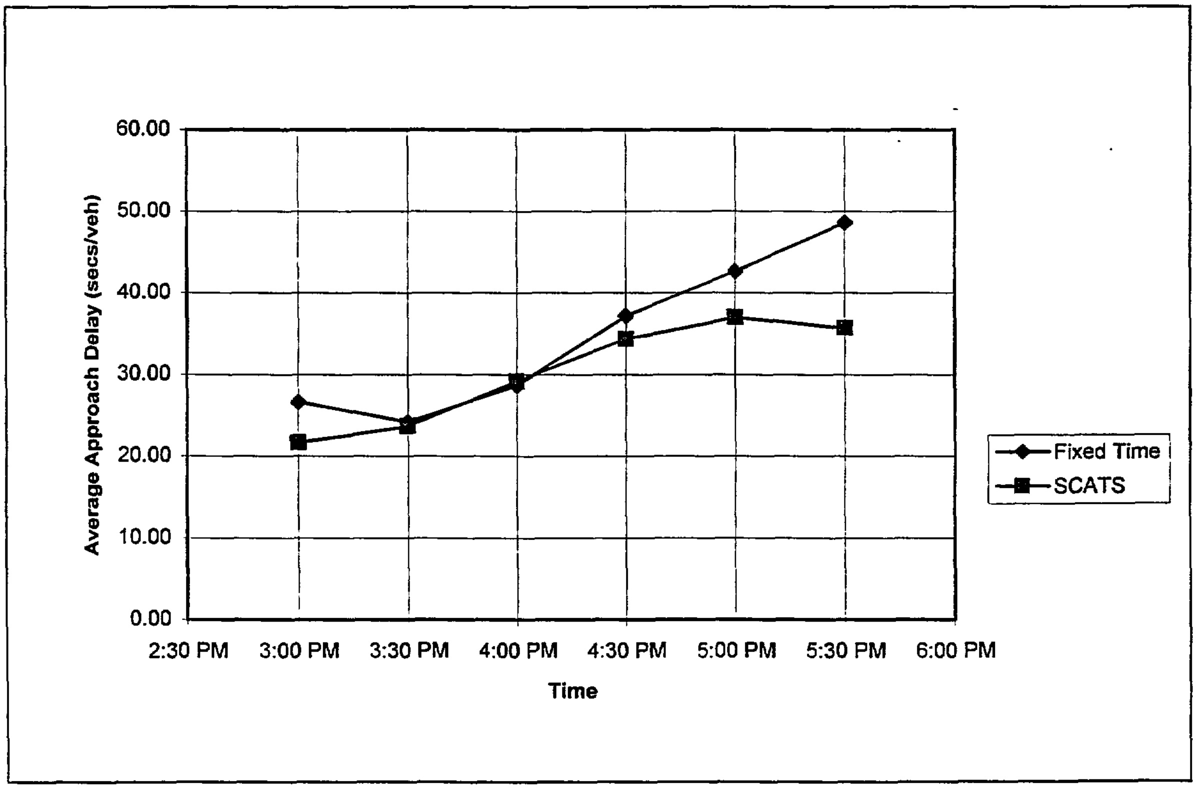


Figure 7.10 Before/After Delay For Maple Road Westbound Through Traffic (Orchard Lk. Road & Maple Road Intersection)



8 Before/After Green Time Analysis

There are three possible ways an adaptive signal can contribute to a reduction in delay for the major street traffic. The first is to allocate more green time to this approach; the second is to utilize the existing green time more effkiently, (i.e. with less lost time); and the third is to improve the corridor progression, and thus reduce the stopped time component of delay, Figure 8.1. Each of these components was analyzed in this study. The green time allocation and offset data for the after period were obtained from SCATS system monitoring files. The files report the cycle-by-cycle green time allocated for each approach, the actual number of vehicles that departed during the green phase per lane per approach, and the link and offset plans employed during this cycle.

The total effective green time per hour allocated to each movement during the before and after periods were compared for all intersections along the corridor. The effective green time for each phase represents the combined green and amber periods minus the lost time at the beginning and end of that phase. The lost time was assumed to be four seconds per phase for both the before and after periods. Because the cycle length was different for the before and after periods, and was variable in the after period, it was necessary to examine the total effective green time per hour. The effective green time during SCATS is the average value over a ten day period

The results showed that SCATS, in general, allocated additional green time to the N-S through traffic while reducing the green time for all other approaches. During peak periods, SCATS also used longer cycle lengths, with less lost time per hour, thus utilizing the green time more efficiently.

To measure how effectively the green time allocation was utilized, the mean and standard deviation of the degree of saturation by hour of the day for the SCATS and a fixed time system were compared. Since data on the degree of saturation is not available for the before period, the degree of saturation for the fixed time system was calculated as the degree of saturation that would result if the volume recorded by the SCATS detection system were present while the intersection was operating in the fixed time mode. The volumes were obtained from SCATS monitoring files and represent the average volume per hour for each approach. The saturation flow was assumed to be 1800 vehicles per hour. The results showed that, in general, by extending the green time for the North and South traffic SCATS reduced the average degree of saturation during both rush and non-rush periods. Consequently, when SCATS reduced the green time for the minor approach (westbound/eastbound), the degree of saturation increased. The results of a comparison of the effective green time and degree of saturation for each intersection are presented in the following sections.

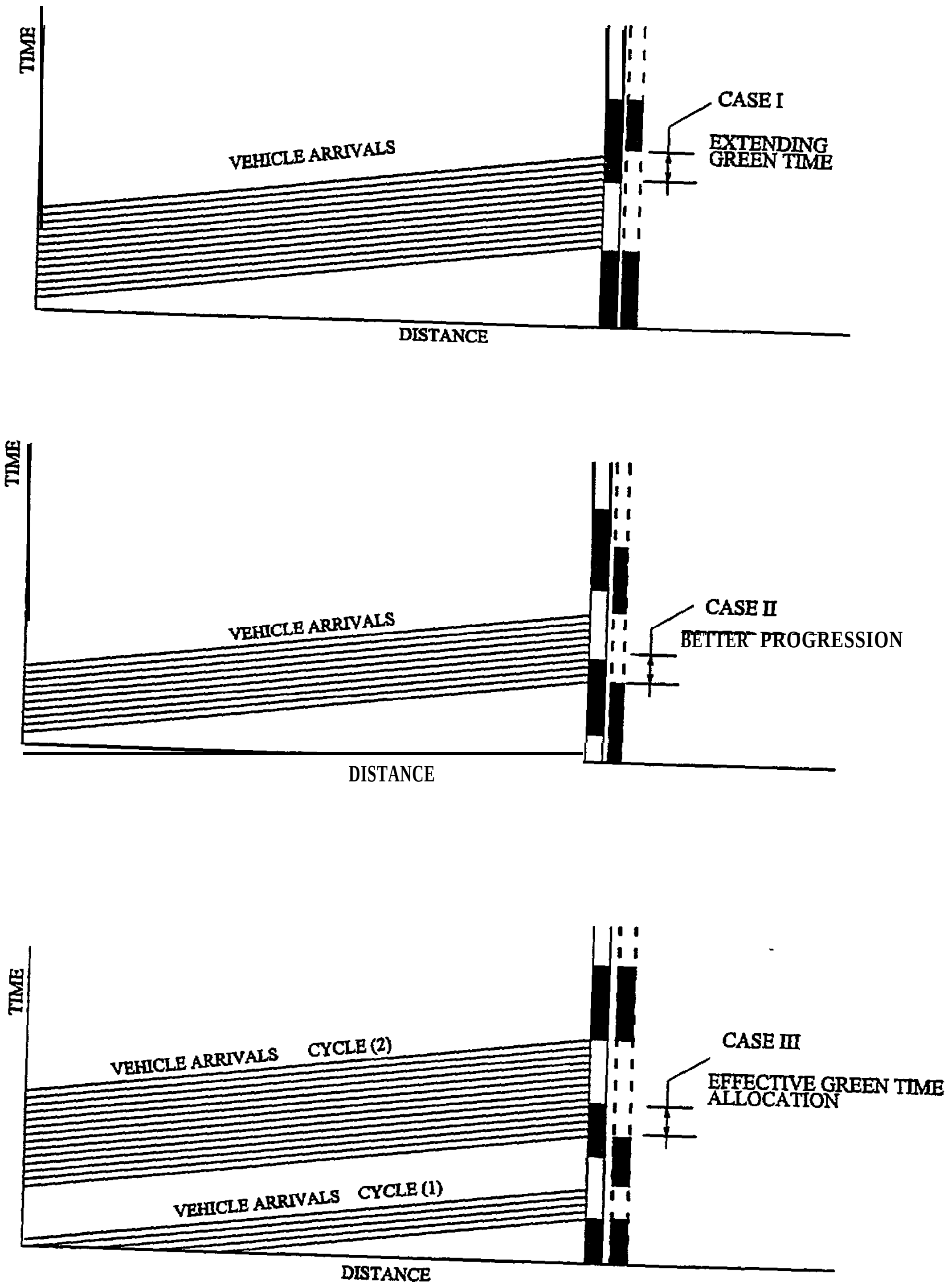


Figure 8.1 Example of Possible Delay Reduction by An Adaptive Signal Control

8.1 Orchard Lake – Maple Road Intersection

Prior to SCATS installation, this intersection was controlled by a four phase fixed time signal with protected left turn phases for both approaches. The cycle length was 120 seconds during rush periods and 80 seconds during non-rush periods. Table 8.1 presents the green time and G/C ratio for all approaches under SCATS control. The average, minimum and maximum green times for each approach are presented followed by the G/C ratio for each phase. The final four columns present the green time and G/C ratio for the adjacent signals to the south of this intersection.

Table 8.2 lists the total effective green time per hour for all approaches for both the before and after periods. The results are also presented in Figure 8.2. The results show that SCATS assigned more green time for the main corridor traffic (Orchard Lake), for each hour except at 3:00 PM. During the morning peak, the effective green time for the main street through traffic was increased from 25.5 minutes to 28.7 minutes (12.6%). The green time for the main street left turn traffic was also increased from 5.5 minutes per hour to 6.5 minutes (17.3%). To accommodate this increase, SCATS reduced the green time for the minor street through traffic (Maple Road) from 16.5 minutes to 14.5 minutes (13.7%), and the minor street left turn traffic from 6.5 minutes to 4.5 minutes (30.7%).

During the afternoon peak period, SCATS increased the green time for both the minor and major street through traffic as well as the minor street left turn traffic, reducing the green time for the major street left turn traffic. The effective green time for the major street through traffic increased from 26.5 minutes to 29.4 minutes (10.9%). The effective green time for the minor street through traffic increased from 11.0 minutes to 12.0 minutes (9.1 %) The effective green time for the minor street left turn traffic increased slightly from 6.0 to 6.2 minutes (4.0%), while the effective green time for the major street left turn traffic decreased from 10.5 minutes to 7.1 minutes (32.8%). Some of the increase in green times are attributed to the reduced total loss time per hour as a result of increasing the average cycle length from 120 seconds to 140 seconds under SCATS control.

To investigate how these changes in green time affected the degree of saturation and the delay for different approaches, the before/after degree of saturation was calculated for each hour, the results are presented in Figure 8.3 for the major and minor road through traffic The results show that, during the morning peak, and as a result of increasing the green time for the major street traffic, the degree of saturation for the southbound traffic decreased from 1.15 to 1.05. Simultaneously, the degree of saturation for the eastbound traffic increased from 0.62 to 0.78 as a result of reducing the green'time for this approach. During the afternoon peak period SCATS reduced the degree of saturation for both northbound and westbound traffic as a result of extending the green time for both approaches. The degree of saturation was reduced from 1.10 to 1.04 for the northbound traffic, and from 0.95 to 0.84 for the westbound traffic. This reduction in degree of saturation explains the reduction in delay in both approaches reported in the intersection delay study.

8.2 Orchard Lake Road – 1/4 Mile South of Maple and Orchard Mall Intersections

These are two minor intersections that control the traffic to/from shopping centers along the corridor. Prior to SCATS installation, the signals were operating under fixed time signals with three different dials. The effective green time, G/C ratio for the main street traffic as well as before/after total effective green time per hour are presented in Tables 8.1 and 8.2, respectively. The before/after effective green time is also presented in Figure 8.4. The results show that SCATS increased the effective green time for the main street traffic for every hour of the day. During peak periods, the green time was extended from an average of 44.0 minutes to 50.0 minutes. During non-peak periods, SCATS increased the green time for the main street traffic from 38.0 minutes to 49.0 minutes.

Figure 8.5 shows how this increase in green time affected the degree of saturation. The average degree of saturation for southbound traffic during the morning peak period decreased from 1.12 to 0.96. During the non-peak period, the average degree of saturation decreased from an average of 0.84 to 0.71. During the afternoon peak, the average degree of saturation decreased from 0.95 to 0.82. This reduction in degree of saturation would result in a corresponding reduction in delay, which contributed to the reduction in overall travel time along the corridor reported in the travel time study.

Table 8.1 Green Time and G/C Radio for Orchard Lk. Rd. And Green &Maple Rd. Intersection (Under SCATS control)

Time		Green Time*				Cycle Length	G/C Ratio*				Green Time		G/C Ratio	
		Orchard Lk		Maple Road			Orchard Lk		Maple Rd		1/4 Mile S. of Maple	Orchard Mall	1/4 Mile S. of Maple	Orchard Mall
		Through	LT	Through	LT		Through	LT	Through	LT				
12:00	Mean	55	10	17	8	90	61	11	19	9				
AM	Min	36	8	0	8	81								
	Max	78	16	33	9	102								
1:00	Mean	40	9	14	8	69	57	13	20	12				
AM	Min	16	0	0	0	37								
	Max	73	17	35	15	100								
2:00	Mean	30	8	8	7	54	56	15	15	14				
AM	Min	13	0	0	0	41								
	Max	76	16	23	17	90								
3:00	Mean	34	6	6	6	59	65	12	11	11				
AM	Min	11	0	0	0	37								
	Max	79	20	21	14	57								
4:00	Mean	31	8	7	7	53	59	14	13	13				
AM	Min	11	0	0	0	37								
	Max	74	19	26	14	90								
5:00	Mean	48	10	17	8	84	57	12	20	10				
AM	Min	16	0	0	0	53								
	Max	99	17	34	13	115								
6:00	Mean	61	18	30	16	127	48	14	24	13				
AM	Min	35	9	0	8	83								
	Max	94	22	37	17	143								
7:00	Mean	69	16	35	12	134	52	12	26	9	110		82	
AM	Min	54	9	22	8	117					101			
	Max	93	34	52	19	145					132			
8:00	Mean	68	20	34	18	140	49	14	25	13	119	113	85	81
AM	Min	57	11	24	11	135					107	99		
	Max	83	28	48	31	145					138	145		
9:00	Mean	64	21	33	19	136	47	15	24	14	117	115	86	84
AM	Min	43	10	25	10	119					97	95		
	Max	80	31	43	31	145					130	133		
10:00	Mean	54	21	32	18	126	43	16	25	14	107	105	85	83
AM	Min	40	10	23	9	116					86	88		
	Max	72	31	42	29	136					122	120		
11:00	Mean	54	21	32	21	128	42	16	25	16	105	104	82	81
AM	Min	44	15	26	17	122					97	92		
	Max	72	33	39	29	146					124	126		
12:00	Mean	56	24	32	20	132	42	18	24	15	110	112	83	85
PM	Min	40	20	24	15	125					97	102		
	Max	69	36	41	28	143					123	124		
1:00	Mean	55	25	33	20	133	41	19	25	15	107	111	80	83
PM	Min	45	21	28	15	127					95	96		
	Max	74	34	41	28	142					122	129		
2:00	Mean	60	23	32	18	134	45	17	24	13	111	109	83	81
PM	Min	46	18	26	15	127					98	99		
	Max	76	31	38	23	145					119	120		
3:00	Mean	59	24	33	18	135	44	18	24	13	109	108	81	80
PM	Min	53	16	24	11	122					92	101		
	Max	74	30	40	25	151					130	132		
4:00	Mean	64	22	31	17	134	48	16	23	13	119	116	89	87
PM	Min	53	15	22	12	98					105	99		
	Max	93	28	43	22	143					130	127		
5:00	Mean	72	19	31	18	140	51	14	22	13	121	119	86	85
PM	Min	60	14	22	11	138					109	99		
	Max	84	28	36	25	140					128	124		
6:00	Mean	72	19	32	16	140	52	14	23	12	116	116	83	83
PM	Min	55	14	25	10	133					99	104		
	Max	87	25	42	22	140					129	135		
7:00	Mean	64	19	30	14	129	50	15	23	11	119	116	93	90
PM	Min	30	9	19	9	90					100	102		
	Max	83	29	39	24	143					130	131		
8:00	Mean	60	19	28	11	118	51	16	23	10				
PM	Min	28	9	20	8	87								
	Max	88	29	36	19	132								
9:00	Mean	57	19	24	11	113	50	17	21	9				
PM	Min	26	9	15	8	87								
	Max	89	31	33	18	130								
10:00	Mean	61	12	23	10	106	57	12	21	9				
PM	Mini	36	9	0	8	90								
	Maxi	93	20	36	18	135								
11:00	Mean	54	11	19	9	94	58	11	20	9				
PM	Min	32	8	0	8	81								
	Max	80	15	32	10	112								

Table 8.2 Before/After Total Effective Green Time per Hour

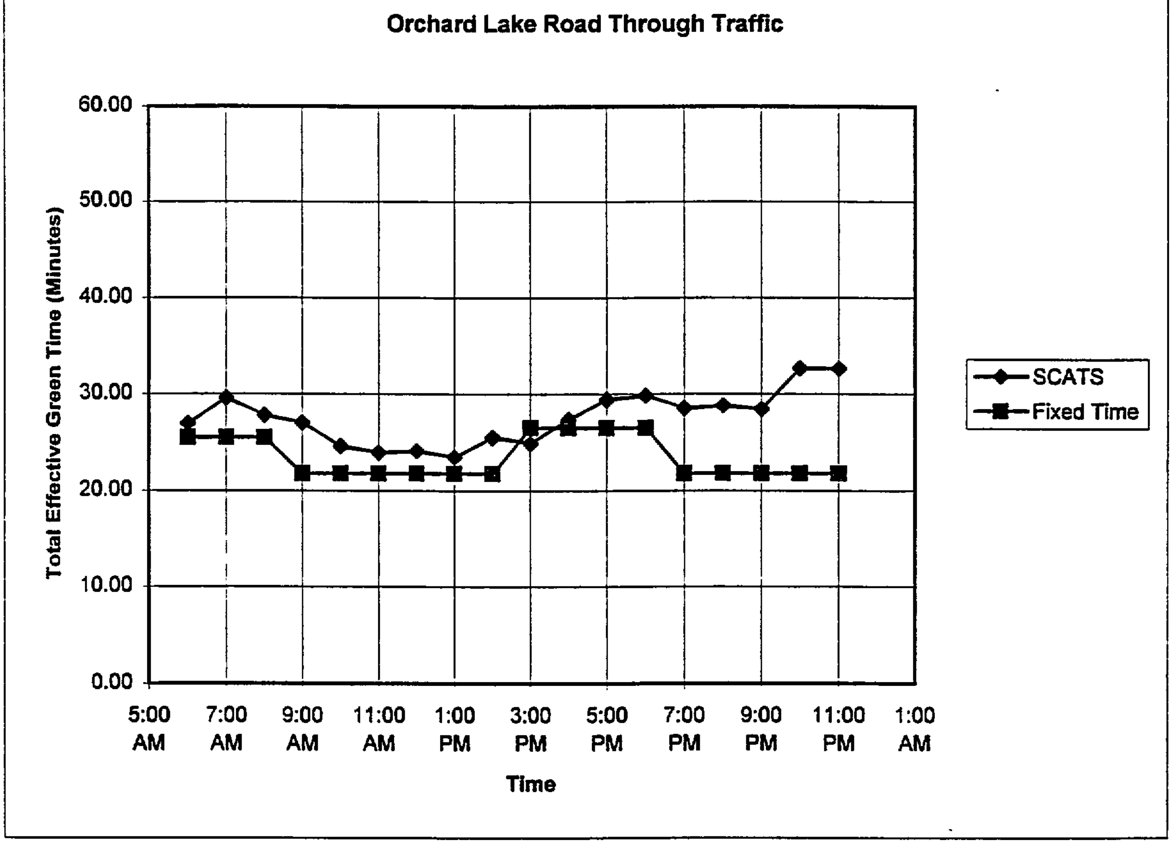
Orchard Lk Road & Maple Road Intersection

	Orchard Lk Through		Orchard Lk LT		Maple Rd. Through		Maple Rd. LT	
	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time
6:00 AM	26.98	25.50	6.98	5.50	14.42	16.50	6.05	6.50
7:00 AM	29.61	25.50	5.82	5.50	14.50	16.50	4.00	6.50
8:00 AM	27.81	25.50	7.14	5.50	13.49	16.50	6.25	6.50
9:00 AM	27.03	21.75	7.95	7.50	13.10	15.75	6.88	6.00
10:00 AM	24.58	21.75	8.45	7.50	13.72	15.75	7.19	6.00
11:00 AM	23.92	21.75	8.44	7.50	13.60	15.75	8.44	6.00
12:00 PM	24.09	21.75	9.55	7.50	13.18	15.75	7.73	6.00
1:00 PM	23.46	21.75	9.92	7.50	13.53	15.75	7.67	6.00
2:00 PM	52.52	21.75	8.96	7.50	12.99	15.75	6.72	6.00
3:00 PM	24.89	26.50	9.33	10.5	13.33	11.00	6.67	6.00
4:00 PM	27.41	26.50	8.54	10.5	12.58	11.00	6.29	6.00
5:00 PM	29.43	26.50	7.06	10.5	11.99	11.00	6.24	6.00
6:00 PM	29.83	26.50	6.90	10.5	12.32	11.00	5.77	6.00
7:00 PM	28.54	21.75	7.61	7.50	12.45	15.75	5.13	6.00
8:00 PM	28.80	21.75	8.12	7.50	12.48	15.75	4.28	6.00
9:00 PM	28.43	21.75	8.70	7.50	11.13	15.75	3.99	6.00
10:00 PM	32.66	21.75	5.22	7.50	11.10	15.75	3.88	6.00
11:00 PM	32.63	21.75	4.93	7.50	10.29	15.75	3.63	6.00

Orchard Lk Road & Orchard Mall and 1/4 Mile S. of Maple Intersections

	Orchard Mall		1/4 Mile S. of Maple	
	SCATS	Fixed Time	SCATS	Fixed Time
7:00 AM	0.80	0.78		
8:00 AM	0.83	0.78	0.79	0.75
9:00 AM	0.84	0.78	0.82	0.75
10:00 AM	0.83	0.66	0.81	0.63
11:00 AM	0.80	0.66	0.79	0.63
12:00 PM	0.81	0.66	0.83	0.63
1:00 PM	0.78	0.66	0.81	0.63
2:00 PM	0.81	0.66	0.79	0.63
3:00 PM	0.79	0.78	0.78	0.75
4:00 PM	0.87	0.78	0.85	0.75
5:00 PM	0.84	0.78	0.83	0.75
6:00 PM	0.81	0.78	0.81	0.75
7:00 PM	0.90	0.66	0.88	0.63

Figure 8.2 Before/After Total Effective Green Time Per Hour of the Day (Orchard Lake Road & Maple Road Intersection)



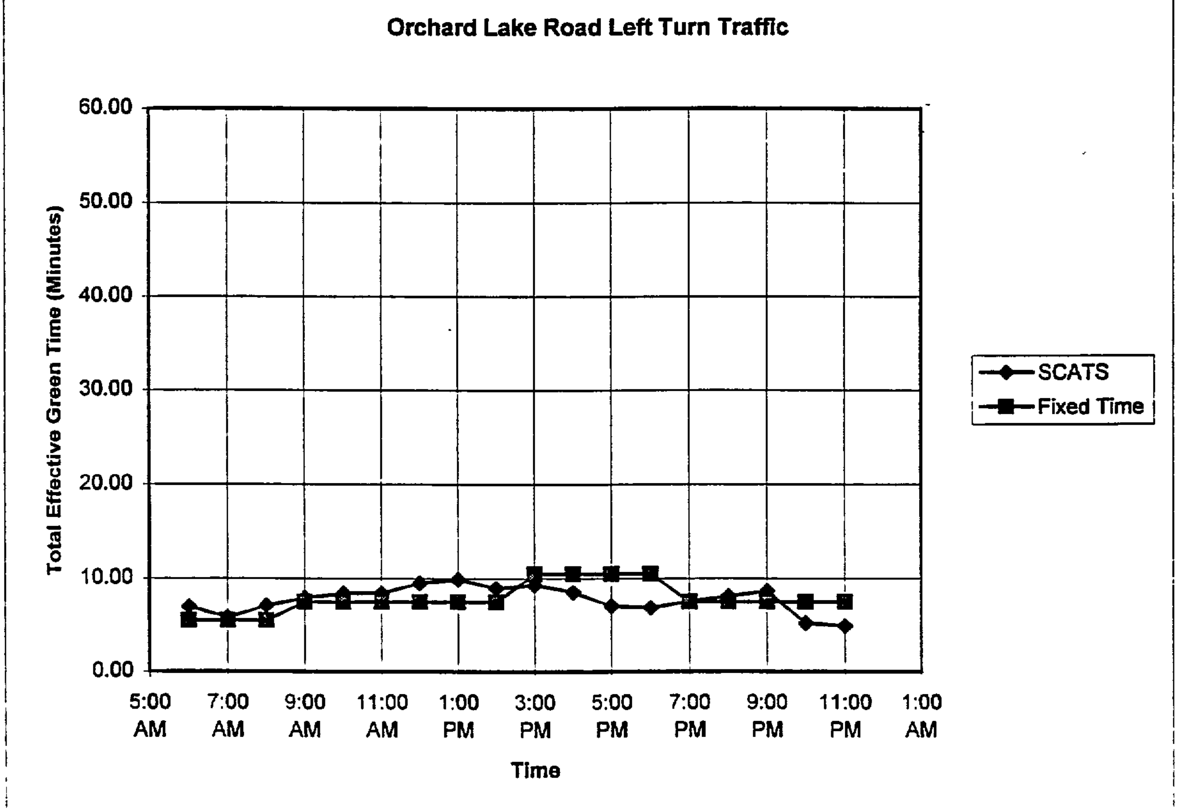
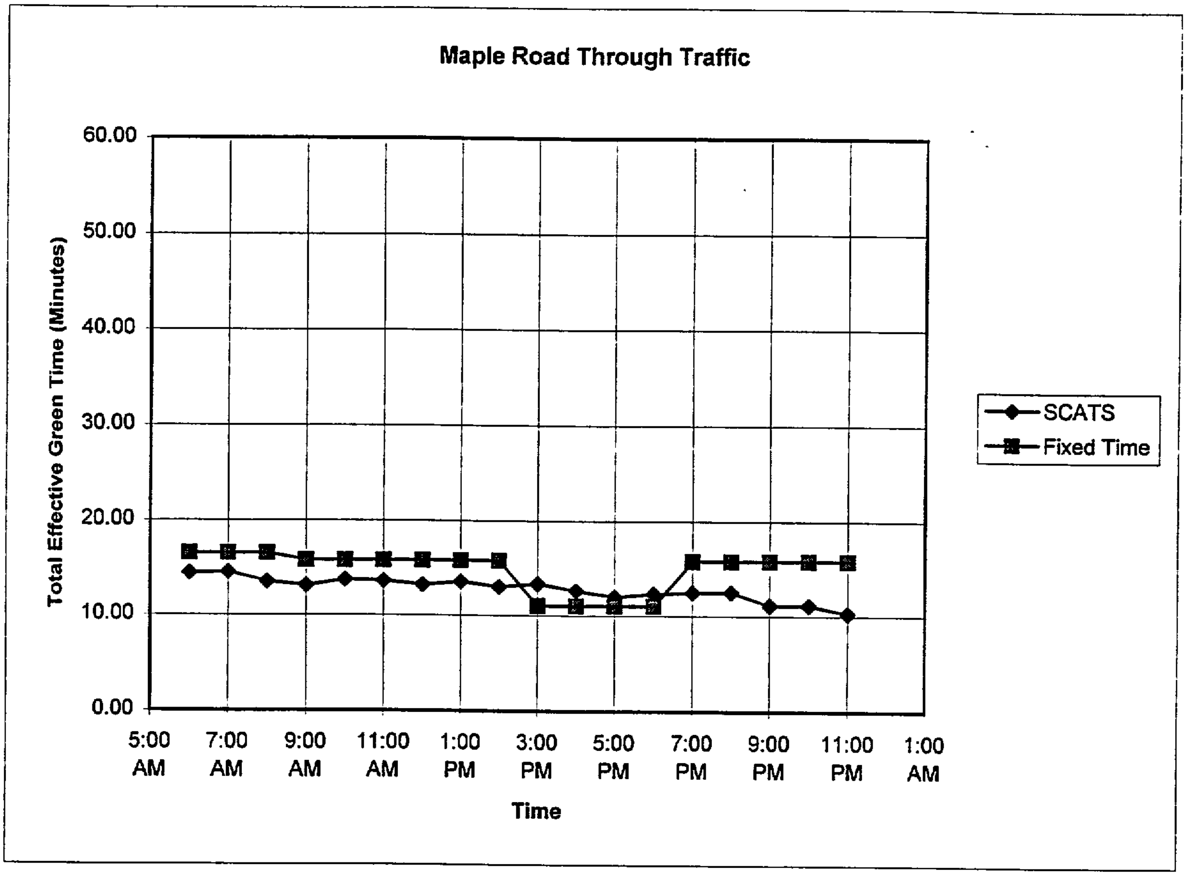


Figure 8.2 (Cont.) Before/After Total Effective Green Time Per Hour of the Day (Orchard Lake Road & Maple Road Intersection)



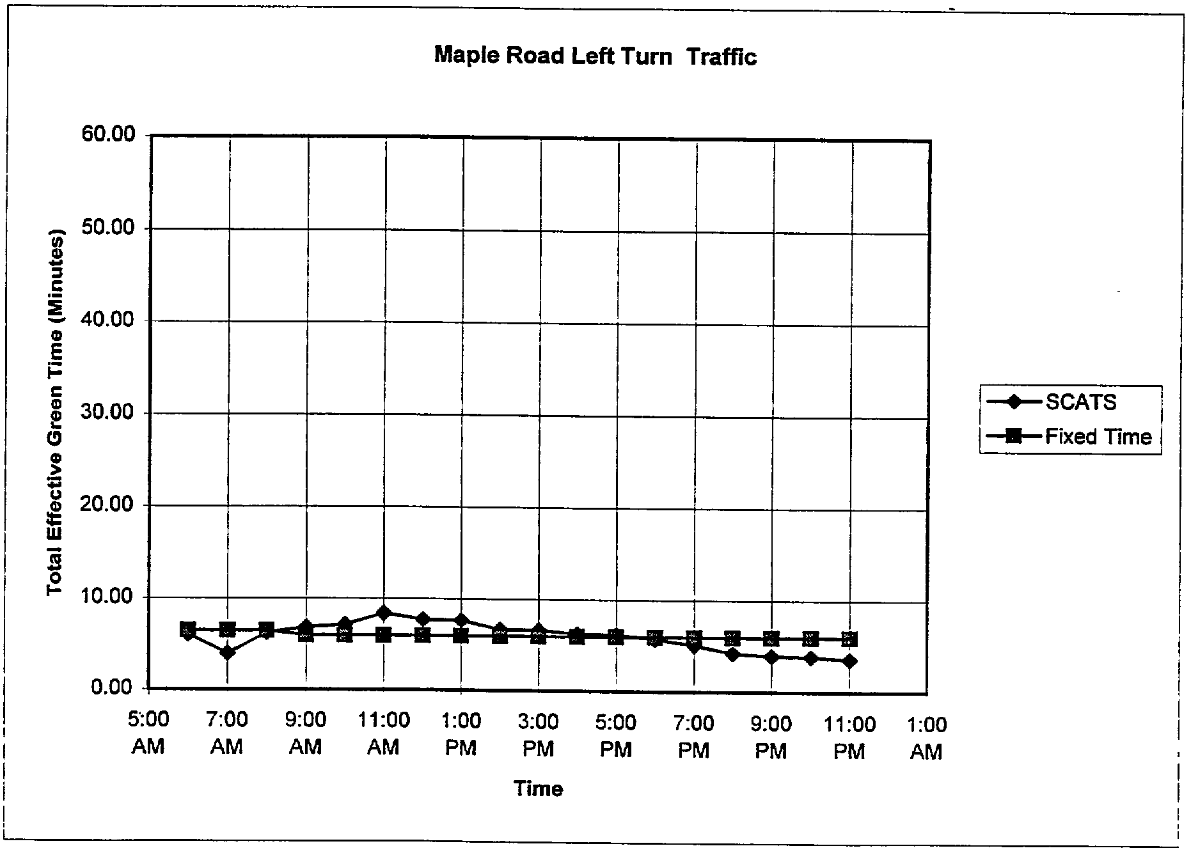
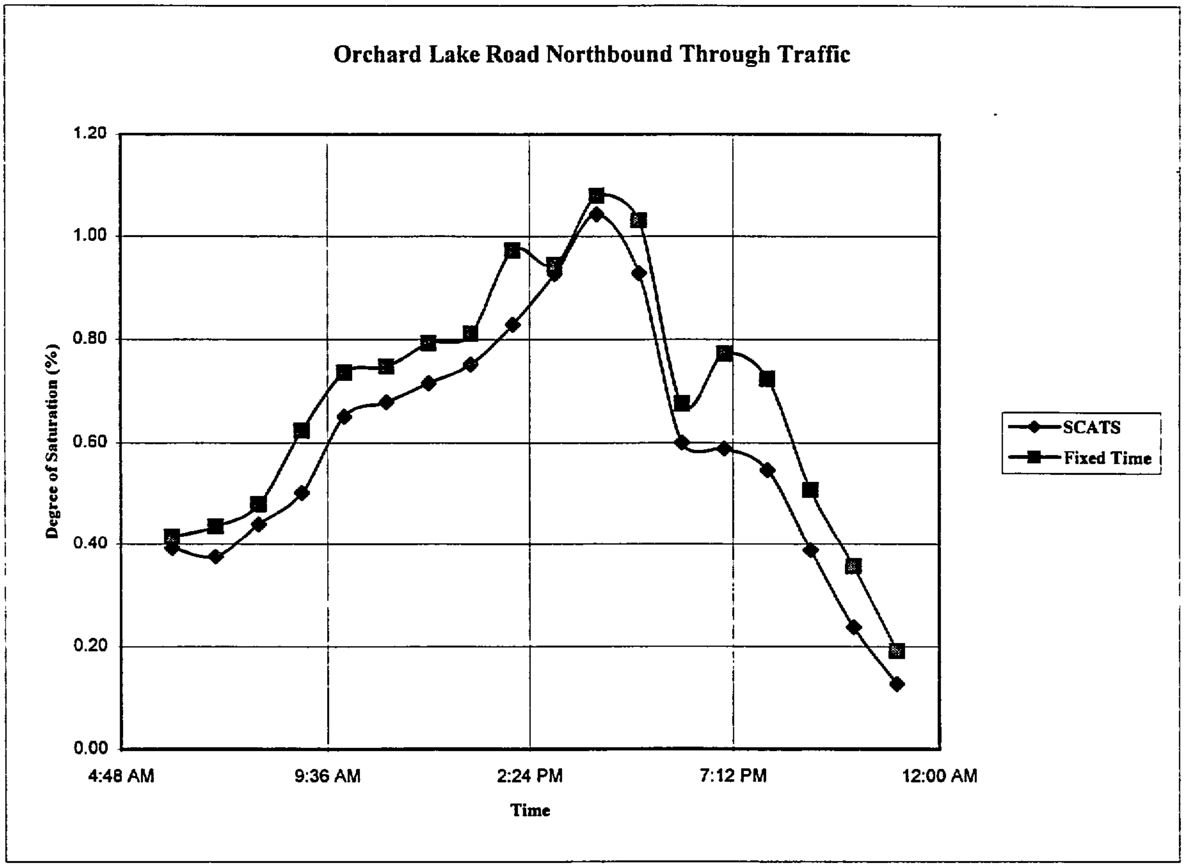


Figure 8.3 Before/After Average Degree of Saturation (Orchard Lake Road & Maple Road Intersection)



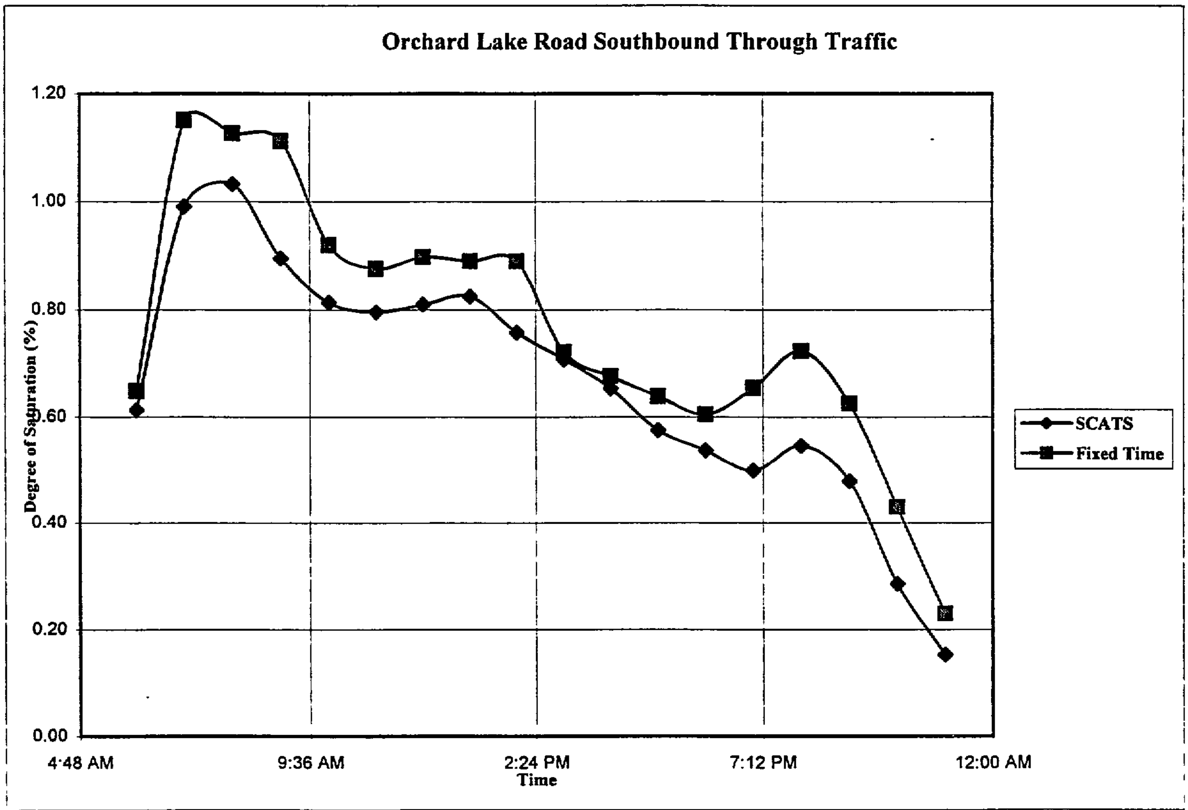
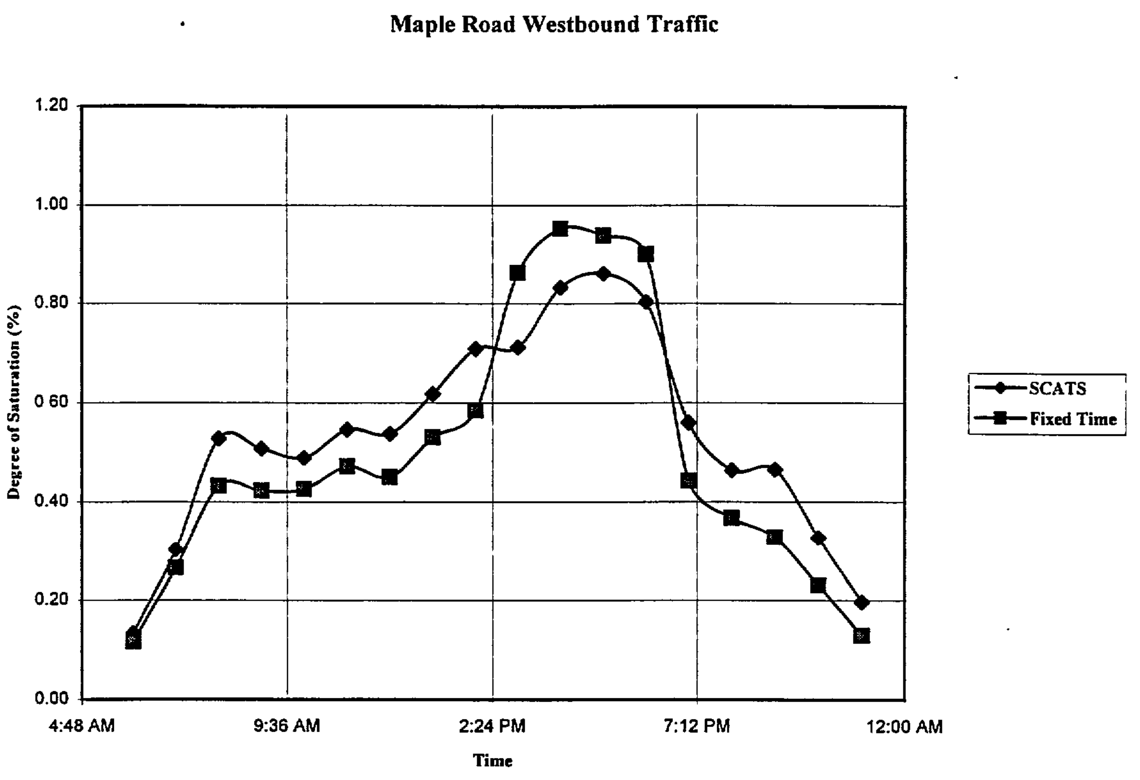


Figure 8.3(Cont.) Before/After Average Degree of Saturation (Orchard Lake Road & Maple Road Intersection)



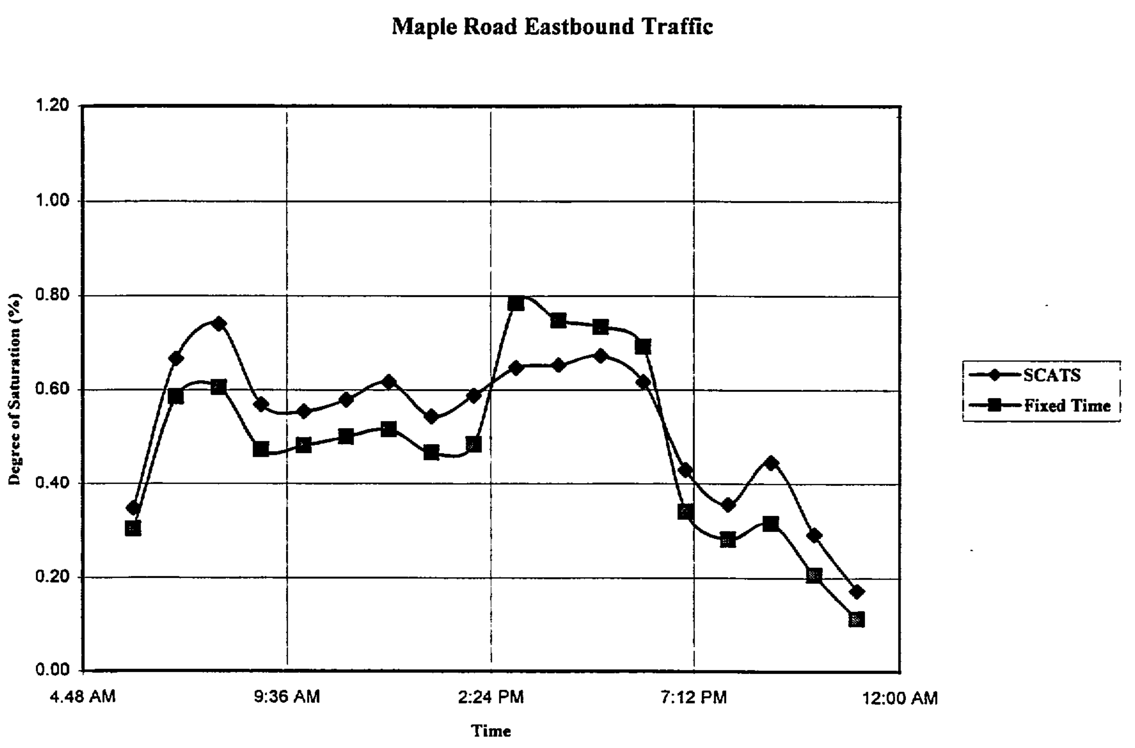


Figure 8.4.a Before/After Effective Green Time

(Orchard Lake Road & 1/4 Mile S. of Maple Road Intersection)

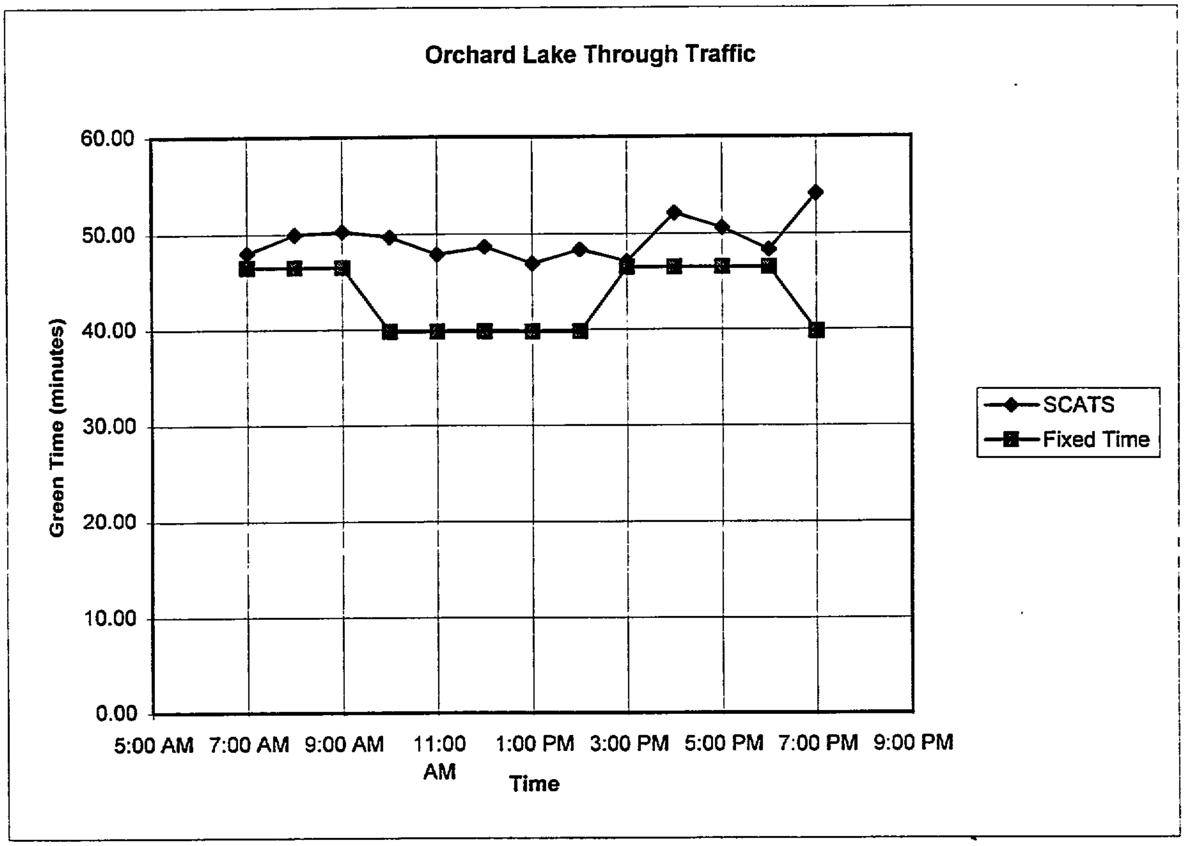


Figure 8.4.b Before/After Effective Green Time

(Orchard Lake Road & Orchard Mall Intersection)

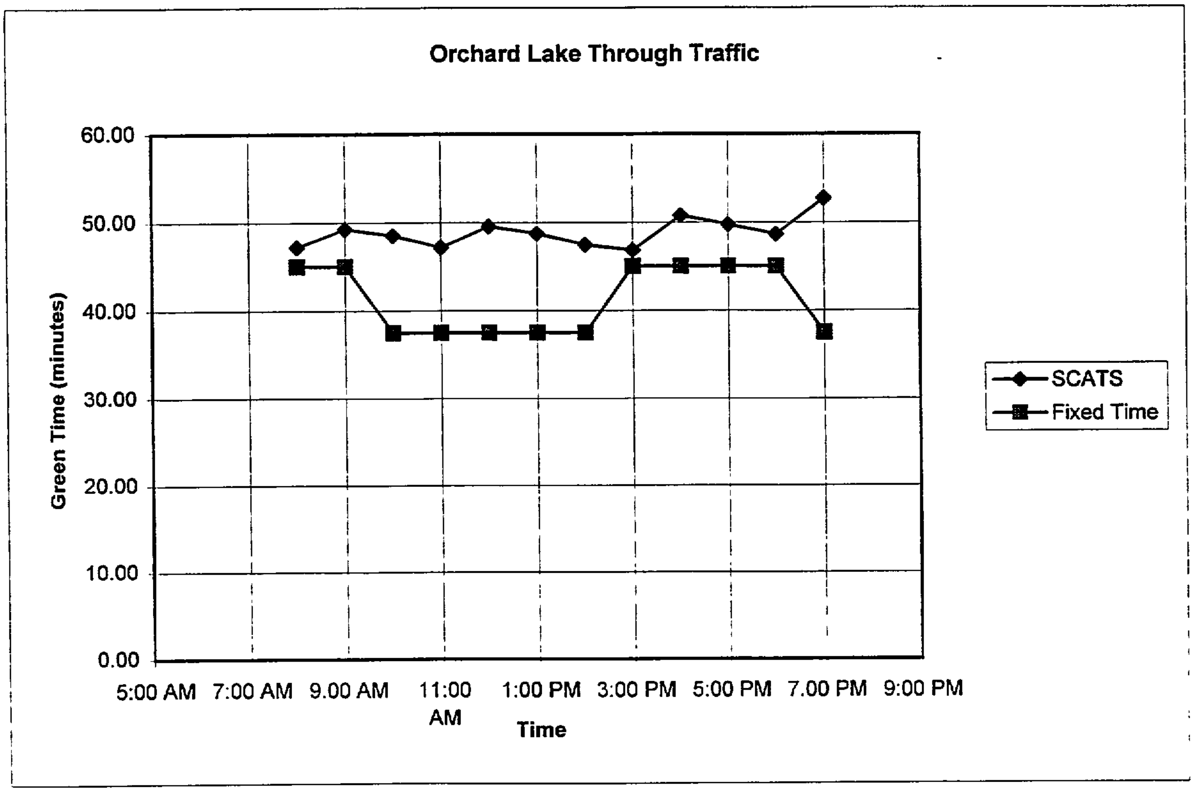
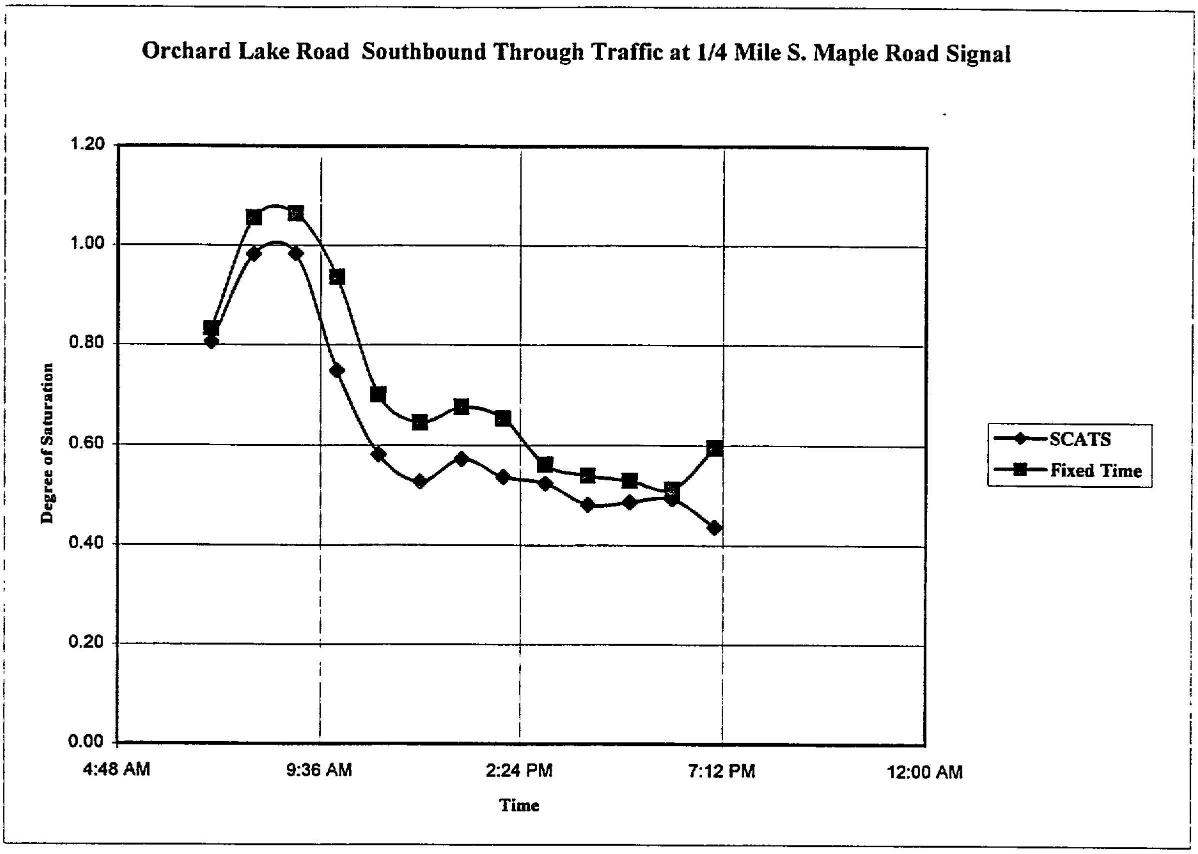


Figure 8.5.a Before/After Average Degree of Saturation (Orchard Lake Road & 1/4 Mile S. of Maple Road Intersection)



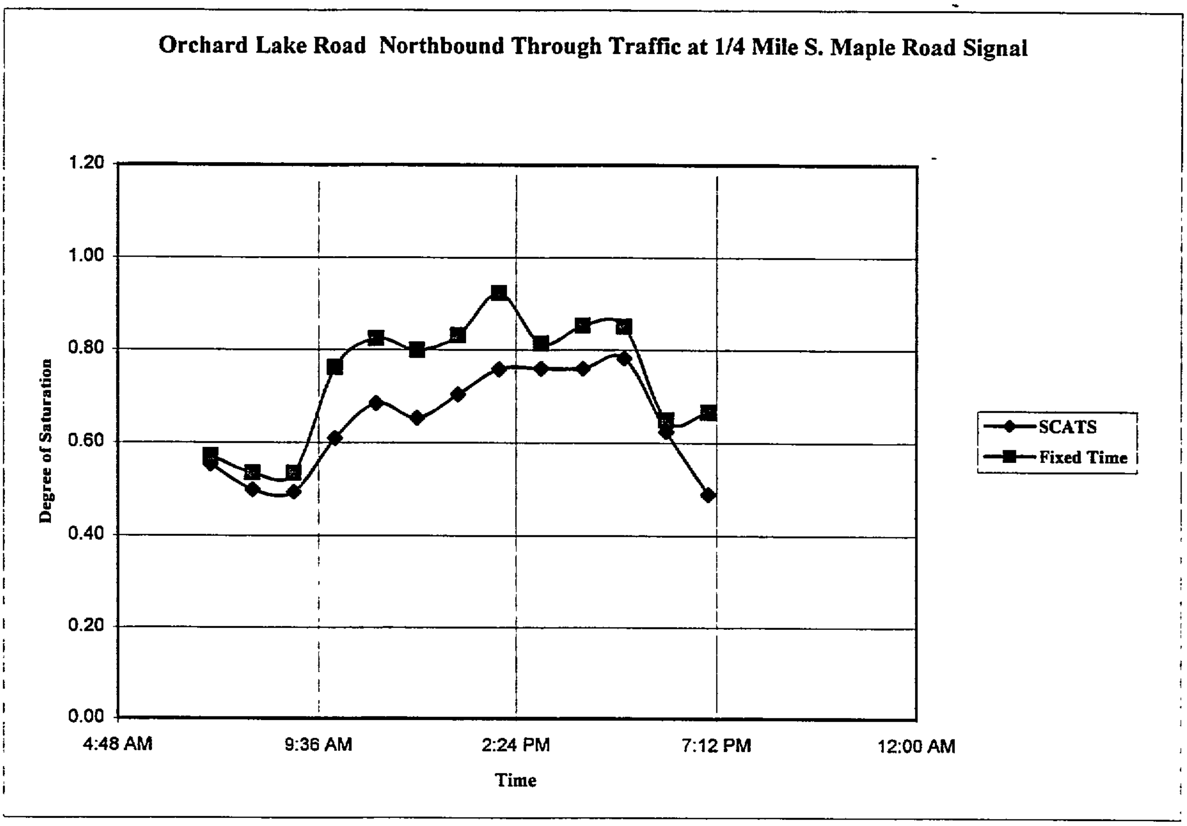
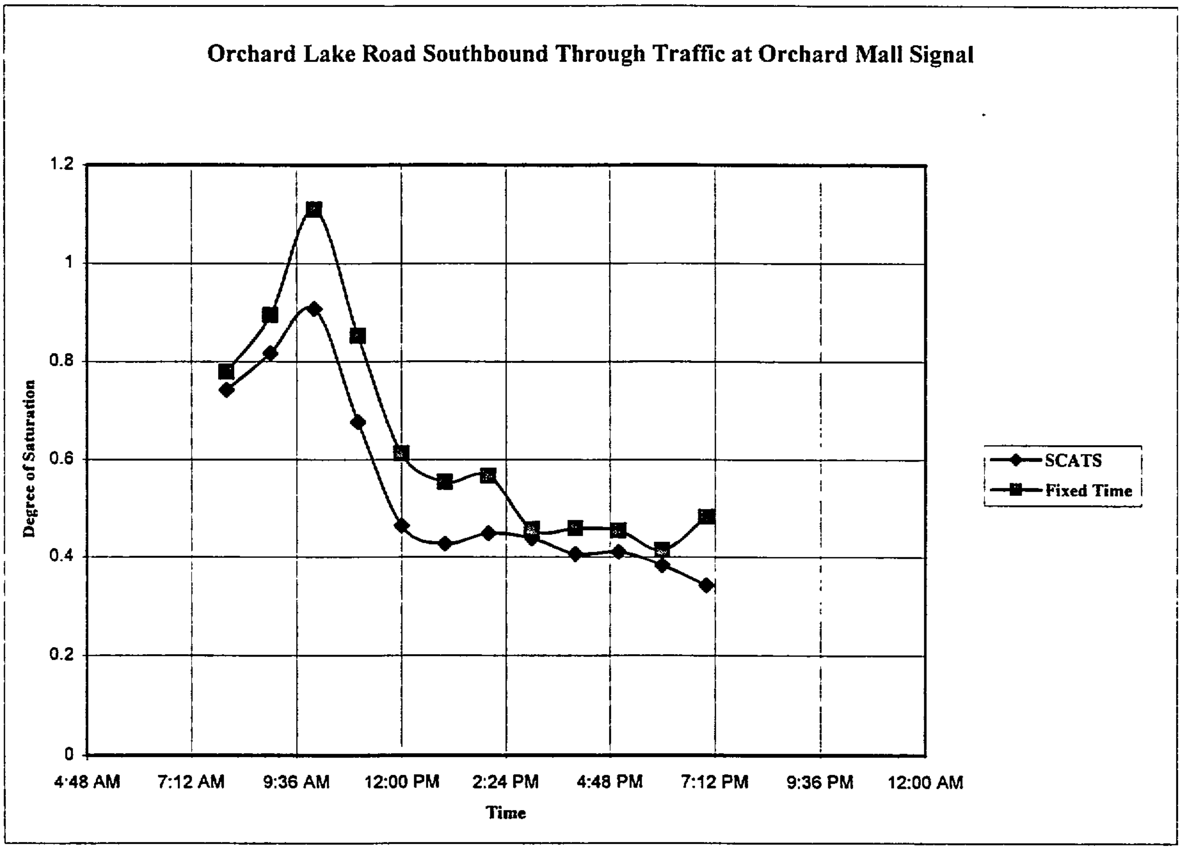
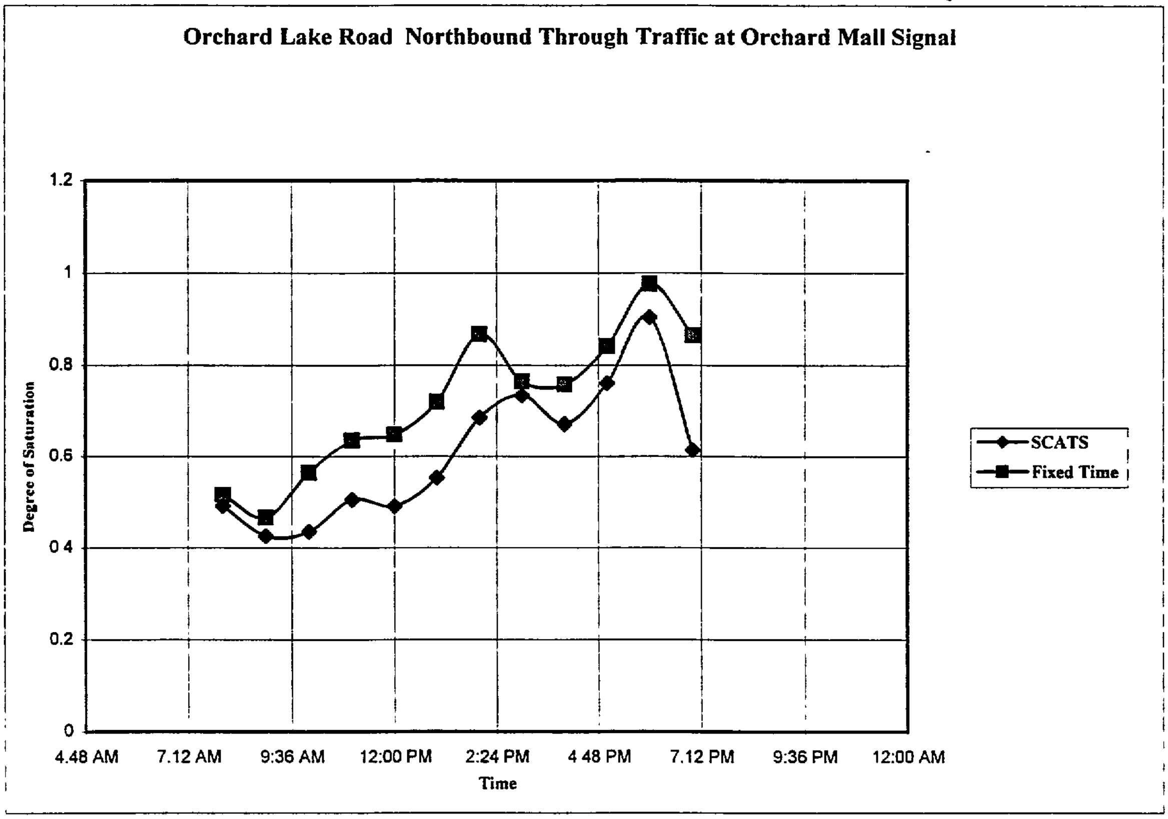


Figure 8.5.b Before/After Average Degree of Saturation (Orchard Lake Road & Orchard Mall Intersection)





8.3 Orchard Lake Road-Walnut Lake Road Intersection

Walnut Lake Road is a major intersection along the Orchard Lake Corridor. Walnut Lake Road runs East-West with most of the morning traffic heading east, and the afternoon traffic heading west. Prior to SCATS, the signal was operating under a fixed time mode with three different dials. Table 8.3 presents the maximum, minimum, and average green time and cycle length as well as the G/C ratio for different approaches under SCATS control. Similar to the results at Maple Road, SCATS increased the cycle length during peak periods from 120 seconds to an average of 140 seconds.

Table 8.4 presents the before/after total effective green time. The results are also presented in Figure 8.6. In general, SCATS increased the green time for the main street through traffic, reducing the green time for all other approaches. However, during the afternoon peak hour, there was a slight increase in the total effective green time for the minor street through and left-turn traffic, mainly due to the reduction in total loss time as a result of increasing the cycle length during this period. During the non-peak period, the effective green time for the main street through traffic increased from 26 minutes per hour to an average of 34 minutes per hour (30.8%). The effective green time for minor street traffic were reduced from 16 minutes per hour to 14 minutes per hour (12.5%). The effective green time for the minor and main street left-turn traffic decreased from 5.0 minutes per hour to 3 .O minutes per hour (40.0%).

Table 8.5 and Figure 8.7 present the before/after degree of saturation for the main and minor street traffic. During the morning peak, the average degree of saturation for the southbound through traffic decreased from 1.18 percent to 0.96 percent as a result of increasing the green time for this movement. The average degree of saturation for the eastbound through traffic increased from 1.16 percent to 1.19 percent as a result of reducing the green time for this movement.

A similar pattern was found during the afternoon peak hour. The northbound through traffic degree of saturation decreased from 1.12 to 1.02 percent. The degree of saturation for westbound through traffic increased from 1.02 to 1.06 percent. During the non-peak period, the average degree of saturation for the main street through traffic decreased from 0.78 to 0.66 percent. The minor street through traffic average degree of saturation increased from 0.73 to 0.82 percent. These changes in degree of saturation explain the output from the intersection delay study, which reported a decrease in main street average delay and an increase in minor street average delay during both peak and non peak periods.

Table 8.8 Green Time and G/C Radio for Orchard Lk. And Walnut Lk Intersection (Under SCATS Adaptive control)

Time		Cycle Length	Green Time				G/C Ratio			
			Orchard Rd.		Walnut Lk Rd.		Orchard Rd.		Walnut Lk Rd.	
			Through	LT	Through	LT	Through	Lt	Though	LT
12:00 AM	Mean	89	47	9	24	9	53	10	27	10
	Minimum	65	18	7	14	8				
	Maximum	106	87	13	38	12				
1:00 AM	Mean	69	34	9	17	9	49	13	25	12
	Minimum	39	11	8	13	7				
	Maximum	100	74	13	31	10				
2:00 AM	Mean	59	27	9	15	8	45	15	25	14
	Minimum	42	13	8	14	8				
	Maximum	61	51	12	18	9				
3:00 AM	Mean	57	26	9	15	8	45	16	25	15
	Minimum	41	13	8	14	8				
	Maximum	57	52	10	16	9				
4:00 AM	Mean	59	27	9	15	8	45	15	25	14
	Minimum	39	11	8	14	7				
	Maximum	57	51	13	17	9				
5:00 AM	Mean	80	43	9	19	9	54	11	24	11
	Minimum	53	13	8	14	8				
	Maximum	120	115	12	32	13				
6:00 AM	Mean	102	59	9	25	9	58	9	25	9
	Minimum	77	36	7	14	7				
	Maximum	131	109	12	35	14				
7:00AM	Mean	134	71	10	39	13	53	8	29	10
	Minimum	112	51	8	23	8				
	Maximum	155	99	17	62	29				
8:00 AM	Mean	140	73	11	43	13	52	8	31	9
	Minimum	135	50	8	32	8				
	Maximum	145	89	17	60	21				
9:00 AM	Mean	136	82	10	34	11	60	7	25	8
	Minimum	117	57	8	26	8				
	Maximum	145	101	15	50	18				
10:00 AM	Mean	126	75	10	31	10	60	8	25	8
	Minimum	114	57	7	26	7				
	Maximum	140	90	20	43	16				
11:00 AM	Mean	128	75	10	32	10	59	8	25	8
	Minimum	98	51	8	23	8				
	Maximum	151	103	18	46	20				
12:00 PM	Mean	125	73	10	32	10	58	8	26	8
	Minimum	92	45	8	22	8				
	Maximum	146	97	17	45	18				
1:00 PM	Mean	126	73	11	33	10	58	8	26	8
	Minimum	96	44	8	23	7				
	Maximum	144	97	16	43	20				
2:00 PM	Mean	130	76	11	32	11	59	9	25	8
	Minimum	97	39	8	25	8				
	Maximum	146	95	22	44	21				
3:00 PM	Mean	133	66	14	38	16	50	11	28	12
	Minimum	104	41	9	28	8				
	Maximum	153	97	23	54	39				
4:00 PM	Mean	134	62	15	39	19	46	11	29	14
	Minimum	98	35	8	20	8				
	Maximum	144	77	25	52	38				
5:00 PM	Mean	140	59	15	45	20	42	11	32	14
	Minimum	138	42	9	34	13				
	Maximum	140	77	25	57	29				
6:00 PM	Mean	140	65	15	42	19	47	10	30	13
	Minimum	133	46	8	34	8				
	Maximum	144	84	25	50	27				
7:00 PM	Mean	129	73	10	35	11	57	8	27	8
	Minimum	90	43	8	25	8				
	Maximum	152	89	20	59	18				
8:00 PM	Mean	118	69	10	29	10	58	9	25	9
	Minimum	87	42	8	21	8				
	Maximum	136	98	15	43	18				
9:00 PM	Mean	113	64	10	29	9	56	9	26	8
	Minimum	82	37	8	20	8				
	Maximum	135	85	18	51	16				
10:00 PM	Mean	106	59	9	29	9	56	9	28	8
	Minimum	80	39	8	20	8				
	Maximum	145	81	12	54	12				
11:00 PM	Mean	92	49	9	25	9	53	10	27	9
	Minimum	65	23	8	14	8				
	Maximum	120	81	14	40	15				

Table 8.4.a Green Time and Cycle Length (Walnut Lk. Road Intersection)

Time	Cycle Length		Orchard Lk. Rd.				Walnut Lk. Rd.			
			Through		Left Turn		Through		Left Turn	
	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS
6:00 AM	120	102	55	59	13	9	39	25	13	9
7:00 AM	120	134	55	71	13	10	39	39	13	13
8:00AM	120	140	55	73	9	11	39	43	13	13
9:00AM	80	136	38	82	9	10	24	34	9	11
10:00 AM	80	126	38	75	9	10	24	31	9	10
11:00 AM	80	128	38	75	9	10	24	32	9	10
12:00 PM	80	125	38	73	9	10	24	32	9	10
1:00 PM	80	126	38	73	9	11	24	33	9	10
2:00 PM	80	130	38	76	3	11	24	32	9	11
3:00 PM	120	133	51	66	13	14	40	38	16	16
4:00 PM	120	134	51	62	13	15	40	39	16	19
5:00 PM	120	140	51	59	13	15	40	45	16	20
6:00 PM	120	140	51	65	13	15	40	42	16	19
7:00 PM	80	129	38	73	9	10	24	35	9	11
8:00 PM	80	118	38	69	9	10	24	29	9	10
9:00 PM	80	113	38	64	9	10	24	29	9	9
10:00 PM	80	106	38	59	9	9	24	29	9	9
11:00 PM	80	92	38	49	9	9	24	25	9	9

Table 8.4.b Total Effective Green Time per hour (Walnut Lk. Road Intersection)

Time	Cycle Length		Orchard Lk. Rd.				Walnut Lk. Rd.			
			Through		Left Turn		Through		Left Turn	
	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS
6:00 AM	120	102	26	33	5	4	18	13	5	3
7:00 AM	120	134	26	30	5	3	18	16	5	4
8:00AM	120	140	26	30	5	3	18	17	5	4
9:00AM	80	136	26	35	5	3	16	14	5	3
10:00 AM	80	126	26	34	5	3	16	14	5	3
11:00 AM	80	128	26	34	5	3	16	14	5	3
12:00 PM	80	125	26	34	5	3	16	14	5	4
1:00 PM	80	126	26	33	5	4	16	14	5	3
2:00 PM	80	130	26	34	5	4	16	14	5	4
3:00 PM	120	133	24	28	5	5	19	16	7	6
4:00 PM	120	134	24	27	5	5	19	16	7	7
5:00 PM	120	140	24	24	5	5	19	18	7	7
6:00 PM	120	140	24	27	5	5	19	17	7	7
7:00 PM	80	129	26	33	5	3	16	15	5	4
8:00 PM	80	118	26	34	5	4	16	13	5	4
9:00 PM	80	113	26	32	5	4	16	14	5	3
10:00 PM	80	106	26	32	5	4	16	15	5	3
11:00 PM	80	92	26	30	5	4	16	14	5	4

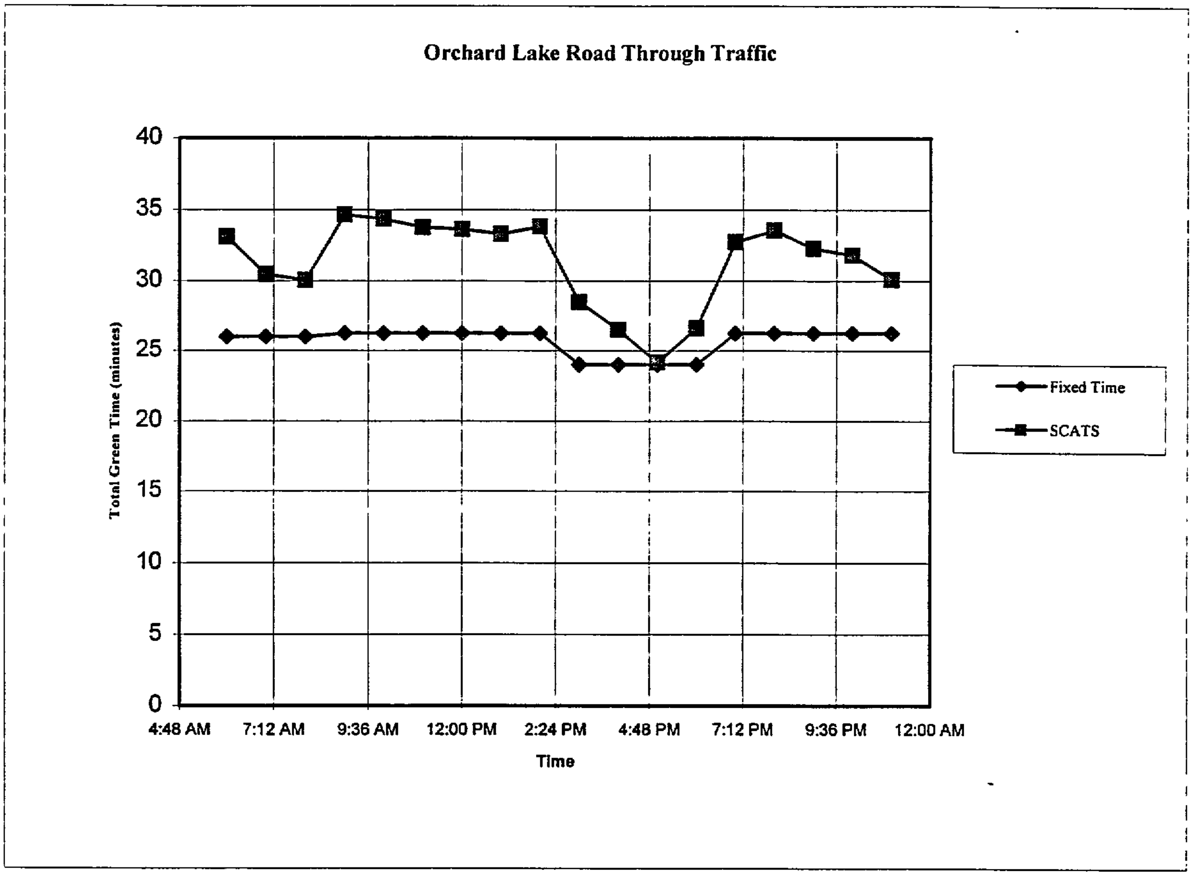
Table *.5a Green Time and Volumes (Walnut Lk Road Intersection)

Time	Orchard Lk. Rd. Through Fixed Time	Orchard Lk. Rd. Through SCATS	Orchard Lk. Rd. Volume SB	Orchard Lk. Rd. Volume NB	Walnut Lk. Rd. Through Fixed Time	Walnut Lk. Rd. Through SCATS	Walnut Lk. Rd. Volume EB	Walnut Lk. Rd. Volume WB
6:00 AM	26	33	757	295	18	13	351	65
7:00 AM	26	30	1678	690	18	16	620	160
8:00 AM	26	30	1703	700	18	17	589	215
9:00 AM	26	35	1204	620	16	14	353	195
10:00 AM	26	34	986	739	16	14	298	184
11:00 AM	26	34	969	948	16	14	318	198
12:00 PM	26	34	985	905	16	14	311	241
1:00 PM	26	33	931	885	16	14	271	228
2:00 PM	26	34	1076	1057	16	14	324	228
3:00 PM	24	28	946	1164	19	16	375	398
4:00 PM	24	27	890	1397	19	16	378	474
5:00 PM	24	24	918	1626	19	18	384	613
6:00 PM	24	27	968	1476	19	17	348	534
7:00 PM	26	33	885	1134	16	15	303	240
8:00 PM	26	34	880	1021	16	13	278	201
9:00 PM	26	32	887	884	16	14	273	196
10:00 PM	26	32	527	551	16	15	247	183
11:OOPM	26	30	299	388	16	14	150	131

Table 8.5.b Average Degree of Saturation (Walnut Lk Road Intersection)

Time	Orchard Lk. Rd. SB Fixed Time	Orchard Lk. Rd. SB SCATS	Orchard Lk. Rd. NB Fixed Time	Orchard Lk. Rd. NB SCATS	Walnut Lk. Rd. EB Fixed Time	Walnut Lk. Rd. EB SCATS	Walnut Lk. Rd. WB Fixed Time	Walnut Lk. Rd. WB SCATS
6:00 AM	0.51	0.40	0.20	0.16	0.69	0.96	0.13	0.18
7:00 AM	1.14	0.97	0.47	0.40	1.09	1.20	0.31	0.35
8:00 AM	1.16	1.00	0.48	0.41	1.15	1.22	0.42	0.44
9:00 AM	0.81	0.61	0.42	0.32	0.79	0.90	0.44	0.50
10:00 AM	0.66	0.51	0.50	0.38	0.67	0.78	0.41	0.48
11:00 AM	0.65	0.51	0.64	0.50	0.71	0.82	0.44	0.51
12:00 PM	0.66	0.52	0.61	0.48	0.70	0.78	0.54	0.60
1:00 PM	0.63	0.49	0.59	0.47	0.61	0.68	0.51	0.57
2:00 PM	0.72	0.56	0.71	0.55	0.73	0.84	0.51	0.59
3:00 PM	0.70	0.59	0.86	0.72	0.72	0.85	0.76	0.90
4:00 PM	0.65	0.59	1.03	0.93	0.72	0.83	0.90	1.04
5:00 PM	0.68	0.67	1.13	1.06	0.73	0.75	1.05	1.07
6:00 PM	0.71	0.64	1.09	0.98	0.66	0.74	1.02	1.13
7:00 PM	0.59	0.48	0.76	0.61	0.68	0.72	0.54	0.57
8:00 PM	0.59	0.46	0.69	0.54	0.62	0.74	0.45	0.53
9:00 PM	0.60	0.48	0.59	0.48	0.61	0.69	0.44	0.50
10:00 PM	0.35	0.29	0.37	0.31	0.55	0.58	0.41	0.43
11:00 PM	0.20	0.18	0.26	0.23	0.34	0.37	0.29	0.32

Figure 8.6 Total Effective Green Time per Hour of the Day (Orchard Lake Road & Walnut Lake Road Intersection)



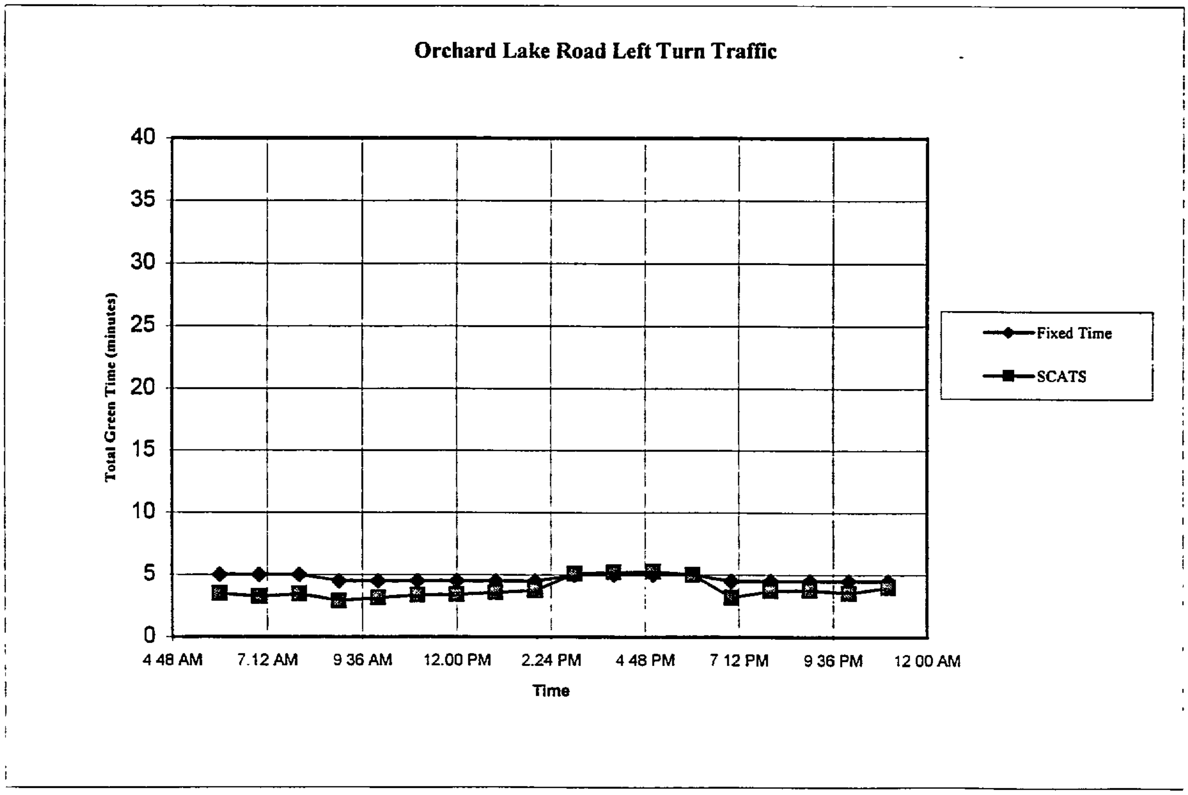
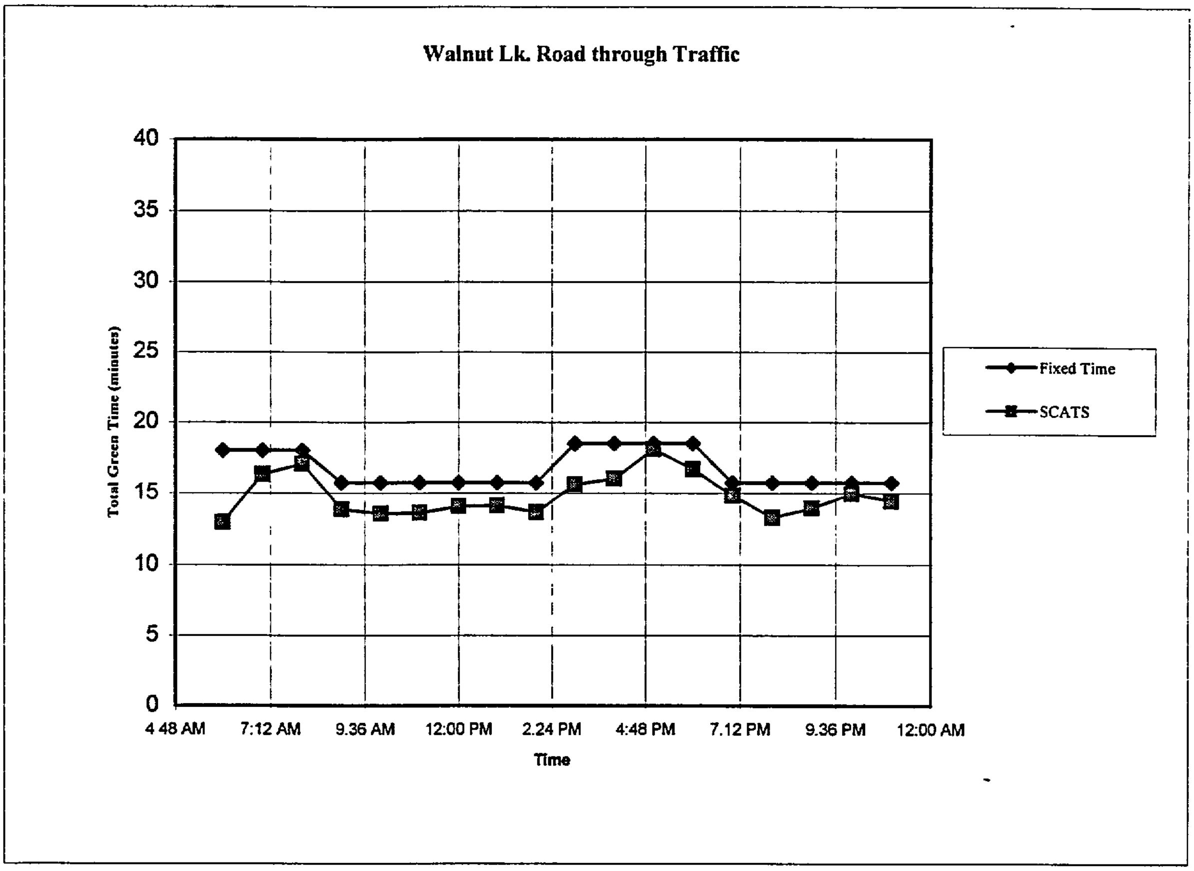


Figure 8.6 (Cont) Total Effective Green Time per Hour of the Day (Orchard Lake Road & Walnut Lake Road Intersection)



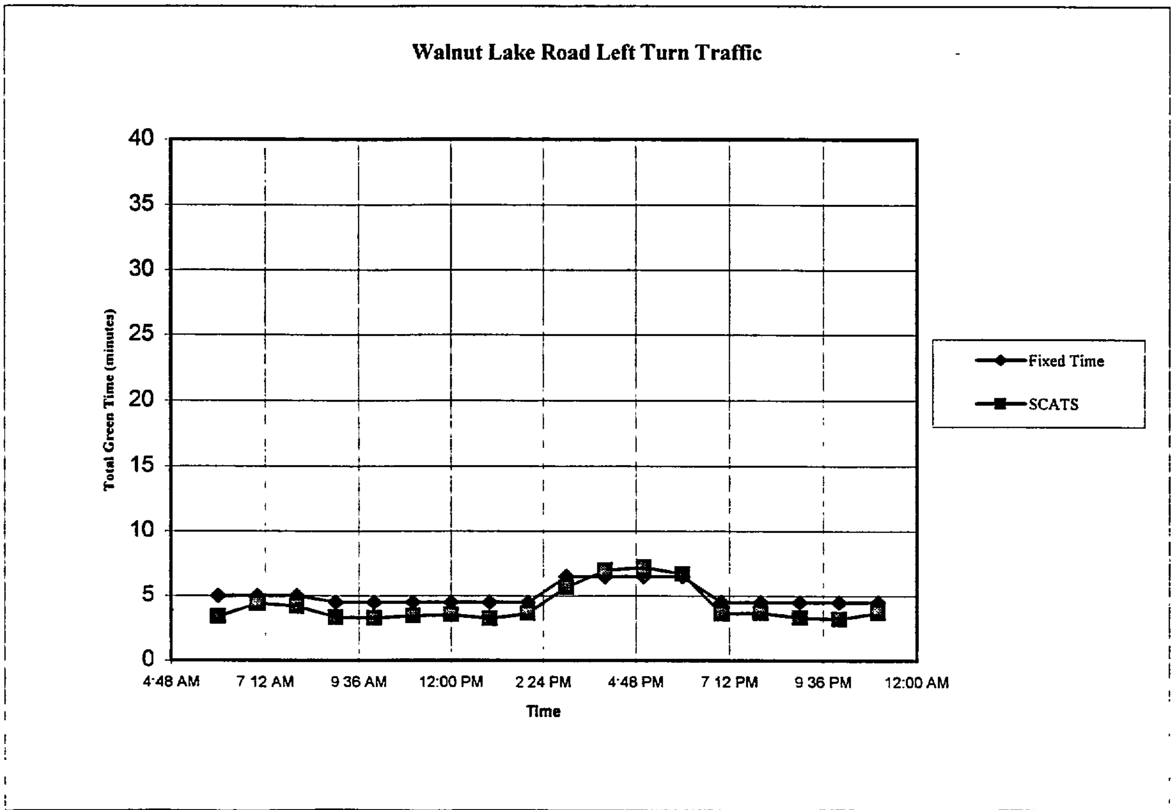
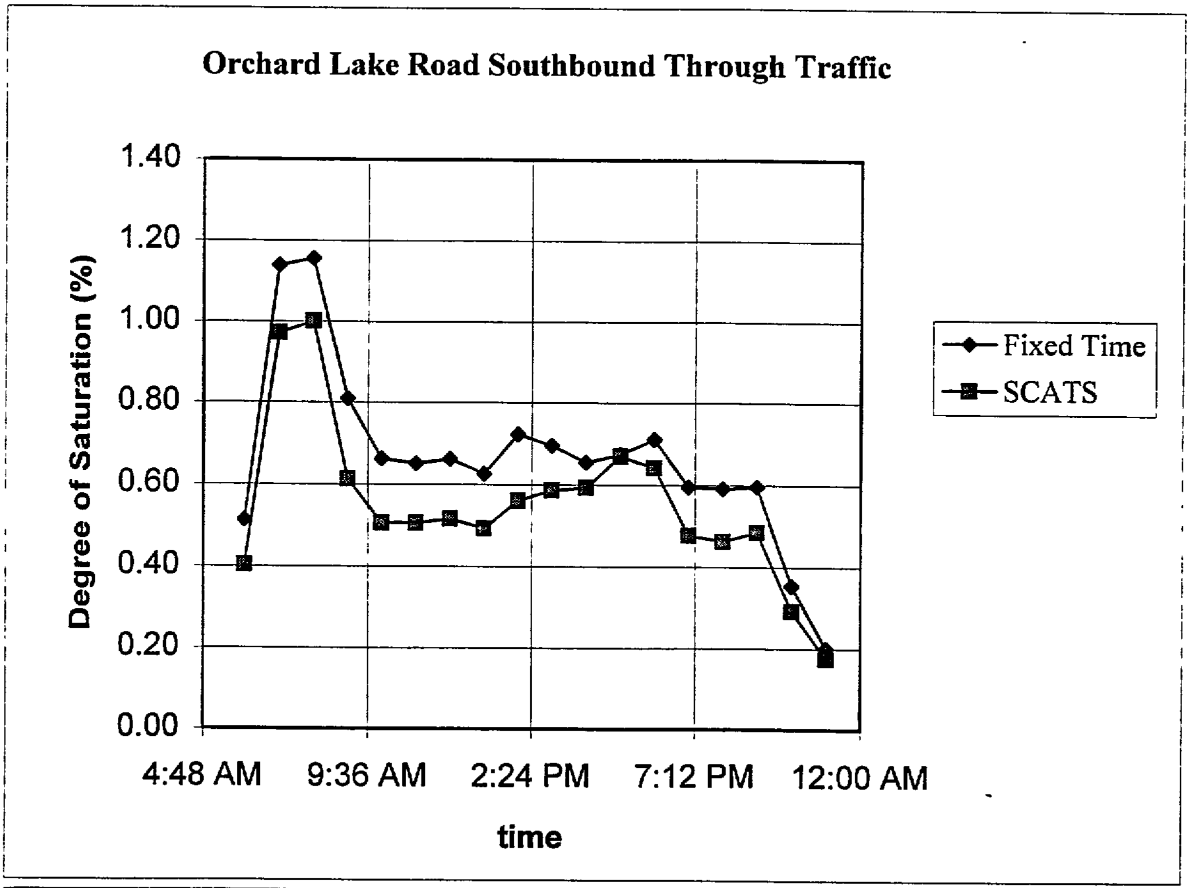


Figure 8.7 Before/After Degree of Saturation (Walnut Lake Road Intersection)



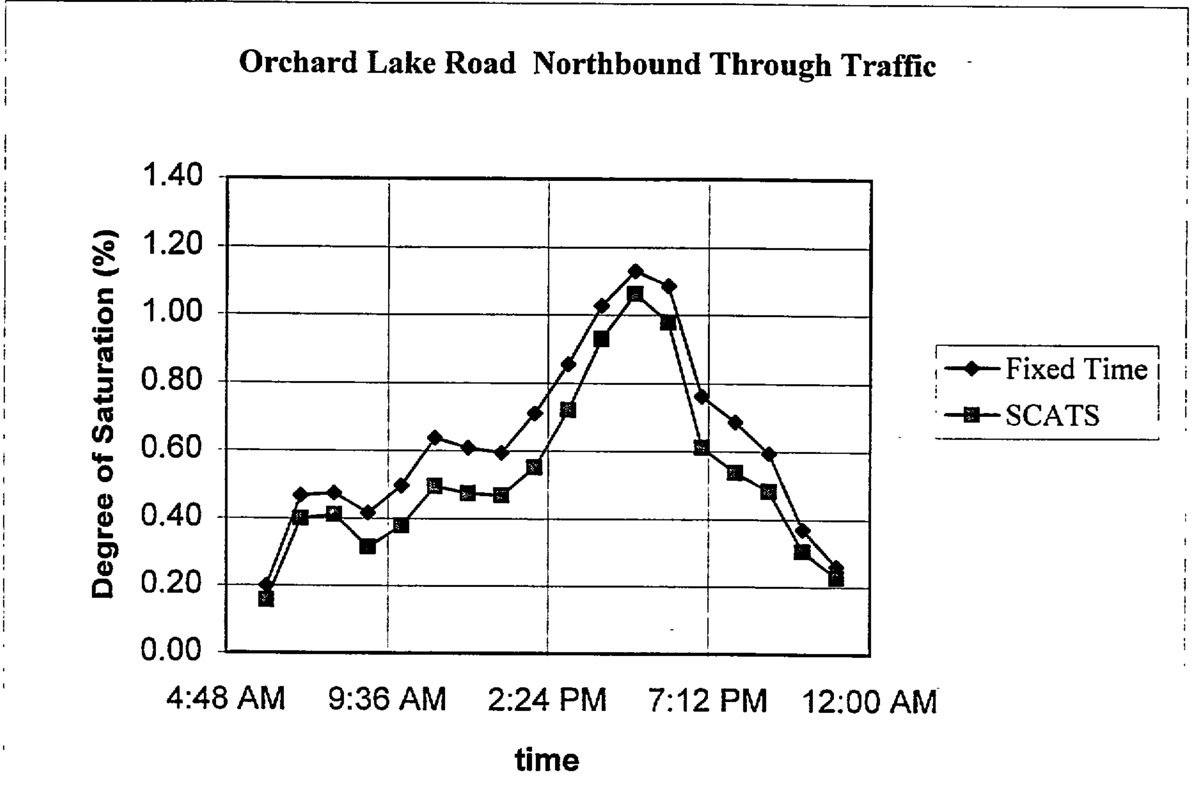
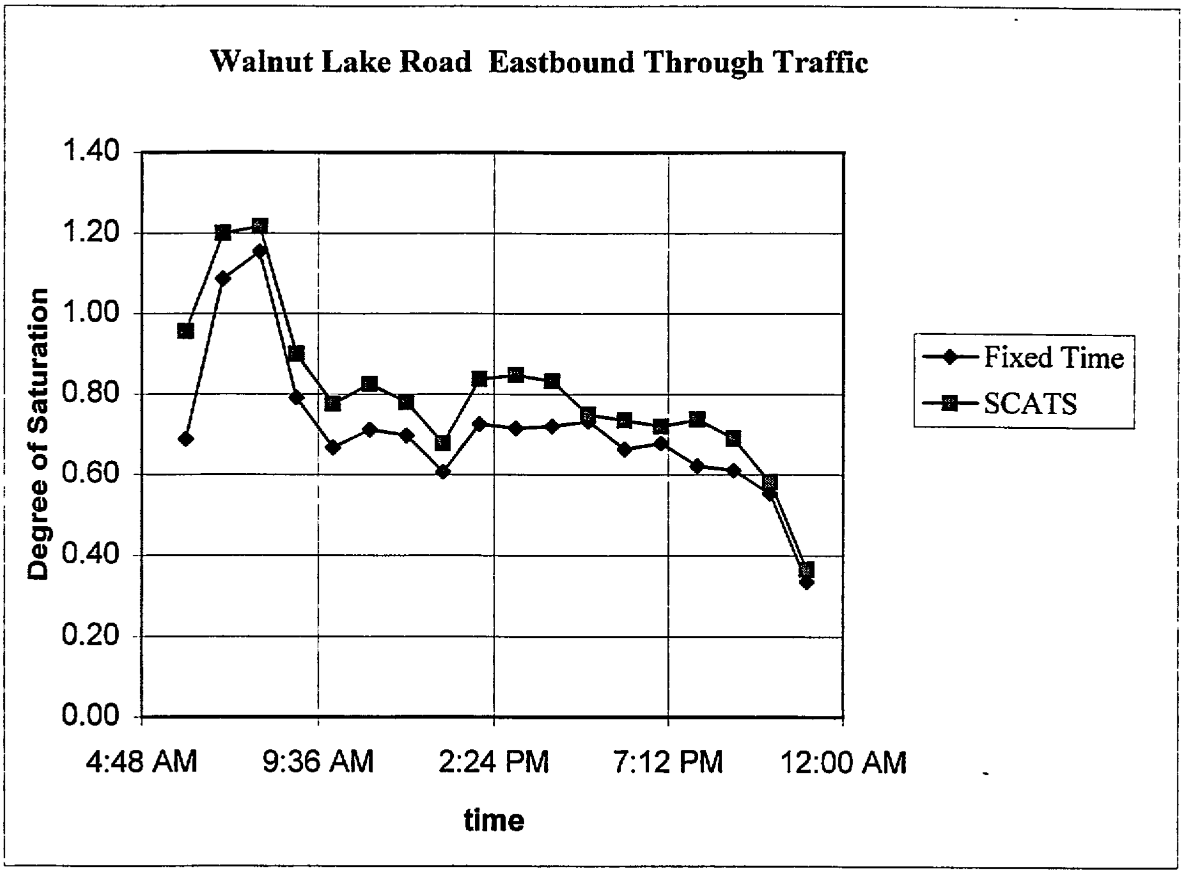
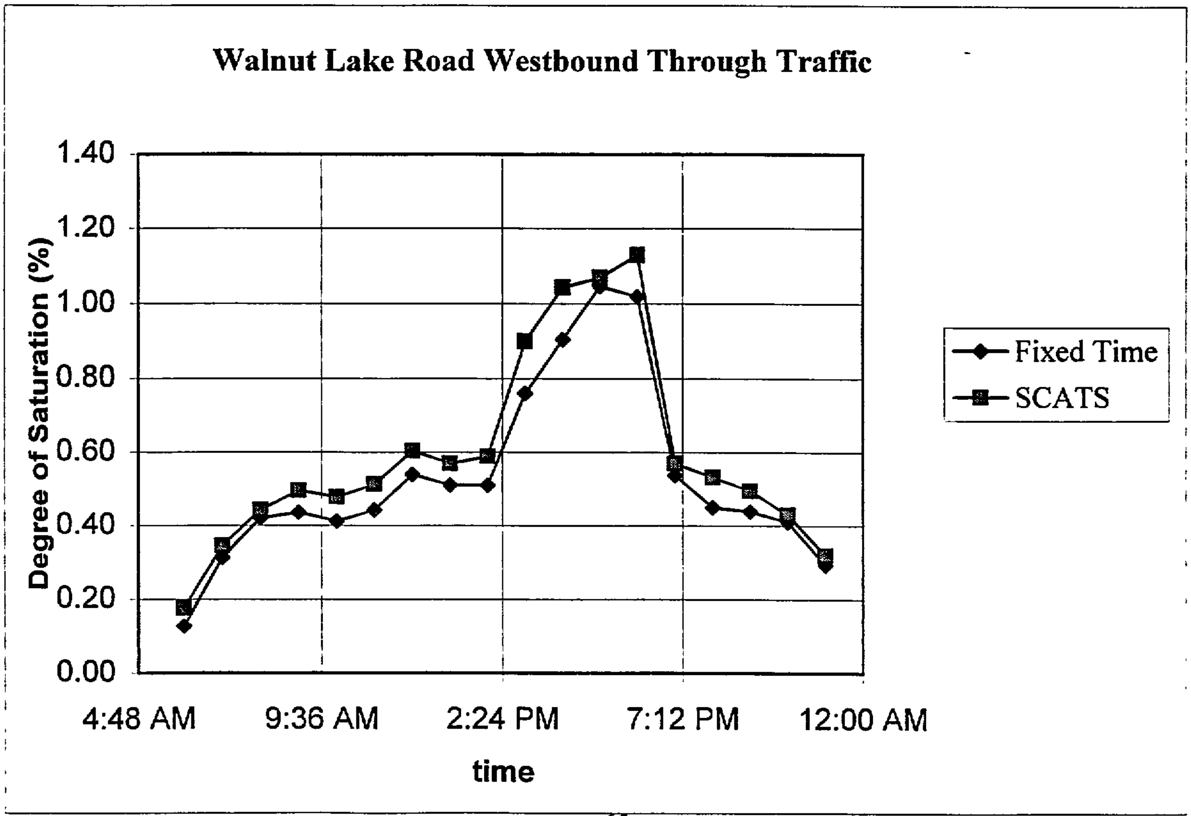


Figure 8.7 (Cont.) Before/After Degree of Saturation





8.4 Orchard Lake Road – Green Road Intersection.

Green road is a minor intersection along the Orchard Lake Corridor. The intersection has a unique characteristic as it controls the traffic to/from the high school, and thus experiences different traffic pattern and peak periods than the other intersections. Prior to SCATS, the signal was operating as a fixed time signal with four different dials. Table 8.6 presents green times and G/C ratios from different approaches under SCATS control.

Table 8.7 presents the total effective green time during the before and after periods. The results are also presented in Figure 8.8. The results show that SCATS extended the green time for the main street through traffic reducing the green time for all other approaches. During the non-peak period, the effective green time for the main street through traffic was extended from 28 minutes per hour to an average of 43 minutes per hour (53.6%). During the afternoon peak period, the effective green time was also increased from 38 minutes per hour to an average of 44 minutes per hour (15%).

Figure 8.9 presents the before/after average degree of saturation for different movements. During the morning peak, the average degree of saturation for southbound traffic decreased from 1.16 to 0.78. At 2:00 PM, the degree of saturation for the school traffic was 0.90 under SCATS control versus an average of 0.45 under the fixed time signal. The degree of saturation for the main street through traffic during this time decreased from 0.78 to 0.52, as a result of transferring green time from the school traffic to the main street through traffic.

Table 8.6 Green Time and G/C Radio for Orchard Lk. Rd. And Green Rd. Intersection (Under SCATS control)

Time		Cycle Length	Green Time						G/C Ratio					
			NB Orchard Throu	SB Orchard Throu	SB Orchard LT	NB Orchard LT	Green Rd	School Drive-way	NB Orchard Through	SB Orchard through	NB Orchard LT	SB Orchard LT	Green Rd	School Drive-Way
12:00 AM	Mean	82	81	81	0	0	1	0	99	99	0	0	1	0
	Min	53	53	53	0	0	0	0						
	Max	106	106	106	0	0	14	13						
1:00 AM	Mean	53	53	53	0	0	0	0	100	100	1	0	0	0
	Min	37	25	31	0	0	0	0						
	Max	80	80	80	9	10	11	0						
2:00 AM	Mean	53	53	53	0	0	0	0	100	100	0	0	0	0
	Min	42	24	33	0	0	0	0						
	Max	62	52	52	9	0	11	10						
3:00 AM	Mean	53	52	53	1	0	0	0	99	101	1	0	1	0
	Min	37	23	31	0	0	0	0						
	Max	57	51	51	8	9	11	10						
4:00 AM	Mean	53	53	53	0	0	0	0	100	100	1	0	0	0
	Min	37	23	30	0	0	0	0						
	Max	62	51	51	9	9	11	0						
5:00 AM	Mean	65	59	61	2	0	1	1	91	94	3	0	2	1
	Min	42	25	33	0	0	0	0						
	Max	117	105	105	10	9	15	15						
6:00 AM	Mean	99	86	86	7	2	6	5	87	87	7	2	6	5
	Min	69	35	43	0	0	0	0						
	Max	131	128	127	14	12	26	19						
7:00 AM	Mean	134	87	89	14	12	18	16	65	67	10	9	14	12
	Min	104	29	42	8	0	0	0						
	Max	163	137	131	32	23	26	39						
8:00 AM	Mean	140	108	108	9	9	16	8	77	77	6	6	12	5
	Min	134	89	85	8	0	0	0						
	Max	146	133	132	11	17	26	16						
9:00 AM	Mean	136	106	107	9	8	13	9	78	79	6	6	9	7
	Min	117	76	85	8	0	0	0						
	Max	145	143	141	11	17	27	17						
10:00 AM	Mean	126	101	105	9	5	10	7	80	83	7	4	8	5
	Min	114	63	66	8	0	0	0						
	Max	138	141	140	13	15	26	20						
11:00 AM	Mean	127	89	89	9	9	14	14	70	70	7	7	11	11
	Min	90	29	38	0	0	0	0						
	Max	154	156	152	13	23	27	32						
12:00 PM	Mean	124	96	99	9	6	11	8	77	80	7	5	9	7
	Min	92	48	49	8	0	0	0						
	Max	148	134	134	11	12	26	15						
1:00 PM	Mean	126	98	102	9	5	10	9	78	81	7	4	8	7
	Min	94	53	57	0	0	0	0						
	Max	183	160	161	16	14	26	17						
2:00 PM	Mean	129	96	98	9	7	12	13	75	76	7	5	9	10
	Min	94	34	45	8	0	0	0						
	Max	174	148	145	11	23	26	26						
3:00 PM	Mean	128	95	97	9	7	14	11	74	76	7	5	11	9
	Min	80	38	48	7	0	0	0						
	Max	154	145	145	12	15	26	19						
4:00 PM	Mean	132	101	102	9	8	14	8	76	77	7	6	11	6
	Min	93	43	42	8	0	0	0						
	Max	144	141	138	10	25	26	16						
5:00 PM	Mean	140	105	110	10	5	15	10	75	78	7	4	11	7
	Min	140	82	90	8	0	0	0						
	Max	140	144	144	28	11	26	25						
6:00 PM	Mean	140	104	108	11	7	15	11	74	77	8	5	10	8
	Min	133	83	89	0	0	0	0						
	Max	144	139	140	20	14	26	17						
7:00 PM	Mean	126	94	98	9	5	12	10	75	78	7	4	10	8
	Min	89	37	46	8	0	0	0						
	Max	146	143	155	13	13	24	21						
8:00 PM	Mean	117	83	87	9	5	12	14	71	74	8	4	10	12
	Min	87	25	35	7	0	0	0						
	Max	142	117	135	18	14	26	25						
9:00 PM	Mean	112	84	87	8	5	9	11	75	78	7	4	8	10
	Min	79	35	33	0	0	0	0						
	Max	148	154	154	12	15	26	42						
10:00 PM	Mean	103	89	93	6	2	5	3	86	90	6	2	5	3
	Mini	71	30	38	0	0	0	0						
	Maxi	158	151	151	10	12	26	13						
11:00 PM	Mean	88	79	82	4	1	3	3	90	93	5	1	3	3
	Min	63	30	38	0	0	0	0						
	Max	133	138	138	11	12	14	14						

Table 8.7.a Green Time for Orchard Lake Rd. & Green Rd. Intersection Under SCATS control

Time	Cycle LENGTH	Green Time: NB Orchard Through	SB Orchard Through	SB Orchard LT	NB Orchard LT	Green Rd.	School Driveway
12:OOAM	82	81	81	0	0	1	0
1:OOAM	53	53	53	0	0	0	0
2:00 AM	53	53	53	0	0	0	0
3:00 AM	53	52	53	1	0	0	0
4:00 AM	53	53	53	0	0	0	0
5:00 AM	65	59	61	2	0	2	2
6:00 AM	99	81	86	7	2	6	5
7:00 AM	134	87	89	14	12	18	16
8:00 AM	140	108	108	9	9	16	8
9:00 AM	136	106	107	9	8	13	9
10:00 AM	126	101	105	9	5	10	7
11:00 AM	127	89	89	9	9	14	14
12:00 PM	124	96	99	9	6	11	8
1:00 PM	126	98	102	9	5	10	9
2:00 PM	129	96	98	9	7	12	13
3:00 PM	128	95	97	9	7	14	11
4:00 PM	132	101	102	9	8	14	8
5:00 PM	140	105	110	10	5	15	10
6:00 PM	140	104	108	11	7	15	11
7:00 PM	126	94	98	9	5	12	10
8:00 PM	117	83	87	9	5	12	14
9:00 PM	112	84	87	8	5	9	11
10:00 PM	103	89	93	6	2	5	3
11:00 PM	88	79	82	4	1	3	3

Table 8.7.b Green Time for Orchard Lake Rd. & Green Rd. Intersection (Fixed Time)

Time	Cycle LENGTH	Green Time: NB Orchard Through	SB Orchard Through	SB Orchard LT	NB Orchard LT	Green Rd.	School Driveway
12:00 AM	80	39	39	11	11	15	15
1:00 AM	80	80	80	0	0	0	0
2:00 AM	80	80	80	0	0	0	0
3:00 AM	80	80	80	0	0	0	0
4:00 AM	80	80	80	0	0	0	0
5:00 AM	80	80	80	0	0	0	0
6:00 AM	120	60	55	15	20	20	25
7:00 AM	120	60	55	15	20	20	25
8:00 AM	120	69	69	11	11	20	20
9:00 AM	80	39	39	11	11	15	15
10:00 AM	80	39	39	11	11	15	15
11:00 AM	80	39	39	11	11	15	15
12:00 PM	80	39	39	11	11	15	15
1:00 PM	80	39	39	11	11	15	15
2:00 PM	120	60	55	15	20	20	25
3:00 PM	120	79	79	11	11	15	15
4:00 PM	120	79	79	11	11	15	15
5:00 PM	120	79	79	11	11	15	15
6:00 PM	120	79	79	11	11	15	15
7:00 PM	80	39	39	11	11	15	15
8:00 PM	80	39	39	11	11	15	15
9:00 PM	80	39	39	11	11	15	15
10:00 PM	80	39	39	11	11	15	15
11:00 PM	80	39	39	11	11	15	15

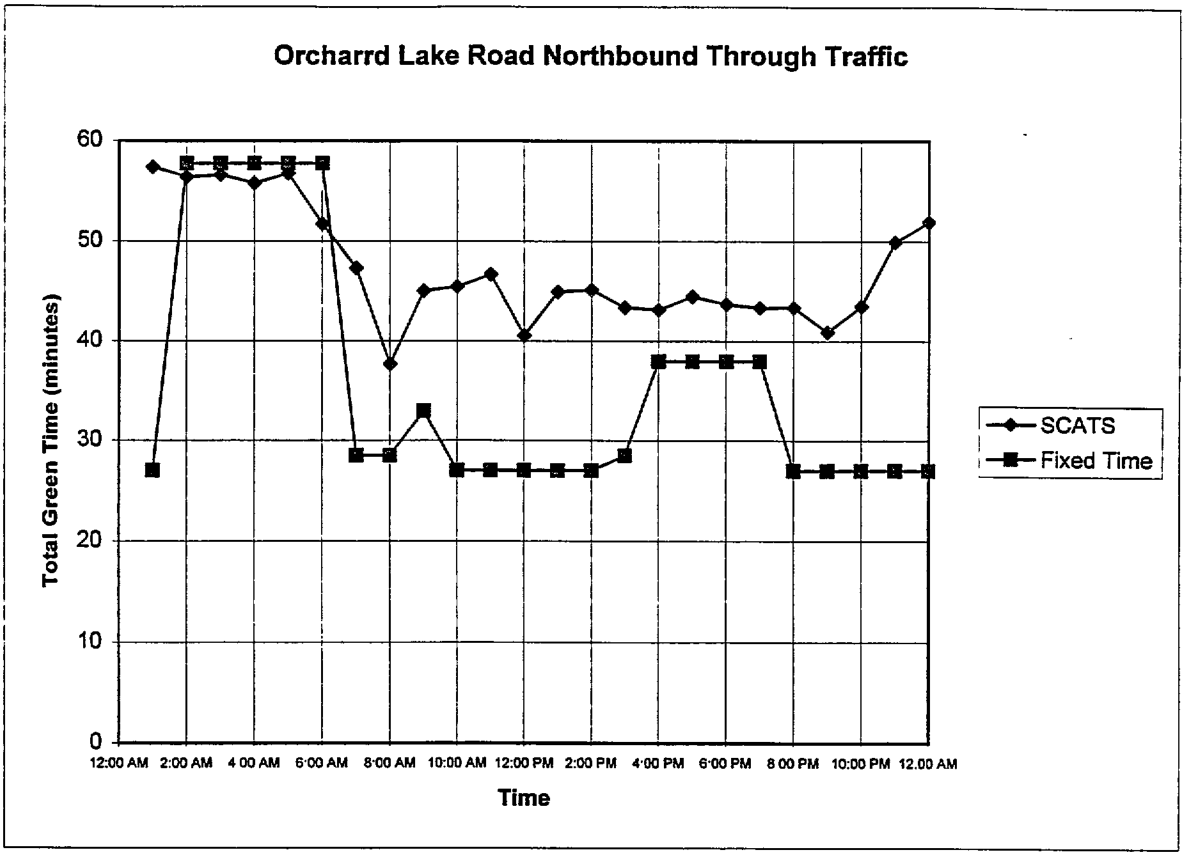
Table 8.7.c Total Effective Green Time Under SCATS control

Time	Green Time					
	NB Orchard	SB Orchard	SB Orchard LT	NB Orchard LT	Green Rd.	School Driveway
1:00 AM	57	57	0	0	0	0
2:00 AM	56	56	0	0	0	0
3:00 AM	57	57	0	0	0	0
4:00 AM	56	57	1	0	0	0
5:00AM	57	57	0	0	0	0
6:00 AM	52	54	2	0	0	0
7:00 AM	47	50	4	1	2	1
8:00 AM	38	39	6	5	7	6
9:00 AM	45	45	4	4	6	2
10:00 AM	45	46	4	3	4	3
11:00 AM	47	49	4	2	3	2
12:00 PM	41	41	4	4	5	5
1:00 PM	45	46	4	3	4	3
2:00 PM	45	47	4	3	3	3
3:00 PM	43	44	4	3	4	5
4:00 PM	43	44	4	3	5	4
5:00 PM	45	45	4	3	5	2
6:00 PM	44	46	4	2	5	3
7:00 PM	43	45	5	3	5	3
8:00 PM	43	45	4	3	4	3
9:00 PM	41	43	5	2	4	6
10:00 PM	44	45	4	3	3	5
11:00 PM	50	52	4	1	1	0
12:00 AM	52	54	3	1	0	0

Table 8.7.d Total effective Green Time under Fixed Time Signal control

Time	Green Time					
	NB Orchard	SB Orchard	SB Orchard LT	NB Orchard LT	Green Rd.	School Driveway
12:00 AM	27	27	8	8	0	0
1:00 AM	58	58	0	0	0	0
2:00 AM	58	58	0	0	0	0
3:00 AM	58	58	0	0	0	0
4:00 AM	58	58	0	0	0	0
5:00AM	58	58	0	0	0	0
6:00 AM	29	26	8	10	9	11
7:00 AM	29	26	8	10	9	11
8:00 AM	33	33	6	6	9	9
9:00 AM	27	27	8	8	9	9
10:00 AM	27	27	8	8	9	9
11:00 AM	27	27	8	8	9	9
12:00 PM	27	27	8	8	9	9
1:00 PM	27	27	8	8	9	9
2:00 PM	29	26	8	10	9	11
3:00 PM	38	38	6	6	6	6
4:00 PM	38	38	6	6	6	6
5:00 PM	38	38	6	6	6	6
6:00 PM	38	38	6	6	6	6
7:00 PM	27	27	8	8	9	9
8:00 PM	27	27	8	8	9	9
9:00 PM	27	27	8	8	9	9
10:00 PM	27	27	8	8	9	9
11:00 PM	27	27	8	8	9	9

Figure 8.8 Before/After Total Effective Green Time Per Hour of The Day (Orchard Lake Road and Green Road Intersection



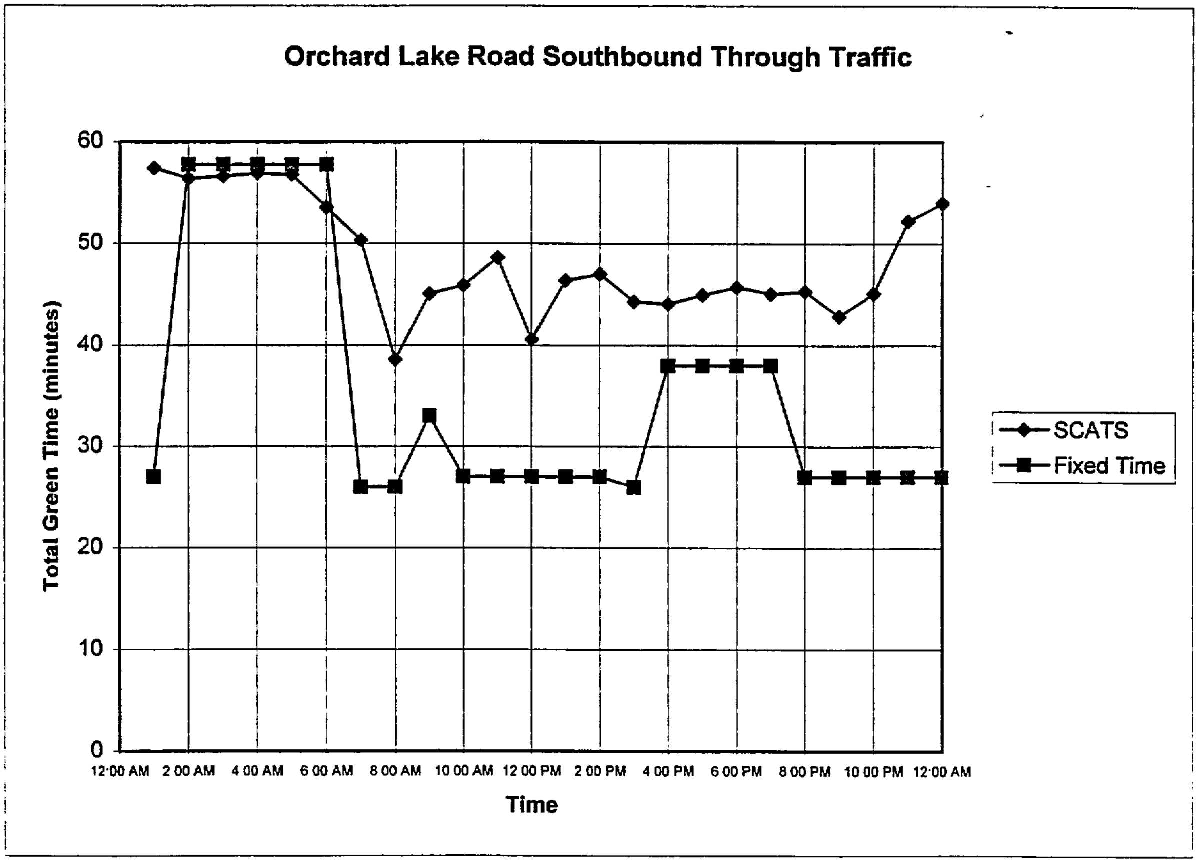
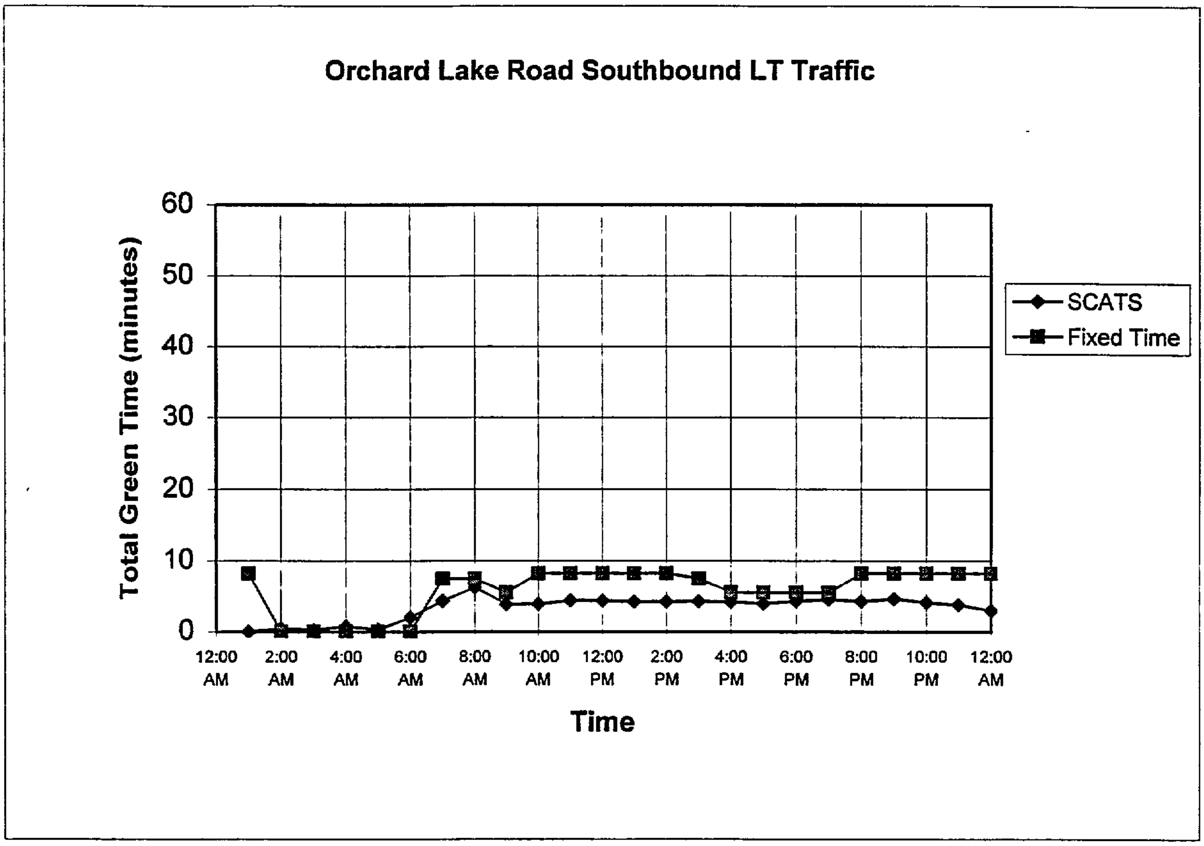


Figure 8.8 (Cont.) **Before/After Total Effective Green Time (Orchard Lake Road and Green Road Intersection**



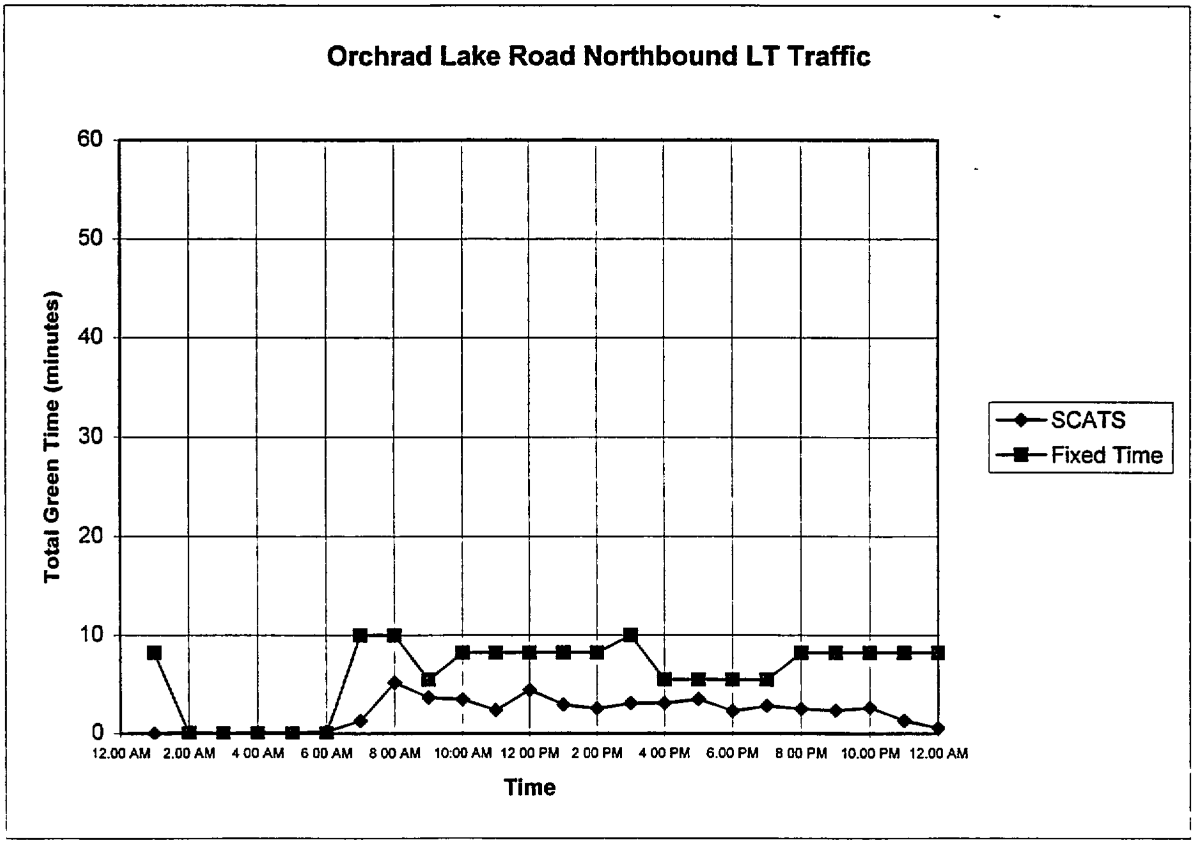
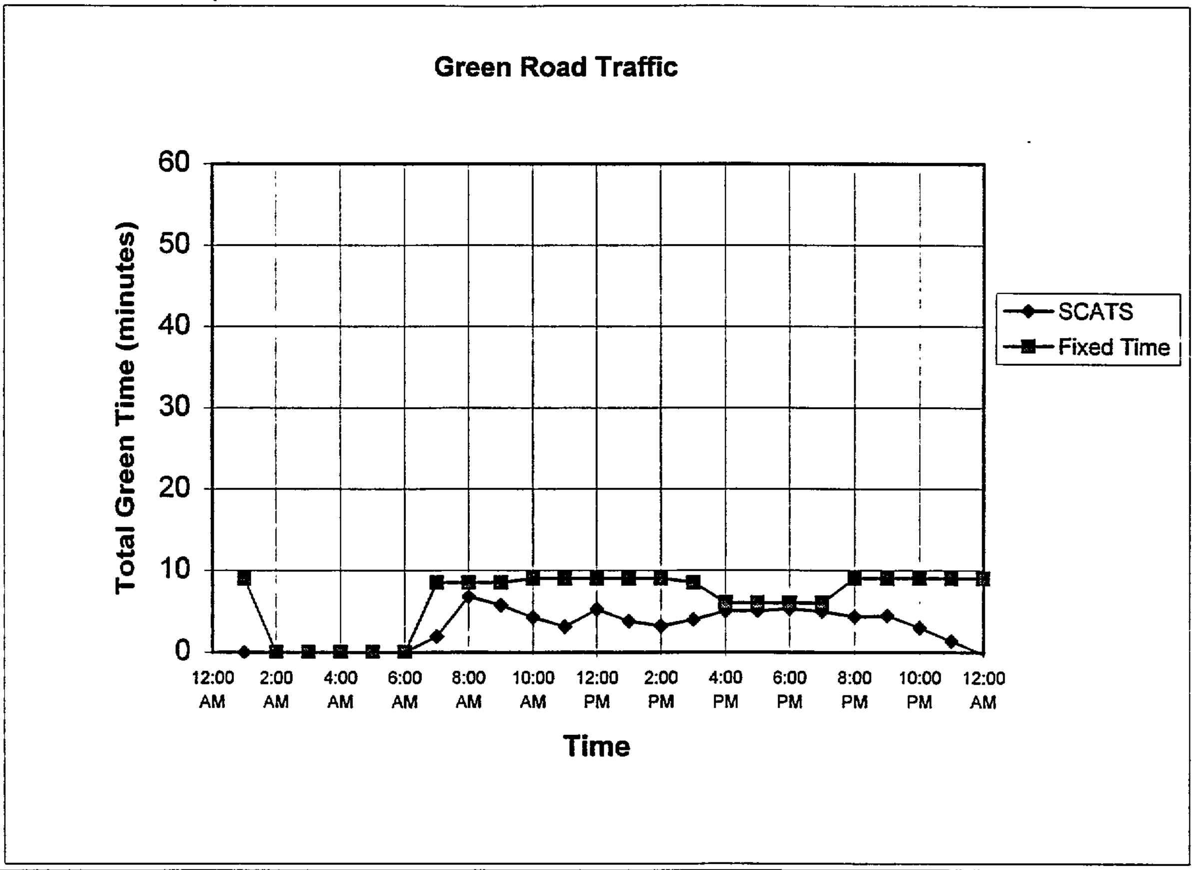


Figure 8.8 (Cont.) Before/After Total Effective Green Time
(Orchard Lake Road and Green Road Intersection



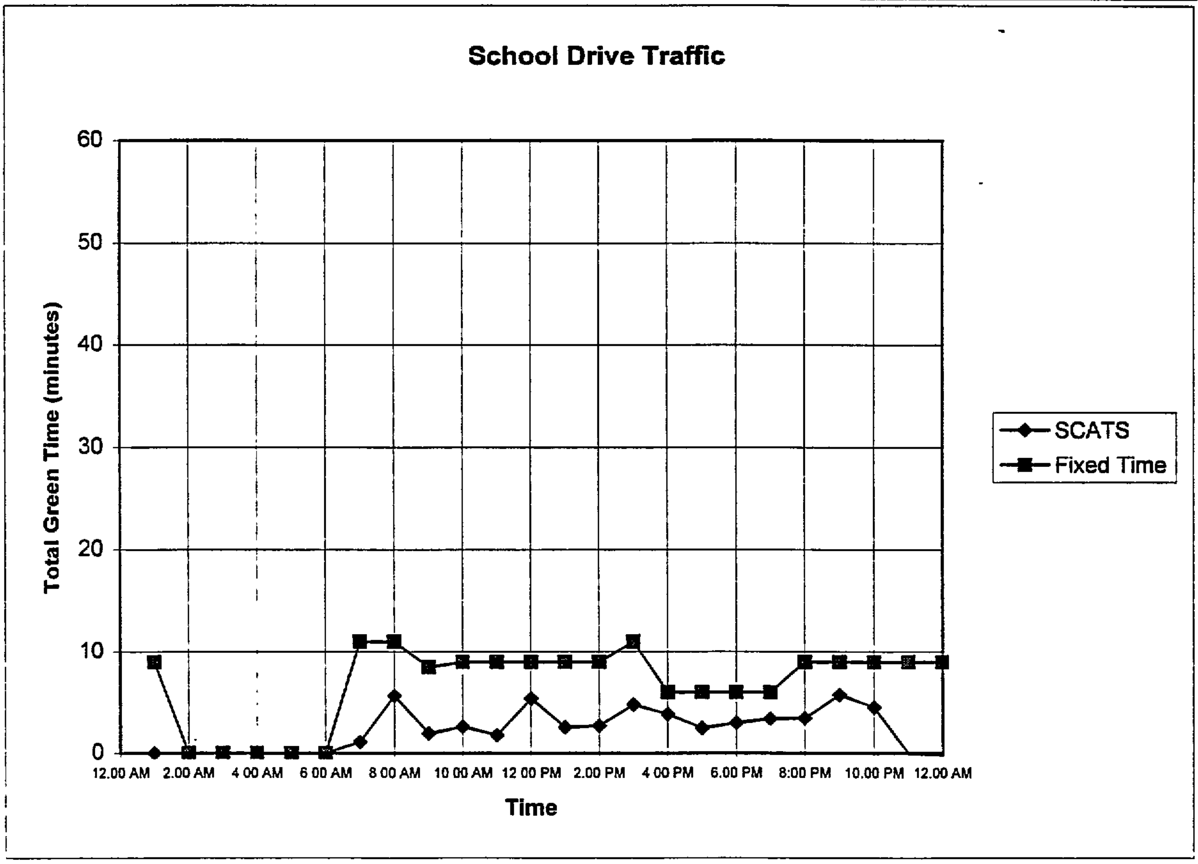
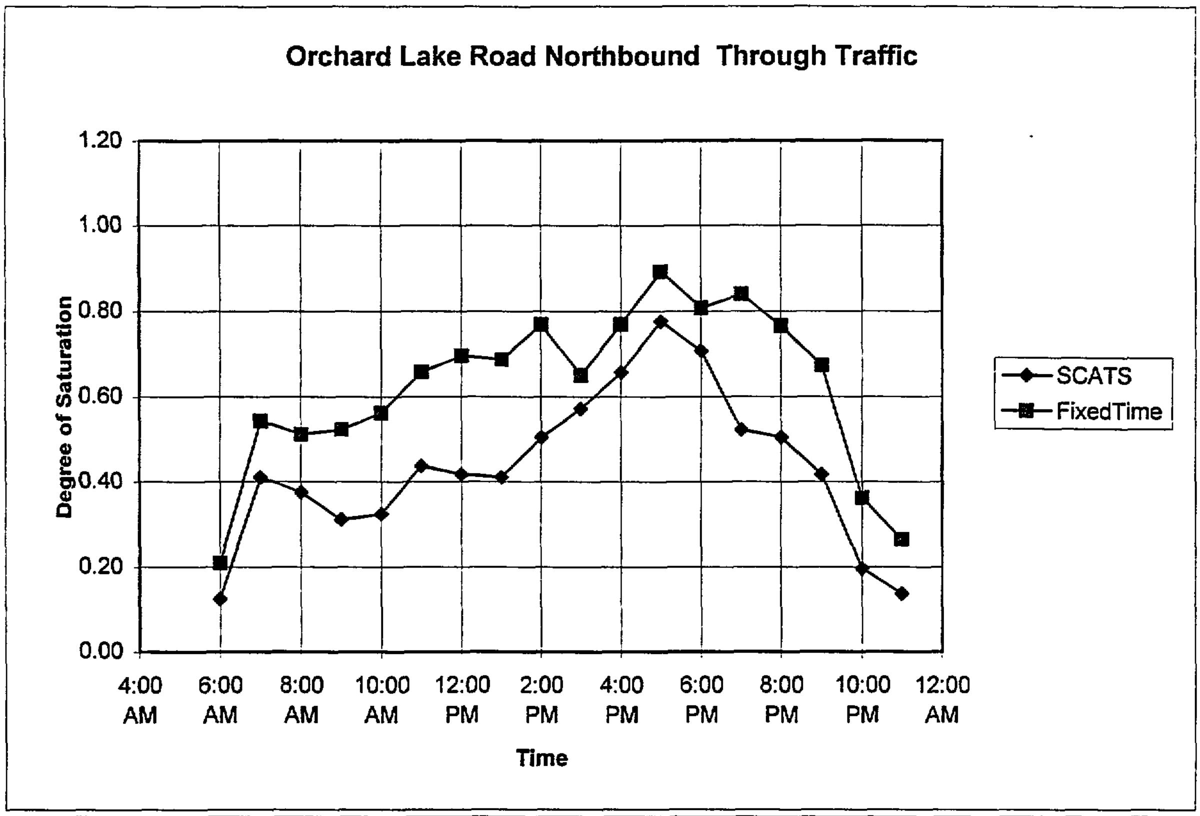


Figure 8.9 Before/After Degree of Saturation (Orchard Lake Road and Green Road Intersection



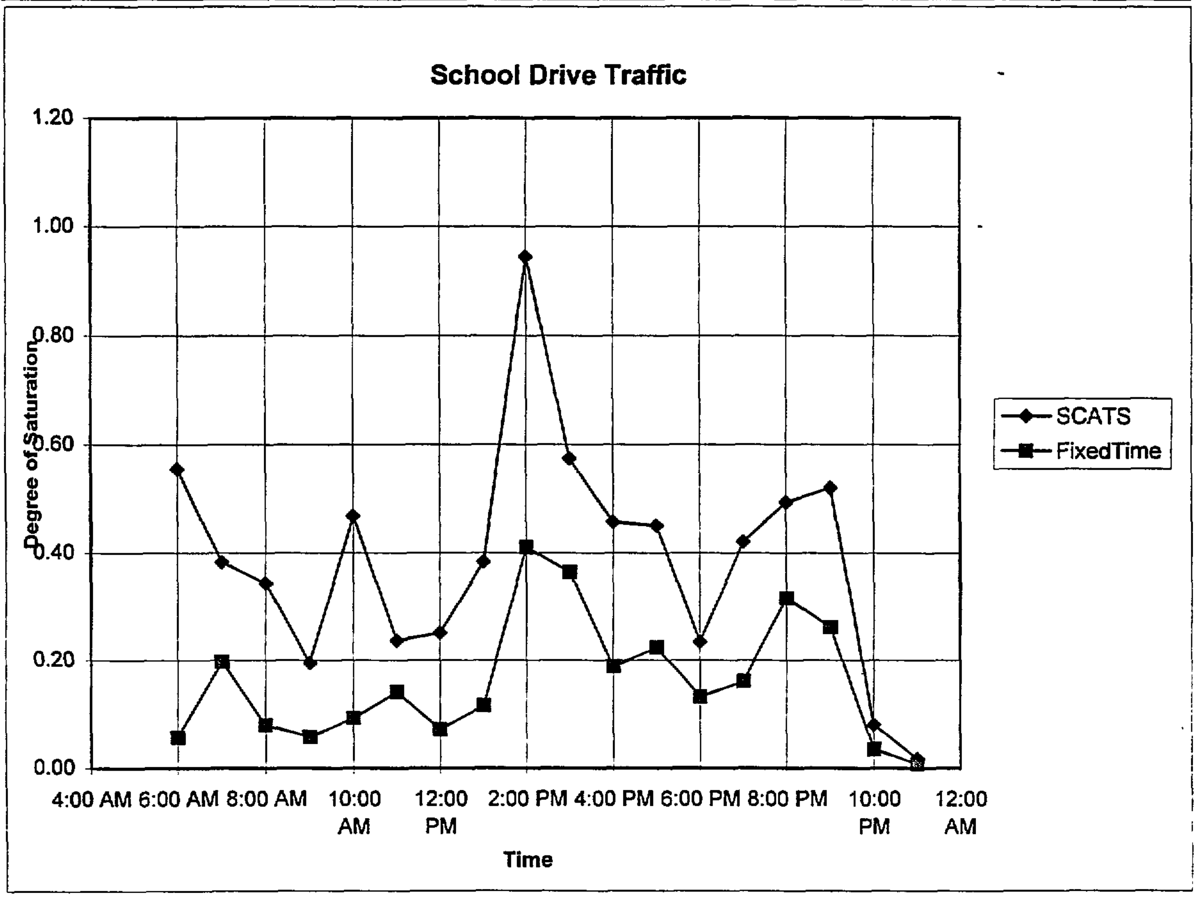
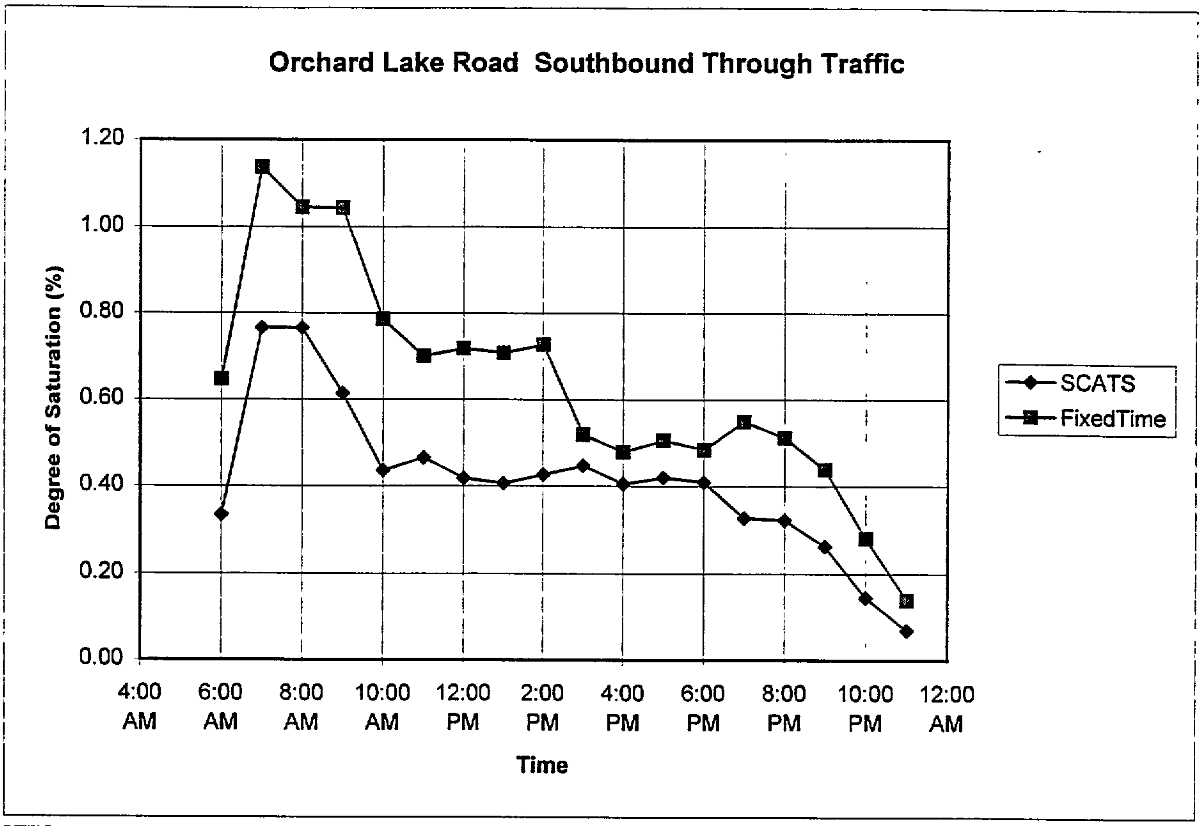
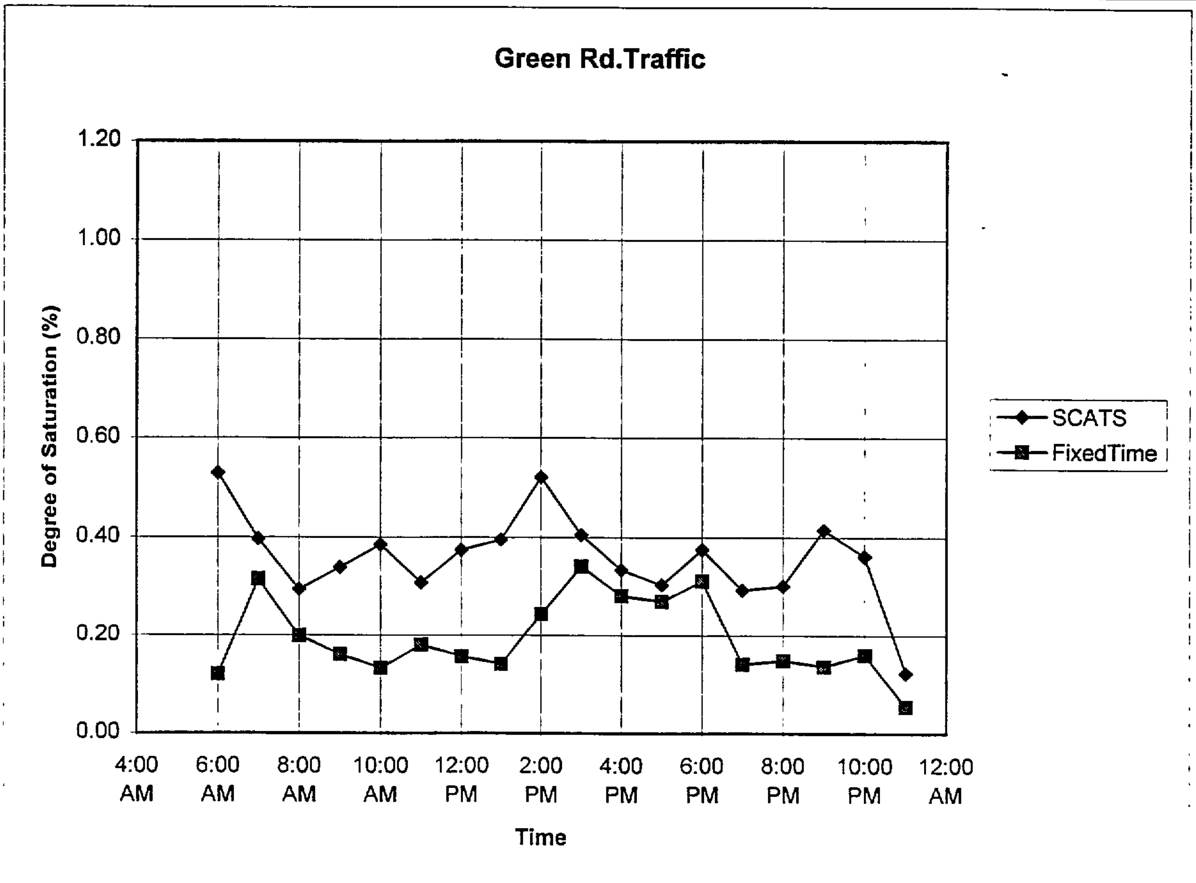


Figure 8.9 (Cont.) **Before/After Degree of Saturation**
(Orchard Lake Road and Green Road Intersection





8.5 Orchard Lake Road – Lone Pine Intersection

Lone Pine is a major intersection along the Orchard Lake corridor. The intersection is a three legged intersection . Traffic from Lone Pine has to turn either left of right on Orchard Lake Road. Lone Pine has a relatively low volume compared to Maple or Walnut Lake roads. Table 8.8 lists the green time and G/C ratio for different approaches.

Table 8.9 presents before/after effective green times for different approaches to the intersection. Before/after effective total green time graphs are presented in Figure 8.10. The results show that SCATS extended the green time for the main traffic at all times, except during the afternoon peak period when it assigned more green time to Lone Pine traffic. During the morning peak period, SCATS extended the effective green time for the main street through traffic from 43 minutes per hour to 48 minutes per hour (11.6%). During the non-peak period, the effective green time was extended from 35 minutes per hour to an average of 46 minutes per hour (3 1%). However, during the afternoon peak, SCATS reduced the effective green time for main street through traffic from 43 minutes per hour to 41 minutes per hour (4.7%), and increased the effective green time for Lone Pine traffic from 14 minutes per hour to 16 minutes per hour (14.3%).

Figure 8.11 presents the before/after degree of saturation graphs. During the morning peak, the degree of saturation for southbound traffic was reduced from an average of 0.96 to 0.76 as a result of extending the green time for this traffic. The degree of saturation for Lone Pine traffic increased from 0.22 to 0.43 . During the non peak period, the degree of saturation for Orchard Lake traffic was decreased from an average of 0.58 to 0.41.

During the afternoon peak period, SCATS maintained an average degree of saturation of 0.85 for both the main and minor street traffic.

Table 8.8 Green Time and G/C Radio for Orchard Lk. And Lone Pine Intersection Under SCATS control.

Time		Cycle Length	Green Time		G/C Ratio	
			Orchard Rd.	Lone Pine Rd.	Orchard Rd.	Lone Pine Rd.
12:00 AM	Mean	88	83	5	95	5
	Minimum	53	29	0		
	Maximum	102	97	7		
1:00 AM	Mean	57	54	3	95	5
	Minimum	37	31	0		
	Maximum	90	90	16		
2:00 AM	Mean	53	51	2	96	4
	Minimum	42	35	0		
	Maximum	62	59	12		
3:00 AM	Mean	53	51	2	96	4
	Minimum	37	30	0		
	Maximum	90	90	15		
4:00 AM	Mean	53	51	2	96	4
	Minimum	37	27	0		
	Maximum	62	61	11		
5:00 AM	Mean	67	63	4	94	6
	Minimum	42	25	0		
	Maximum	133	113	16		
6:00 AM	Mean	99	89	10	90	10
	Minimum	69	38	0		
	Maximum	135	123	21		
7:00AM	Mean	134	113	21	84	16
	Minimum	107	56	0		
	Maximum	163	138	36		
8:00 AM	Mean	140	113	27	80	20
	Minimum	134	95	11		
	Maximum	146	133	42		
9:00 AM	Mean	136	110	27	80	20
	Minimum	116	83	20		
	Maximum	145	126	41		
10:00 AM	Mean	126	100	26	79	21
	Minimum	112	74	20		
	Maximum	139	117	37		
11:00 AM	Mean	128	102	26	80	20
	Minimum	95	63	18		
	Maximum	155	127	39		
12:00 PM	Mean	125	98	27	78	22
	Minimum	91	59	19		
	Maximum	148	124	41		
1:00 PM	Mean	126	100	26	79	21
	Minimum	95	67	15		
	Maximum	145	121	40		
2:00 PM	Mean	130	103	27	79	21
	Minimum	98	57	20		
	Maximum	149	124	38		
3:00 PM	Mean	133	103	30	78	22
	Minimum	107	51	22		
	Maximum	153	121	44		
4:00 PM	Mean	134	101	33	76	24
	Minimum	98	57	21		
	Maximum	144	134	45		
5:00 PM	Mean	140	99	41	71	29
	Minimum	140	81	23		
	Maximum	140	126	53		
6:00 PM	Mean	140	102	38	73	27
	Minimum	133	85	25		
	Maximum	144	118	49		
7:00 PM	Mean	129	102	27	79	21
	Minimum	90	50	17		
	Maximum	156	118	39		
8:00 PM	Mean	119	96	23	81	19
	Minimum	87	50	16		
	Maximum	141	147	32		
9:00 PM	Mean	114	97	17	85	15
	Minimum	79	48	0		
	Maximum	145	134	29		
10:00 PM	Mean	105	91	14	86	14
	Minimum	75	60	0		
	Maximum	155	148	23		
11:00 PM	Mean	89	80	9	89	11
	Minimum	63	42	0		
	Maximum	131	128	19		

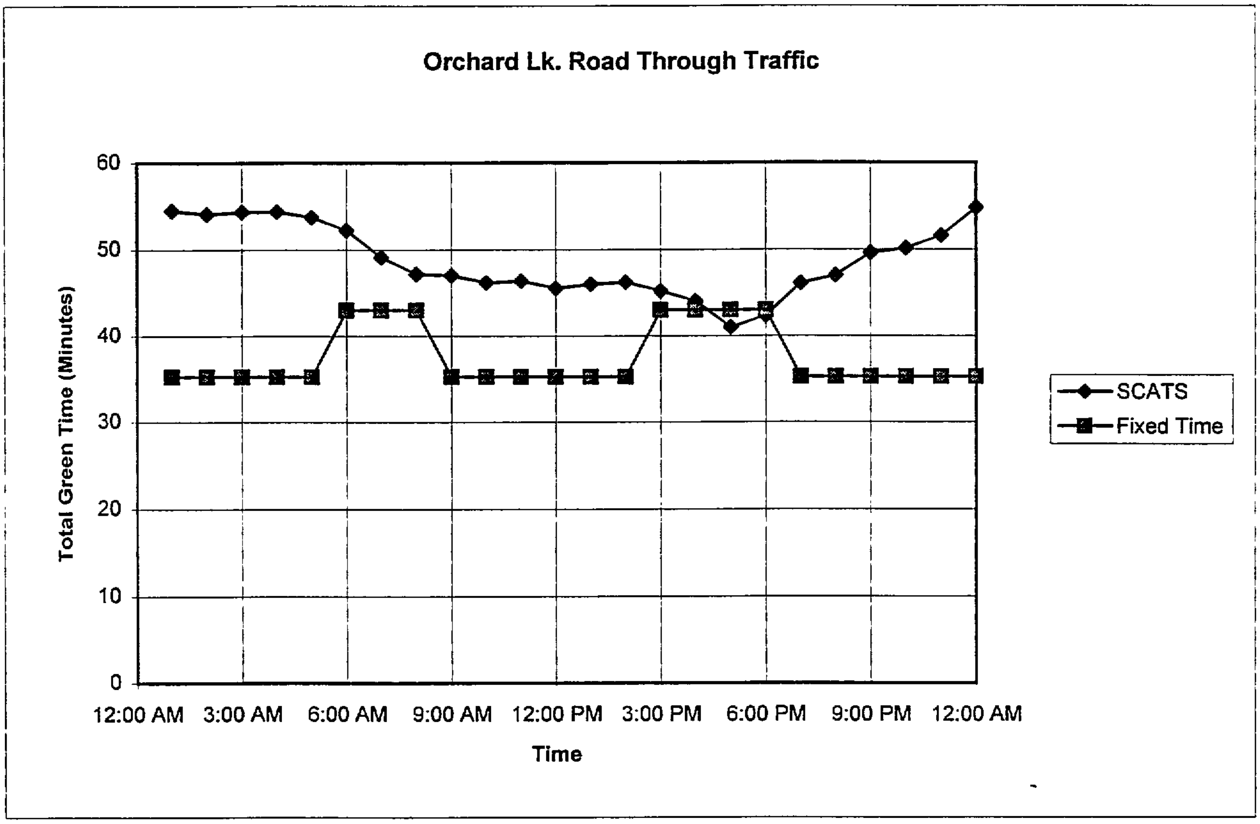
Table 8.9.a Before/After Cycle Length and Green Time (Orchard Lake Road and Lone Pine Road Intersection)

	Cycle Length		Orchard Lk Rd.		Lone Pine Rd.	
Time	SCATS	Fixed Time	SCATS	Fixed Time	SCATS	Fixed Time
1:00 AM	88	80	83	50	5	30
2:00 AM	53	80	51	50	2	30
3:00 AM	53	80	51	50	2	30
4:00 AM	53	80	51	50	2	30
5:00AM	67	80	63	50	4	30
6:00 AM	99	120	89	89	10	31
7:00 AM	134	120	113	89	21	31
8:00 AM	140	120	113	89	27	31
9:00 AM	136	80	110	50	27	30
10:00 AM	126	80	100	50	26	30
11:00 AM	128	80	102	50	26	30
12:00 PM	125	80	98	50	27	30
1:00 PM	126	80	100	50	26	30
2:00 PM	130	80	103	50	27	30
3:00 PM	133	120	103	89	30	31
4:00 PM	134	120	101	89	33	31
5:00 PM	140	120	99	89	41	31
6:00 PM	140	120	102	89	38	31
7:00 PM	129	80	102	50	27	30
8:00 PM	119	80	96	50	23	30
9:00 PM	114	80	97	50	17	30
10:00 PM	105	80	91	50	14	30
11:00 PM	89	80	80	50	9	30
12:00 AM	88	80	83	50	5	30

Table 8.9.b Total Effective Green Time Per Hour (Orchard Lake Road and Lone Pine Road Intersection)

Time	Orchard Lk Rd.		Lone Pine Rd.	
	SCATS	Fixed Time	SCATS	Fixed Time
1:00 AM	55	35	3	3
2:00 AM	54	35	3	20
3:00 AM	54	35	3	20
4:00 AM	54	35	3	20
5:00AM	54	35	3	20
6:00 AM	52	43	3	14
7:00 AM	49	43	8	14
8:00 AM	47	43	10	14
9:00 AM	47	35	10	20
10:00 AM	46	35	11	20
11:00 AM	46	35	11	20
12:00 PM	46	35	12	20
1:00 PM	46	35	11	20
2:00 PM	46	35	11	20
3:00 PM	45	43	12	14
4:00 PM	44	43	13	14
5:00 PM	41	43	16	14
6:00 PM	42	43	15	14
7:00 PM	46	35	11	20
8:00 PM	47	35	10	20
9:00 PM	50	35	7	20
10:00 PM	50	35	6	20
11:00 PM	52	35	4	20
12:00 AM	55	35	1	20

Figure 8.10 Before/After Total Effective Green Time (Orchard Lake Road and Lone Pine Road Intersection)



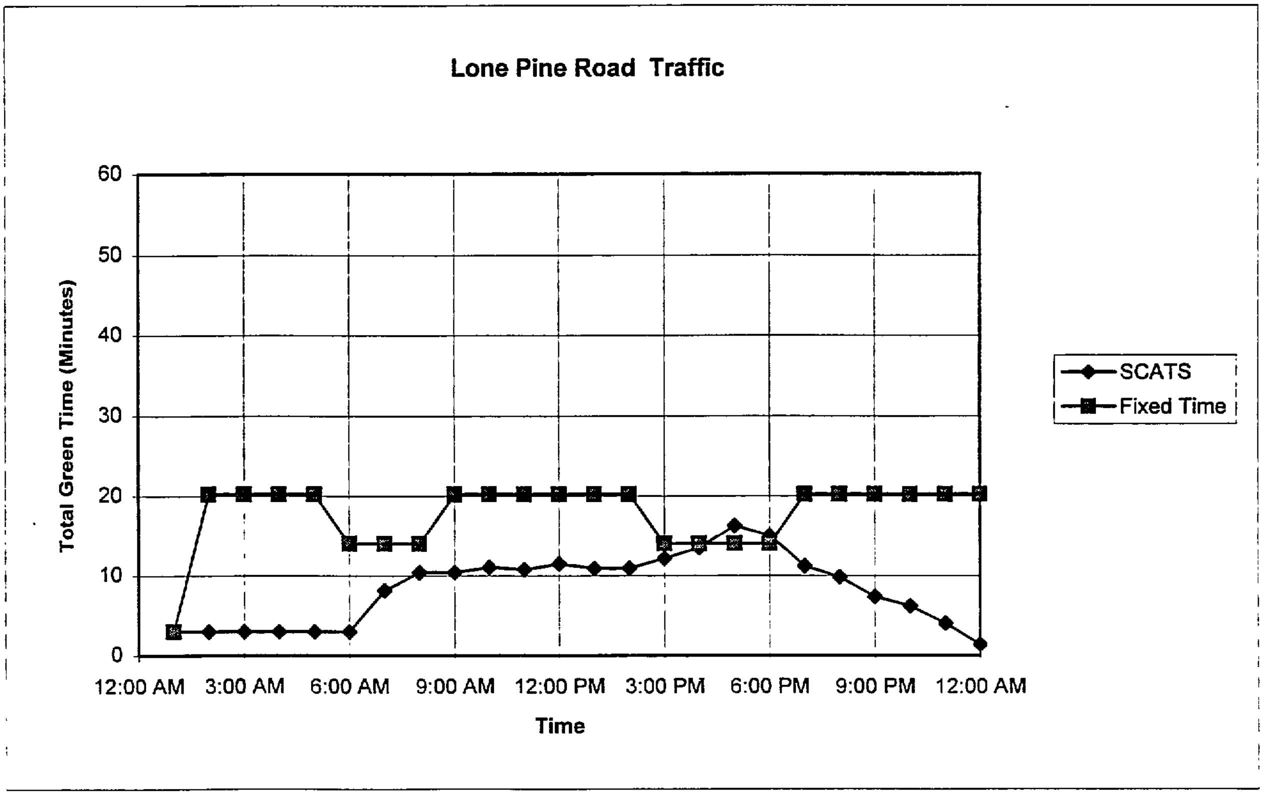
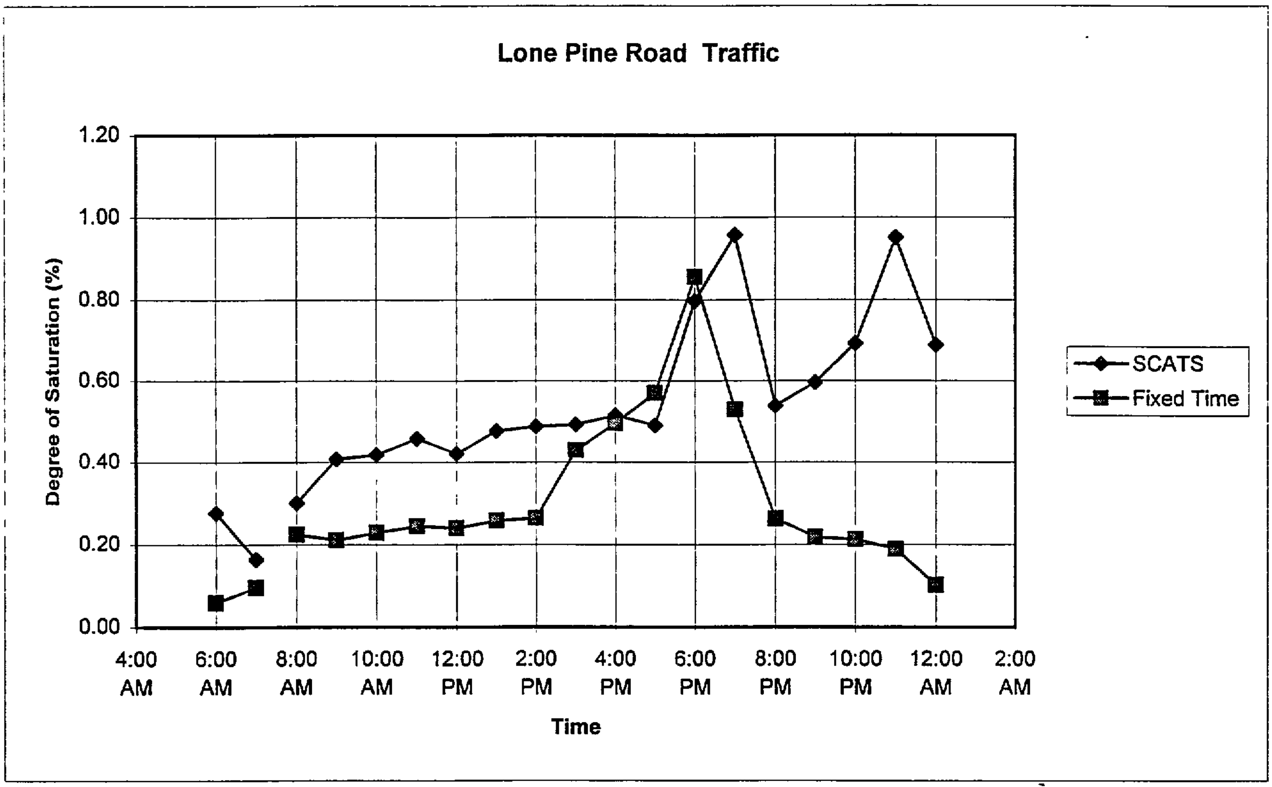


Figure 8.11 Before/After Average Degree of Saturation (Orchard Lake Road and Lone Pine Road Intersection)



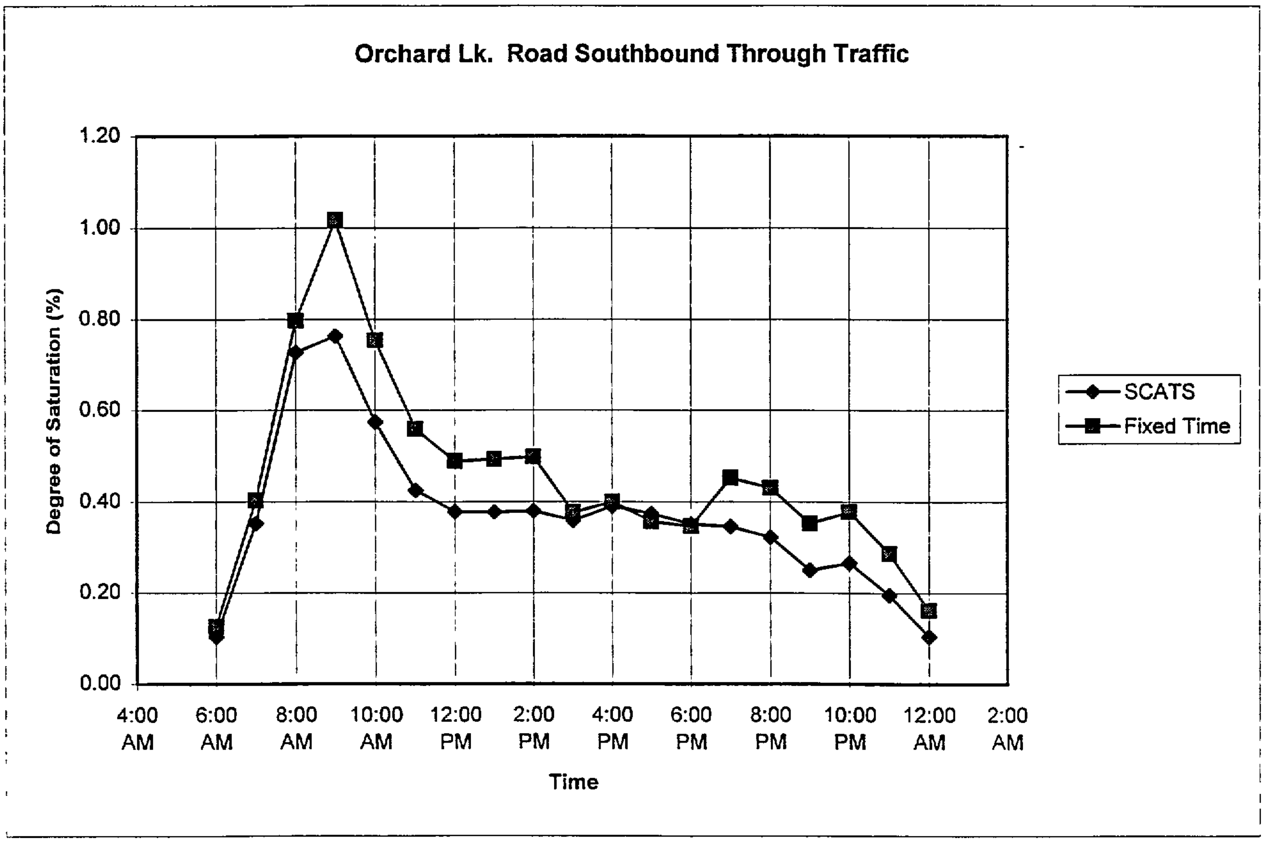
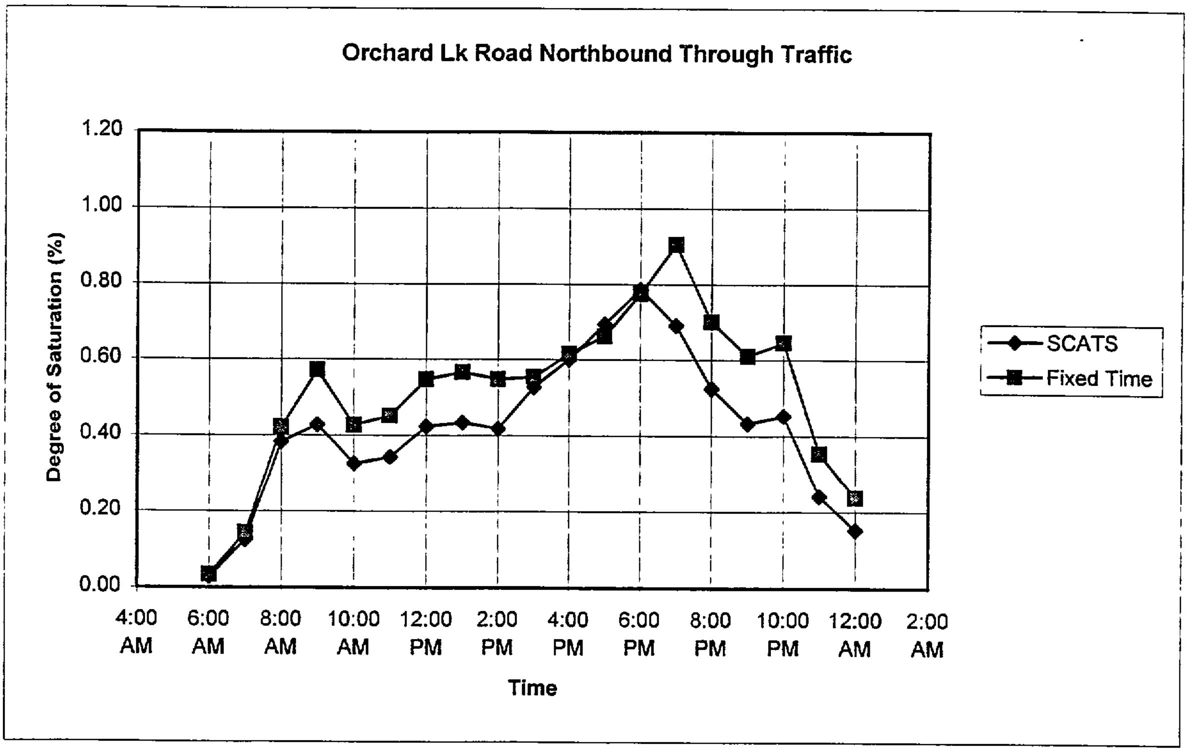


Figure 8.11 (Cont.)Before/After Average Degree of Saturation (Orchard Lake Road and Lone Pine Road Intersection)



The before/after green time study revealed that SCATS, in general, extended the effective green time for the major road traffic (northbound/southbound traffic). This increase in green time led to a corresponding reduction in delay and stops. Extending the green time increases the percentage of non-stopped vehicles, reduces the stopping time for stopped vehicles, and, in the case of over-saturated flow, reduces or eliminates the number of vehicles that have to wait for another cycle, (the first diagram in Figure 8.1). However, increasing the green time for one traffic stream results in less green time being available for the other traffic using the intersection.

Another possible delay reduction potential for an adaptive signal is to maintain the same total green time over a period of time, but to more effectively allocate the green time during each cycle to meet the variation in demand, (the third diagram in figure 8.1). An optimal green phase for an approach would reduce or eliminate the amount of excessive green, which causes unnecessary delay for other approaches, and maintain an optimal degree of saturation for all approaches. This, presumably, is one of the objectives of SCATS adaptive control.

The evaluation of the SCATS control logic, as reflected in the degree of saturation looked at two parameters:

l-How effectively the green time was allocated for each cycle to meet the cycle-by-cycle variation in demand; and

2-How effectively the green time was distributed between competing approaches, reducing the amount of excessive green time for each approach.

A cycle-by-cycle degree of saturation comparison, rather than an average degree of saturation, was used in this part of the study. The degree of saturation for an approach is an indicator of how effectively the green phase was used for each approach during a cycle. When the total traffic volume entering approaches the intersection capacity, a degree of saturation equal to or near an optimal value of 0.90, would mean that the system effectively assigned the right amount of green for that approach. The percentage of cycles that had a degree of saturation between 0.80 and 1.00 during the peak periods was chosen as a measure of effectiveness (MOE) in this study. Another MOE used in this analysis is the average and standard deviation of the difference in degree of saturation between any two consecutive cycles. These MOE's measure the effectiveness of the system in distributing the green time between different approaches and in allocating the green time for each approach to meet the cycle-by-cycle variation in demand.

Figure 8.12 and 8.13 present the before/after cycle-by-cycle degree of saturation for northbound and westbound traffic, respectively (Orchard Lake Road and Walnut Lake Road intersection). The fixed degree of saturation is a hypothetical value and represents the degree of saturation that would have resulted if the volumes reported by the SCATS system had passed through the intersection while controlled by a fixed time signal.

Under SCATS control, the average difference in the degree of saturation for northbound traffic between any two consecutive cycles was 0.10 with standard deviation 0.093. This average would have been 0.16 with standard deviation 0.132 if the signals were operating in fixed time mode. Similarly, for the westbound traffic, the average difference was 0.17 with standard deviation of 0.137 under SCATS control versus an average of 0.2 1 and a standard deviation of 0.175 under the fixed time mode. The results show, in general that SCATS provided more consistent degree of saturation versus the fixed time control. However, the average difference in the degree of saturation between any two consecutive cycles under SCATS control (0.10 for northbound traffic and 0.17 for westbound traffic) is larger than might be expected from an adaptive/responsive system. This might be a result of the SCATS logic which only allows the phase plan or cycle length to change after receiving two votes in any three consecutive cycles. This limits the ability of the system to respond to cycle-by-cycle changes in demand. A second factor is that each intersection is forced, under the marriage mode, to have a common cycle length even if it is longer than the intersection optimal cycle length.

SCATS resulted in an overall reduction in the degree of saturation when compared to a fixed time signal during peak traffic period, Figures (8.14 and 8.15). Under SCATS control, 48.4% of the cycles (from 4:00 PM to 7:00 PM) had a degree of saturation between 0.8 and 1.0 for the northbound Traffic. This percentage would have been 25.8% if the signals were operating under the fixed time mode. The percentage of cycles where the degree of saturation exceeded 1.0 (over-saturation condition) was 8.2% under SCATS versus 38.1% under fixed time control. SCATS maintained a lower degree of saturation in 100% of the cycles during this time period.

This reduction in the degree of saturation was accomplished with no detrimental effect on the degree of saturation for the opposing major traffic movement. For westbound traffic, 46.7% of the cycles had a degree of saturation between 0.8 and 1.0 under SCATS control. This percentage would have been 38.4% if the signals operated under the fixed time mode. The percentage of cycles that had a degree of saturation higher than 1.0 would have been the same (27.8%).

The results show that SCATS succeeded in maintaining a relatively equal degree of saturation for both northbound and westbound traffic. The degree of saturation was relatively low for both approaches during the non-peak period, which indicates that the total demand during this times was lower than the capacity of the intersection.

Figure 8.12 SCATS/Fixed Time Cycle-By-Cycle Degree of Saturation for Northbound Traffic

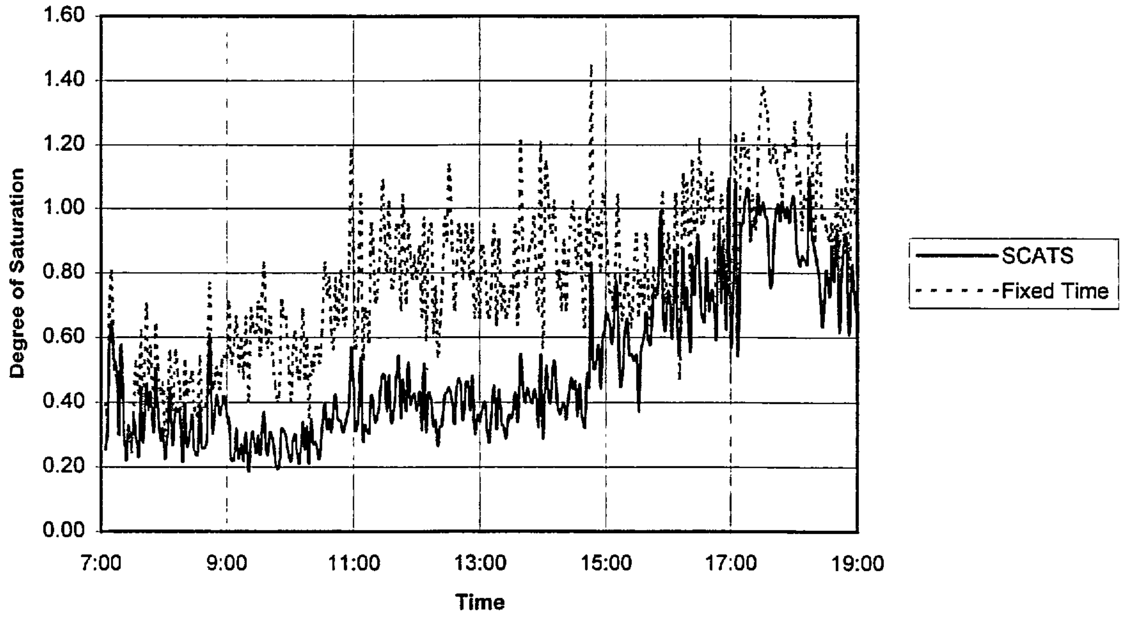


Figure 8.13 SCATS/Fixed Time Cycle-By-Cycle Degree of Saturation for Westbound Traffic

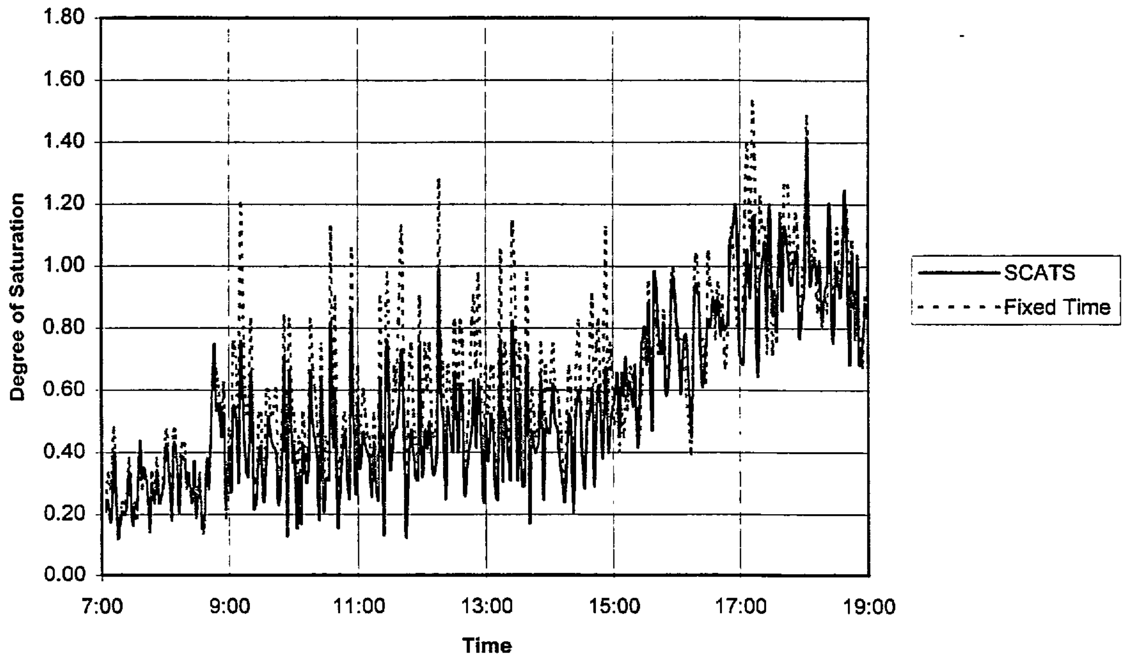


Figure 8.14 SCATS/Fixed Time Cycle-By-Cycle Degree of Saturation for Northbound Traffic (4:00PM to 7:00 PM)

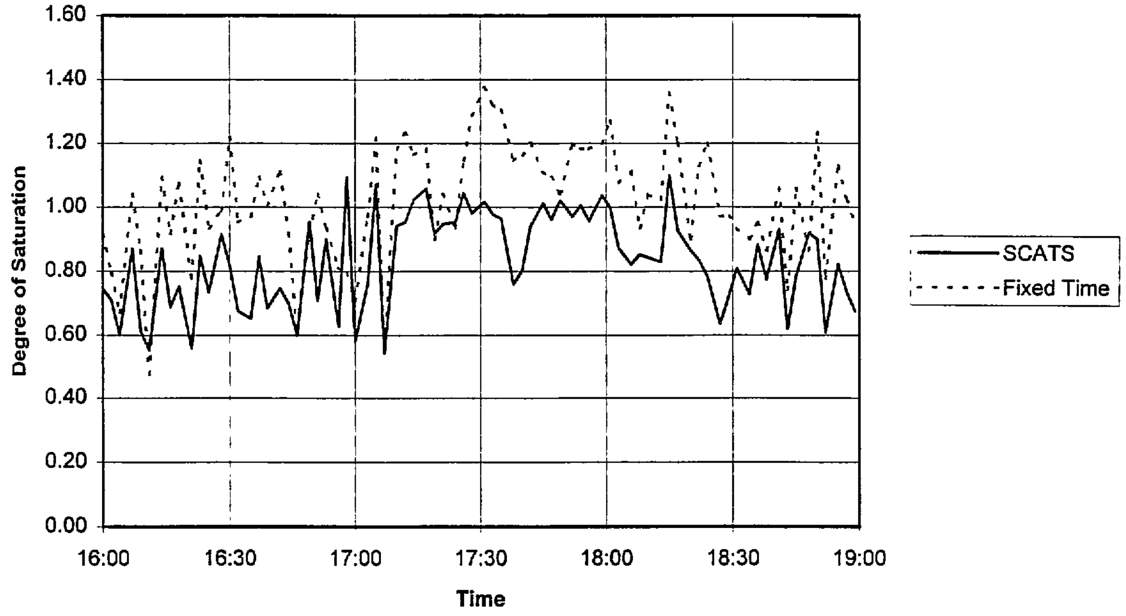
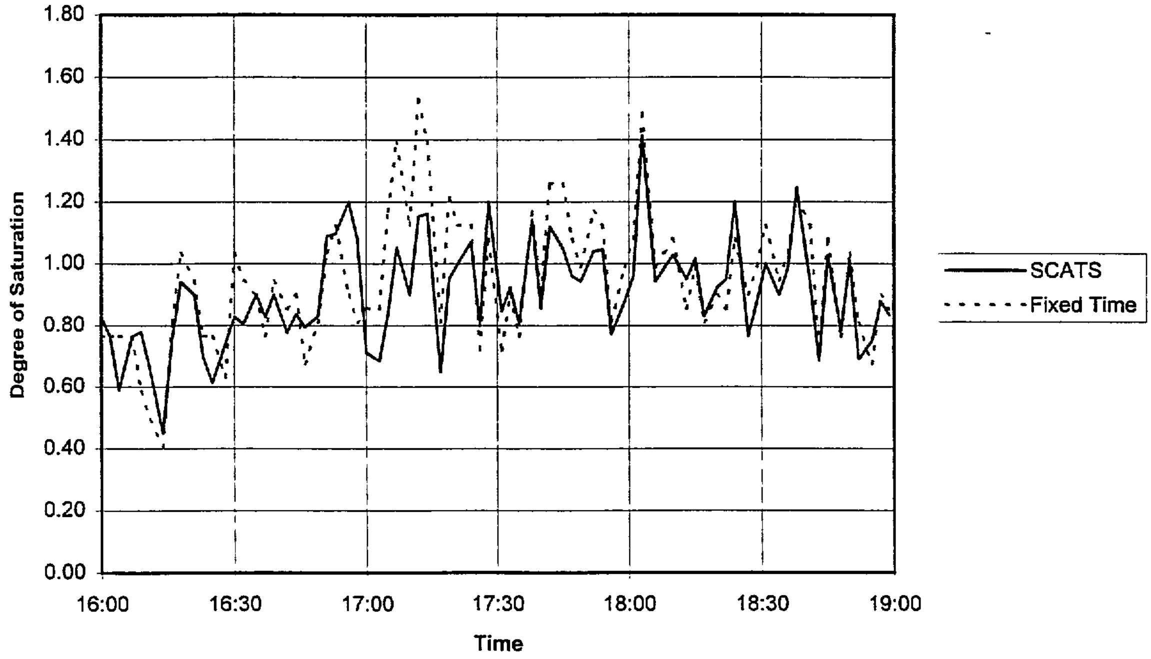


Figure 8.15 SCATS/Fixed Time Cycle-By-Cycle Degree of Saturation for Westbound Traffic (4:00PM to 7:00 PM)



9 Before/After Progression Analysis

Improving progression for the traffic along the corridor is another potential method of achieving a reduction in delay. Improving the progression would minimize the number of vehicles arriving during red phase, thus reducing the delay and stops, (the second diagram in Figure 8.1).

A before/after progression analysis was conducted to investigate how SCATS dynamic progression and offset plan contributed to the savings in delay and travel time. Before the implementation of SCATS, the signals were operating under the fixed time mode with three different offset plans according to the time of the day and the day of the week, Table 4.1. The plans were the output of TRANSYT optimization with additional tuning to accommodate for the local traffic conditions.

The SCATS dynamic offset plan was described in detail in section 4.2.4 of this report. Basically, the system chooses from four different pre-defined offset plans. For each plan, two different offset values “PPl” and “PP2” are defined. PPl is to be used if the cycle length is equal to or less than a pre-defined value “Cl” and PP2 is to be used if the cycle length is higher than or equal to a pre-defined value “C2”. If the cycle length is between “Cl” and “C2”, the system chooses the offset linearly between PP1 and PP2. Unlike the fixed time mode where all the signals are coordinated to one intersection, SCATS coordinates the leading phase in one intersection with a designated phase in another intersection, typically the preceding one.

Progression diagrams were used to compare the effectiveness of the before and after progression. The total width of the through bandwidth per hour was chosen to be the measure of effectiveness (MOE) in this analysis. This measure takes into consideration the difference in cycle length between the before and after periods as well as the variation in cycle length during the after period. The analysis was done for three time periods; the morning peak hour (7:30 AM to 8:30 AM), a non-peak hour (1:00 PM to 2:00 PM), and the afternoon peak hour (5:00 PM to 6:00 PM). The offset plan and the cycle length during the after period were obtained from SCATS monitoring files. No SCATS data were available for the minor intersections (shopping malls and driveway intersections) along the corridor, thus those intersections were not included in the progression diagrams. However, the length of the green phase for northbound and southbound traffic is greater than that available at the major intersections, so these minor intersections do not constrain the through bandwidth for the corridor.

Figures 9.1 and 9.2 show the progression diagram under SCATS control during the morning and the afternoon peak periods, respectively. The results show that both fixed time and SCATS controls achieved optimal through bandwidth for the peak direction traffic during both the morning and the afternoon peak periods. The through bandwidth under each control had an optimal through bandwidth equal to the total green time per hour for the intersection that had the lowest green time for the northbound/ southbound traffic. During the morning peak period, the through bandwidth increased from 26.0 minutes/hour during the before period to 32.0 minutes/hour during the after period (23.1%). During the afternoon peak period, the through bandwidth increased from 24.0

minutes/hour during the before period to 26.2 minutes/ hour during the after period (9.2%). This increase in the through bandwidth is attributable to the increase in the green time allocated for the northbound/southbound traffic under SCATS control.

During the before period, the morning non-peak direction (northbound traffic) had a through bandwidth of 14.2 minutes/hour. During the after period the through bandwidth for this traffic increased slightly to 15.0 minutes/hour (5.6%). During the afternoon peak period, the non-peak direction (southbound traffic) had virtually no through bandwidth during both the before and after period. However, during the after period, there was a through bandwidth equal to 19.0 minutes/hour from the Green Road intersection to Maple Road.

Figures 9.3 shows the before/after progression diagrams during the noon non-peak period under SCATS control. The through bandwidth for the northbound traffic increased from 19.3 minutes/hour to 27.4 minutes/hour (42.0%). Again, this increase in through bandwidth is mainly due to the increase in green time allocated for the main street traffic during the after period. The through bandwidth for the southbound traffic increased during the same period from 12.1 minutes/hour to 13.0 minutes/hour (7.4%).

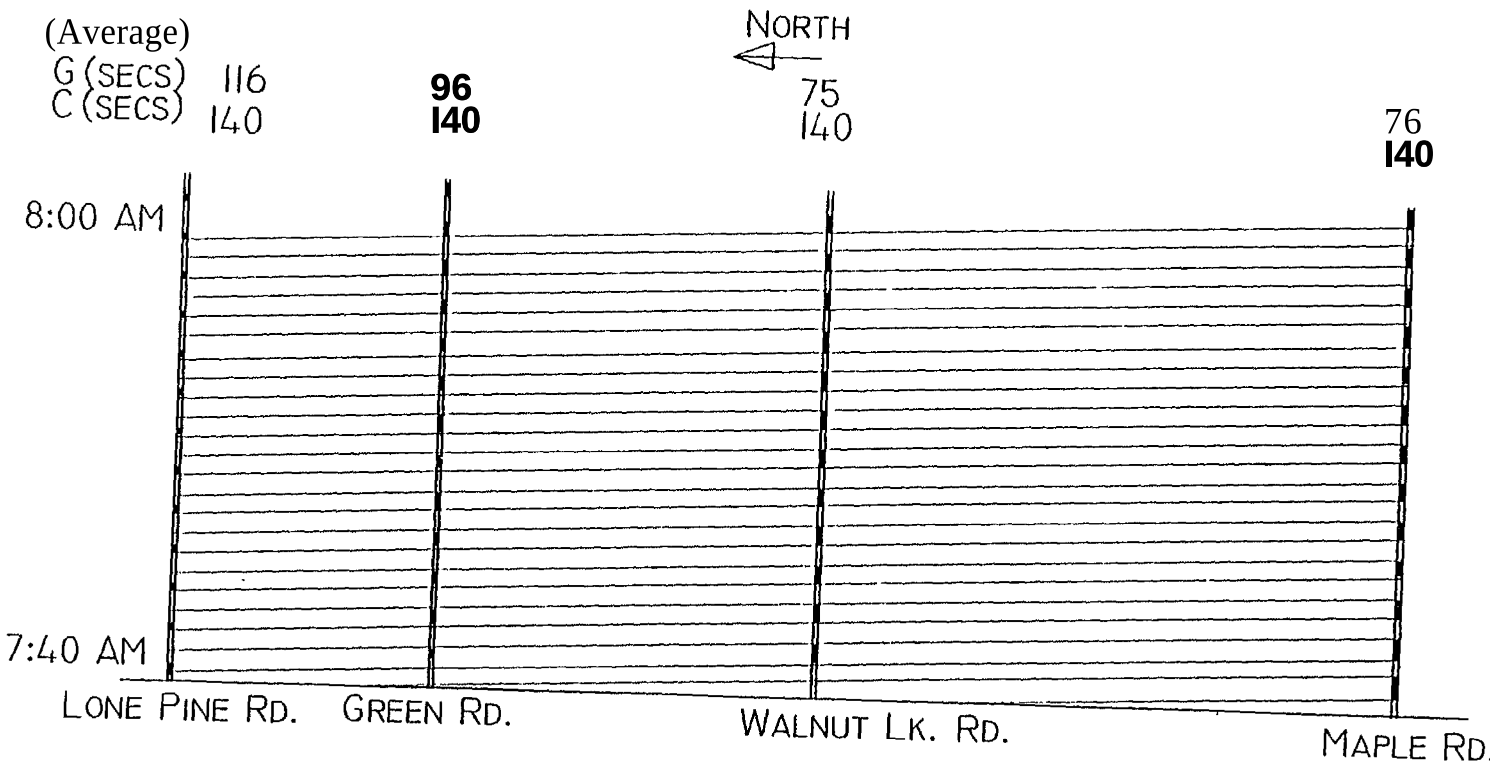


FIGURE 9.1 PROGRESSION DIAGRAM UNDER SCATS CONTROL (MORNING PEAK)

OPTIMAL SPEED = 49 MPH

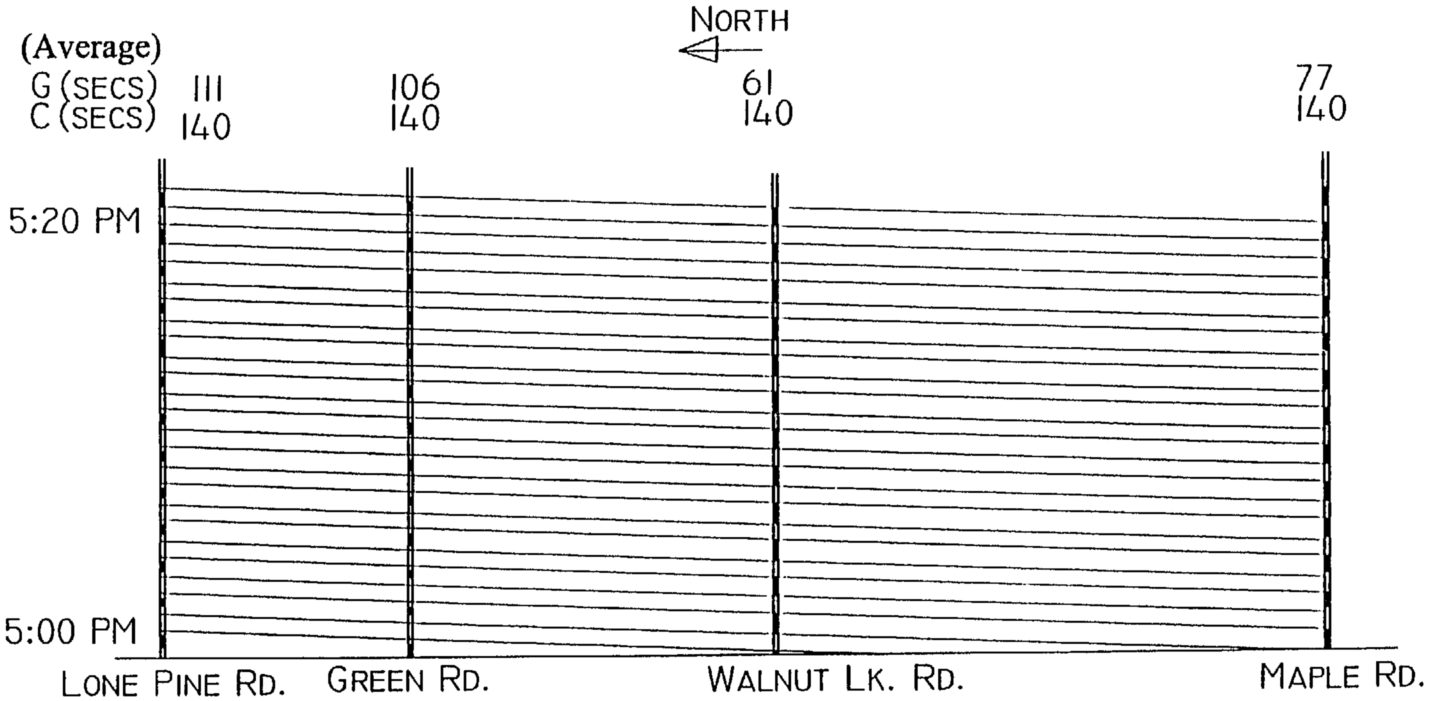


FIGURE 9.2 PROGRESSION DIAGRAM UNDER SCATS CONTROL (AFTERNOON PEAK)
OPTIMAL SPEED = 49 MPH

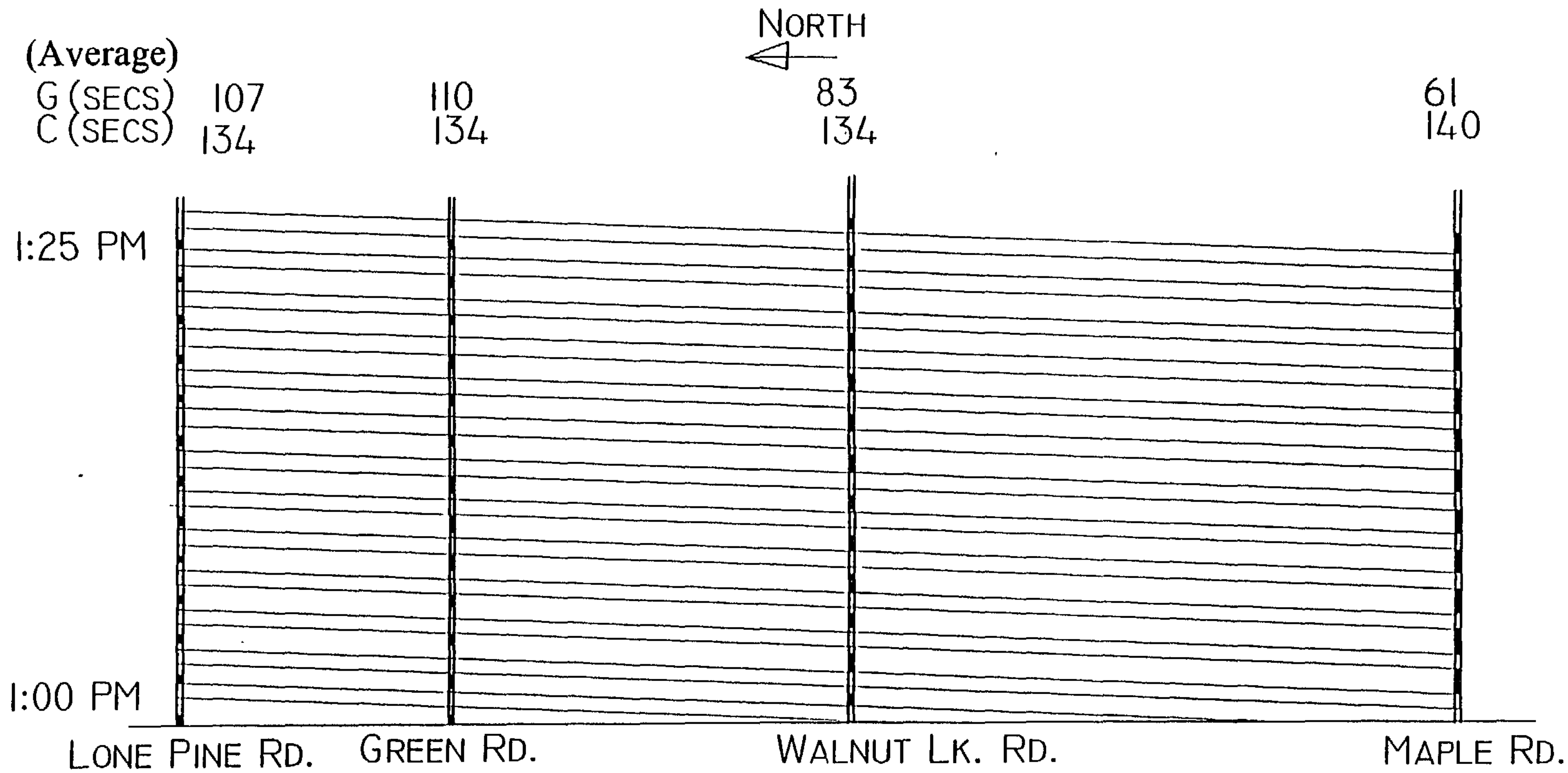


FIGURE 9.3 PROGRESSION DIAGRAM UNDER SCATS CONTROL (NOON NON-PEAK)
OPTIMAL SPEED = 50 MPH

10 SCATS Response to Congestion

One of the features that adaptive signal control can provide over the conventional fixed time signals is the ability to detect and respond to congestion. This part of the study looks into how SCATS dealt with recurrent congestion (SCATS response to incident situations is comprehensively covered in another report). The intersection considered for this purpose is Orchard Lake Road and Pontiac Trail Road, Figure 10.1, During the afternoon peak period, when most of the traffic is heading northbound, the intersection experiences recurrent congestion due to the reduction in capacity for the northbound Orchard Lake Road as the number of lanes decreases from two to one just 140 feet north of this intersection. When the traffic volume heading northbound becomes greater than the capacity of the one lane segment, the congestion starts to block this part of the road, preventing the northbound traffic on Orchard Lake Road from proceeding through the intersection. In this part of the study, two parameters were investigated:

l-Whether SCATS was able to detect this congestion; and

2- How the system dealt with this congestion.

SCATS monitoring files were used to analyze the system performance during the congested period. The study covered the time from 5:00 PM to 6:30 PM. Figure 10.2 presents an example of SCATS monitoring files out put.

The basic measurement used by SCATS for strategic control is the degree of saturation on each approach or, more accurately, a measure analogous to the degree of saturation.

SCATS does not rely on vehicle counts but rather on the measurement of space time between vehicles. Detectors, pointed to the stop line of a specific approach, are used to collect flow and occupancy data during the green phase of the approach. The local controller then sends these data to the regional computer and this data is used, together with the calibrated saturation flow data, to calculate the degree of saturation. The degree of saturation is defined as the ratio of the effectively used green time to the total available green time of the approach. The system measures the wasted green (the difference between the effectively used green and the available green) by summing the periods of non-occupancy of the detector during the green period and from this subtracting the spaces which must necessarily accompany each vehicle under saturation flow condition. From the degree of saturation measured for each lane, the system calculates a normalized (reconstituted) flow rate which is analogous to passenger car unit flow. This value is obtained by multiplying the value of the measured degree of saturation by the saturation flow rate. The reconstituted volumes are used in plan voting.

Figure 10.3 plots the actual vehicle counts versus the reconstituted vehicle counts (obtained from the degree of saturation measured through detector occupancy) for northbound traffic for two different days. On June 25-1997, the actual number of vehicles departing from the intersection was significantly lower than the reconstituted number of vehicles, calculated from the degree of saturation measured by the detector. The detector reported a high occupancy rate, and hence degree of saturation, mainly due to the blockage of the intersection as a result of congestion rather than a high volume departing from the intersection.

On June 24,1997, when the traffic volume was not high enough to cause congestion and blockage of the intersection, the actual and reconstituted volumes were similar. This indicates that the degree of saturation measured by the detectors is comparable to the actual degree of saturation.

The comparison of the green time showed no significant difference in the green time allocated to the northbound traffic during these two days, (Figure 10.4), although the intersection was blocked due to congestion on June 25. It is apparent that the system did not detect nor respond to the congestion on this day. Measuring the degree of saturation based on the detector occupy, does not allow the detector to differentiate between these two different cases. A high flow rate (high occupancy and high number of vehicles departing from the intersection), and intersection blockage (high occupancy but low number of vehicles departing from the intersection).

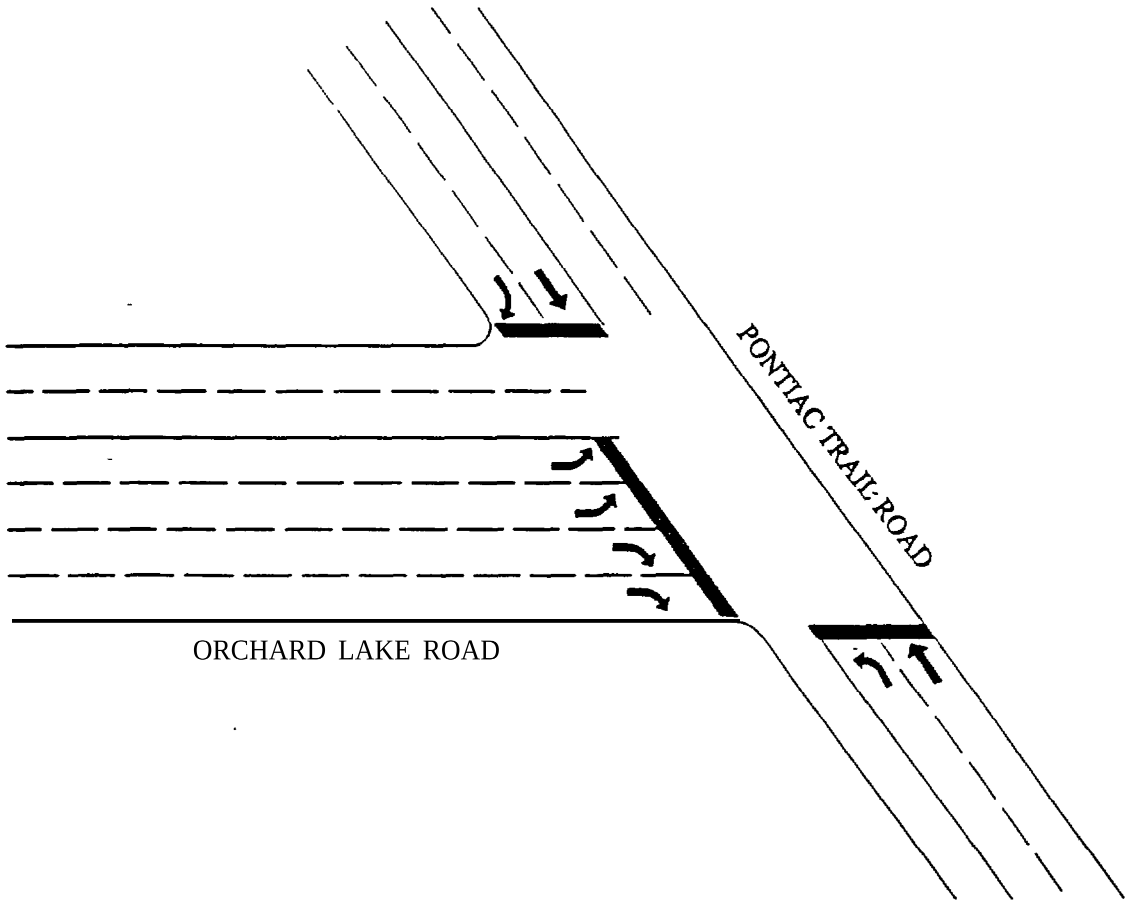


Figure 10.1 Layout of Orchard Lake Road & Pontiac Trail Road Intersection

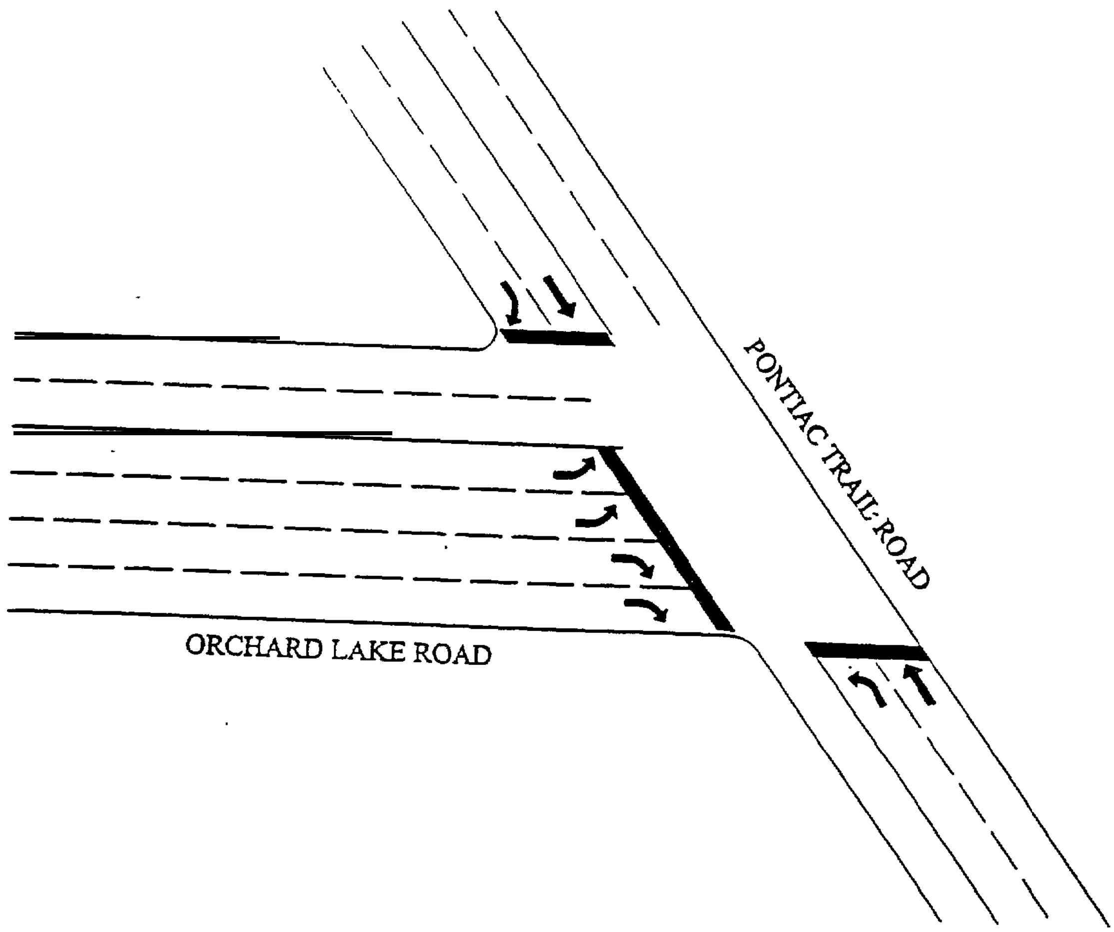


Figure 10.1 Layout of Orchard Lake Road & Pontiac Trail Road Intersection

STRATEGIC APPROACH (SA) DISPLAY IN AN SM

637 S 3 AB "69! 22 6 7! 52 17 17! 25 9 9! - -! 52

where:

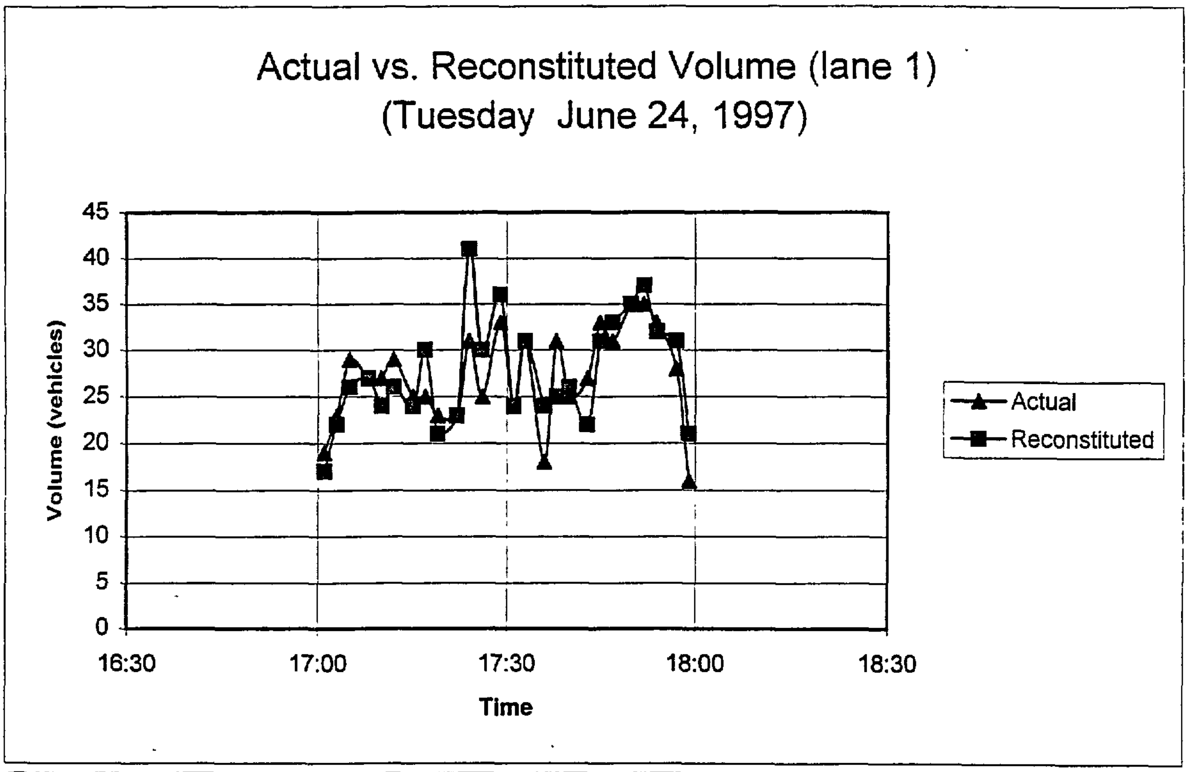
637	shows the Intersection no. (5 chars max.) of the Strategic Input (SI), which supplied the volume data for the SA
S	indicates SA data
3	is the Strategic Approach (SA) number If followed by: blank this SA controls Cycle Length and Split Plan selection # this SA controls only Cycle length ^ this SA controls only Split Plan selection * this SA controls NOTHING!
AB	indicates the stages specified in the SI at int 637. If the SI has a signal group specified instead of a stage. the signal group number will be displayed. e.g. 6375 3 2
..	indicates VF' was exceeded. is used for VF'
69	is the seconds Stage Time for the stage(s) (or seconds green' time plus 5 for a signal group).
!	is the lane separator
22	is the percentage Degree of Saturation of the detector specified in position no.1 in the SI. This exclamation mark normally preceding this value will be replaced by
>	if the DS is between 100-199 or a '*' if the DS is 200 or greater.
6	indicates an actual count (VO) of 6 vehicles
7	is the reconstiruted volume (VK) used in plan young If sub system keys contains FU (Flag Update). a non zero VO followed by a zero VK flags a valid MF update.
'	is the lane separator

The remaining figures show the DS. VO and VK values for the next 3 lanes with dashes indicating either the lane is not specified in the SI. else a non-acnve lane in the SA.

52	(at end of the line) indicates the AVERAGE DS (AS) for the approach.

Figure 10.2 SCATS Monitoring Files Output

Figure 10.3 Actual vs. Reconstituted volumes For Orchard Lake Road Northbound Traffic (Orchard lake Road & Pontiac Trail Road Intersection)



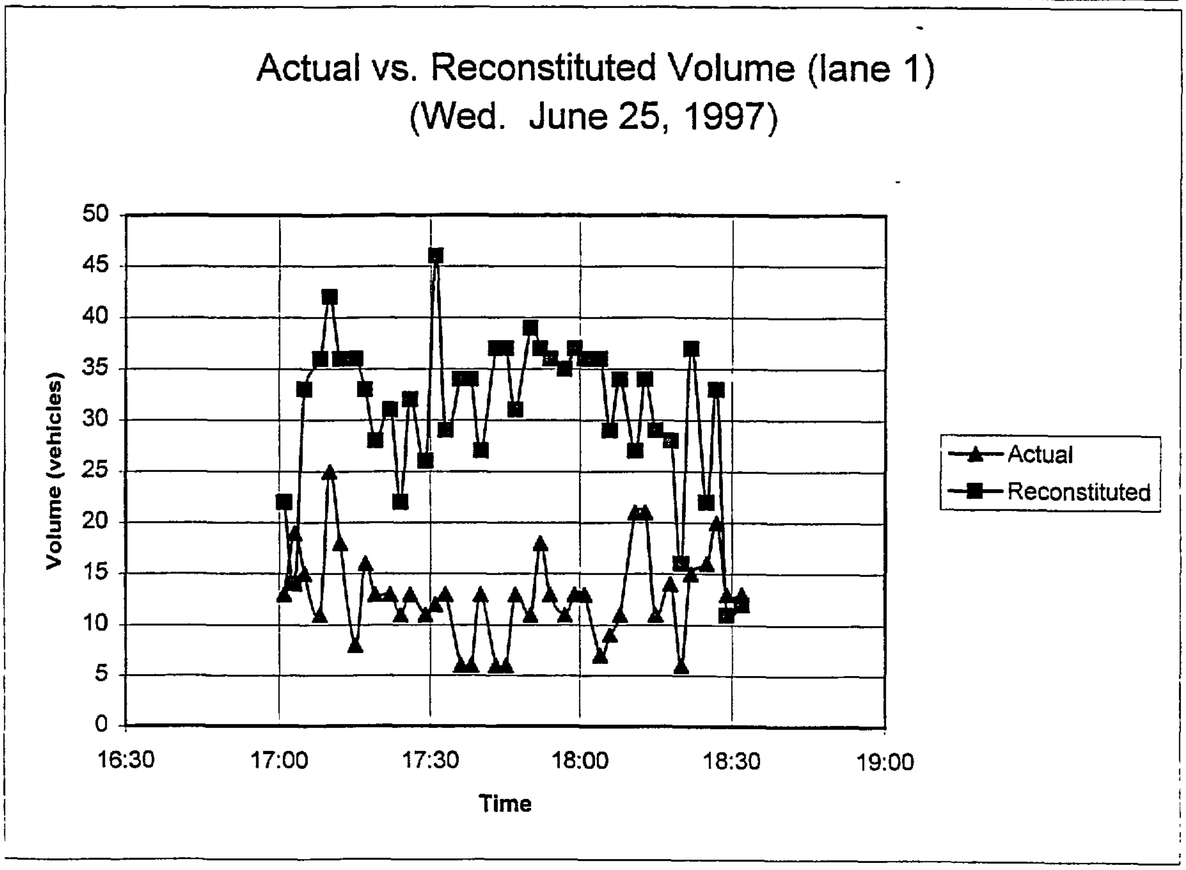
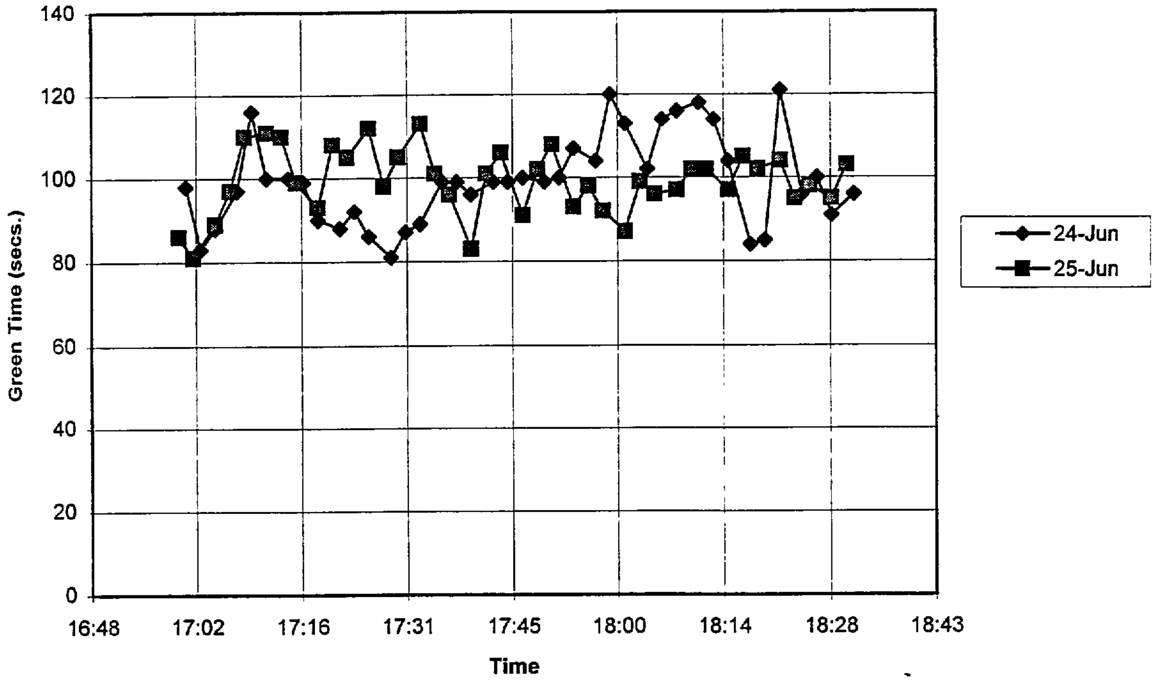


Figure 10.4 Green Time Allocated for Northbound Orchard Lake Road



11. CONCLUSIONS

The results of the study showed that corridor travel-time and intersection delay for the main street traffic improved as a result of SCATS implementation. The reduction in delay and travel time is primarily attributable to the increase in green time allocated for the main street through traffic under SCATS control. Extending the green time contributed to the reduction in delay in many ways. It reduced the degree of saturation, reduced the red time (the stopping time) for the main street through traffic and provided a wider through bandwidth along the corridor. In over-saturation cases, extending the green time often eliminated the number of vehicles that had to stop for more than one cycle.

The reduction in travel time ranged from 6.6% to 31.8% During the morning peak period, the southbound travel time (peak direction) improved 7.9% (the average speed increased from 29.4 mph to 32.0 mph), while the reduction in travel time for the northbound traffic (non-peak direction) was 20.3%. The northbound non-peak traffic had the largest reduction in travel time, 3 1.8%. For the same period, southbound traffic travel time improved by 15.2%. During the evening peak hour, the northbound traffic travel time (peak direction) improved by 7.8% (the average speed increased from 25.3 mph to 27.3 mph). The southbound evening travel time improved by 7.2%.

The reduction in travel time was greatest during the non-peak period and decreased as intersection volumes approached (or exceeded) saturation. This was expected as SCATS achieved this reduction in intersection delay by utilizing the excessive green allocated for the minor approach by reassigning it to the main street traffic. When the intersection volumes approached saturation, there was no excess green time to be re-allocated. Under these conditions, the signals assigned the maximum permitted green time for each approach, quite similar to that during the fixed time mode. In the non-peak period, however, the flow variation is higher, permitting the system to allocate the excess green time optimally.

The reduction in intersection delay for the main street traffic was associated with an increase in delay for other approaches. This again, was expected as SCATS reduced the green time allocated for these approaches and, at the same time, increased the red time. However, the average intersection delay decreased due to the relatively high traffic volume on the main street.

The offset analysis revealed that both SCATS and fixed-time controls succeeded in providing a through bandwidth equal to the full length of green time allocated for the main street traffc(for the peak direction). SCATS, however, provided a wider through bandwidth as it assigned more green time for the main street traffic. This was another factor that contributed to the reduction in the main street travel time.

SCATS resulted in an overall reduction in the degree of saturation on the major street when compared to a fixed time signal during the peak traffic period. This reduction in the degree of saturation was accomplished with little detrimental effect on the degree of saturation for the opposing traffic movement. The results show that SCATS succeeded in maintaining a relatively equal degree of saturation for both northbound and westbound traffic. The degree of saturation was relatively low for both approaches during the non-peak period, which indicates that the total demand during these times was lower than the capacity of the intersection.

One of the features of an adaptive signal control is the ability to detect and respond to congestion. However, this feature is negated when the queue from one intersection completely fills the link and blocks the upstream intersection. SCATS did not respond to congestion, which occurred due to a reduction in capacity at one of the intersections. Since SCATS measures the degree of saturation based on detector occupancy, rather than the actual volume departing from the intersection, the detector can not differentiate between a high flow rate (high occupancy and large number of vehicles departing from the intersection) and intersection blockage (high occupancy but low number of vehicles departing from the intersection).

12. REFERENCES

l-Road Commission for Oakland County, “FAST-TRAC is on the Cutting Edge of Traffic Management Technology”, Beverly Hills, Michigan, 1993.

2- Road and Traffic Authority of New South Wales, “SCATS User Manual - V4.7”, Road and Traffic Authority of New South Wales, Sydney, Australia, 1991.

3-Lowrie, P. R., “ SCATS, Sydney Coordinated Adaptive Traffic System, A Traffic Responsive Method of Controlling Urban Traffic", Road and Traffic Authority of New South Wales, Sydney, Australia, 1990.

4-Lorie P. R., “The Sydney Coordinated Adaptive Traffic System- Principles, Methodology and Algorithm”, International Conference on Road Traffic Signals, pp.67-70, London, 1982.

5-Simms, A.G. and K. W. Dobison, “ S.C.A.T.- The Sydney Coordinated Adaptive Traffic System Philosophy and Benefits”, International Symposium on Traffic Control Systems, Vol. 2B, 1979.

Transportation Systems
Research Laboratory

200 Engineering Programs Bldg.
2609 Draper Drive
Ann Arbor, MI
48109-2140

Program Offices Telephone:
313·764·4333

Program Offices Facsimile:
313·763·1674

The University of Michigan