A Before and After Study Delay at Selected Intersections In South Lyon

FAST-TRAC Phase III Deliverable

#9. Comparison of SCATS control versus a simulated control Algorithm
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A Before and After Study of Delay at Selected Intersections in South Lyon

(Comparison of SCATS control versus a simulated alternative control Algorithm)

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(Part 2 of Deliverable Number 9)

ABSTRACT

The City of South Lyon converted the traffic signals on the street network from fixed time control to the Sydney Coordinated Adaptive Traffic System (SCATS). The objectives of this research study were to analyze the differences in certain delay parameters between SCATS control, the pre-existing signal system, and a simulated fixed time control.

The analyses included direct observations under the fixed time signal system in place before SCATS was implemented and under SCATS control and the simulation of a fixed time system using identical approach volumes. The measures of effectiveness included total intersection delay in the comparison between the fixed time system and SCATS, and both total delay and the average delay per vehicle on each approach to the intersection when comparing SCATS to the simulated system.

In the comparison between field data collected under the system in place before SCATS, and the SCAT system, the new system resulted in lower average delay in spite of an increase in volume. This change was composed of a decrease in delay for the major movements and an increase in delay to the minor traffic movements.

When compared to a simulated fixed time system, SCATS control resulted in a decrease in intersection delay for the minor traffic movements and an increase in delay for the major movements. This is because SCATS redistributes the green time to decrease the difference in the degree of saturation across various approaches to an intersection. This results in lower delays to the minor traffic movement accompanied by a higher delay to the major traffic movements under SCATS.

The change in delay varied by time of day (and thus volume), with small increases and decreases in delay observed in the midnight to 1:00 a.m. time period and an increase of several seconds per vehicle during the afternoon peak periods.

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1.0 Introduction

The City of South Lyon recently converted the control of its signalized traffic network from optimized fixed-time control to the Sydney Coordinated Adaptive Traffic System (SCATS). SCATS is an automated, real time, traffic responsive signal control strategy. Under SCATS, the timing of the signals is governed by a computer-based control logic. The system has the ability to modify signal timings on a cycle-by-cycle basis using traffic flow information collected at the intersection approach stop lines.

The expected benefit from such a system comes from its ability to constantly modify signal timing patterns to most effectively accommodate changing traffic conditions. While the potential benefits from this control structure may be significant, few research studies have compared the effect of implementing this method of signal control against other alternative signal control strategies. The objectives of this research study are to:

1. Compare the delay at selected intersections in The City of South Lyon between the existing traffic signal timing plan and the SCAT system: and to
2. Compare the differences in certain delay parameters between SCATS and a simulated traffic signal timing plan using the same pattern of arrivals. The simulated timing plan is not an existing system, nor is it achievable in real life. This plan was based on determining the fixed time plan that would minimize delay if the hourly arrivals (as measured by SCATS) were equally distributed across all cycles during that hour. The actual arrival distribution was then used in the simulation and the resultant delay recorded. The comparison is thus between a system that adapts each cycle to a system that changes timing only once per hour.

1.1 FAST-TRAC and SCATS

The South Lyon signal improvement project is a small segment of the FAST-TRAC (Faster and Safer Travel - Through Routing and Advanced Controls) Project.(1) FAST-TRAC has involved the conversion of more than 300 pretimed and actuated signalized intersections in Oakland County to SCATS control and has established a regional, route navigation system.(2,3) While FAST-TRAC has been managed primarily by the Road Commission for Oakland County (RCOC), it has been a cooperative effort between many federal, state, county, and local government agencies; as well as private corporations and universities.

The SCATS system was originally developed in the 1970’s by the Roads and Traffic Authority of New South Wales, Australia. The system used in this study is version 5.03A. The operational aspect of SCATS has been compared to the type of control “provided by a traffic control officer stationed at the intersection controlling traffic to insure that congestion is reasonably equal among the various approaches. The primary difference is that today’s real time adaptive control systems can anticipate the arrival of vehicles from preceding intersections and adjust the signal timing to provide a green phase to match the arrival time."(4) It functions by making constant modifications to traffic signal timings in real-time in response to the variations in traffic demand and system capacity. It has advantages over the police officer by evaluating and controlling the signal system on a system wide basis rather than on an isolated intersection by intersection basis. It operates by using traffic sensors to monitor flow conditions and thus coordinate signal timings in order to minimize stops and delay time when the system is at or near capacity. SCATS attempts to maximize the system capacity and minimize the possibility of traffic jams by controlling the formation of queues. One of the ways that

SCATS accomplishes this is by providing a progression of green signal phases to reduce stopped vehicle queues, thereby reducing delay and decreasing the network travel times.(3)

Input data for the SCATS system is collected via a system of traffic sensors. The sensors may be inductive loop detectors imbedded in the pavement, or, as in the case of the South Lyon system, video image devices mounted overhead on the signal strain poles or attached on mast arms. The traffic information collected in the field involves the discharge characteristics (i.e., flow and occupancy during the green phase) on each intersection approach. This data is transmitted to a regional control center where the SCATS control program attempts to most effectively maintain the highest degree of saturation on the intersection downstream of the collected traffic data.

SCATS divides the network into systems and subsystems. Each subsystem contains a single “critical“ intersection, usually where two high volume roadways intersect. SCATS control logic incorporates a dynamic process whereby intersection signal phasing is coordinated. This system is known as “marriage” and “divorce.” Married intersections coordinate timings to allow platoons of traffic to pass through. A divorce occurs when two intersections no longer require coordination to maximize traffic flow through the network. The divorce is implemented after three consecutive cycles warrant a divorce, ensuring additional stability within the system.

Other advantages which SCATS provides over conventional fixed timed systems are its abilities to modify timing strategies to fit various control philosophies and to collect, process, and maintain a history of traffic statistics for an area. Signal phases can be set to equalize saturation on all approaches or they can be arranged to give priority to a particular direction of importance. Since the SCATS system requires the use of certain traffic data information it has the ability to record and store these statistics to monitor the strategic performance of the system, detect signal faults, and allow manual overrides of the signals under special operating circumstances.

1.2 The South Lyon Traffic Network

Oakland County is located in the southeastern corner of Michigan, immediately north of the City of Detroit. Throughout the past 15 to 20 years Oakland County has experienced an explosion in commercial and residential development. Accompanying the growth in development was an equally significant increase in traffic congestion.(5) The City of South Lyon is located in the southwest corner of Oakland County, approximately 40 miles northwest of the City of Detroit. It is presently a small, semi-rural/suburban community of approximately 25,000 people. The traffic congestion problems are comparatively minor compared to many cities in Oakland County. However, like the rest of Oakland County, the land within the City and surrounding Township is experiencing considerable commercial and residential development and increases in the amount of traffic congestion are expected to follow. It was expected that the introduction of the SCATS system of advanced traffic management will allow the community of South Lyon to accommodate the anticipated increases in traffic in a cost effective and efficient manner.

The South Lyon road network is arranged in a perpendicular grid system of primary roadways. The major roads are spaced at approximately one mile intervals. The lone exception to the grid layout is Reynold Sweet Parkway. The Parkway serves as a bypass route for through traffic around the central business district. The layout of the South Lyon street system can be seen in more detail in Figure 1.1 The majority of the South Lyon traffic load is carried on Pontiac Trail and Ten Mile Road. Pontiac Trail is the main north-south arterial roadway in South Lyon, providing access to Interstate 96 which is located approximately four miles north of town. The overwhelming majority of commercially developed land within South Lyon is located directly adjacent to Pontiac Trail. Ten Mile Road is the prime east-west arterial serving the traffic demand to the commercial centers located to the east.

The local street network is also arranged in an approximate grid layout. The density, as is common, is considerably greater than the primary road system. The area of greatest density is located within the vicinity of the central business district, surrounding the intersection of Ten Mile Road and Pontiac Trail. As a result of the dense commercial development, two minor street intersections with Pontiac Trail have been signalized. The South Lyon road network under study also incorporates two at-grade railroad intersections. One of these, to be described in detail later, forms an awkward triple intersection at a point where two roads and the railroad tracks all coincide.

There were six signalized intersections in operation within the South Lyon traffic network during the study period of 1995-1996. The installation, operation, and maintenance of these signals are under the jurisdiction of the Road Commission for Oakland County, which has a policy of checking the coordination of their signal systems at least once every two years. Originally, all of these signals operated on a coordinated pre-timed basis. No traffic adaptive control measures, like actuated signal timing, were initially at work within South Lyon. The relative isolation of South Lyon and its small

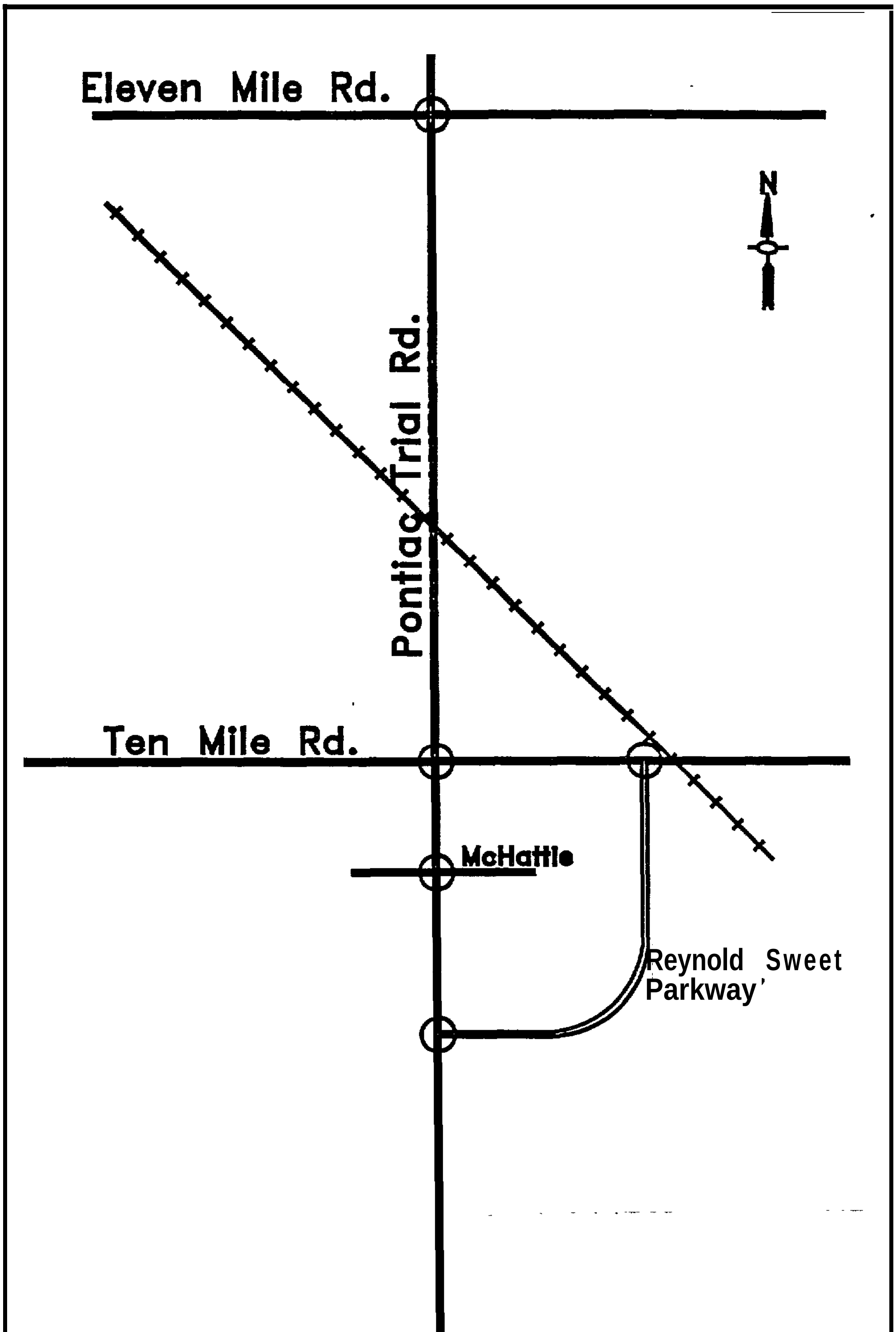


Figure 1 SOUTH LYON MAP

signal network make it a good “laboratory” for an evaluation of the SCATS system of advanced traffic management. The Oakland County ATMS project involved the conversion of all six signals to SCATS control.

2.0 Literature Review

A literature search was performed to accomplish four primary goals. First, the current limits of knowledge in the field of traffic engineering research relative to SCATS signal control were explored. Second, the literature search lead to an understanding of the “gaps” resulting from past research. The research gaps included the absence of studies performed specifically on the comparative benefits gained from adaptive signal control. The literature review also established a base of knowledge from which to launch the proposed study and demonstrated certain techniques which have been successful in past research. Some of these were applied to the South Lyon evaluation study to aid in the accuracy and efficiency of the experiment. Finally, the review of past published literature gave insights into the way in which current theories, technology, and implementation of adaptive traffic signal systems have developed over the years.

2.1 Adaptive Traffic Control Systems

The majority of travel delay experienced on arterial roadways is governed by the intersections along the route. Reductions in stop delay at intersections can enhance the efficiency of a road and reduce the amount of time required to travel through a particular corridor or network. One of the best ways to achieve a reduction in delay is to provide an efficient progression of signals. A method of providing effective signal progression is to anticipate the arrival of vehicles and modify signal timings to match the arrival pattern. The Sydney Coordinated Adaptive Traffic System is one of several forms of advanced traffic management which are in operation or under development that anticipates the arrival of queues of traffic and uses adaptive techniques to increase the efficiency of the road network.

The concept of modifying traffic signal systems to more efficiently move traffic has been studied for many years. The practice of traffic signal optimization began in the 1920's.(6) As signal control technology became more advanced, signal systems began to use pretimed coordination plans. The original "traffic responsive" signal systems were merely pretimed signal control systems which could be modified to fit the anticipated traffic demand patterns.(7) Such systems, still prevalent today, are designed to optimize traffic based on average time-of-day and day-of-week conditions with different timing plans for the AM peak, PM peak and off peak periods. These types of control work well and are considerably less expensive to install, operate, and maintain than more complex computer controlled systems. The use of average volumes during these three time periods leads to inefficient operation as the actual volumes vary from these average values.

A step toward today's advanced traffic management systems was made in 1967 with the development of a computer program and methodology to gather and process data from loop detectors placed near intersections to determine certain traffic flow parameters. This research and development project(8) also demonstrated how such data could be used to determine queue lengths and delay at signalized intersections. By today's standards this model was primitive. However, the technology demonstrated in this project has evolved into one of the integral elements which allow real-time adaptive control systems to function today. The development and implementation of adaptive control systems have become possible over the past five to ten years due to advancements in computer technology and data processing efficiency.

Several types of advanced control systems are currently in operation, serving in experimental traffic control management roles. Two such systems, the Sydney Co-Ordinated Adaptive Traffic System (SCATS) and the Split, Cycle and Offset Optimizing Technique (SCOOT), have developed into the most prevalent real time adaptive traffic signal control systems.

The SCOOT system was developed in Great Britain in the mid 1970's.(6) The main idea of the SCOOT system was to take an "off-line" model, like the fixed time signal optimization program TRANSYT, and have it operate "on-line." Specifically, the system uses traffic data measurements collected from the existing stream and makes short and long term decisions regarding the traffic signal settings.

The SCAT system offers some distinct advantages over SCOOT. Primary among these is its ability to omit individual signal phases from the signal cycle. For example, a protected left turn phase could be eliminated from the cycle if no vehicles were present; as detected by the sensors. The other advantage of the SCATS is its ability to readjust the phase sequence pattern to best take advantage of the traffic conditions. This feature requires drivers to be more vigilant because one cycle may start with a leading protected left turn phase, while the next cycle might feature a lagging protected left turn phase.

2.2 Traffic Simulation and Model Tools

As the volume of traffic increased and individual signals were coordinated into signal networks, the need to measure the effect of signals on the efficient movement of traffic within networks became more important. Advanced technologies have allowed more sophisticated analysis techniques for the study of traffic control. The advanced methods to study traffic control have been researched and developed concurrently with the advanced controls themselves.

The use of computerized traffic simulation and analysis programs have developed from strictly a research device, to very valuable tools in modem traffic engineering practice. Two programs, SOAP and TRANSYT-7F, were developed independently during the 1970’s. After years of separate use, the two programs are often used together for the evaluation and analysis of traffic signal plans. TRANSYT was developed in England to analyze coordinated progression of traffic signals on arterial roadways. It helps a user to evaluate various signal cycle lengths which will promote the movement of traffic through a particular corridor. The system attempts to promote the formation of traffic platoons and minimize the number of stops at red lights. The program will also produce space-time diagrams which are also helpful in the analysis of traffic flow. The Signal Operation and Analysis Package (SOAP) was developed for the analysis of single isolated signalized intersections. It was originally coded at the University of Florida in the 1970’s and, like TRANSYT, has undergone numerous modifications. It can be used to evaluate traffic signal design alternatives at four-legged intersections with or without protected left turning phase intervals in the signal sequence, including fixed time, semi-actuated, and fully actuated control. One of the benefits of the SOAP program is that it allows the operating characteristics of an individual intersection to be expressed in terms of specific measures of effectiveness (MOE). SOAP MOE's include the calculation of various vehicle approach delays, number of stopped vehicles, fuel consumption, queue lengths, and other flow characteristics. Its primary limitation, however, is the lack of a mechanism to adjust vehicle arrival distributions. The SOAP delay analysis algorithms assume a random arrival pattern in all analyses.

Development of increasingly more detailed and sophisticated traffic simulation continued through the 1970's and 80's. Simulation has developed into a standard application tool for the modem traffic engineer. One of the most widely used traffic simulation programs today is the NETSIM computer mode1.(22) NETSIM, as its name suggests, is a microscopic road network simulation program. It was initially developed by the Federal Highway Administration in the mid-1970's as a method of modeling traffic events on arterial road networks. It is extensively used by transportation engineers and planners to analyze various highway design and traffic planning scenarios. The NETSIM program has continued to evolve and add more complex features to keep pace with advancements in traffic control technology. The next version of NETSIM, currently under development, will include a subroutine to model adaptive signal control.

2.3 Comparative Studies of Adaptive Traffic Signal Systems

Many studies have been completed which claim to have evaluated adaptive traffic signal systems. Several of the more recent studies have involved the two most widely used real-time traffic responsive signal systems, SCATS and SCOOT. Past studies have completed comparisons of these systems against various forms of less sophisticated forms of signal control like coordinated fixed time actuated control. The depth and level of detail incorporated into these comparative studies has varied, although none of the previous studies has used simulation nor stopped delay as a performance measure.

Many studies of adaptive control have been carried out by the creators of SCATS, the Australian Road Research Board (ARRB) and the Road and Traffic Authority of New South Wales. One study evaluated SCATS against various forms of non-adaptive forms of signal traffic control.(42) The study measured the performance of SCATS against the control characteristics afforded by systems with isolated fixed time signal phasing and TRANSYT optimized fixed time control with and without local vehicle actuation.

The ARAB study made their comparison using the floating car travel time estimation technique to record the "journey" or travel time on each link, the number of stops in each link, the stopped time in each link, and the amount of fuel used in each trip. The recorded stopped times were later found to be unreliable, so they could not be used in the analysis. The study was able to compare the different signal systems in terms of travel time. number of stops, and a derived "Performance Index." The Performance Index was a weighted measure of travel time incorporating the number of stops during the trip. The study found that on one arterial highway, SCATS resulted in a 23% reduction in travel time and a 46% reduction in stops over isolated fixed time signals. In the central business district (CBD) study area, the travel time was not effected and the reduction in stops was 8%. When compared to Linked Vehicle Actuated (LVA) control, SCATS showed some benefits and some degradations in the recorded performance measures on the arterial and in the CBD areas. The comparison of SCATS and TRANSYT optimized fixed times concluded that SCATS can improve travel time and number of stops from 3% to 18%. The actual improvement depends upon the type of road system (CBD network, arterial corridor, etc.) under study.

A comparative study of SCATS versus SCOOT was conducted by the Australian Road Research Board. (44) It detailed the similarities and differences in the data requirements, hardware, and operation of the two systems. Unfortunately, a direct field comparison of the operational differences between SCATS and SCOOT was not possible. Direct comparisons using simulated or actual data are very difficult, due to the different locations where traffic flow data is gathered. In SCATS, traffic information is collected at the approach stop lines. The required traffic flow information for SCOOT is collected upstream of the stop lines. The two systems also differ in their operating requirements for computer processing. The paper stated that SCATS is better in some applications because it has the capacity to estimate congestion better than SCOOT. By contrast, SCOOT can be more effective in certain heavy flow situations because it incorporates an automatic double-cycling mechanism which SCATS does not have.

2.4 Literature Review Conclusions

The review of past published literature has demonstrated the interest in and importance of comparative studies of the various forms of traffic signal control. A review of the literature has shown the important role that ATMS will play in more efficiently utilizing our transportation infrastructure. Today, real-time adaptive signal control systems like SCATS and SCOOT are available for mainstream use in the United States. As a result, studies which can assist current and future users of such systems to determine their expected benefits are extremely valuable.

The primary reason for the lack of detailed analysis has been the lack of sophisticated data collection and analysis methods and tools. Now, traffic flow databases can be compiled using automatic collection and storage techniques. Traffic flow data can be collected continuously; at any time and under any flow condition. This is possible because of systems like Autoscope sensing technology and complex and high-speed computer systems. As a result of commercially available computer simulation modeling and analysis tools like SOAP, NETSIM and THOREAU, traffic flow analyses can be completed quickly and inexpensively under repeatable and controlled conditions.

3.0 Research Objectives and Approach

3.1 Objectives

The objectives of the South Lyon ATMS evaluation project were to analyze the intersection delay within the South Lyon signalized road network as a result of the addition of the SCATS signal control management system. To accomplish this objective, this study incorporated a detailed process of data collection, simulation model construction, and statistical analysis. Data collection was carried out using various means, including field observation, and video image sensing. To determine the extent of the difference in quantifiable terms and document the results, the study addressed the specific questions:

1) What is the difference in the total intersection delay at selected intersections for the existing non-adaptive, pretimed, signal scheme and the SCATS adaptive control mode? Is the measured difference in the total intersection delay time statistically significant?
2) What is the difference in the delay at selected intersections within the South Lyon road network

between a simulated signal system that changes the signal scheme hourly and the SCATS adaptive control mode? Is the measured difference in intersection delay statistically significant?

The research questions established the measures of performance to compare the two different signal control strategies during the "before" and "after" periods of the study. The improvement brought about by changes in traffic control can be assessed using many different measures (i.e., safety, delay, travel time, etc.). The two measures selected for this study were based on their relevance to the goal of reducing traffic delays in the community of South Lyon. Each is described in detail in the following sections.

3.1.1 Total Intersection Delay

The delay at an intersection is defined as the difference in travel time experienced by a vehicle as it is affected by the traffic control at an intersection. It includes the "lost" time due to deceleration and stopped delay. (48) The stopped delay includes queue delay at over-saturated intersections and "unnecessary" stopped delay. Unnecessary stopped delay is defined as "the portion of the stopped delay which occurs when there is no vehicle entering an approach on the opposing legs of the intersection."(35)

Many different analysis techniques for the calculation of total intersection delay have been developed.(49) The most widely used employ mathematical models to calculate various aspects of total delay which are the result of vehicle arrival patterns. The comparison of total delay was accomplished through the use of the SOAP simulation model.

3.1.2 Approach Delay

The research study also assessed the difference in the average approach delay. The term approach delay as used in this study is defined as the length of time that vehicles approaching the intersection from a particular direction are delayed due to a red signal phase and/or a stopped queue in front of them which prohibits their travel through the intersection.(49) To express approach delay in more useful terms it is often converted to average stopped delay per vehicle on a given approach during a specified time interval. This is the measure by which the Highway Capacity Manual(50) assigns a Level of Service (LOS) rating to signal controlled intersections.

3.2 Analysis Approach

The initial approach to the evaluation was to compare the delay before and after SCATS was installed. This approach was used on a limited basis, and the results are shown in Table 4.1. These results showed that SCATS control reduced total delay at the intersections used in the analysis.

However, it became obvious that this approach was not appropriate for the overall evaluation because:

1) The data collection for the before period was time consuming. There were no permanent detectors in place prior to implementing SCATS control, and thus data were collected by videotaping traffic and determining individual vehicle delay using video reduction procedures.
2) The daily variation in traffic flow was sufficient to mask the difference in delay between the before and after periods. Thus, with a small sample. it was not possible to determine the

statistical significance of the observed changes in delay.

3) Video taping could not be conducted in the very low volume time periods (midnight to 4:00 A.M.) because there was insufficient light during this time period.

The only possible way to test alternative traffic signal control strategies against the identical traffic patterns is to record the traffic pattern and the delay using one control strategy and then to determine the delay if you replicate the traffic pattern in a simulation environment while altering the control strategy. The alternate control strategy does not have to be one that has been (or even could be) implemented in the field. In this study the alternate signal control was to determine the cycle length and phase plan for a fixed time signal that "optimized" the delay for the average arrivals per cycle during a simulation period of one hour.

The analysis of the SCATS condition was conducted prior to the analysis of the simulation condition. The simulation analysis used the identical traffic flows to evaluate an optimized fixed time control system. The same measures of operational effectiveness; total intersection delay and average intersection approach delay were used to assess both conditions.

As is often the case with research, using field data analysis techniques contains some inherent weaknesses. Some of the shortcomings of this technique stem from the lack of total control over the factors involved in the experiment. The experimental assumption is that all factors remain constant and all recorded changes would be the result of the change to SCATS signal control. Unfortunately, traffic volumes, turning movements, and incident occurrences can vary significantly from hour to hour, day to day, and week to week. Therefore, it would be impossible to hold all of the factors constant in the field. Simulation allows controlled and repeatable experiments to be performed on the traffic stream. With the use of the SOAP intersection simulation and analysis program, it is also possible to calculate detailed information about the performance of a signal at an intersection.

The research strategy incorporated data collection, simulation experimentation, and a comparative statistical analysis. Each of the steps built upon the results gained from its predecessor. The first step involved the collection and sorting of all data elements required to construct and execute the comparative traffic simulation models. The second and third steps included the assembly of the models to conduct the analyses. The final step of the study framework was the statistical comparison of the measures of effectiveness.

3.2.1 Data Collection

The data collection phase of the study involved the collection of both physical elements and traffic flow parameters of the South Lyon traffic network. The physical elements of the system include features of the South Lyon road network such as the number of road segments, intersections, approach lanes and use configurations, as well as traffic control items such as posted speed limits. The original fixed time signal timing information was also recorded during this time and subsequently verified against the Road Commission's signal log records. All of these data elements were collected manually, primarily through visual inspection.

The traffic volumes data were computed from SCATS data files. These files are created by the

SCATS control software and are stored at the Road Commission for Oakland County Traffic Operations Center. Traffic flow information is collected at the intersections in South Lyon by the Autoscope video image detection system. The Autoscope detection architecture allows the presence of vehicles to be acknowledged at each approach to the SCATS intersections. Traffic information is collected primarily for the purpose of selecting an appropriate timing plan for the intersection. However, this information can also be stored for later analysis.

A typical SCATS data file contains several important pieces of data which can be used to analyze the operation of the signal and traffic conditions. It is made up of a stream of data records that include a cycle-by-cycle history of signal phase splits, cycle length, and approach degree of saturation. Using relatively simple computer programs, the files can be sorted and the pertinent traffic volume and signal timing information extracted for use.

The traffic volume and signal timing data for the SCATS analyses were collected only after a sixty day "acquaintance and adjustment" period had taken place. The adjustment period was required for several reasons. Most important, it allows drivers to adjust to the new signal phasing strategies. SCATS is not only real-time adaptive, it may also adjust, rearrange, or eliminate certain phases from cycle to cycle. Thus, drivers who were familiar with the fixed time signal operation were allowed to adjust their driving habits to fit the new SCATS control plans. The adjustment period also allowed the Road Commission for Oakland County time to "fine tune" the operation of the SCATS system.

3.2.2 The SCATS Traffic Analysis

The second step of the experimental approach strategy was to complete the "after" analysis study. The "after" analyses was to be conducted using the stored signal and traffic data and physical features of the South Lyon collected in the first step. Separate models were constructed for each of the six SCATS controlled intersections within the network.

Unfortunately, neither the SOAP modeling environment, nor any other currently commercially available traffic modeling software, allow modifications of traffic signal timings in response to traffic volume to be made during program execution. To overcome this lack of sophistication, the "after" analyses was conducted using a series of incremental SOAP simulation runs. Each SOAP model series corresponds to a time interval as it was recorded in South Lyon. Each increment in the series represents a single signal cycle time "slice." The SCATS implemented signal phase split plan, offset, and cycle length for each one cycle increment recorded in the data file were used to code the model. The length of each time slice depended on the length of signal cycle length which was selected by the SCATS control program. The output data from this sequence of simulation runs was then compiled to analyze the full one hour period.

The approach traffic volumes used in the simulation models were stratified by direction of movement based on turning movement volumes counted in the field. This is useful since the SCATS control structure implements signal timing plans based on a "saturation equalization" concept. Some of the intersections have phase splits that are modified based on the degree of saturation for critical movements on the constituent approaches. Additionally, SCATS implements cycle length and phase splits changes based on the efficiency of the preceding cycle. If one particular movement was below saturation during a cycle, it will in theory, receive less green time during the next cycle.

The final phase of the analysis was to use the traffic model output to calculate the various measures of effectiveness (MOE). These measures include the total intersection delay, and the average intersection stopped delay within the network and will serve as the basis for comparison against the simulation results.

3.2.3 The Simulation Analysis

Step three was the simulation analysis. Instead of using field traffic volume data collected in South Lyon under the fixed time signal settings, this analysis used the same traffic volumes as the SCATS study. This arrangement ensured a direct comparison of conditions, with only the traffic signal timings modified from the SCATS models. An optimized version of the RCOC fixed time signal phase split, cycle, and offset timing plans were used to process the traffic demand. Separate models for each intersection were executed to calculate the signal MOE's. Each run modeled a full one hour period instead of the multi-step approach used in the SCATS analysis.

An optimized version of the original RCOC fixed timing plan was used so that an objective comparison could be made between SCATS and fixed time control. The original Road Commission pretimed signal phase split, cycle, and offset timing plans were developed to efficiently accommodate peak and off-peak traffic demand using historical traffic volumes. Since the existing RCOC signal timing plans may be as much as two years old, and may not represent the time settings for the minimum delay for todays traffic volume, the fixed signal timings were optimized using the TRANSYT-7F signal offset and SOAP phase split optimizer before being used to calculate the output MOE's. In this way, any improvement gained from SCATS will represent the result of its utility rather than the result of a comparison to a poorly coordinated fixed time system.

Separate simulation models representing each of the six SCATS controlled intersections were constructed and executed during the analyses. In contrast to the segmented SCATS models, each of the simulation models were executed as a single continuous model for an hour. The same one hour total traffic volumes and turning movement percentages were used in both analyses. The sole difference between the two analyses was the traffic signal timings.

The final phase of the simulation analysis was to determine the output measures of effectiveness. As in the SCATS analysis, the measures included the total intersection delay, and average intersection approach stopped delay.

3.2.4 Comparison of Results

The final step of the project was to compare and document the observed differences in the measures of effectiveness between the two analyses. The comparison was performed using statistical testing procedures which have been developed specifically for evaluating the results of experiments identical to that used in this study. The primary statistical testing procedure used to compare the output data was the t-test. The t-test incorporates a procedure which is ideal for making paired comparisons of two data sets.

4.0 South Lyon Traffic Analysis

4.1 Part One: Field Data Comparison

4.1.1 "Before" Data

The collection of the "before" traffic volume and traffic signal timing data took place during the spring, summer and fall of 1995; prior to the implementation of the SCATS signal control and Autoscope video imaging system. The fixed time signal timing data was collected during a field visit on April 22, 1995 and verified against Road Commission for Oakland County signal log records.

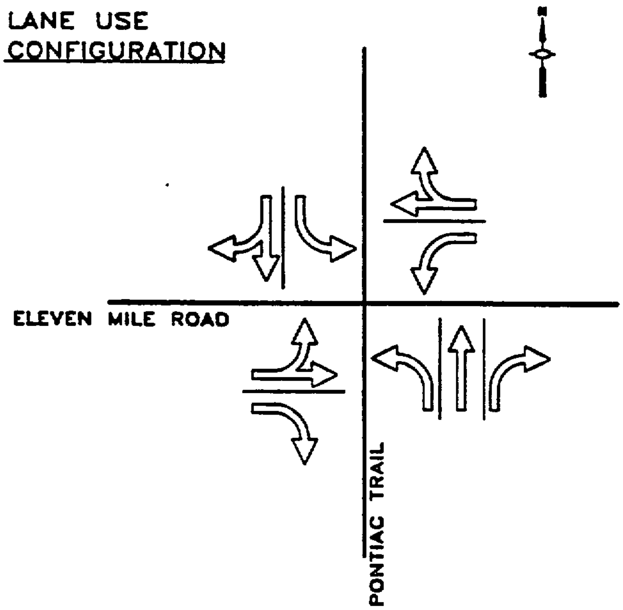
The "before" signal cycle lengths, phase patterns, and intersection approach lane geometry are illustrated in Figures 4.la, 4.lb, and 4.1c. The cycle lengths at all intersections, except for the Pontiac Trail/Eleven Mile Road signal, were 80 seconds. At this location the traffic signal was set to a cycle length of 70 seconds. Thus, there was no coordinated progression on Pontiac Trail between Ten Mile and Eleven Mile Roads. All signals operated under two or four phase operation except for the signals at the Ten Mile Road intersections with Pontiac Trail and Reynold Sweet Parkway. At these two intersections the signal timing configurations allowed for separate left turn intervals on each of the approach legs.

The road geometry of the link segments and intersection approaches was measured at the same time as the traffic signal timings. All of the approaches to the study intersections featured an exclusive left turn lane. With the exception of the south approach to the Pontiac Trail/Eleven Mile Road intersection, all approaches to the study intersections also featured shared through/right turn lanes. None of these approach geometries were altered during or between the “before” and “after phases of the study. Originally, there was no exclusive left turn phasing at the Pontiac Trail intersection at Nine and Eleven Mile Roads. After the completion of the FAST-TRAC project the north and southbound left turn movements at each of these locations were given permissive/protected left turn phasing.

Most of the road segments, or links, between the intersections featured two lane cross sections. The exceptions to the two lane cross section were segments of Pontiac Trail and Reynold Sweet Parkway. A continuous center lane for left turns exists on Pontiac Trail between Ten Mile Road and Reynold Sweet Parkway. The common center left turn lane also extended north of Ten Mile Road for 500 feet. A continuous center lane for left turns existed on Pontiac Trail for a distance of approximately one half mile north of Nine Mile Road. The center turn lane also extended south of Nine Mile Road for a distance of approximately 700 feet. At the intersection approaches, the standard two lane cross sections were increased to more than two lanes. The widened approaches were constructed to accommodate exclusive and shared through/turn lanes.

A schematic diagram of the Reynold Sweet Parkway and Ten Mile Road intersection is shown in Figure 4.1c. The position of the railroad track at this location required the construction of a “double signal” at the westbound approach to the intersection. Westbound traffic is controlled by a multi-phase signal allowing a pre-emptive red for train crossings or permissive/protective left turn when no trains are expected.

LANE USE
CONFIGURATION

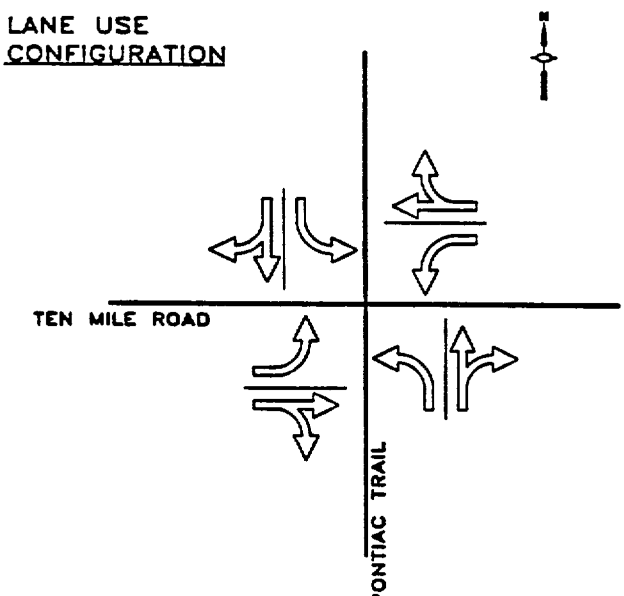


SIGNAL TIMING INTERVALS

	MOVEMENT N/S	MOVEMENT E/W	TIME INTERVAL
1	GREEN	RED	34 SEC.
2	AMBER	RED	4 SEC.
3	RED	RED	1 SEC.
4	RED	GREEN	28 SEC.
5	RED	AMBER	4 SEC.
6	RED	RED	1 SEC.

CYCLE LENGTH: 70 SEC.

LANE USE
CONFIGURATION



SIGNAL TIMING INTERVALS

	MOVEMENT N/S	MOVEMENT E/W	TIME INTERVAL
1	GREEN (PERMIS. L.T.)	RED	35 SEC.
2	AMBER (PERMIS. L.T.)	RED	4 SEC.
3	RED (PROTEC. L.T.)	RED	3 SEC.
4	RED (AMBER L.T.)	RED	4 SEC.
5	RED	RED	1 SEC.
6	RED	GREEN (PERMIS. L.T.)	24 SEC.
7	RED	AMBER (PERMIS. L.T.)	4 SEC.
8	RED	RED (PROTEC. L.T.)	3 SEC.
9	RED	RED (AMBER L.T.)	4 SEC.
10	RED	RED	1 SEC.

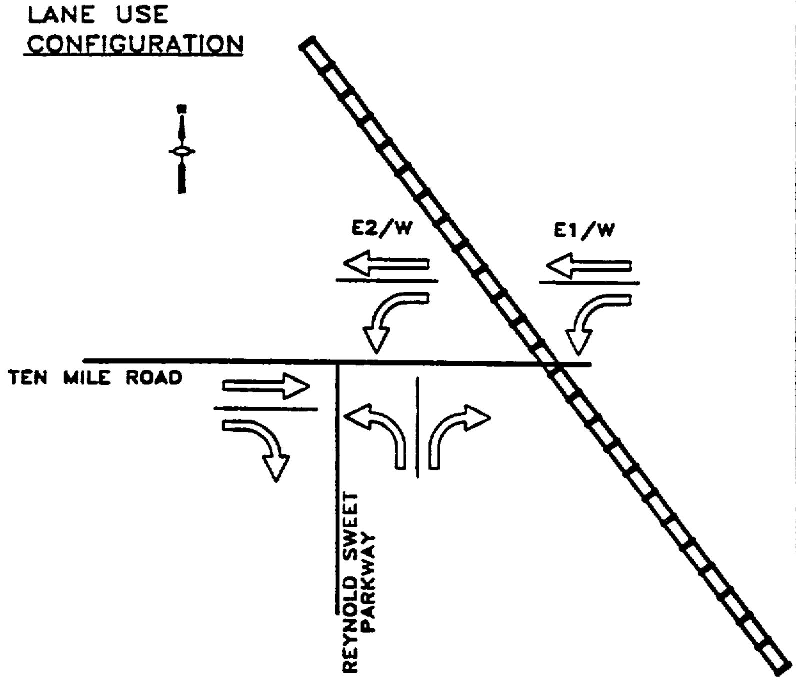
CYCLE LENGTH: 80 SEC.

FIGURE 4.1a

SIGNAL PHASING DIAGRAMS AND LANE USE CONFIGURATIONS

SOUTH LYON ATMS EVALUATION STUDY

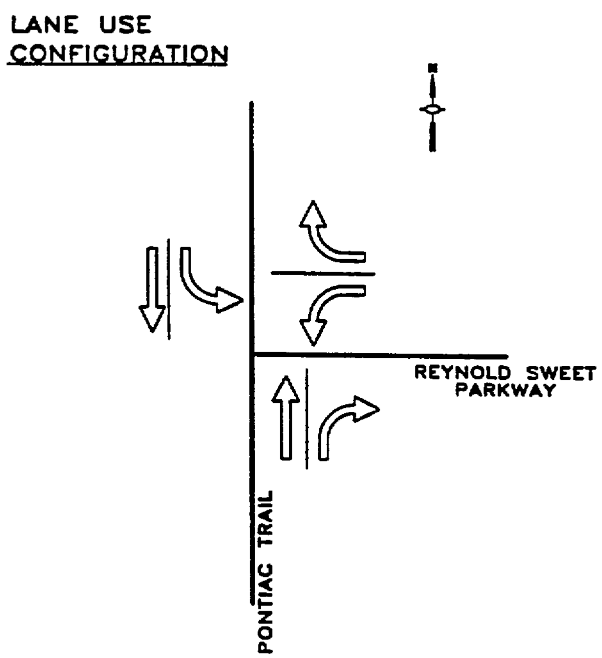
MICHIGAN STATE UNIVERSITY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING



SIGNAL TIMING INTERVALS

	MOVEMENT			TIME INTERVAL
	SOUTH	E2/W	E1/W	
1	GREEN	RED	RED	12 SEC.
2	AMBER	RED	RED	4 SEC.
3	RED	RED	RED	1 SEC.
4	RED	GREEN (PERMIS. L.T.)	GREEN	50 SEC.
5	RED	GREEN (PERMIS. L.T.)	AMBER	4 SEC.
6	RED	GREEN (PROTEC. L.T.)	RED	4 SEC.
7	RED	AMBER (AMBER L.T.)	RED	4 SEC.
8	RED	RED	RED	1 SEC.

CYCLE LENGTH: 80 SEC.



SIGNAL TIMING INTERVALS

	MOVEMENT		TIME INTERVAL
	N/S	E/W	
1	GREEN	RED	54 SEC.
2	AMBER	RED	4 SEC.
3	RED	RED	1 SEC.
4	RED	GREEN	16 SEC.
5	RED	AMBER	4 SEC.
6	RED	RED	1 SEC.

CYCLE LENGTH: 80 SEC.

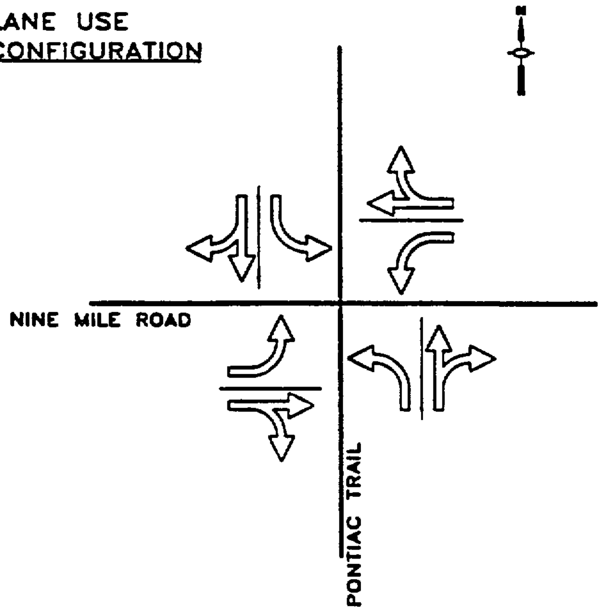
FIGURE 4.1b

SIGNAL PHASING DIAGRAMS AND LANE USE CONFIGURATIONS

SOUTH LYON ATMS EVALUATION STUDY

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

LANE USE
CONFIGURATION

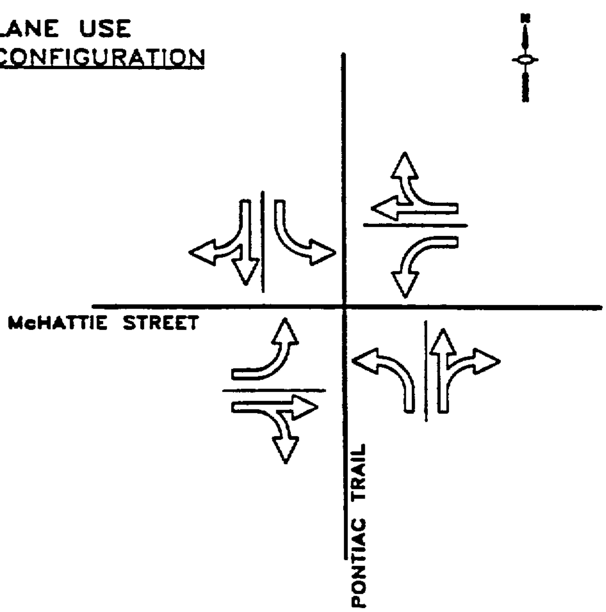


SIGNAL TIMING INTERVALS

	MOVEMENT N/S	MOVEMENT E/W	TIME INTERVAL
1	GREEN	RED	48 SEC.
2	AMBER	RED	4 SEC.
3	RED	RED	1 SEC.
4	RED	GREEN	22 SEC.
5	RED	AMBER	4 SEC.
6	RED	RED	1 SEC.

CYCLE LENGTH: 80 SEC.

LANE USE
CONFIGURATION



SIGNAL TIMING INTERVALS

	MOVEMENT N/S	MOVEMENT E/W	TIME INTERVAL
1	GREEN	RED	44 SEC.
2	AMBER	RED	4 SEC.
3	RED	RED	1 SEC.
4	RED	GREEN	26 SEC.
5	RED	AMBER	4 SEC.
6	RED	RED	1 SEC.

CYCLE LENGTH: 80 SEC.

FIGURE 4.1c

SIGNAL PHASING DIAGRAMS AND LANE USE CONFIGURATIONS

SOUTH LYON ATMS EVALUATION STUDY

MICHIGAN STATE UNIVERSITY
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

The posted speed limits varied in the South Lyon network. In the central business district vicinity of the Ten Mile Road/Pontiac Trail intersection, speeds were restricted to 2.5 miles per hour. Posted speed limits on Pontiac Trail were 35 miles per hour immediately outside the core commercial district and 45 miles per hour in the vicinity of Nine and Eleven Mile Roads, and 50 miles per hour north of 11 Mile Road. The posted speed limit on Reynold Sweet Parkway was 35 miles per hour.

4.1.2 "After" Data

The collection of the "after" traffic volume and signal timing information took place during the week of May sixth through May tenth, 1996. The "after" data elements of the system were composed primarily of the traffic volume and traffic signal timing features of the system. Both of these key statistics were collected automatically by the SCATS data processing system. In addition to adaptive signal control, the SCATS system has the capability to collect and store a number of important details relating to the flow of traffic and control of signals at the intersection.

Each of the signals controlled by SCATS incorporates a system of video imaging cameras which are positioned to record the presence of vehicles for critical movements at the stop line. A "critical movement" is a left turn, right turn, or through movement which is allotted green time during the signal cycle. At a minimum, through movements must be recorded to allot green time to the approaches. At locations where a separate left turn phasing is used, detection zones are added to record the left turn traffic volumes. No right turn traffic volume information is collected in South Lyon. The right turn and through traffic both use the through lane and are unopposed by conflicting traffic movements.

The SCATS output file consists of a stream of cycle-by-cycle information containing key performance statistics for each critical movement on the constituent approaches. It also contains signal control information like the current mode of operation, (tactical or strategic), the primary split plan and cycle length, the controlling strategic approach, and the intersection degree of saturation.

Since all six of the signalized intersections were converted to SCATS control, all of the necessary traffic volume information was collected remotely, using the SCATS/Autoscope data processing system. Unfortunately, not all of the intersections were equipped to collect all of the data that was required for analysis in this study. The SCATS configuration at the intersections of Pontiac Trail at McHattie Street and Reynold Sweet Parkway did not allow for the collection of left turn movement data. The traffic volumes collected by the SCATS system at these locations are limited solely to the through movements. Using this information signal timings are interpreted by SCATS in the local controller. The coordination of the cycle length and offset between adjacent intersections is computed at the regional traffic operations center. The lack of recorded traffic signal output files for these two intersections made the delay parameter assessment impossible in this study. Delay parameters were calculated only at the four intersections of Pontiac Trail and Nine Mile Road, Pontiac Trail and Ten Mile Road, Pontiac Trail and Eleven Mile Road, and Reynold Sweet Parkway and Ten Mile Road.

4.1.3 Related Data

The collection of this intersection approach directional turning movement and delay data took place prior to the activation of SCATS in December, 1995 and later after the activation of SCATS in May, 1996. The data were collected with the use of video cameras positioned to record the arrival characteristics of oncoming traffic. Specific approach movements at the intersections of Nine Mile and Eleven Mile Roads with Pontiac Trail were video taped on Wednesday, December sixth, Thursday, December seventh, and Friday, December eighth 1995. The delay data was recorded during the hours of noon to five o'clock p.m. Taping during the usual peak hour of 5:00 p.m. to 6:00 p.m. was not possible due to the low visibility conditions after 5:00 p.m.

Two cameras were positioned at the southeast corner of the Nine Mile Road/Pontiac Trail intersection. The cameras were aimed to record oncoming traffic on the north and west approaches to the intersection. Two different cameras were positioned on the southwest corner of the Eleven Mile Road/Pontiac Trail intersection. These cameras were aimed to record oncoming traffic on the north and east approaches to the intersection. Data reduction took place when the video tapes were reviewed using a television, video cassette recorder, and stop watch. Although time consuming, this method of data collection and reduction resulted in accurate and detailed time measurements of individual vehicles. Tapes could be played, rewound, and replayed to record the arrival and delay time characteristics for simultaneously arriving vehicles. To accomplish the same results in a field setting would have required up to eight people per intersection. Summarized results showing the "before" and "after" volume, delay, and signal information is presented in Table 4.1.

Table 4.1 Field Recorded Traffic Data

South Lyon SCATS Delay Evaluation Study												
Pontiac Trail and Nine, Mile Road	Average Volume (veh/hr)		Average Cycle Length (sec)		Average Green Time (sec)		Average Delay (sec/veh)		Average Time in Queue (sec/veh)		Time Delay (veh-hr)	
	"before"	"after"	"before"	"after"	"before"	"after"	"before"	"after"	"before"	"after"	"before"	"after"
Southbound Through	508	592	80	85	48	50	13.13	12.78	28.22	25.37	1.85	2.11
Southbound Left Turn	41	52	80	85	-na-	8	17.37	21.07	29.00	29.62	-na-	-na-
Eastbound Left Turn	140	140	80	85	22	19	36.12	40.61	37.43	54.54	1.40	2.14
Pontiac Trail and Eleven MIle Road	Average Intersection Delay (sec/veh)										18.10	17.93
Southbound Through	450	490	96/70	82	40/34	46	14.84	11.32	24.19	21.40	1.89	1.54
Southbound Left Turn	35	35	-na-	85	-na-	6	17.72	13.45	23.65	18.92	-na-	-na-
Eastbound Left Turn	125	130	90	86	40	28	31.33	44.32	39.97	56.29	-na-	-na-
	Average Intersection Delay (sec/veh)										20.37	18.62

Source: Michigan State University, Department of Civil Engineering

At both intersections, the total delay was reduced when SCATS was installed. This result was achieved even though there was an increase in the volume of traffic served by the intersection. The lower volume intersection (Pontiac Trail and Eleven Mile) experienced the greatest reduction in average delay per vehicle. This was probably due to the fact that there was more flexibility in assigning green time and reducing individual phase lengths.

The through traffic experienced a reduction in average delay at both intersections, while the minor movements (left turning vehicles) showed mixed results. The left turning vehicles approaching in the cross street experienced relatively large increases in average delay, while the heavier movements experienced a reduction in delay. This is an indication that SCATS was allocating the green time to reduce the saturation flow, as is intended.

4.2 Part Two: Simulation Model Comparison

The original intent of this study was to use the SOAP traffic signal analysis software to directly model the SCATS operation in South Lyon on an incremental. cycle-by-cycle, basis. Unfortunately, it was discovered that certain aspects of the SOAP program would make the use of this approach impossible. To complete an effective comparison, a new computerized methodology was developed. To remain consistent, this system was also used to analyze the simulated fixed time operation.

4.2.1 The SOAP Program and Its Limitations

SOAP was developed for the analysis of traffic signal design alternatives at four-legged intersections with or without protected left turning phase intervals in the signal sequence, including fixed time, semi-actuated, and fully actuated control. One of the benefits of the SOAP program is that it allows the operating characteristics of an individual intersection to be expressed in terms of specific measures of effectiveness (MOE). SOAP MOE's include the calculation of various vehicle approach delays, number of stopped vehicles, fuel consumption, queue lengths, and other flow characteristics. A further benefit to the system is that it allows these MOE to be calculated for relatively short time intervals. It's design allows a user the ability to analyze up to 48 separate time increments in a single program execution. Thus it was originally hoped that a series of forty five 80 second time increments could be used to evaluate one hour of delay at intersection with an 80 second signal cycle length.

Unfortunately, it was quickly discovered that this approach would not be possible with SOAP. The initial plan was to use SOAP to model the South Lyon intersections based on the RCOC fixed traffic signal timings and the traffic volumes recorded in the SCATS output files. The SCATS conditions were to be modeled on a cycle-by-cycle basis using the same traffic volumes and modifying the signal timings after each signal cycle. However, the minimum allowable SOAP analysis time interval is five minutes, while SCATS control modifies the traffic signal phasing plan every signal cycle. As a result, some of the cycle length settings for intersections in South Lyon were as short as 50 seconds.

After understanding the SOAP program's delay calculation methodology, it was possible to duplicate the procedure and incorporate additional features for use in this study. The new procedure incorporated a mechanism to shorten the allowable analysis window from the SOAP imposed minimum of five minutes, to a time interval of 50 seconds. Thus, it was possible to calculate average approach vehicle delays and total intersection delays for the intersections in South Lyon directly from the SCATS output file data.

4.2.2 SCATS Delay Calculation Model

A computer program was developed to calculate the delay of critical movements within South Lyon under SCATS control. The program used the SOAP calculation methodology as well as a data extraction system to read traffic and signal timing information from a SCATS output data file. To analyze these traffic conditions, the program used the Autoscope recorded volumes and SCATS signal phase timings to calculate average approach delay for each signal cycle. Total delay was calculated using the product of hourly vehicular volume and average approach delay. The same program configuration was used to complete the simulated system analysis, using the optimized fixed time signal plan, in which the signal timings did not vary from cycle to cycle.

The analysis models were divided into two separate groups. The first set of models were developed to analyze the SCATS conditions. The simulation analysis required the completion of a SOAP signal timing optimization analysis to determine the most effective signal phase split arrangement to accommodate the hourly traffic volumes. The same analysis technique and cyclical traffic volume data were used for both conditions, with a sole variant between the two groups being the traffic signal timing.

Four separate computer programs, one for each of the four intersections analyzed in South Lyon, were coded using the Fortran programming language. Each intersection required a separate program to accommodate various SCATS output data file formats. Each intersection had a different number and order of the critical approaches within each data set. The intersection of Ten Mile Road and Pontiac Trail incorporated eight critical approaches. Each of the four intersection approach legs included a single shared through/right turn lane and a single exclusive left turn lane. The intersections of Nine and Eleven Mile Roads with Pontiac Trail included through lane information only for two of the four approach legs. Separate left turn data was recorded for the north and southbound approaches at both intersections. The Ten Mile Road/Reynold Sweet Parkway intersection data set included through and left turn data for the westbound approach, through data for the eastbound approach, and a single unopposed left turn approach volume and signal data on the northbound approach. The data collection configuration at the Ten Mile Road/Reynold Sweet Parkway location was different from the other three because it has only three approach directions.

An output listing of the program source code was written to analyze the intersection of Pontiac Trail and Ten Mile Road is included in Appendix A of this report. The program is composed of three separate components of data retrieval, delay calculation, and delay output information. The program was designed to read the SCATS output data file to extract the traffic volume detected, and the green time dedicated to each of the eight critical intersection approach movements. This information was used to “feed” the modified Webster/TRANSYT delay equation. The average approach delay was calculated separately for each movement during each cycle. The average approach delay as well as the total intersection delay for each hour were calculated and written to an output file.

Three input parameters used in the SCATS models were not taken directly from the SCATS output data files. These were the vehicle start-up lost time, headway, and critical movement saturation flows. Each of these parameters is critical in determining the delay at signalized intersections. The headway and saturation flow rates determine the capacity that a particular lane group has to service the traffic demand. A traffic demand in excess of the capacity of the approach will experience greater delay. The lost time value reflects the amount of time that a green signal phase can not service the approach traffic demand. The lost time parameter is also critical because its effects are felt during each signal phase. A few seconds of lost time for a four phase signal with a one minute cycle can result in over nine hours of wasted green time every day. The values for lost time, headway, and saturation flow for each of the intersection approach locations were collected from Road Commission for Oakland County Traffic Operations Center records.

SCATS data files were recorded for the South Lyon intersections during a one week time period starting at midnight Monday May 5, 1996 and ending at midnight Saturday May 10, 1996. From the recorded data it was possible to analyze twenty separate periods for each critical intersection approach movement as part of this study. As a result, the total size of the comparison sample data set included 480 records each of the two systems.

The analysis program calculated the average approach delay and total intersection delay for each hour of the day. To analyze a varying sample of traffic conditions, four separate daily analysis periods were selected. The first was the hour between 12:00 a.m. and 1:00 a.m. This hour represents one of the low traffic demand periods of the day. Often, several traffic signal cycles would occur before a single vehicle was detected on a particular approach. Under these conditions it was thought that SCATS would function at its best. Only the minimum green time would be allocated to the low volume movements. Correspondingly, it was expected that delays for the remaining approaches would also be minimized.

Two peak traffic demand periods, 7:00 a.m. to 8:00 a.m. and 5:00 p.m. to 6:00 p.m., were also analyzed. These intervals were selected for the opposite reason. The comparison of SCATS to fixed time signal control would help to illustrate the differences in operation during high demand periods in which SCATS could implement a longer cycle length and better allocate green time to the high demand movements in an effort to minimize delay. The final analysis period was the hour from 12:00 p.m. to 1:00 p.m. During this hour the demand was between the high demand volume of the morning and evening peak hours, and the midnight low level volume.

4.2.3 Delay Calculation Model

The simulation delay analysis incorporated a two step approach. Rather than using the actual RCOC signal timings for South Lyon, a set of "optimized" fixed time settings were used. The decision to use optimized fixed time was made to more accurately assess the benefit of real time adaptive signal control. A comparison against the original timing plans may have showed a benefit based on a poorly timed fixed system. Therefore, the benefit would be from improving a bad condition instead of comparing two different, though equally good, systems.

The SOAP program was also used to determine an "optimized" fixed timing plan to compare the adaptive and fixed control strategies. The explicit SOAP optimization strategy attempts to minimize delay by using a cycle length, green split, and dial assignment optimization process. All of these parameters can be calculated automatically by the program. SOAP also allows an implicit optimization method. The implicit method requires some judgement on the part of the user with regard to the use of permissive versus protected left turn control, actuated control, and phase sequence selection. All of the implicit optimization methods and some of the explicit ones were based on the SCATS minimum parameters to assure a fair comparison.

The SOAP optimization process works by attempting to minimize the total intersection delay for the time period under analysis. Earlier it was shown that SCATS reduces the delay by equalizing the degree of saturation for each of the constituent intersection approaches. By contrast, SOAP attempts to reduce stops and delay on a “global” scale. This philosophy is best illustrated by a major street/minor cross street intersection situation. In this situation the major street volumes are significantly higher than the minor street traffic. SOAP would minimize the intersection delay by allocating a proportionately higher percentage of green time to the major street approaches. However, the benefit realized by the heavier movement delay reductions would be gained at the expense of the minor street traffic. In extreme cases the minor street approach traffic could experience average delay greatly in excess of those experienced by the major street approaches. The total delay is minimized because the inordinately average high delays are experienced by a relatively low number of vehicles.

As noted in the SOAP manual. this method results in an unfair allocation of green time. Especially in situations where one of the minor street approach volumes is relatively high. However, this method can result in substantial savings in vehicle emissions and operating costs because the total amount of stops and delay at the intersection is minimized.

The optimization procedure used to determine the fixed time signal plan did not take full advantage of the SOAP optimization process. The signal cycle lengths used for the fixed plans were the same as the SCATS average in each of the four analysis periods. The similar cycle lengths were used to account for the need for coordinated progression between the signals. In reality SCATS may have been limited in its selection of a more suitable cycle length by the need to maintain coordination with adjacent signals. Minimum green time restrictions were also placed on the SOAP system. In several instances SOAP attempted to allocate very low green times to minor street movements. However, these green times would not allow adequate time for pedestrian clearance and could result in safety problems with drivers attempting turning movements into a traffic stream with inadequate gaps. Two other restrictions were placed on the SOAP selection process. The same permissive/protected left turn phasing was maintained between both of the test groups. Once again, this decision was based on real-world safety considerations in which protected left turn phasing would be warranted by the lack of acceptable left turn gaps. The final restriction was the forced use of the same phase sequence pattern. It was felt that this would result in a more balanced comparison without significantly effecting the signal performance parameters.

Separate optimization trials were completed for each time period at each of the four intersections. These signal timings were based on the average traffic volume recorded during the week of data collection. The fixed time plan did not vary from day to day. The program was modified so that the timing plan was fixed throughout the analysis while the SCATS traffic volumes were read for each cycle. The signal timing plans used to analyze each of the various analysis periods are shown in Tables 4.2a through 4.2d.

4.3 Model Limitations

Like all traffic models, the modeling technique used to calculate delay conditions in South Lyon had some inherent weaknesses. These weakness were the result of two primary sources, The first came from the SOAP program and delay calculation procedures. The second main area of limitation came from the architecture of the SCATS system. The SCATS/Autoscope architecture is designed to collect and process the data required to most efficiently implement signal timings.

Unfortunately, the data necessary for the operation of the system is not perfectly designed for the completion of comprehensive and detailed delay studies.

The Robertson modification to the Webster equation was incorporated to more accurately assess delay for traffic volumes which approach or exceed the design capacity of the intersection. The Webster equation, by itself, is useful when analyzing approaches with a degree of saturation between approximately 15 and 97 percent. When the degree of saturation exceeds 97 percent, the Webster equation produces delay value which are negative and do not become positive until a degree of saturation in excess of 130 percent is attained. To illustrate this concept the following example is presented. When the volume of a particular approach with a saturation flow of 1,600 vehicles per

Table 4.2a Green Phase Split in Optimized Fixed Time Operation

South Lyon SCATS Delay Evaluation Study Intersection of Pontiac Trail and Ten Mile Road - Optimized Signal Timings								
Approach Movement	12:00 am – 1:00 am		7:00 am – 8:00 am		12:00 pm – 1:00 pm		5:00 pm – 6:00 pm	
	Green Phase Allocation		Green Phase Allocation		Green Phase Allocation		Green Phase Allocation	
	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle
Northbound Through	35	63.6%	52	61.5%	45	52.9%	42	46.9%
Northbound Left Turn	4	7.3%	7	8.3%	7	8.2%	7	7.8%
Southbound Through	35	63.6%	52	61.5%	45	52.9%	42	46.9%
Southbound Left Turn	4	7.3%	7	8.3%	7	8.2%	7	7.8%
Westbound Through	11	20.0%	17	20.1%	24	28.2%	32	35.8%
Westbound Left Turn	4	7.3%	7	8.3%	7	8.2%	7	7.8%
Eastbound Through	11	20.0%	17	20.1%	24	28.2%	32	35.8%
Eastbound Left Turn	4	7.3%	7	8.3%	7	8.2%	7	7.8%
"All-Red" Clearance Intervals	2	3.6%	3	3.6%	2	2.4%		3.4%
Total Cycle Length (sec)	55		85		85		90	

note: Phase split optimization is completed using the Signal Optimization and Analysis Package (SOAP)

Table 4.2b Green Phase Split in Optimized Fixed Time Operation

South Lyon SCATS Delay Evaluation Study Intersection of Pontiac Trail and Nine Mile Road - Optimized Signal Timings								
Approach Movement	12:00 am – 1:00 am		7:00 am – 8:00 am		12:00 pm – 1:00 pm		5:00 pm – 6:00 pm	
	Green Phase Allocation		Green Phase Allocation		Green Phase Allocation		Green Phase Allocation	
	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle
Northbound Through	37	14.0%	58	68.6%	57	67.5%	61	67.8%
Northbound Left Turn	6	10.0%	5	5.9%	5	5.9%	5	5.6%
Southbound Through	37	14.0%	58	68.6%	57	67.5%	61	67.8%
Southbound Left Turn	5	10.0%	5	5.9%	5	5.9%	5	5.6%
Westbound Through	7	14.0%	20	23.7%	21	24.9%	23	25.6%
Eastbound Through	7	14.0%	20	23.7%	21	24.9%	23	25.6%
"All-Red" Clearance Intervals		4.0%	3	3.6%	3	3.6%	2	2.2%
Total Cycle Length (sec)	50		85		85		90	

note: Phase split optimization is completed using the Signal Optimization and Analysis Package (SOAP)

Table 4.2c Green Phase Split in Optimized Fixed Time Operation

South Lyon SCATS Delay Evaluation Study Intersection of Pontiac Trail and Eleven Mile Road - Optimized Signal Timings								
Approach Movement	12:00 am – 1:00 am		7:00 am – 8:00 am		12:00 pm – 1:00 pm		5:00 pm – 6:00 pm	
	Green Phase Allocation		Green Phase Allocation		Green Phase Allocation		Green Phase Allocation	
	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle
Northbound Through	43	78.2%	60	70.6%	62	77.5%	65	76.5%
Northbound Left Turn	6	10.9%	5	5.9%	5	6.3%	7	8.2%
Southbound Through	43	78.2%	60	70.6%	62	77.5%	65	76.5%
Southbound Left Turn	6	10.9%	5	5.9%	5	6.3%	7	8.2%
Westbound Through	5	9.1%	19	22.4%	12	15%	12	14.1%
Eastbound Through	5	9.1%	19	22.4%	12	15%	12	14.1%
"All-Red" Clearance Intervals	2	3.6%	2	2.4%	2	2.5%	2	2.4%
Total Cycle Length (sec)	55		85		80		85	

note: Phase split optimization is completed using the Signal Optimization and Analysis Package (SOAP)

Table 4.2d Green Phase Split in Optimized Fixed Time Operation

South Lyon SCATS Delay Evaluation Study Intersection of Reynold Sweet Parkway and Ten Mile Road - Optimized Signal Timings								
Approach Movement	12:00 am – 1:00 am		7:00 am – 8:00 am		12:00 pm – 1:00 pm		5:00 pm – 6:00 pm	
	Green Phase Allocation		Green Phase Allocation		Green Phase Allocation		Green Phase Allocation	
	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle	Time (sec)	Percentage of the Cycle
Westbound Through	43	78.2%	60	70.6%	62	77.5%	64	75.3%
Westbound Left Turn	4	7.3%	5	5.9%	5	6.3%	8	9.4%
Eastbound Through	43	78.2%	60	70.6%	62	77.5%	64	75.3%
Northbound Left Turn	6	10.9%	18	21.2%	11	13.8%	11	12.9%
"All-Red" Clearance Intervals	2	3.6%	2	2.4%	2	2.5%	2	2.4%
Total Cycle Length (sec)	55		85		80		85	

note: Phase split optimization is completed using the Signal Optimization and Analysis Package (SOAP) hour is increased from 1,300 to 1,400 vehicles per hour, the average delay predicted by the TRANSYT model increases from 20.6 to 27.3 seconds per vehicle. The same average delay value calculated with the unmodified Webster equation shows an increase from 23.9 to 74.5 seconds per vehicle.

The most important limitation of the SOAP environment is that it lacks a mechanism to adjust the approach traffic arrival distribution. SOAP considers distribution of vehicle arrivals to be uniform with respect to any cycle. No attempt is made to model coordinated progression and the arrival of vehicles is assumed not to be influenced by upstream signals.

As a result a direct assessment of the benefits of coordinated progression was not possible in this study. Even so, the distance between signals on Pontiac Trail (1 mile) would limit the effectiveness of coordination anyway.

Another limitation of the SOAP program was the lack of ability to assess the conditions on a stochastic basis. Unlike analysis packages like NETSIM, SOAP does not differentiate drivers by their various driving habits. Differences in these parameters would primarily impact the start-up lost time and vehicle headway. While the impact of variability of these parameters was not accounted for in this study, these parameters were estimated from field data as discussed earlier in this report.

The operational configuration of the Autoscope/SCATS system in South Lyon also presented some limitations in this study. Most notable was the ability to calculate delay for all movements at the intersections. The system was configured to detect vehicles and modify signal timings for only the critical approach movements. Left turning traffic was detected only in locations where an exclusive left turn phase was present. In all cases the right turning was combined with the through traffic movement. Therefore, no delay parameters were calculated exclusively for right turning traffic at any of the intersections. However, the impact of the lack of this data was not critical since the right turn traffic shared the through traffic lane with the through traffic.

While the utility of using the SCATS output data files was obvious, the use of these files also presented other limitations in the study. The original plan was to assess the delay conditions at all six of the South Lyon SCATS controlled intersections. Due to the data collection configuration of the system, the intersections of Pontiac Trail at Reynold Sweet Parkway and McHattie Street could not be analyzed. The SCATS data input requirement at these two intersections was such that the approach through volumes were all that were necessary to control the timing of the signals. The cycle lengths at these two locations are coordinated at the RCOC Traffic Operations Center. The phase splits, however, are controlled locally at the intersection signal controller. No volume or timing data is transmitted or stored at the control center. As a result, there were no data files to analyze in this study.

4.4 Delay Model Output Data

After ail of the programs were debugged and fully operational they were executed to produce the output statistics required to compare the delay conditions in South Lyon with and without SCATS signal control. The comparative MOE for average approach delay and total intersection delay are presented in Tables 4.3a through 4.6f. The first set of tables, 4.3a through 4.3f, are for the intersection of Pontiac Trail and Ten Mile Road. Tables 4.4a through 4.4f, 4.5a through 4.5f,4.6a through 4.6f, illustrate the same statistics for the intersection of Pontiac Trail and Nine Mile Road, Pontiac Trail and Eleven Mile Road, and Ten Mile Road and Reynoid Sweet Parkway, respectively.

The tables are structured to illustrate the hourly volume and delay statistics for each of the critical approach movements. The tables are further divided into four sets of columns, one for each of the analysis intervals. Below each of the hourly approach delay values is the total intersection delay statistic for both the fixed time and SCATS adjusted signal control delay groups. Under the total intersection delay statistic, the average cycle length for the analysis interval is also shown.

The first five tables for each location, designated “a” through “e,” illustrate the delay statistics for the days of Monday through Friday. The final table for each location, labeled “f,” shows the weekly average for all of the volume, delay, and cycle length statistics for the week. In the following section of the report these statistics will be more closely analyzed and compared in an effort to assess their significance and relevance.

Table 4.3a Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Monday, May 6, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control
Northbound Through	62	5.7	9.1	447	30.8	43.2	400	17.0	29.6	463	33.7	45.3
Northbound Left Turn	4	4.5	7.8	17	22.7	25.0	21	46.8	53.2	44	39.0	37.9
Southbound Through	67	3.6	7.7	401	22.7	38.6	441	19.6	37.3	589	58.7	78.9
Southbound Left Turn	9	4.8	8.7	16	68.9	37.3	34	24.4	30.3	90	41.0	45.3
Westbound Through	13	30.3	26.7	194	27.8	31.4	250	38.0	33.3	445	62.3	75.5
Westbound Left Turn	2	18.1	17.0	50	67.5	34.9	18	30.3	23.5	37	44.5	43.1
Eastbound Through	10	26.8	30.0	336	39.0	52.6	187	31.4	28.3	218	32.4	33.2
Eastbound Left Turn	0	0.0	0.0	67	48.9	30.7	28	73.6	34.6	65	55.4	43.2
Intersection Delay (veh-hr)		0.42	0.51		13.75	17.61		9.78	12.63		26.56	32.88
Average Cycle		55.0	53.0		85.0	85.8		85.0	81.0		90.0	89.6

Table 4.3b Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Tuesday, May 7, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control
Northbound Through	158	5.7	13.6	456	33.8	48.8	376	16.2	30.7	501	48.9	58.8
Northbound Left Turn	4	3.4	7.8	26	28.8	29.3	36	25.6	30.4	34	68.2	39.3
Southbound Through	194	6.1	19.0	407	20.6	39.1	449	17.0	34.2	560	50.5	65.1
Southbound Left Turn	4	5.2	11.6	2	26.7	31.5	29	22.9	28.3	78	73.2	61.2
Westbound Through	60	32.9	21.8	196	27.3	33.5	231	43.4	39.5	431	56.7	75.9
Westbound Left Turn	4	18.1	13.2	34	79.5	37.6	30	31.9	25.0	45	30.9	43.3
Eastbound Through	35	33.1	23.8	338	44.5	51.8	202	30.8	27.8	203	27.3	32.8
Eastbound Left Turn	10	21.3	11.4	52	44.1	37.2	34	39.6	28.2	76	56.9	41.2
Intersection Delay (veh-hr)		1.53	2.29		13.86	11.42		9.40	12.06		26.81	32.36
Average Cycle		55.0	53.5		85.0	86.7		85.0	80.0		90.0	19.7

note: through traffic movements include right turn traffic

Table 4.3c Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Wednesday, May 8, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control
Northbound Through	155	5.7	9.7	449	33.7	43.0	414	17.0	30.3	511	42.5	47.0
Northbound Left Turn	0	0.0	0.0	18	55.1	31.0	14	28.8	35.5	37	59.4	42.4
Southbound Through	146	6.4	16.3	400	25.3	37.9	431	17.7	36.2	597	59.7	66.5
Southbound Left Turn	6	4.2	6.9	21	58.5	34.5	23	25.3	28.8	94	54.1	40.3
Westbound Through	103	49.4	31.4	156	25.5	31.2	225	42.7	38.5	377	46.4	76.1
Westbound Left Turn	6	18.1	18.1	43	47.4	36.2	21	31.8	23.5	44	23.8	25.2
Eastbound Through	28	28.4	23.3	307	34.3	60.2	178	30.7	28.0	191	26.3	29.7
Eastbound Left Turn	2	28.7	39.6	77	43.6	36.9	25	46.6	27.8	70	55.3	49.0
Intersection Delay (veh-hr)		2.20	2.23		13.16	17.64		9.04	12.26		25.58	30.01
Average Cycle		55.0	57.7		85.0	86.0		85.0	81.5		90.0	90.2

Table 4.3d Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Thursday, May 9, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) "Optimized" Plan	Approach Delay (sec) SCATS Control
Northbound Through	239	6.2	8.9	439	32.7	47.4	403	16.7	31.6	479	29.5	54.9
Northbound Left Turn	2	7.0	13.0	22	27.3	27.2	20	25.8	30.0	37	41.4	38.6
Southbound Through	163	5.8	10.6	387	22.1	39.9	468	18.7	37.1	565	55.6	71.9
Southbound Left Turn	20	6.4	10.5	17	38.9	33.0	39	25.0	31.0	115	49.8	55.9
Westbound Through	117	49.7	36.5	164	27.0	33.6	259	45.7	50.0	467	66.7	77.0
Westbound Left Turn	6	18.1	9.8	31	32.9	32.5	39	32.3	25.6	38	25.9	26.1
Eastbound Through	47	37.8	30.2	343	38.5	48.4	196	31.6	29.0	208	30.1	31.2
Eastbound Left Turn	3	19.9	11.4	39	25.1	23.0	32	51.3	28.3	75	61.7	44.4
Intersection Delay (veh-hr)		2.86	2.75		12.40	17.06		10.53	13.92		26.67	33.76
Average Cycle		55.0	55.3		85.0	84.5		85.0	81.3		90.0	89.9

note: through traffic movements include right turn traffic

Table 4.3e Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Friday, May 10, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	237	5.9	12.9	484	35.1	47.2	411	16.7	32.6	487	37.5	46.0
Northbound Left Turn	2	7.0	14.9	17	27.0	26.0	29	26.9	31.4	65	45.4	38.1
Southbound Through	188	6.0	9.4	391	21.8	38.8	488	20.3	44.2	579	56.7	73.7
Southbound Left Turn	15	7.4	12.4	25	75.0	35.2	28	23.7	27.4	77	43.0	35.3
Westbound Through	97	41.2	28.4	176	25.6	37.3	266	48.6	40.9	432	55.4	79.0
Westbound Left Turn	2	18.1	9.4	28	37.1	49.8	36	32.0	25.1	40	29.6	28.2
Eastbound Through	33	31.0	23.8	330	35.7	49.8	191	30.7	27.9	230	31.6	35.5
Eastbound Left Turn	14	18.1	14.8	63	32.0	28.7	33	38.9	27.5	115	73.0	56.8
Intersection Delay (veh-hr)		2.21	2.44		13.11	18.17		10.97	15.18		27.26	33.39
Average Cycle		55.0	55.5		85.0	85.0		85.0	81.5		90.0	90.1

Table 4.3f Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Week of 5/6/96 to 5/10/96 – Daily Average

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	170	5.8	10.8	455	33.2	45.9	401	16.7	31.0	488	38.5	50.4
Northbound Left Turn	2	4.4	8.7	20	32.2	27.7	24	30.8	36.1	43	50.7	39.3
Southbound Through	152	5.6	12.6	397	22.5	38.9	455	18.7	37.8	578	56.2	71.2
Southbound Left Turn	11	5.6	10.0	16	63.6	34.3	31	24.3	29.2	91	52.2	47.6
Westbound Through	78	40.7	29.0	177	26.6	33.4	246	43.7	40.4	430	57.5	76.7
Westbound Left Turn	4	18.1	13.5	37	52.9	38.2	29	31.7	24.5	41	30.9	33.2
Eastbound Through	31	31.4	26.2	331	38.4	52.6	191	31.0	28.2	210	29.5	32.5
Eastbound Left Turn	6	17.6	15.4	60	38.7	31.3	30	50.0	29.3	80	60.5	46.9
Intersection Delay (veh-hr)		1.84	2.04		13.26	17.78		9.94	13.21		26.58	32.48
Average Cycle		55.0	55.0		85.0	85.6		85.0	81.1		90.0	89.9

note: through traffic movements include right turn traffic

Table 4.4a Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Monday, May 6, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	77	3.9	1.2	346	7.9	37.2	455	9.2	11.6	856	23.4	46.7
Northbound Left Turn	2	3.4	4.4	32	33.9	38.0	10	19.0	18.6	42	44.0	36.6
Southbound Through	53	3.9	1.1	727	17.9	37.2	567	11.5	20.4	651	12.2	28.6
Southbound Left Turn	0	0.0	0.0	4	9.1	12.2	8	16.8	18.0	20	40.2	35.5
Westbound Through	0	0.0	0.0	51	32.5	28.4	48	30.7	27.6	64	28.1	30.3
Eastbound Through	6	27.4	27.0	256	75.4	47.9	172	38.7	36.9	222	43.3	43.0
Intersection Delay (veh-hr)		0.19	0.09		10.52	12.91		5.33	6.91		11.70	20.11
Average Cycle		50.0	52.0		85.0	85.2		80.0	81.3		90.0	90.2

note: through traffic movements include right turn traffic

Table 4.4b Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Tuesday, May 7, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	167	4.1	2.9	335	7.6	11.7	461	9.6	14.4	870	24.5	48.9
Northbound Left Turn	5	4.4	5.1	19	69.8	43.2	13	59.8	24.5	27	24.9	28.7
Southbound Through	163	4.1	2.5	754	21.7	41.2	540	12.2	16.2	654	10.0	25.6
Southbound Left Turn	0	0.0	0.0	10	12.8	13.6	15	13.8	12.5	20	83.8	40.2
Westbound Through	2	27.4	25.6	27	30.3	27.1	45	29.8	27.1	50	28.0	29.1
Eastbound Through	14	47.2	31.5	263	75.3	61.6	183	40.2	39.5	259	56.4	50.6
Intersection Delay (veh-hr)		0.58	0.39		11.38	14.68		5.75	6.76		12.84	20.96
Average Cycle		50.0	51.5		85.0	86.5		80.0	79.9		90.00	90.5

note: through traffic movements include right turn traffic

Table 4.4c Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Wednesday, May 8, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	151	4.2	1.6	356	8.3	11.9	466	9.3	13.9	877	23.2	56.9
Northbound Left Turn	12	2.7	1.8	22	100.9	36.6	11	17.6	17.5	50	36.1	31.7
Southbound Through	159	3.9	2.0	727	24.4	36.5	554	10.5	19.2	667	12.5	36.9
Southbound Left Turn	2	1.8	1.9	6	13.3	11.5	12	17.0	18.2	23	85.3	39.8
Westbound Through	11	40.0	31.9	44	30.8	26.9	44	29.3	27.2	60	27.9	27.5
Eastbound Through	12	50.5	36.0	256	77.0	56.9	196	55.4	35.1	330	70.7	46.2
Intersection Delay (veh-hr)		0.55	0.38		12.24	13.14		6.30	7.11		16.02	26.11
Average Cycle		50.0	51.4		85.0	86.4		80.0	81.9		90.0	90.7

note: through traffic movements include right turn traffic

Table 4.4d Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Thursday, May 9, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	173	4.1	1.9	327	7.3	11.1	464	9.7	15.0	872	27.0	45.3
Northbound Left Turn	6	2.8	2.5	17	10.7	11.3	5	18.0	15.6	25	25.3	29.0
Southbound Through	209	4.1	2.2	756	22.1	36.7	507	12.0	20.6	661	10.1	22.2
Southbound Left Turn	0	0.0	0.0	29	128.6	50.4	2	10.2	12.6	16	119.7	35.3
Westbound Through	6	27.4	25.2	41	30.7	26.4	36	29.6	28.3	63	28.1	31.0
Eastbound Through	15	55.1	35.3	251	71.7	55.5	170	47.5	43.7	258	31.2	49.0
Intersection Delay (veh-hr)		0.71	0.41		11.73	13.36		5.73	7.57		13.15	19.36
Average Cycle		50.0	51.9		85.0	84.5		80.00	79.3		90.0	89.4

note: through traffic movements include right turn traffic

Table 4.4e Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Friday, May 10, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	172	4.0	2.1	361	9.2	18.6	508	9.9	13.1	903	28.0	54.6
Northbound Left Turn	11	2.9	2.9	47	72.6	47.4	30	22.0	18.3	36	39.9	30.6
Southbound Through	206	4.2	2.7	765	19.9	42.1	565	10.6	14.6	639	12.4	28.2
Southbound Left Turn	0	0.0	0.0	6	11.2	10.8	6	18.6	16.6	22	99.2	37.0
Westbound Through	4	27.4	28.0	44	30.5	28.9	55	30.0	32.3	81	28.4	29.8
Eastbound Through	12	50.5	29.2	247	76.2	46.4	169	38.7	37.7	233	42.9	36.5
Intersection Delay (veh-hr)		0.64	0.39		11.71	14.99		5.55	6.59		13.63	22.26
Average Cycle		50.0	51.9		85.0	85.1		80.0	81.7		90.0	90.3

note: through traffic movements include right turn traffic

Table 4.4f Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Week of 5/6/96 to 5/10/96 – Daily Average

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	148	4.1	1.9	345	8.1	18.1	471	9.5	13.6	876	25.2	50.5
Northbound Left Turn	7	3.2	3.3	27	57.6	35.3	14	27.3	18.9	36	34.0	31.3
Southbound Through	158	4.0	2.1	746	21.2	38.7	547	11.4	18.2	654	11.4	28.3
Southbound Left Turn	0	0.4	0.4	11	35.0	19.7	9	15.3	15.6	20	85.6	37.6
Westbound Through	5	24.4	22.1	41	31.0	27.5	46	29.9	28.5	64	28.1	29.5
Eastbound Through	12	46.1	31.8	255	75.1	53.7	178	44.1	38.6	259	53.0	45.1
Intersection Delay (veh-hr)		0.55	0.33		11.52	13.82		5.73	6.99		13.47	21.76
Average Cycle		50.0	51.7		85.0	85.5		80.0	80.8		90.0	90.2

note: through traffic movements include right turn traffic

Table 4.5a Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Monday, May 6, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	48	3.5	5.9	339	6.5	9.4	317	4.1	7.4	422	5.6	9.0
Northbound Left Turn	2	1.6	1.7	50	10.8	10.9	0	0.0	0.0	15	19.5	21.7
Southbound Through	23	3.4	5.8	299	6.4	8.5	320	4.0	7.1	476	6.0	11.9
Southbound Left Turn	2	3.1	3.2	2	17.7	13.3	14	5.8	6.3	17	12.1	13.5
Westbound Through	3	51.2	41.2	149	62.1	52.9	79	69.2	39.7	101	85.5	60.7
Eastbound Through	0	0.0	0.0	12	31.7	31.5	12	38.4	32.0	10	41.2	34.2
Intersection Delay (veh-hr)		0.14	0.15		3.98	4.04		2.39	2.89		4.09	4.57
Average Cycle		55.0	53.0		85.0	84.1		80.0	80.5		85.0	82.4

note: through traffic movements include right turn traffic

Table 4.5b Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Tuesday, May 7, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	123	3.6	6.2	322	6.7	10.8	309	3.9	6.4	482	9.7	12.6
Northbound Left Turn	2	1.7	1.9	57	10.4	11.3	0	0.0	0.0	6	14.3	14.1
Southbound Through	88	3.5	6.0	290	6.3	9.3	333	4.2	6.9	403	8.9	11.6
Southbound Left Turn	4	2.4	2.4	2	9.8	7.3	7	7.4	7.2	7	10.9	13.8
Westbound Through	11	44.4	30.7	163	71.1	52.6	59	62.8	37.3	84	91.3	49.8
Eastbound Through	2	30.6	26.8	4	30.7	24.8	19	43.4	35.6	8	41.2	31.3
Intersection Delay (veh-hr)		0.37	0.47		4.53	4.30		2.00	2.00		4.57	4.27
Average Cycle		55.0	53.8		85.0	84.7		80.0	79.8		85.0	81.9

note: through traffic movements include right turn traffic

Table 4.5c Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Wednesday, May 8, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control
Northbound Through	140	3.6	6.2	306	6.4	9.7	316	4.1	6.7	458	5.8	8.6
Northbound Left Turn	0	0.0	0.0	45	10.1	11.8	2	5.1	5.3	4	7.0	7.9
Southbound Through	77	3.7	6.6	268	6.2	9.3	285	3.9	6.4	438	7.7	8.1
Southbound Left Turn	0	0.0	0.0	6	8.6	6.2	0	0.0	0.0	7	19..0	19.0
Westbound Through	4	30.6	25.3	152	68.3	49.3	58	64.7	39.2	100	81.7	60.9
Eastbound Through	2	30.6	25.0	15	31.1	29.3	10	38.4	34.0	4	41.2	36.4
Intersection Delay (veh-hr)		0.27	0.43		4.17	3.88		1.82	1.82		4.01	3.88
Average Cycle		55	52.9		85.0	82.9		80.0	80.1		85.0	84.5

note: through traffic movements include right turn traffic

Table 4.5d Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Thursday, May 9, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control
Northbound Through	161	3.6	6.2	339	7.0	10.8	328	4.0	7.3	446	6.0	7.9
Northbound Left Turn	5	2.7	3.1	37	8.8	10.4	2	1.6	2.4	3	4.3	4.2
Southbound Through	120	3.5	6.1	271	6.2	8.4	334	4.6	8.3	413	5.4	8.9
Southbound Left Turn	13	2.7	2.8	0	0.0	0.0	4	9.9	8.9	5	7.9	8.4
Westbound Through	4	27.3	28.1	179	66.3	57.8	65	73.7	38.2	65	78.3	56.3
Eastbound Through	8	30.6	26.1	15	31.1	32.9	9	41.9	34.0	14	41.2	36.3
Intersection Delay (veh-hr)		0.39	0.58		4.65	4.77		2.24	2.22		2.95	3.18
Average Cycle		55	53.2		85.0	81.5		80.0	80.2		85.0	81.7

note: through traffic movements include right turn traffic

Table 4.5e Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Friday, May 10, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	180	3.9	7.1	313	6.6	10.0	376	4.2	7.2	477	8.7	9.2
Northbound Left Turn	2	1.7	1.9	75	8.9	10.5	4	11.2	6.8	6	13.7	14.4
Southbound Through	106	3.4	5.9	260	6.2	8.9	352	4.2	10.8	508	6.3	9.8
Southbound Left Turn	0	0.0	0.0	6	14.0	11.6	14	8.1	8.8	17	14.8	15.6
Westbound Through	2	30.6	25.0	178	73.9	60.8	75	78.9	46.3	79	104.0	63.4
Eastbound Through	2	30.6	26.2	11	31.2	31.9	16	38.4	33.3	12	77.2	69.4
Intersection Delay (veh-hr)		0.33	0.56		4.98	4.86		2.71	2.57		4.66	4.32
Average Cycle		55.0	53.3		85.0	82.4		80.0	81.6		85.0	82.8

note: through traffic movements include right turn traffic

Table 4.5f Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Week of 5/6/96 to 5/10/96 – Daily Average

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Northbound Through	130	3.6	6.3	324	6.6	10.1	329	4.1	7.0	457	7.2	9.5
Northbound Left Turn	2	1.5	1.7	53	9.8	11.0	2	3.6	2.9	7	11.8	12.5
Southbound Through	83	3.5	6.1	278	6.3	8.9	325	4.2	7.9	448	6.9	10.1
Southbound Left Turn	4	1.6	1.7	3	10.0	7.7	8	6.2	6.2	11	12.9	14.1
Westbound Through	5	36.8	30.1	164	68.3	54.7	67	69.9	40.1	86	88.2	58.2
Eastbound Through	3	24.5	20.8	11	31.2	30.1	13	40.1	33.8	10	48.4	41.5
Intersection Delay (veh-hr)		0.30	0.44		4.46	4.37		2.23	2.30		4.06	4.04
Average Cycle		55.0	53.2		85.0	83.1		80.0	80.4		85.0	82.7

note: through traffic movements include right turn traffic

Table 4.6a Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road
Monday, May 6, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Westbound Through	39	2.0	0.2	258	4.8	0.8	273	4.2	0.6	550	13.2	1.7
Westbound Left Turn	0	0.0	0.0	41	15.9	11.0	41	6.5	3.3	60	10.8	5.6
Eastbound Through	29	2.0	0.2	439	6.4	5.3	259	4.2	3.0	303	5.5	4.3
Northbound Left Turn	0	0.0	0.0	2	30.3	52.4	4	32.8	53.4	10	43.4	49.7
Intersection Delay (veh-hr)		0.04	0.00		1.32	0.86		0.72	0.36		2.78	0.85
Average Cycle		50	51.4		75.0	75.8		70.0	73.5		75.0	76.8

note: through traffic movements include right turn traffic

Table 4.6b Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road
Tuesday, May 7, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control
Westbound Through	29	2.1	0.2	258	5.0	0.9	269	4.1	0.6	519	8.7	1.4
Westbound Left Turn	0	0.0	0.0	30	12.8	7.0	57	7.0	4.2	77	10.7	5.6
Eastbound Through	36	2.1	0.2	423	6.7	4.0	246	4.1	3.2	289	5.1	4.0
Northbound Left Turn	0	0.0	0.0	4	30.3	61.2	6	32.8	46.8	12	77.8	45.9
Intersection Delay (veh-hr)		0.15	0.00		1.28	0.65		0.75	0.41		2.15	0.80
Average Cycle		50.0	51.8		75.0	75.7		70.0	71.3		75.0	75.4

note: through traffic movements include right turn traffic

Table 4.6c Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road

Wednesday, May 8, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		“Optimized “ Plan	SCATS Control		“Optimized “ Plan	SCATS Control		“Optimized “ Plan	SCATS Control		“Optimized “ Plan	SCATS Control
Westbound Through	30	2.1	0.2	265	6.2	0.8	273	4.4	1.0	483	7.1	3.6
Westbound Left Turn	0	0.0	0.0	73	18.1	19.0	39	8.7	6.2	65	11.4	7.4
Eastbound Through	23	2.1	0.2	414	8.9	7.5	266	4.5	4.0	318	5.4	5.0
Northbound Left Turn	0	0.0	0.0	5	31.2	51.3	17	58.8	52.3	6	43.5	55.7
Intersection Delay (veh-hr)		0.03	0.00		1.68	1.38		1.03	0.69		1.77	1.19
Average Cycle		50.0	51.9		75.0	77.0		70.0	69.5		75.0	75.1

note: through traffic movements include right turn traffic

Table 4.6d Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road

Thursday, May 9, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)		Traffic Volume (veh)	Approach Delay (sec)	
		“Optimized “ Plan	SCATS Control		“Optimized “ Plan	SCATS Control		“Optimized “ Plan	SCATS Control		“Optimized “ Plan	SCATS Control
Westbound Through	24	2.1	0.2	256	5.4	0.7	324	4.5	1.0	616	6.4	1.9
Westbound Left Turn	0	0.0	0.0	40	9.8	4.9	43	8.0	4.6	60	12.0	7.1
Eastbound Through	20	2.1	0.2	372	6.9	5.7	297	4.2	4.2	349	5.7	4.8
Northbound Left Turn	0	0.0	0.0	6	30.3	40.0	12	32.8	31.8	9	66.3	59.9
Intersection Delay (veh-hr)		0.02	0.00		1.26	0.76		0.70	0.59		1.48	1.05
Average Cycle		50.0	51.6		75.0	72.2		70.0	65.2			76.6

note: through traffic movements include right turn traffic

Table 4.6e Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road
Friday, May 10, 1996

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control
Westbound Through	35	2.1	0.3	244	4.8	0.8	351	4.6	0.8	507	14.2	1.5
Westbound Left Turn	0	0.0	0.0	55	11.4	6.4	51	8.1	4.6	66	12.6	7.7
Eastbound Through	22	2.1	0.2	413	6.2	4.6	301	4.3	3.3	378	7.0	6.0
Northbound Left Turn	0	0.0	0.0	2	30.2	44.7	6	32.8	56.2	23	140.6	55.7
Intersection Delay (veh-hr)		0.03	0.00		1.23	0.70		0.98	0.51		3.86	1.34
Average Cycle		50.0	51.4		75.0	75.3		70.0	75.4		75.0	75.3

note: through traffic movements include right turn traffic

Table 4.6f Delay Model Output

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road
Week of 5/6/96 to 5/10/96 – Daily Average

Approach Movement	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm		
	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control	Traffic Volume (veh)	Approach Delay (sec) “Optimized “ Plan	Approach Delay (sec) SCATS Control
Westbound Through	31	2.1	0.2	256	5.2	0.8	298	4.4	0.8	535	9.9	2.0
Westbound Left Turn	0	0.0	0.0	48	13.6	9.7	46	7.7	4.6	66	11.5	6.7
Eastbound Through	26	2.1	0.2	412	7.0	5.4	274	4.2	3.5	227	5.7	4.8
Northbound Left Turn	0	0.0	0.0	4	30.5	49.9	9	38.0	48.1	12	74.3	53.4
Intersection Delay (veh-hr)		0.05	0.00		1.35	0.87		0.84	0.51		2.41	1.05
Average Cycle		50.0	51.6		75.0	75.2		70.0	71.0		60.0	75.8

note: through traffic movements include right turn traffic

5.0 Comparison and Interpretation of Modeled Delay

In the preceding section, intersection approach delay was calculated for the four South Lyon intersections under the control of both SCATS and fixed time traffic control. The goal of this section was to analyze these data to assess the differences in delay resulting from the two control strategies. The significance of these differences was determined by using various methods of comparison, including direct and indirect statistical tests. The comparisons also assessed the change in delay both within and between the various time and location data groups. Taken together, these comparisons also demonstrate how the control philosophy of SCATS impacted the delay parameters of intersections in South Lyon.

5.1 Total Intersection Delay

The analysis of intersection delay was accomplished through various comparisons of the total intersection delay in the two data sets. Total intersection delay is the sum of the delay experienced by ail vehicles at all approaches to an intersection. It is usually calculated from the product of the average vehicle delay and the total number of vehicles during a particular analysis interval. In this study, an average delay value was calculated for each approach movement during each signal cycle. The total delay was the sum of these cycle-by-cycle delays. The use of total delay as a measure of effectiveness is helpful because it illustrates the overall impact of SCATS control on the operation of an intersection. The comparison of the total delay statistics also helps to illustrate some of the philosophical differences between fixed and adaptive signal control.

The underlying philosophy of SCATS is to balance the degree of saturation on’all of the approach legs to the intersection. The goal is not necessarily to minimize total intersection delay. SCATS manages the signal cycle by strategically distributing green time to each of the approaches. This green time allocation does not, however, guarantee shorter delays to major and minor street traffic. The benefits of this strategy are numerous, including a more effective use of available green time, shorter minor street delays, and reduced driver frustration. The obvious drawback to this approach is the potential for increases in total intersection delay.

The comparison of total intersection delay used both a percentage comparison and specific statistical testing. The tests, detailed in the following paragraphs, resulted in many expected and unexpected outcomes.

To assess the intersection delay differences on a system wide and hourly basis, a statistical comparison of total intersection delay was conducted. The delay data at the four intersections, for the four separate time intervals, during the five days of data recording, resulted in a sample size of 80 records for each period. The two samples were contrasted using a paired comparison t-test. In a paired comparison the difference between the two separate samples is assessed. The computed means, variances, and standard deviations for total intersection delay in the entire South Lyon system as well as each separate time period are shown in Table 5.1.

The mean difference for the total population of vehicles was an increase of 1.46 vehicle hours of delay. The null hypothesis 95% level of significance test statistic and the t value for the observed delay data are shown near the bottom of Table 5.1. A comparison of the t values shows that the

Table 5.1 Statistical Comparison of Total Delay

South Lyon SCATS Delay Evaluation Study Difference in Average Total Intersection Delay, May 6th - 10th 1996					
	12:00 am – 1:00 am	7:00 am – 8:00 am	12:00 pm – 1:00 pm	5:00 pm – 6:00 pm	Overall
Mean	-0.02	-1.56	-1.07	-3.20	-1.46
Variance	0.05	4.33	2.08	16.86	7.15
Standard Deviation	0.23	2.08	1.44	4.11	2.67
Sample Size	20	20	20	20	80
Hypothesis Test					
Critical value of the t-distrib.	2.09	2.09	2.09	2.09	1.98
Observed value of t	-0.39	-3.35	-5.41	-3.48	-3.70
	DO NOT REJECT Ho @ 0.05	**REJECT the Null Hypothesis @ 0.05**	**REJECT the Null Hypothesis @ 0.05**	**REJECT the Null Hypothesis @ 0.05**	**REJECT the Null Hypothesis @ 0.05**

observed difference in the two data sets is outside the range of random variation. Therefore, it must be concluded that the observed increase in total delay is statistically significant.

Additional paired comparison t-tests were conducted to analyze the hourly differences in total intersection delay. Values for the mean, variance, and standard deviation for each of these groups were calculated for each of the four analysis periods. Table 5.1 shows that after SCATS, the mean intersection delay increased during each of the analysis periods. To test the statistical significance of these findings 95% confidence intervals and hypothesis tests were conducted for each of the four analysis periods. The hypothesis tests showed that during three of the four analysis periods the hourly intersection delay differences were statistically significant.

The data were also analyzed using non-statistical methods to identify trends within and between the data sets. These analyses included comparisons of the percentage difference between the two data sets and the calculation of various weekly averages for the groups of the modeled delay output. A tabular comparison of average intersection delay statistics is shown in Table 5.2. The delay difference in the two systems is shown in terms of a percent change in the right column for each time period. This value represents the optimized delay minus the SCATS delay, divided by the optimized delay. The composite hourly difference for all locations are shown at the bottom of each column group. The daily average difference is shown at the far right side of the table. This table is particularly useful because it illustrates some of the general trends within and between the two sets of delay data.

The percentage comparison of the data shows that total delay under SCATS control decreased during 7 of the 16 sample periods. However, Table 5.2 shows that overall, SCATS control showed a system-wide increase of 23.7% in the average value of total intersection delay. The results of the system wide comparison also suggest that SCATS had a minimal effect on total delay during low volume periods. The average difference in the total intersection delay during the midnight hour was 0.01 vehicle hours. The average difference between SCATS and fixed time control during the morning peak hour was 1.56 vehicle hours. The comparable numbers during the noon and evening peak hours were 1.06 and 3.20 vehicle hours, respectively.

The data in Table 5.2 shows that on a daily basis SCATS control produced higher average total intersection delay then the simulated system of control at three of the four study intersections. The lone exception was the Reynold Sweet Parkway/Ten Mile Road Intersection. At this location the average intersection delay during the four analysis periods was 47.7% lower with SCATS.

A substantial variability between the delays shown in fixed and SCATS control was also apparent. The experimental approach was such that the modeled output delay statistics were relatively free of external variables. Identical traffic volumes were used to feed both sets of models. Traffic volumes were not averaged for the fixed time analysis nor modified between the model runs. The number of vehicles contributing to the delay equation during each signal cycle was the same in both cases. Thus, it was expected that the comparison of two signal control strategies would exhibit some consistency in difference of total delay. However, the modeled output data shows a very different result.

Table 5.2 Percentage Comparison of Total Intersection Delay

South Lyon SCATS Delay Evaluation Study
Comparison of Total Intersection Delay

Intersection	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm			Daily Average		
	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)
	"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control	
Pontiac Trail/Nine Mile Road	0.55	0.33	40.0%	11.52	13.82	-20.0%	5.73	6.99	-22.0%	13.47	21.76	-61.5%	7.82	10.73	-37.2%
Pontiac Trail/Ten Mile Road	1.84	2.04	-10.9%	11.30	17.80	-33.8%	9.94	13.21	-32.9%	26.58	32.48	-22.2%	12.92	16.38	-26.8%
Pontiac Trail/Eleven Mile Road	0.30	0.44	-46.7%	4.46	4.37	2.0%	2.23	2.30	-3.1%	4.06	4.04	0.5%	2.76	2.79	-0.9%
Rynld Swt Pkwy/Ten Mile Rd.	0.05	0.00	100.0%	1.35	0.17	35.6%	0.84	0.51	39.3%	2.41	1.05	56.4%	1.16	0.61	-47.7%
Period Average	0.69	0.70	-2.6%	7.66	9.22	-20.3%	4.69	5.75	-22.8%	11.63	14.83	-27.5%	6.16	7.63	-23.7%

Note a minus sign (-) means the delay was larger under SCATS control

The difference in total delay varied widely from location to location and between each of the four time periods. Table 5.2 shows that the difference in total delay ranged from an improvement of 40.0% to a deterioration of 61.5% at the Pontiac Trail and Nine Mile Road intersection. Similar wide variation occurred at the other three intersections and during the separate time periods. The difference recorded during the midnight period was smaller in terms of the absolute time values. However, the difference on a percentage basis varied significantly from one location to another. This tendency is also evident in the comparison between the various time periods. The source of this variation is likely the adaptive nature of SCATS control. The signal timings in the SCATS system change according to the changes in traffic demand. Correspondingly, the delays under SCATS are expected to be different from those under fixed time control during periods of fluctuating demand. Thus, the wide variation in the delay differences between the two systems is consistent with the differences in the control strategies.

5.2 Approach Delay

The strategy used to analyze approach delay was similar to that used for the analysis of total intersection delay. They both incorporated statistical and non-statistical procedures to analyze the differences between the various locations and time periods, as well as the internal differences within an individual location and time period. The primary difference between the two was the increase in the amount of data in the approach delay sample. Since the approach delay data set was larger, additional comparative analyses were required to assess the interrelationships between the various data sub-groups.

The first set of analyses were conducted to determine if, from a statistical standpoint, SCATS was able to lower approach delay. Other comparisons were completed using data averaging techniques. The following sections detail the methods used to conduct the analyses, the outcomes of the comparisons, and their interpretations and conclusions.

Paired t-tests were used to determine the difference between the fixed time and SCATS approach delay data sets. The difference in approach delay was calculated at each location, during each analysis period for the week of data collection, including all critical turning movements at the intersections. This resulted in a comparison sample set of 480 trials. Values for the mean, variance, and standard deviation for each data group were calculated for each of the four analysis periods. To test the statistical significance of these findings hypothesis tests were conducted for each of the four analysis periods. The results of the paired t-tests are shown in Table 5.3.

Overall, the mean difference in the approach delay for all turning movements was 1.59 seconds per vehicle lower in the SCATS control environment. A rejection region at a 95% level of significance was used to test the "no change" null hypothesis. The values for the null hypothesis test statistic (1.98) and observed value oft for the overall approach delay data set (2.49) are shown in Table 5.3. Based on these values the null hypothesis can be rejected and we can conclude the observed decrease in overall approach delay resulting from the implementation of SCATS in South Lyon is statistically significant.

To determine the difference in approach delay for the four separate analysis periods four additional t-tests were conducted. The mean values for the difference in delay for each of the four analysis

Table 5.3 Statistical Comparison of Approach Delay

South Lyon SCATS Delay Evaluation Study Difference in Average Approach Delay, May 6th - 10th 1996					
	12:00 am - 1:00 am	7:00 am - 8:00 am	12:00pm - 1:00 pm	5:00 pm - 6:00 pm	Overall
Mean	1.34	1.71	0.90	2.40	1.59
Variance	32.85	284.35	120.09	344.51	195.75
Standard Deviation	5.73	16.86	10.96	18.56	13.99
Sample Size	120	120	120	120	480
Hypothesis Test					
critical value of the t-distrib.	1.98	1.98	1.98	1.98	1.98
observed value oft	2.56	1.11	0.90	1.42	2.49
	REJECT the Null Hypothesis @ 0.05	**DO NOT REJECT Ho @ 0.05**	**DO NOT REJECT Ho @ 0.05**	**DO NOT REJECT Ho @ 0.05**	**REJECT the Null Hypothesis @ 0.05**

periods are also shown in Table 5.3. The mean difference and confidence interval data support the conclusion that the difference in the delay was not due to chance during three of the four data analysis periods. The noon hour analysis period was the only time segment where the difference in delay fell within the range of random variation. The average difference in delay between the fixed and adaptive control modes from 12:00 p.m. to 1:00 p.m. was 1.34 seconds. The morning, noon, and evening periods all showed an improvement in the average approach delay but the difference was not statistically significant during these periods.

As an additional measure of comparison, the percentage difference in the weekly average approach delay statistics for each critical movement was also determined. Tables 5.4a, 5.4b, 5.4c, and 5.4d present the results of this comparison. Similar to the percentage change comparison of total delay, the delay difference was computed by subtracting the SCATS delay value from the fixed delay value and dividing that difference by the fixed delay. Overall, the tables show that the use of SCATS control resulted in a lower average approach delay during all four analysis periods. The greatest improvement occurred during the two highest daily volume periods.

At the Pontiac Trail/Nine Mile Road intersection the primary through volume movements are northbound and southbound. Table 4.4f shows that the weekly average total of the east and westbound through volumes are a quarter of the averaged north-south through movement total. As such, the SOAP optimization strategy allocated a shorter green phase length to the east-west movements. The fixed time model used a green phase length of 58 seconds for the north-south through movement and 20 seconds for the east-west through movements. This difference, approximately 35%, is roughly proportional to the difference in volume ratios. The resulting average delays were very different.

As shown in Table 5.4b, the approach delay under fixed time control ranged from a minimum average of 8.1 seconds for the northbound through movement to 75.1 seconds for the westbound through movement. The approach delay for the same movement under SCATS control were 18.1 seconds and 53.7 seconds. While a sizeable difference between the two delays was apparent under both control strategies, the difference in SCATS was only about 50% as much as optimized fixed time operation. Table 5.4 shows that the average approach delays for the six critical approach movements averaged 67 seconds per vehicle in optimized fixed time mode and only 36 seconds per vehicle in SCATS mode. From this we see that the approach delays in SCATS are more equally distributed.

The advantage to the optimized fixed strategy was that it resulted in a reduction in overall intersection delay. However, the significance of the a more equalized distribution of delay is substantial. The northbound delay was approximately doubled in the adaptive control mode. While the increase sounds substantial, it was only increased by 10 seconds. During a trip of fifteen minutes, the additional 10 seconds of delay would be barely perceptible. The delay savings to the minor street traffic would be significant. The difference in modeled average delay for the westbound through movement was almost 21 seconds per vehicle. This three minutes would result in a 21% increase in travel time in the same fifteen minute trip. Even greater savings would be realized if the trip were to traverse a series of SCATS adaptive controlled intersections. The same effect, with varying levels of success, can be seen at the other intersections within South Lyon.

Table 5.4a Percentage Comparison of Approach Delay

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Ten Mile Road

Week of 5/6/96 through 5/10/96 -Dally Average

Intersection	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm			Daily Average		
	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)
	"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control	
Northbound Through	5.8	10.8	-86.2%	33.2	45.9	-38.3%	16.7	31.0	-85.6%	38.5	50.4	-30.9%	23.6	34.5	-46.6%
Northbound Left Turn	4.4	8.7	-97.7%	32.2	27.7	14.0%	30.8	36.1	-17.2%	50.7	39.3	22.5%	29.5	28.0	5.3%
Southbound Through	5.6	12.6	-125.0%	22.5	38.9	-72.9%	18.7	37.8	-102.1%	56.2	71.2	-26.7%	25.8	40.1	-55.8%
Southbound Left Turn	5.6	10.0	-78.6%	63.6	34.3	46.1%	24.3	29.2	-20.2%	52.2	47.6	8.8%	36.4	30.3	16.9%
Westbound Through	40.7	29.0	28.7%	76.7	33.4	56.5%	43.7	40.4	7.6%	57.5	76.7	-33.4%	54.7	44.9	17.9%
Westbound Left Turn	18.1	13.5	25.4%	52.9	38.2	27.8%	31.7	24.5	22.7%	30.9	33.2	-7.4%	33.4	27.4	18.1%
Eastbound Through	31.4	26.2	16.6%	38.4	52.6	-37.0%	31.0	28.2	9.0%	29.5	32.5	-10.2%	32.6	34.9	-7.1%
Eastbound Left Turn	17.6	15.4	12.5%	38.7	31.3	19.1%	50.0	29.3	41.4%	60.5	46.9	22.5%	41.7	30.7	26.3%
Period Average	16.2	15.8	2.3%	44.8	37.8	15.6%	30.9	32.1	-3.9%	47.0	49.7	-5.8%	34.7	33.8	2.5%

Table 5.4b Percentage Comparison of Approach Delay

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Nine Mile Road

Week of 5/6/96 through 5/10/96 -Dally Average

Intersection	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm			Daily Average		
	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)
	"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control	
Northbound Through	4.1	1.9	53.7%	8.1	18.1	-123.5%	9.5	13.6	-43.2%	25.2	13.6	46.0%	25.2	50.5	-100.4%
Northbound Left Turn	3.2	3.3	-3.1%	57.6	35.3	38.7%	27.3	18.9	30.8%	34.0	18.9	44.4%	34.0	31.3	7.9%
Southbound Through	4.0	2.1	47.5%	21.2	38.7	-82.5%	11.4	18.2	-59.6%	11.4	18.2	-59.6%	11.4	28.3	-148.2%
Southbound Left Turn	0.4	0.4	0.0%	35.0	19.7	43.7%	15.3	15.6	-2.0%	15.3	15.6	-2.0%	85.6	37.6	56.1%
Westbound Through	24.4	22.1	9.4%	31.0	27.5	11.3%	29.9	28.5	4.7%	29.9	28.5	4.7%	28.1	29.5	-5.0%
Eastbound Through	46.1	31.8	31.0%	75.1	53.7	28.5%	44.1	38.6	12.5%	44.1	38.6	12.5%	53.0	45.1	14.9%
Period Average	13.7	10.3	25.1%	38.0	32.2	15.4%	22.9	22.2	3.0%	26.7	22.2	16.6%	39.6	37.1	6.3%

Table 5.4a Percentage Comparison of Approach Delay

South Lyon SCATS Delay Evaluation Study
Intersection of Pontiac Trail and Eleven Mile Road

Week of 5/6/96 through 5/10/96 -Dally Average

Intersection	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm			Daily Average		
	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)
	"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control	
Northbound Through	3.6	6.3	-75.0%	6.6	10.1	-53.0%	4.1	7.0	-70.7%	7.2	9.5	-31.9%	5.4	8.2	-53.0%
Northbound Left Turn	1.5	1.7	-13.3%	9.8	11.0	-12.2%	3.6	2.9	19.4%	11.8	12.5	-5.9%	6.7	7.0	-5.2%
Southbound Through	3.5	6.1	-74.3%	6.3	8.9	-41.3%	4.2	7.9	-88.1%	6.9	10.1	-46.4%	5.2	8.3	-57.9%
Southbound Left Turn	1.6	1.7	-6.2%	10.0	7.7	23.0%	5.2	6.2	0.0%	12.9	14.1	-9.3%	7.7	7.4	3.3%
Westbound Through	36.8	30.1	18.2%	68.3	54.7	19.9%	69.9	40.1	42.6%	88.2	58.2	34.0%	65.8	45.8	30.4%
Eastbound Through	24.5	20.8	15.1%	31.2	30.1	3.5%	40.1	33.8	15.7%	48.4	41.5	14.3%	36.1	31.6	12.5%
Period Average	11.9	11.1	6.7%	22.0	20.4	7.3%	21.4	16.3	23.6%	29.2	24.3	16.8%	21.1	18.0	14.6%

Table 5.4b Percentage Comparison of Approach Delay

South Lyon SCATS Delay Evaluation Study
Intersection of Reynold Sweet Parkway and Ten Mile Road

Week of 5/6/96 through 5/10/96 -Dally Average

Intersection	12:00 am – 1:00 am			7:00 am – 8:00 am			12:00 pm – 1:00 pm			5:00 pm – 6:00 pm			Daily Average		
	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)	Ave. Intrsctn Delay (sec)		Percent Change (Decrease)
	"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control		"Optimized" Plan	SCATS Control	
Westbound Through	2.0	0.2	90.0%	5.2	0.8	84.6%	4.4	0.8	81.8%	9.9	2.0	79.8%	5.4	1.0	82.3%
Westbound Left Turn	0.0	0.0	0.0%	13.6	9.7	28.7%	7.7	4.6	40.3%	11.5	6.7	41.7%	8.2	5.3	36.0%
Eastbound Through	2.0	0.2	90.0%	7.0	5.4	22.9%	4.2	3.5	16.7%	5.7	4.8	15.8%	4.7	3.5	26.5%
Northbound Left Turn	0.0	0.0	0.0%	30.5	49.9	-63.6%	38.0	48.1	-26.6%	74.3	53.4	28.1%	35.7	37.9	-6.0%
Period Average	1.0	0.1	90.0%	14.1	16.5	-16.9%	13.6	14.3	-5.0%	25.4	16.7	34.0%	13.5	11.9	12.0%

5.3 Delay Data Comparison Conclusions

In this chapter the delay resulting from SCATS real-time adaptive control and fixed time traffic control in South Lyon were compared. The two types of delay that were analyzed were the total intersection delay and the average approach delay. While these two methods of delay measurement are similar in some respects, they are quite different in the manner in which they assess delay. It is because of these similarities and differences that an apparent contradiction exists in the experimental outcome.

The overall conclusion of the study was that approach delay was lower with SCATS control while total intersection delay increased. The overall increase in total delay was 1.46 vehicle hours. However, the overall decrease in approach delay under SCATS control was 1.59 seconds per vehicle. The reason the apparent conflict arises is that total delay at an intersection is a weighted sum of the constituent approach delays. The experimental results showed that while total delay increased, the average approach delay decreased.

The objective of SCATS is to balance the degree of saturation on the approach legs of an intersection, not to minimize total intersection delay; although this often occurs. It is possible to increase one while decreasing the other. The data showed this to have been the case in South Lyon. The data also showed that in many cases both total and approach delay was lower under SCATS control. However, the longer delay at a small number of locations and time intervals, when multiplied by the volume on these approaches, was enough to raise the overall delay.

6.0 Summary and Conclusions

The purpose of this study was to document the difference in traffic delay in the South Lyon, Michigan traffic network resulting from the installation of a SCATS traffic control system. Computer analysis techniques were used to model and evaluate the effect of real-time adaptive traffic control. The study demonstrated some of the limitations in the existing delay models and the need for the development of more sophisticated modeling techniques to more effectively assess the merits of real-time adaptive traffic signal control.

A predictive delay model was developed using a combination of the Webster and TRANSYT delay equation to assess the delay conditions after SCATS was operational in South Lyon. The added dimension of this new model was its ability to read a SCATS output file and compute the resulting approach delay on a cycle-by-cycle basis. Separate models were coded to represent delay conditions at four South Lyon intersections during four different time periods of the day. The modeled delay output data was also compared to field data recorded in South Lyon after the activation of the SCATS control system. The comparison of modeled and field data showed that the model represented a reasonably close match to the field conditions.

To determine the extent to which the ability of SCATS to adapt the signal timing on a cycle by cycle basis contributed to the difference in delay, the results of the model were compared to a theoretical optimized fixed time plan. This plan used the total hourly volume from SCATS to determine the signal timing plan that would have produced the minimum total delay over that hour under the assumption that these volumes were equally divided across the number of cycles in the hour.

Obviously this system could not be implemented in practice since it uses future volumes to determine the present signal timing plan.

If the day to day volumes are not too variable, this simulated system will approximate a **system** which is adaptive hour by hour as compared to SCATS, which is adaptive cycle by cycle.

Various statistical comparisons of the data sets highlighted the differences which resulted from the simulation of SCATS and a fixed time system. These comparisons showed that adaptive control resulted in an improvement to the performance measures under certain conditions. The comparison showed that the SCATS controlled signals produced a 27.6 second per vehicle savings in the average approach delay for the 24 critical approaches in the South Lyon road network. The most significant improvement occurred at the Ten Mile Road/Reynold Sweet Parkway intersection. The comparative analysis also showed that SCATS resulted in 1.46 additional vehicle hours of delay in the system. However, this difference was not statistically significant.

6.1 Conclusions

The most obvious and direct conclusion which can be drawn from this study is that the use of SCATS resulted in an improvement to the average approach delay in South Lyon when compared to the existing system. However, the improvement was not universal. The amount of improvement varied, with the largest improvement occurring when traffic volumes are below capacity.

The second conclusion is that the average total intersection delay, on a system wide basis, was greater under SCATS control than the simulated system. This is not surprising since the objective of SCATS is to equalize saturation flows rather than to minimize total intersection delay. This increase, was also not universal, as three of the four intersections experienced a lower delay. However, the significant increase in delay at the Pontiac Trail/Nine Mile Road intersection lowered the overall system performance.

The third conclusion was that SCATS more equally distributes average approach delays to the various approach movements. This is consistent with the SCATS control objective in which the approach degrees of saturation are equalized. As a result of the redistribution of delay SCATS appeared to be more effective at reducing overall delay during low volume periods compared to high volume periods. While a reduction of delay during high volume periods is more critical to the overall efficiency of a traffic signal network, it is considerably more difficult to obtain through adjustments in signal operation.

The comparison of delay in South Lyon has been addressed in this study. However, the question of whether or not similar outcomes could be expected in other networks is difficult to answer. The traffic volumes within the South Lyon road system are relatively low compared to those found in the other more congested suburbs in Oakland County. The results of the study indicate that SCATS improved total intersection delay most significantly during lower flow periods. Thus, in areas where the traffic volumes approach or operate above capacity, real time adjustment to signal timings may not enhance the operation of the network to a measurable degree. The delay experienced in these situations is not the result of poor signal timings, rather, it results from a lack of capacity provided by the approach geometry or the network road segments.

The contribution of SCATS can not be discounted during all high demand periods. In high volume situations where heavy traffic volumes are moving primarily in one direction, a real time adaptive control system has some definite advantages. Among other features, systems like SCATS allow the implementation of coordinated progression on the major arterial street. The major street green phases are interrupted only when minor street traffic is present.

6.2 Future Research Needs

This study has taken another step toward the use of more comprehensive and sophisticated simulation techniques to model adaptive signal control systems. While useful by itself, this study has also identified a number of needs and questions relating to the modeling of larger and more complex systems and the comparative assessment of alternative traffic control strategies; including real-time adaptive, actuated, and fixed time.

The most obvious area of need to forward the knowledge into the analysis of adaptive control systems is currently under development. The TRAF-NETSIM simulation system is the most widely used network simulation package. Unfortunately, it does not yet permit the simulation of adaptive control systems. The Federal Highway Administration awarded contracts to incorporate a communication architecture into NETSIM that permits the simulation of adaptive traffic control. The goal of this research is the creation of a modeling system capable of relaying traffic information to an external traffic control routine on a real time basis. The control routine could be modified to permit the use of any signal control algorithm, including SCATS. All currently available NETSIM output statistics and MOE information including delay, travel time, and stops could be collected for a proposed system. In contrast to the procedure used in this study, the proposed NETSIM system would also be able to model the effect of varying driver behavior, lane blockages, transit systems, on-street parking and pedestrian movements. Unfortunately, the operational version of this system remains years away.

The results of this study could also be used to make improvements to the existing SCATS control algorithms. The study showed that under SCATS total intersection delay was up to 3.2 vehicle hours higher during certain time intervals than a simulated optimal fixed time system. Further refinements of the cycle, phasing, and coordination selection algorithms, coupled with this testing procedure could be used to analyze methods to increase signal efficiency.

Another logical extension of using the real-time adaptive signal control modeling techniques is their incorporation into combined models of adaptive signal control with real-time incident detection and route guidance structures. Truly effective traffic responsive traffic systems need to include the ability to adapt to fluctuations in travel demand conditions. Systems with the ability to detect an incident, then implement signal control changes and route guidance in response to the incident would be very useful. The use of advanced simulation modeling techniques accompanied by the incident producing capability of NETSIM or route guidance algorithms could be used to test proposed ITS systems prior to full scale field trials.

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