CALIFORNIA PATH PROGRAM
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test: Introduction and Task A: Evaluation of SCOOT Performance

James E. Moore, II, R.Jayakrishnan, M.G. McNally, C. Arthur MacCarley

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Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test: Final Report

Introduction & Task A: Evaluation of SCOOT Performance

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July 1999

EVALUATION OF THE ANAHEIM
ADVANCED TRAFFIC CONTROL SYSTM FIELD OPERATIONAL TEST

FINAL REPORT

Introduction & Task A: Evaluation of SCOOT Performance

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July 1999

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Task A: Evaluation of SCOOT Performance

ACKNOWLEDGMENTS

The independent evaluation of the Anaheim Advanced Traffic Control System Field Operation Test is summarized in three volumes, corresponding to the three primary evaluation tasks. The principal authors of this Task A report, Evaluation of SCOOT Performance, are James E. Moore, II and R. Jayakrishnan. Significant contributions, however, were made by all members of the Evaluation Team, particularly graduate research assistants Seongkil Cho, His-Hwa Hu, and Steven P. Mattingly. The primary authors of the Task B report, Evaluation of Institutional Issues, are Michael G. McNally and Stephen P. Mattingly. The primary author of the Task C report, Video Traffic Detection System Evaluation, was C. Arthur MacCarley.

The authors acknowledge the support of the Federal Highway Administration of the U.S. Department of Transportation, the California Department of Transportation (Caltrans), and the California PATH program. In particular, we wish to acknowledge the support of Frank Cechini of FHWA, Richard Macaluso of Caltrans, and Robert Tam of PATH. We would also like to acknowledge the support and assistance of all the individuals associated with the firms and agencies who participated in this project, particularly, Keith Jasper of Booz Allen & Hamilton. The statements and conclusions of this report are those of the Evaluation Team and do not necessarily represent those of FHWA, Caltrans, or PATH.

EVALUATION OF THE ANAHEIM
ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST

Task A: Evaluation of SCOOT Performance

ABSTRACT

This report provides an overview of the federally-sponsored *Anaheim Advanced Traffic Control System Field Operations Test*, and of the technical issues associated with the evaluation of SCOOT performance during this test. The primary FOT objective was the implementation and performance evaluation of adaptive traffic signal control technologies including an existing second generation approach, SCOOT, and a 1.5 generation control (1.5GC) approach under development. Also selected for implementation was a video traffic detection system (VTDS). The SCOOT evaluation was defined relative to existing, first generation UTCS-based control but using standard field detectorization rather than that normally associated with SCOOT. Furthermore, SCOOT was installed to operate in parallel to UTCS. The 1.5GC system was planned to be efficiently utilized to update baseline timing plans. The VTDS was planned for use as a low cost system detector for deployment in critical areas.

Both SCOOT and the VTDS were implemented with some degree of success, with technical and institutional issues limiting expected performance. Technical issues that limited SCOOT performance included existing communication and controller systems of lower quality than anticipated. Corresponding institutional factors included inconsistent project management due to staff changes and delays due to contractual issues. Both SCOOT and a modified version of the VTDS are in current use in selected areas, with plans for system expansion.

This evaluation report summarizes an introduction to the project, the evaluation objectives for Tasks A and B, and Task A of the three part evaluation project. Separate reports summarize Tasks B and C, assessment of institutional issues and the advanced Video Detection Systems, respectively

EVALUATION OF THE ANAHEIM
ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST

EXECUTIVE SUMMARY

A systematic evaluation of the performance and effectiveness of a Field Operational Test (FOT) of a Advanced Traffic Control System was conducted from fall 1994 through spring 1998 in the City of Anaheim, California. The FOT was conducted by a consortium consisting of the California Department of Transportation (Caltrans), the City of Anaheim, and Odetics, Inc., a private sector provider of advanced technology systems, with the City of Anaheim as the lead agency. The FOT was cost-share funded by the Federal Highway Administration (FHWA) as part of the Intelligent Vehicle Highway System (IVHS) Field Operational Test Program. The FOT involves an integrated Advanced Transportation Management System (ATMS) which extends the capabilities of existing arterial traffic management systems in the City of Anaheim. The evaluation entailed both a technical performance assessment and a comprehensive institutional analysis.

The City of Anaheim has a population of 300,000 and 150,000 jobs within an area of nearly 50 square miles. Four major event centers with a combined maximum attendance of 200,000 and 15,000 hotel/motel rooms are located within a 3 square mile area of the City. An urban area such as Anaheim has many signalized intersections and short road links, with intersection delay being a significant problem. Speeds or travel times in such urban areas are dominated by queue delay at intersections rather by delays associated with midblock cruising. Further, Anaheim's arterial street system is often impacted in unpredictable ways due to special event traffic and to ongoing expansion of the City's Convention Center, construction of a new Disney theme park and hotels, and widening of Interstate 5.

The arterial traffic control systems planned for implementation, 1.5GC and SCOOT, respectively represent a partial automation of existing UTCS (Urban Traffic Control System) control and the separate installation of an adaptive traffic control system as an independent control option. Since 1.5GC maintains the existing control system and algorithms, the key evaluation issue involved an assessment of the man-in-the-loop operational format more so than a direct assessment of technical feasibility. Similarly, SCOOT has been installed and evaluated in numerous locations throughout the world, thus, the key evaluation issues involve the limited implementation of SCOOT as an option of Anaheim Traffic Management Center operations, the development of operational policies for SCOOT operation, and the resultant operational effectiveness for defined scenarios (particularly for special events). The third technology, the VTDS, was planned as a low cost alternative to existing video detection systems. Its performance would be measured in terms of it's capability to replace inductance loop detectors currently utilized.

Project evaluation was divided into three tasks:

A evaluation of SCOOT performance,

B assessment of institutional issues, and

C evaluation of the VTDS.

Only an Introduction and Task A are summarized here. See the separate task reports and the consolidated Executive Summary documents for further information.

Evaluation Task A1: SCOOT's Internal Representation of Traffic Flow

Lead Evaluator: James E. Moore, II, University of Southern California

Context

The SCOOT (Split, Cycle and Offset Optimizer Technique) adaptive traffic control system was developed in the United Kingdom by three companies, Ferranti, GEC, and Siemens, under the supervision of the Transportation Road and Research Laboratory (TRRL), and is employed extensively in Great Britain. SCOOT is intended to control the operation of systems of signals rather than isolated intersections. The SCOOT traffic model uses data that varies over time, such as the green and red time of the signal and vehicle-presence measurements, together with data that are fixed for the area under control, such as the detector locations, signal stage order, and a variety of other parameters. The SCOOT system collects traffic data from induction loop detectors embedded in the pavement of intersection approaches. The SCOOT system uses this data to project conditions in the form of Cyclic Flow Profiles (CFP), simulating traffic characteristics (stops, delays, flows and queue length) downstream from the detectors. SCOOT's split, cycle and offset optimizers (locally) optimize signal timing by searching for improvements in terms of the CFP. This makes the quality of SCOOT's internal representation of real traffic conditions pivotal to its ability to optimize signal timings. If SCOOT is able to model traffic conditions accurately, then it may also be able to improve these conditions. However, SCOOT cannot function if it cannot model intersection conditions.

Theoretically, the benefits of SCOOT should be highest when traffic flow is heavy, complex, and unpredictable. In the best case, SCOOT both delays the onset of congestion, and provides early relief from congestion. In unsaturated networks, under certain conditions, SCOOT can prevent congestion by delaying it long enough to permit a short duration demand overload to be completely overcome by appropriate adjustments in supply.

The Anaheim Implementation

The core traffic control measure deployed for the Anaheim Advanced Traffic Control System Field Operation Test (FOT) consists of implementation of the SCOOT system, making possible adaptive optimization of traffic flow across subareas of the Anaheim network. A version 3.1 SCOOT system was installed by Siemens for the City of Anaheim network near Arrowhead Pond and Anaheim Stadium, two large special event facilities.

The quality of SCOOT implementation and performance are each constrained by the system's ability to represent traffic conditions at intersections. Anaheim has existing system detectors that are located upstream of the intersection being controlled, at approximately mid-block locations. These system detectors can provide traffic volume counts for use by SCOOT. However, SCOOT is designed to rely on detectors that are located further away from the intersection being controlled. SCOOT detectors are usually locations just downstream of intersections upstream from the intersection being controlled.

The FOT proposal hypothesizes that the existing infrastructure will be adequate for SCOOT implementation; however, there is no certainty that the existing infrastructure will provide optimal (or even acceptable) results. This evaluation investigates SCOOT's ability to represent traffic conditions on approaches given the existing detector pattern. Evaluation Task A.1:

1. assesses the value of Anaheim's existing UTCS inductive loop detectors as effective data sources for SCOOT, and

2. assesses the quality of SCOOT's internal representation of traffic conditions.

Full evaluation of the constraints associated with using nonstandard detector information would require installing upstream loops in a standard SCOOT configuration in addition to existing mid-block detectors, and then comparing SCOOT's operation with different sets of detectors. A fully detectorized installation is not feasible. Consequently the impact of using mid-block detectors is combined with the treatment effects associated with SCOOT.

Our null hypothesis is that SCOOT does not accurately represent traffic conditions at intersections. Rejecting this null hypothesis provides statistically significant evidence that the SCOOT system does indeed meet this necessary condition for improving traffic conditions. It is impossible for SCOOT to meet sufficient conditions for improvements unless this necessary condition has been met. However, necessary conditions might be met even if sufficient conditions are not. Meeting necessary conditions without also meeting sufficient conditions is an inconclusive outcome that leaves open the possibility that SCOOT can provide improvements, but did not because of reasons that might be changed.

Field Observation

A pair of traffic data sets is used to test the quality of SCOOT's representation of intersection conditions. The first is directly from the SCOOT model, provided by collecting loading message reports from the SCOOT system. The second data set consists of empirical field observations, provided by post-processing video tapes of conditions on approaches to intersections subject to SCOOT control. SCOOT model messages provide information regarding how SCOOT assesses traffic conditions of the road network. Estimates of queue length and queue clearance time can be compared with conditions recorded on video. During data collection, a graduate research assistant working in the Anaheim Transportation Management Center (TMC) carefully coordinated the estimated values reported in SCOOT messages with real time videotapes of traffic conditions recorded via TMC cameras.

A real time display of the traffic conditions estimated by SCOOT can also be invoked via SCOOT's Node Fine Tuning Display (NFTD). The NFTD command reports the times at which all approaches to a given intersection begin the green phase, shows the queue length when an approach is green, and the associated queue clearance time. By comparing real time green starts and queue clearance times reported by SCOOT to real time video images, large inconsistencies were identified at some intersections.

Internal Representation Results

As a result of cumulative communication or other system faults, these intersections were unexpectedly being isolated from SCOOT control. In most cases, these faults can be cleared manually, but this requires active intervention on the part of the operator. If faults are actively cleared rather than being permitted to accumulate, the signals involved usually remain under SCOOT control. The number of signals slipping from SCOOT control decreased substantially once Anaheim TMC operators were notified of the need to clear faults as they occurred. This produced substantial data loss for this portion of the evaluation, because SCOOT message data associated with signals subject to cumulative communication faults are meaningless. The conditions reported in such messages diverge from conditions observed via video. As a result, seven of the ten hours of data collected in the Anaheim TMC could not be used because of cumulative SCOOT system errors or related communications problems. The three hours of data remaining still provide statistically significant results. Correlation coefficients between the SCOOT message data and the videotape data were estimated for stops, delays, flows, queue length, and queue clearance times. If the SCOOT system is accurately representing traffic conditions on approaches, then the correlation coefficient between the SCOOT message data and the video data will tend toward unity.

The overall correlation coefficient of 0.86 was estimated between observed flows and flows reported in SCOOT system messages. Coefficients for other traffic indicators are lower, but this is to be expected, because these other measures are derived from flow measures and additional modeling steps are likely to introduce more errors into the values appearing in SCOOT messages. The estimated correlation between observed and SCOOT measures of intersection delay. 0.65, was the lowest value obtained. Approach delay is also more difficult to compute from video observations than the other quantities. The estimated correlation coefficients for observed stops, queue length, and queue clearance times fall between these values. These are aggregate estimates combining data for three intersections. Estimates for individual intersections have more variance, producing some values above and below this interval.

Evaluation Conclusions Relative to SCOOT's Internal Representation of Traffic Flow

In all cases, it is both qualitatively and quantitatively clear that the data provided by the SCOOT messages covaries moderately to strongly with the data extracted from video tapes. In all cases, the null hypothesis of no relationship between the information in the SCOOT messages and the flows captured on videotapes is strongly rejected. However, the estimated correlation coefficients observed in Anaheim are lower than values obtained in other locations where SCOOT has been deployed. A pre-version 2.3 SCOOT installation in Leicester, England, produced a correlation coefficient of 0.93 for flows, subsequently improved to 0.96 (Martin, 1992). The Anaheim results are most likely a function of nonstandard detector locations. While SCOOT successfully modeled traffic conditions on the intersection approaches observed during the data collection period, there is room for improvement. Improvements could be generated either by changing the locations of detectors, or possibly by adjusting SCOOT's global control settings to try and further compensate for the effect of nonstandard detector locations.

Evaluation Task A2: Traffic Performance under SCOOT

Lead Evaluators: R.Jayakrishnan and M.G. McNally, University of California, Irvine

James E. Moore, II, University of Southern California

Context

This component of the Task A technical evaluation focuses on the performance of the identified anaheim sub-network under SCOOT, in terms of delays at the intersections, as well as running times, stop times, and total times on selected routes in the SCOOT network. A standard "before-after" format was adopted focused on traffic conditions in the PM-peak and evening off-peak both during special events and during non-event traffic conditions.

Field Observation

The Field Observation Plan utilized delay measurement teams posted at intersections and travel time measurement teams driving on specified routes. Ten observation periods were selected for the before study (utilizing existing UTCS control) and ten subsequent observation periods were selected for the after study under SCOOT operation.

Intersection delays were measured at specified times including some measurement periods during the peak (PM) and off-peak (evening) conditions. Resource limitations prevented full-time measurements at all intersections. Intersection delays were calculated by counting the stopped cars at small sample intervals, accumulating totals, and multiplying by the sample interval. The delays were not disaggregated for each turning movement.

Routes for the floating-car travel time studies were selected to obtain a reasonable coverage of the network with sufficient turning movements to capture delay patterns. Five routes were selected, with one being a control study network away from the SCOOT network to capture any unrelated travel pattern or demand variations. Floating car measurements were made for running, stopped, and total travel times by using one driver and one observer in each car. The observers used stop watches and observed times were aggregated and averaged for each route for each observation day.

Traffic Performance Results

The results focused on SCOOT performance under peak and off-peak conditions, under special event and no-events scenarios, and under various ranges of traffic volumes. Key insights derived from the intersection delay analysis include:

1. Based on intersection delays, the SCOOT system in general performed better under off-peak conditions than under peak conditions.

2. Based on intersection delays, the relative performance of SCOOT in comparison to the baseline system improves under special-event conditions compared to no-event conditions for smaller volume intersections, although the reverse occurred for some higher-volume intersections.

3. Based on intersection delays, SCOOT definitely performed very well at two intersections getting heavy exit traffic from the special event location.

4. The SCOOT system produced lower intersection delays in some cases, and higher delays in some cases (but higher delays more frequently), compared to the baseline system. As such there is insufficient evidence to show that it performs significantly worse or better than the baseline system in peak-periods.

5. In cases where SCOOT performed worse than the baseline system relative to intersection delays, the worsening was rarely more than 10 percent; in cases where SCOOT performed better, improvements were normally less than 5 percent.

6. In most cases, delays are comparable between SCOOT and the baseline system. In the few cases where SCOOT performed noticeably worse, special circumstances associated with the project are believed to be contributing reasons.

   The high-volume Katella and State College intersection is a case in point. The delays under SCOOT were lower for three of the four approaches (generally a delay reduction between 4 and 8 percent); however, the overall delay was higher than the baseline case, because one approach was showing delay increases up to 60 percent in the peak period. Further consultation with the City revealed that the parameters were likely set non-ideally. Note that this problem is addressed in the institutional evaluation and perhaps could have been avoided had project management, training, and overall project delays not limited operational experience prior to evaluation.

   Another example of the worsening of results occurred at the low-volume intersection at Cerritos and Sunkist, where strikingly high delays resulted under

SCOOT. Further examination suggests that the reason is the incorrect inclusion of this intersection as part of the SCOOT system. The volumes were very low at the intersection, however, it was included in the system as part of the project requirements, since it is an intersection that receives special event exit traffic for short periods. The SCOOT vendor indicated that it would normally not be included in the SCOOT system, as it forces a common signal cycle length which is not appropriate for the intersection, thus causing excessive delays.

7. The SCOOT system, despite the substandard implementation, did not cause any unacceptably higher intersection delays and did not cause any catastrophic problems in the system, while it produced delay reduction at some intersections.

   Only two situations (the likely non-ideal setting of parameters for an approach at a high-volume intersection and the inclusion in the network of an intersection with very small volumes) showed delays that may be considered unacceptable. In almost all other cases, the SCOOT system generally did not show worsening by more than 5 to 10 percent from the baseline, and in many cases showed benefits of a similar range.

8. Travel times on selected routes showed the effect of directional settings in SCOOT. A route's opposing directions which had different travel times under the baseline system showed, in one case, similar travel times under SCOOT, and the reverse in another case.

9. Route travel times under SCOOT showed reductions under 10 percent in some cases and increases under 15 percent in others. On the more circuitous, longer routes covering more of the network, SCOOT showed reductions as much as 2 percent and increases as much as 6 percent. The relative performance against the baseline system was better under no-event conditions than under special event conditions.

Evaluation Conclusions Relative to Traffic Performance Under SCOOT

SCOOT amply demonstrated that it can operate in a network with significantly non-ideal detectorization, and control the traffic in a manner that does not cause substantial and unacceptable increases in intersection delays and route travel time increases. In the case of two intersections near the special event traffic generation, the delays were definitely substantially lower than under the baseline system during the sudden traffic egress periods, pointing to SCOOT□s ability to make adaptive adjustments. It did not, however, show the kind of benefits shown by other proper implementations of SCOOT around the world, which is perhaps to be expected, considering that the performance comparisons were made against traffic under a baseline system which is considered state-of-the-art in US practice. A proper comparison with an ideally detectorized SCOOT network in Anaheim would have proved very useful, but this was not attempted in this FOT, thanks to SCOOT being accepted as a traffic control system with proven benefits at other installations. The abilities of SCOOT were possibly not fully reflected in Anaheim due also to the minimal time spent in fine-tuning the SCOOT parameters. The reason for the non-ideal fine-tuning were the project time deadlines and the City TMC staff not being fully trained in doing the adjustments within the short period before the field study was conducted. The fact that traffic still performed acceptably under SCOOT and that no serious traffic problems arose, point to SCOOT being certainly a system worth pursuing in Anaheim and other US cities. Further studies on SCOOT implementation in a more elaborate network with less peaking and special-event characteristics than Anaheim may prove beneficial in the future.

EVALUATION OF THE ANAHEIM
ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST

INTRODUCTION

Principal Author:
James E. Moore, II

1. OVERVIEW OF THE FIELD OPERATIONAL TEST AND EVALUATON

The core of the Anaheim Field Operation Test (FOT) traffic control element is the real time integration of the SCOOT (Split Cycle Offset Optimization Technique) system into the Anaheim Transportation Management Center (TMC) and traffic control system. This integration makes possible adaptive optimization of traffic flow across subareas within the Anaheim network. Evaluation Task A assesses the implementation and performance of SCOOT with an emphasis on the SCOOT system's ability to represent traffic flows, and on the quality of the resulting traffic conditions in the network.

The City of Anaheim has a population of 300,000 and 150,000 jobs within a land area of nearly 50 square miles. Four major event centers and 15,000 hotel/motel rooms are located within 3 square mile area of the City. These event centers and maximum attendance potential are listed Table 1.

An urban area such as Anaheim has many signalized intersections connected by short network links. Delay at intersections is a significant problem. Speeds or travel times in these urban areas are dominated by queue delay at intersections rather by delays associated with mid-block cruising. Further, Anaheim's arterial street system is often impacted in unpredictable ways by ongoing expansion of the City's Convention Center, construction of a new Disney theme park and hotels, and the widening of Interstate 5 by the California Department of Transportation. In view of the economic significance of the Anaheim Resort event center area, the SCOOT deployment has the potential to provide substantial benefits.

1.1 SCOOT Overview

SCOOT was developed in the United Kingdom by three companies, Ferranti, GEC, and Seimens, under the supervision of the Transportation Road and Research Laboratory (TRL) for the operation of systems of signals rather than isolated intersections. SCOOT is employed extensively in Great Britain, including the Cities of London, Oxford, Southampton, Leicester, and Glasgow. SCOOT systems have also been deployed internationally, including such diverse locations as Toronto and Beijing. Before and after tests on these systems suggest that delay reductions of about 12 % have been achieved relative to the performance of an updated, fixed time, plan based system.

Table 1: Event Centers in Anaheim, California

Event Center	Maximum Potential Attendance
Anaheim Convention Center	55,000
Disneyland	80,000
Arrowhead Pond of Anaheim	20,000
Edison International Field of Anaheim	45,000
Total	200,000

Theoretically, the benefits of SCOOT should be highest when traffic flow is heavy, complex, and unpredictable. In the best case, SCOOT both delays the onset of congestion, and provides early relief from congestion. In unsaturated networks, under certain conditions, SCOOT can prevent congestion by delaying it long enough to permit a short duration overload to be completely overcome. SCOOT's first US application occurred shortly before the Field Operational Test in Oxnard, CA.

Siemens Traffic Controls Ltd., the UK arm of Siemens' Worldwide Traffic Control Systems Group, installed SCOOT version 3.1 in the City of Anaheim as part of the FOT. The City of Anaheim uses SCOOT on the portion of their network near Arrowhead Pond and Anaheim Stadium, two large special event facilities. A nearby portion of the Anaheim network as a control area for the evaluation. Figure 1 displays the SCOOT test area. The control portion of the network is North of the SCOOT region. The control area remained under UTCS 1.0 control throughout the evaluation. Figure 2 shows the configuration of the Anaheim TMC and location of the SCOOT computer and displays.

SCOOT is based on the TRANSYT 7F model and uses the same traffic flow algorithm. The primary objective is to minimize the sum of the queue lengths in the area. This criterion is expressed in terms of a Performance Index (PI) that is used to compare alternative courses of action. SCOOT also allows users to specify performance objectives such as journey time improvement, and reductions in delay and stops.

SCOOT divides time into small intervals, usually four intervals per second. SCOOT requires upstream detectors, typically placed just downstream of the preceding intersection. These upstream detectors give advance information about approaching vehicle platoons. Using Robertson's platoon dispersion algorithm, detected platoons are dispersed to give approximate flow rates at the downstream stop line. In addition, the system may require additional detectors when there is a high flow source or sink in a mid-block position.

SCOOT simultaneously evaluates the advisability of altering the cycle offset at the intersection with respect to the master schedule by four seconds in either direction. Every five minutes, SCOOT explores the option of changing the cycle length for individual

Figure 1: Map of the Anaheim Field Operational Test and Evaluation Control Areas.

subareas, usually consisting of three to four intersections, by plus or minus four seconds. Typically, SCOOT makes about 10,000 decisions per hour for every 100 intersections in the system. All decisions are made by the central computer. In addition to using detectors to collect and use real time information about volumes and speeds to support traffic control functions, SCOOT archives this information for future use. This information is also used in dynamic graphic displays of the traffic network.

SCOOT version 2.4 was a major product upgrade that added on-line Saturation Flow Technique (SOFT) software that gathers information from vehicle detectors at intersection exits. This enables adjustment of the saturation value and improvement in SCOOT's reaction to incidents. The feedback facility provides information on the actual phases run on the street. This facilitates determination of the link green times. When SCOOT detects that saturation levels are unacceptable, SCOOT reacts with actions at a distance, i.e, with gating. Bicycle SCOOT software permits definition of bicycle-flow-only links in a SCOOT network. This version of SCOOT also has an improved method for dealing with filter links where the approaching demand flow cannot be accurately measured.

SCOOT version 3.1 contains the same features as previous versions of SCOOT, in addition to some new features. Under Siemens' SCOOT UTC system, intersections that are physically close together can have fixed offsets. The two controllers can form a single network node, or one controller can control both junctions. A phase transition allows more than one UTC phase to be allocated to a SCOOT stage. Finally, node transfer software allows the transfer of a node between two SCOOT cycle time regions.

SCOOT version 3.1 also handles bus priority. User Configurable Optimizer Authorities provide the user with control of the authority levels for the Split and Offset optimizers. The user can configure node-based target saturation levels. This version handles faulty links in an improved manner. Links with faulty detectors move towards the default stage (phase) length (DEFS).

Emergency vehicles can preempt SCOOT controllers. During preemption, the controllers continue accumulating queue lengths and other pertinent data so that optimum flow levels are achieved as soon as control is returned. Different approaches can be given different weights to bias the objective function towards favoring certain routes. Bandwidth can also be given priority, ensuring reasonable progression along major routes (Siemens *UTC Handbooks: SCOOT Handbook*). Figure 2 shows the location of the SCOOT computer and displays in the Anaheim TMC.

1.2 SCOOT Traffic Model

The SCOOT traffic model uses data that vary over time, such as the green and red time of the signal and vehicle-presence measurements, together with the fixed data for the area, such as detector locations, signal phase order, and a variety of other parameters. The dectector data stored in the SCOOT computer reveal the variation in demand during each cycle and are used during offset optimization to ensure good signal conditions.

The data described above are used to predict traffic queues, delays and stops on each link. SCOOT traffic models make these predictions according to the principles illustrated in Figure 3, which shows a typical cyclic flow profile alongside a detector and a "time now" datum that moves to the right along the profiles as time advances. Vehicles recorded at the upstream detector progress along the link according to a cruise time modified to take into account of platoon dispersion, and are added to back of any queue being modeled at the stop line. Alternatively, vehicles might proceed through the intersection on green instead of stopping. Any queue remaining at the end of green is carried over to form the initial queue length at the start of the following green. Figure 3 illustrates how SCOOT predicts the back of the queue and queue length at any point in time. The total approach delay during the cycle is equal to the area within the shaded triangle. SCOOT's objective function is a Performance Index (PI) consisting of a weighted sum of the delay and the number of stops at the intersections in the study area.

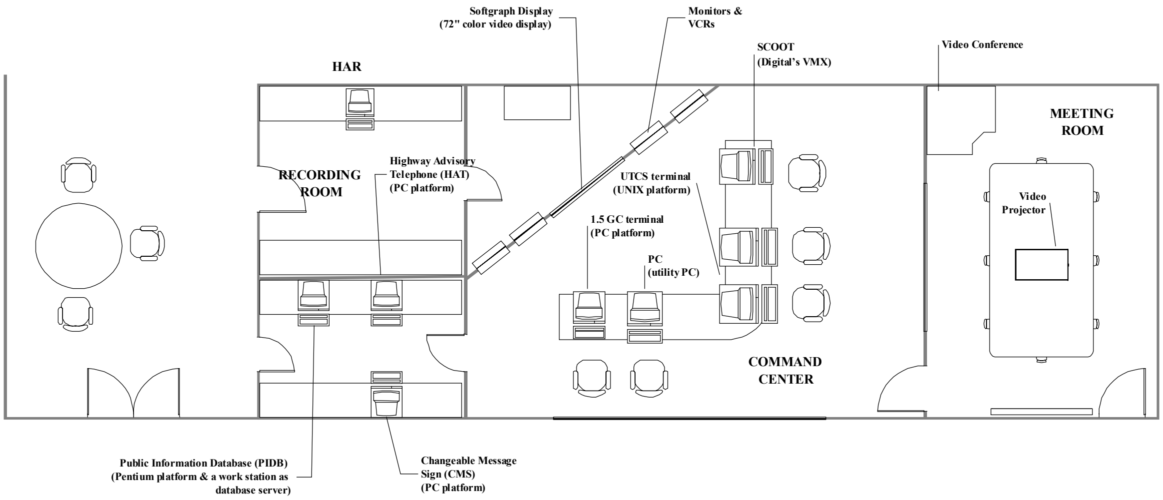

Figure 2: Organization of the Anaheim Traffic Management Center.

$$PI = \sum_{i=1}^{N} \left[W w_i d_i + \frac{k}{100} k_i s_i \right], \tag{1}$$

where N = number of links,
W = overall cost per average passenger car unit (pcu) hour of delay,
w_i = the delay weight on link i,
d_i = the delay on link i,
k_i = the stop weighting on link i, and
s_i = the number of stops on link i.

SCOOT adjusts the cycles, splits, and offsets in the control area to achieve the optimum (minimum) Performance Index.

2. EVALUATION GOALS AND OBJECTIVES

The overarching objectives of the strategies being implemented in Anaheim are to decrease the total vehicle hours traveled for any constant number of vehicle miles traveled, to improve the efficiency of the traffic system (based on several criteria), and to achieve this in an institutionally acceptable and efficient manner.

The objective of evaluating network performance is to identify technical and institutional constraints on implementation, and to quantify improvements to the maximum extent possible. This objective can be met only if the state of the network can be assessed in appropriate terms. The Anaheim network is a vector quantity with a vector state, and the changes in the vector elements should be individually and collectively examined. Ideally, the evaluators would acquire information at the level of individual travelers, including average origin-destination travel times by trip type occurring on the Anaheim network.

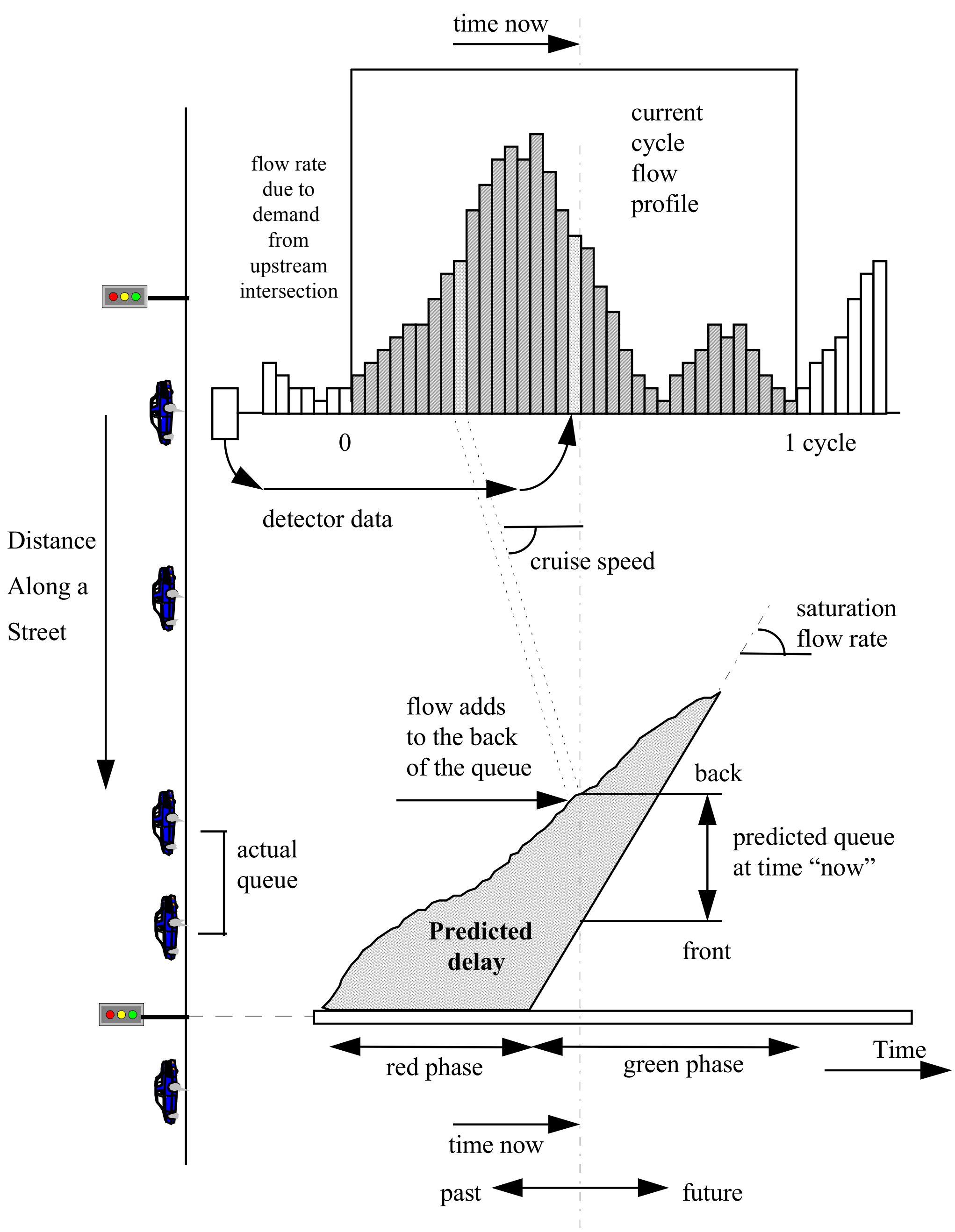

Figure 3: Graphical Summary of the SCOOT Traffic Model.

Source: Hunt P.B., Robertson D.I., Bretherton R.D., Winton R.I. (1981) "SCOOT – A traffic responsive method of coordinating signals," TRRL report LR1014, Crowthorne.

However, this is not feasible. Changes in network performance resulting from the implementation of SCOOT have been measured in terms of surveillance information provided by the system and from limited field observations such as floating car studies and intersection delay studies. Each of the evaluation goals relates to at least one of the goals in the Intelligent Transportation Society of America National Program Plan. Evaluation objectives are associated with each goal. The objectives clarify and add detail to the evaluation goals.

2.1 Goal I

The first evaluation goal addresses the national ITS goal of increasing the efficiency of ground transportation systems by increasing the capacity of existing facilities. The first goal of the evaluation is to assess the viability of SCOOT as an alternative to conventional, centrally controlled traffic control systems. In this FOT, SCOOT is installed in addition to Anaheim's existing UTCS system. The evaluation objectives for this goal are listed below. This evaluation

1) assesses problems associated with implementing SCOOT, and

2) assesses SCOOT's transferability to other agencies.

We assume that Anaheim's existing geometry and level of detectorization is sufficiently representative of a typical North American city to draw inferences about transferability.

2.2 Goal II

The second evaluation goal relates to the national ITS goal of creating an environment in which the deployment of ITS can flourish. This second goal is to assess the adaptability of the SCOOT model. This goal investigates SCOOT's ability to adapt to changes in traffic flows given the existing detector pattern.

The quality of SCOOT implementation and performance are both constrained by the program's ability to represent traffic conditions at intersections. Anaheim has existing system detectors that are located upstream of the intersection being controlled. However, SCOOT usually relies on detectors that are located downstream from intersections that are upstream from the intersection being controlled. See Figure 4. The benefits derived from traditional SCOOT detectorization schemes are documented and accepted, but SCOOT's effectiveness with Anaheim's existing infrastructure is unknown. This is the first time SCOOT has ever been installed over an existing set of loop detectors. The FOT project proposal hypothesizes that the existing infrastructure will be adequate for the implementation of SCOOT. This field operational test integrates SCOOT into the existing Anaheim infrastructure to determine its effectiveness with nonstandard detector locations and to evaluate its transferability to other existing systems. However, there is no certainty that the existing infrastructure will provide optimal (or even acceptable) results. The evaluation objectives for this goal are listed below. This evaluation

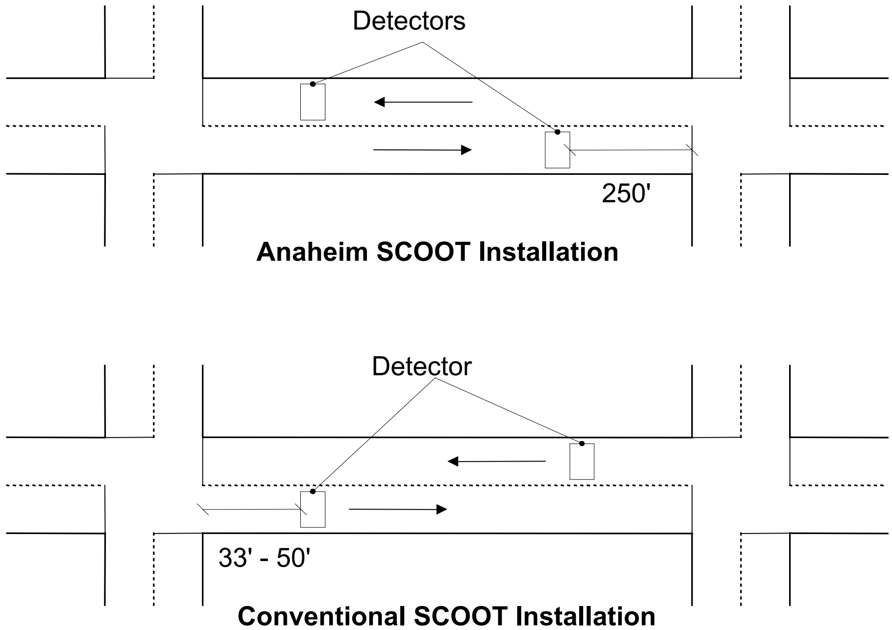

Figure 4: Anaheim and Conventional SCOOT Loop Detector Locations.

1) assesses the value of Anaheim's existing UTCS inductive loop detectors as effective data sources for SCOOT,

   - H_0: Existing UTCS loop detectors do not provide appropriate data for the SCOOT system.
   - H_1: Existing UTCS loop detectors do provide appropriate data for the SCOOT system.

2) and, assesses the quality of SCOOT's internal representation of traffic conditions.

   - H_0: SCOOT does not reflect real traffic conditions in its internal measures of effectiveness (MOEs) and related measures.
   - H_1: SCOOT's internal MOEs do accurately reflect real traffic conditions.

Full evaluation of the constraints associated with using mid-block or other nonstandard detector information to supply SCOOT with information about upstream demand requires that some test intersections be subject to redundant loop installations. This would permit the impact of nonstandard detectorization to be separated from the improvements provided by SCOOT control. This would require installing upstream loops at some intersections in a standard SCOOT configuration in addition to existing mid-block detectors, and then examing SCOOT's performance against different detector configurations. Resource constraints preclude a fully detectorized installation in the context of this FOT. Consequently, the impact of using mid-block detectors is combined with the treatment effects associated with SCOOT.

2.3 Goal III

The third evaluation goal also addresses the national ITS goal of increasing the efficiency of ground transportation systems by increasing the capacity of existing facilities. The FOT project proposal anticipates that the use of the SCOOT approach will increase the efficiency of urban traffic control operations by allowing the control system to adapt to real-time traffic conditions. The evaluation's third goal is to determine if SCOOT can indeed provide improvements given Anaheim's existing geometry and level of detectorization. The evaluation objectives for this third goal are listed below.

1) This evaluation assesses the changes in queue delays and travel times during normal traffic conditions. SCOOT improvements can be demonstrated in a statistical sense by rejecting the following set of null hypotheses and accepting the respective alternative hypotheses.

- H_0: SCOOT does not reduce travel times under nonevent, off peak conditions.
- H_1: SCOOT reduces travel times under nonevent, off peak conditions.
- H_0: SCOOT does not reduce queue delays under nonevent, off peak conditions.
- H_1: SCOOT reduces queue delays under nonevent, off peak conditions
- H_0: SCOOT does not reduce number of stops under nonevent, off peak conditions.
- H_1: SCOOT reduces number of stops under nonevent, off peak conditions
- H_0: SCOOT does not reduce travel times under nonevent, PM peak conditions.
- H_1: SCOOT doe reduces travel times under nonevent, PM peak conditions.
- H_0: SCOOT does not reduce queue delays under nonevent, PM peak conditions.
- H_1: SCOOT reduces queue delays under nonevent, PM peak conditions
- H_0: SCOOT does not reduce number of stops under nonevent, PM peak conditions.
- H_1: SCOOT reduces number of stops under nonevent, PM peak conditions

2) This evaluation should assess the changes in queue and travel times during special event conditions. SCOOT improvements can be demonstrated in a statistical sense by rejecting the following set of null hypotheses and accepting the respective alternative hypotheses.

   - H_0: SCOOT does not reduce travel times under event conditions.
   - H_1: SCOOT reduces travel times under event conditions.

   - H_0: SCOOT does not reduce queue delays under event conditions.
   - H_1: SCOOT reduces queue delays under event conditions

   - H_0: SCOOT does not reduce number of stops under event conditions.
   - H_1: SCOOT reduces number of stops under event conditions

2.4 Goal IV

The fourth evaluation goal also relates to the national ITS goal of creating an environment in which the deployment of ITS can flourish. The fourth goal is to assess operator acceptance of SCOOT technology. TMC organization is inevitably idiosyncratic. Public agencies rely heavily on technology vendors and consulting engineers for expertise in decisions relating to systems architecture, procurement, and integration. This leads to system configurations that differ considerably across sites, making it difficult to generalize the experiences of a specific vendor at a specific site to other vendors developing systems at other sites.

The FOT project proposal expects the Anaheim operators to accept SCOOT control as a viable improvement relative to the existing system. The evaluation objectives for this goal are listed below. This evaluation

1) assesses operators' estimate of SCOOT effectiveness,

2) assesses the operators' frequency of SCOOT implementation during nonevent conditions

   - H_0: Operators are unwilling to implement SCOOT during nonevent conditions.
   - H_1: Operators are willing to implement SCOOT during nonevent.

3) assess the operators' frequency of SCOOT implementation during nonevent conditions,

   - H_0: Operators are unwilling to implement SCOOT during event conditions.
   - H_1: Operators are willing to implement SCOOT during event.

4) and, assesses the operators' opinion of the SCOOT user interface.

Table 2 outlines the data sources the evaluation team used to address each of the goals and corresponding objectives, and the members of the evaluation team with primary for collecting and data from these sources.

Table 2: Evaluation Data Collection Requirements

Goal No.	Objective	Data Source	Responsible Party
I	Assess SCOOT's implementation problems	Interviews	UCI
I	Assess SCOOT's transferability to other agencies	Interviews	UCI
II	Assess the changes in queue and travel times during normal conditions	Floating-car Study Intersection Delay Study	UCI/USC UCI/USC
II	Assess the changes in queue and travel times during special event conditions	Floating-car Study Intersection Delay Study	UCI/USC UCI/USC
II[a]	Assess link volumes on floating car routes	UTCS System Detectors	UCI/ USC
III	Assess the quality of SCOOT's internal representation of traffic conditions	SCOOT Message Data, and Video	USC
III	Assess the value of Anaheim's existing UTCS inductive loop detectors as effective data sources for SCOOT	Floating-car Study Intersection Delay Study Real Time SCOOT Reports, Video and TMC Logs	UCI UCI/USC USC
IV	Assess operators' estimate of SCOOT effectiveness	TMC Observation and Interviews	USC USC
IV	Assess the operators' frequency of SCOOT implementation during event conditions	TMC Observation TMC Logs	UCI USC
IV	Assess the operators' frequency of SCOOT implementation during nonevent conditions	TMC Observation TMC Logs	UCI USC
IV	Determine the operators' opinion of SCOOT's user interface	TMC Observation Interviews	UCI USC

Note: a. This was a redundant data source, from which data ultimately proved unavailable for purposes of the evaluation.

Task A: EVALUATION OF SCOOT PERFORMANCE

Principal Authors:
James E. Moore, II and R. Jayakrishan

1. SCOOT'S INTERNAL REPRESENTATION OF TRAFFIC FLOW[1]

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This element of the evaluation determines the quality of the SCOOT system's internal representation of traffic conditions at intersections. SCOOT is designed to provide detailed information describing estimated conditions on intersection approaches subject to SCOOT control. The quality of SCOOT's performance is necessarily constrained by the system's ability to represent traffic conditions at intersections.

1.1 Objective

The SCOOT system collects traffic data from induction loop detectors embedded in the pavement of intersection approaches. The SCOOT system uses this data to project conditions in the form of Cyclic Flow Profiles (CFP), simulating traffic characteristics (stops, delays, flows and queue length) downstream from the detectors. SCOOT's Split, Cycle and Offset Optimizers (locally) optimize signal timing by searching for improvements in terms of the CFP across the subarea. The offset optimizer operates on upstream and downstream intersection clusters. The split optimizer operates intersection by intersection. In all cases, the quality of SCOOT's internal representation of real traffic conditions is pivotal to its ability to optimize signal timings. If SCOOT is able to model traffic conditions accurately, then it may also be able to improve these conditions. However, SCOOT cannot function if it cannot model intersection conditions.

[1] Several people provided review, comments, and assistance with this section of the report. We are particularly grateful to Tim Allan, Siemens Traffic Controls Ltd.; Mike Hudgins, Eagle Traffic Control Systems, a Business Unit of Siemens Energy and Automation; Prof. Peter Martin, Dept. of Civil and Environmental Engineering, University of Utah; Robert Tam and Joy Dahlgren, Partnership for Advanced Transit and Highways (PATH), University of California at Berkeley; Richard Macaluso, California Department of Transportation (Caltrans) New Technology and Research Program; Keith Jasper, Booz, Allen and Hamilton; and John Lower and John Thai, City of Anaheim.

Conditions sufficient to ensure the SCOOT system's capacity to improve traffic conditions at intersections subject to SCOOT control are examined in the following section. It is impossible for SCOOT to meet sufficient conditions for improvements unless necessary conditions have been met. However, necessary conditions might be met even if sufficient conditions are not. Meeting necessary conditions without also meeting sufficient conditions is an inconclusive outcome. Under such circumstances, SCOOT does not provide traffic improvements, but has the potential to do so if aspects of the SCOOT installation are changed. Meeting necessary conditions leaves open the possibility that SCOOT would provide improvements if additional, sufficient conditions are also met. If necessary conditions are not met, there is no point in trying to meet sufficient conditions, because SCOOT cannot provide traffic improvements. See Table 3. Sufficient conditions are examined in Section 2. Traffic Performance Under SCOOT.

Our null hypothesis (see Goal II) is that SCOOT is unable to accurately represent traffic conditions at intersections. Rejecting this null hypothesis provides statistically significant evidence that the SCOOT system does indeed meet this necessary condition for improving traffic conditions.

- H_0: The inputs to SCOOT's internal measures of effectiveness (MOEs) and related measures do not reflect real traffic conditions. The inputs to SCOOT's internal MOEs and observed traffic conditions do not covary closely.
- H_1: SCOOT internal MOEs does reflect real traffic conditions. SCOOT's internal MOEs and observed traffic conditions do covary closely.

1.2 Data Requirements

A pair of traffic data sets is used to test the quality of SCOOT's representation of intersection conditions,

1) one from the SCOOT model, provided by downloading loading message reports from the SCOOT system, and

2) another consisting of empirical field observations, provided by post-processing video tapes of conditions on approaches to intersections subject to SCOOT control.

1.2.1 SCOOT Messages

These SCOOT model messages provide information regarding how SCOOT assesses the real traffic conditions of the road network (*SCOOT User Guide*, p. 115-120). The evaluation team downloaded reports for SCOOT model messages M02, M10, and M11. Message M02 provides approach information on stops, delays, and flows at about 2-minute intervals. Message M10 reports queue lengths by approach at the start of the green phase. Message M11 provides queue clearance time by approach. Estimates of stops, delays, and flows can be compared with values drawn from an intersection delay study. Estimates of queue length and queue clearance time can be compared with conditions recorded on video.

Table 3: Evaluation Outcomes Expressed in Terms of Necessary and Sufficient Conditions for SCOOT Improvements in Traffic Flows

	Necessary Conditions Unmet	**Necessary Conditions Met**
Sufficient Conditions Unmet	SCOOT did not and cannot be expected to provide improvements in traffic conditions.	SCOOT did not provide improvements in traffic conditions, but might given changes in the installation.
Sufficient Conditions Met	Apparent improvements in traffic conditions are spurious, and should not be attributed to SCOOT	SCOOT did provide improvements in traffic conditions.

1.2.1.1 Message M02: Stops, Delays, and Flows

M02 data are defined as follows:

1) Stops: the estimated number of vehicle stops per hour.

2) Delays: the estimated delay in vehicle hours per hour.

3) Flows: the estimated flow in vehicles per hour.

The SCOOT system deployed in Anaheim reports these values at intervals of 112 or 120 seconds, though reports can be provided for shorter intervals. These values are SCOOT estimates of real traffic conditions during the interval. The M02 data are displayed on a per-hour basis, not per actual report interval. We converted the M02 data to values for the actual report interval for comparison with empirical data provided by video cameras.

1.2.1.2 Message M10: Queue Length

M10 data gives the length of the queues waiting at the stop line at the beginning of the green phase. Queue lengths are expressed in Link Profile Units (LPUs). The number of vehicles corresponding to each LPU is a dynamic value that ranges from 8 to 22 (*SCOOT User Guide* § 4.6.6). The message is provided once per cycle at the start of link green (*SCOOT User Guide* § 4.5.5). Queue length is reported as “-1” if communication with the approach loop detectors or signal controller is faulty (*SCOOT User Guide* § 14.2.7).

1.2.1.3 Message M11: Queue Clearance Time

M11 data gives the time required to discharge the M10 queue in seconds. This is reported as the time when the last queued vehicle crosses the stop line. If the approach fails to clear in the available green time, then the value "–1" is (*SCOOT User Guide* § 4.5.5). Queue clearance time is reported as "0" if communication with the approach loop detectors or signal controller is faulty (*SCOOT User Guide* § 14.2.8).

1.2.2 Empirical Observations: Videotape Data

Videotapes of traffic flows provide more detailed information about traffic conditions at a given intersection than either floating cars studies or real time intesection delay studies. Videotaped data provide more accurate estimates of queue length and queue delay than real time observations permit.

Forteen cameras are controlled by Anaheim Traffic Management Center (TMC) for the purpose of observing traffic conditions during ingress and egress from event sites. Most of these cameras are installed near event generators or other important intersections. Using these cameras, TMC staff can observe traffic conditions on video monitors,and record them on VCRs. The evaluation team inventoried TMC facilities: cameras, monitors, and VCRs. The TMC staff ensured that all VCRs were connected, and ready to use.

1.3 Data Collection Sequence

The City of Anaheim agreed to permit a USC graduate research assistant supporting the evaluation team to work as an intern at Anaheim TMC. This provided the research assistant an opportunity to learn how to use the SCOOT system, how to download SCOOT model messages, and to familiarize himself with TMC resources and facilities. In addition to regular duties as a TMC operator, the graduate research assistant collected videotaped data for the evaluation of SCOOT's internal representation of traffic flows, provided technical support for intersection delay and floating car studies taking place in the field, and logged the responsibilities and activities of TMC operators. Data collection for the evaluation of SCOOT's internal representation of traffic conditions consisted of coordinating downloads of SCOOT model messages with videotapes of intersection approaches. He also monitored SCOOT operations, and identified and logged problems during data collection.

1.3.1 Downloading SCOOT Model Messages

SCOOT model messages can be stored as a file in the SCOOT system, but cannot be directly saved to a floppy data diskette. A laptop computer was connected to the SCOOT system computer, and SCOOT messages were downloaded to the personal computer after they were generated and stored by SCOOT. These files are in DBASE 4 (.dbs) format, which can be processed by spreadsheet software, such as Excel.

The MESS command allows operators to store SCOOT messages. For example, an operator can store SCOOT model message M02 for the intersection at Howell and Katella with the command:

MESS M02 N23111 >SCOOT_LOG*

The exact procedure to download this file onto the laptop computer is as follows:

1) Set the parameters of the laptop computer:
   IP address: 64.50.0.148
   Subnet Mask: 255.0.0.0
   Gateway: 64.5.0.25

2) Run Telnet on the laptop computer to connect to the SCOOT system computer:
   Parameters: 64.5.0.30
   Username: type SCOOT operator user name
   Password: type SCOOT operator password

3) Run WFTPD
   Write a TXDF command to transfer the SCOOT file to the laptop computer:
   TXDF M02 SCOOT DBASE 6-OCT-97 >TIMSPC
   "DBASE" sets the format of the file to be DBASE 4
   "6-OCT-97" sets the filename to be the date the data was collected and stored.

4) Open the DBASE 4 file with Microsoft Excel

See Appendix 1 for a sample of SCOOT system data. Additional information explaining SCOOT event driven messages is available in the <u>*SCOOT User Guide*</u>, p. 114. The SCOOT commands MESS and TXDF, are explained in the <u>*SCOOT Operator Handbook*</u>, p. 156 and p. 222.

1.3.2 Videotaping Traffic Conditions

The evaluation team used Anaheim TMC equipment to videotape record traffic conditions on approaches while the SCOOT system was collecting, processing, and reporting data from loop detectors. TMC cameras provide a view of 360 degrees, but provides only a limited view of vehicle queues on the intersection approach directly below the camera. The cameras are operated manually. Each camera must be selected by an operator, and then positioned.

The SCOOT data and the video data collected in the TMC had to be synchronized to permit comparisons. The Anaheim TMC's VCRs cannot record with a time stamp. The evaluation team substituted a camcorder that can provide a time stamp. This permitted the time difference between SCOOT data sequence and the video data to be controlled to within 1 second. A summary of the data collection scheme appears in Figure 5. The evaluation team over-sampled, recording a total of ten-hours of videotapes.

1.3.3 Processing Video Data

Unfortunately, the images from TMC cameras are not subject to automatic data processing. Consequently, the empirical data describing traffic conditions had to be obtained by post-processing the videotapes manually. The work was completed by

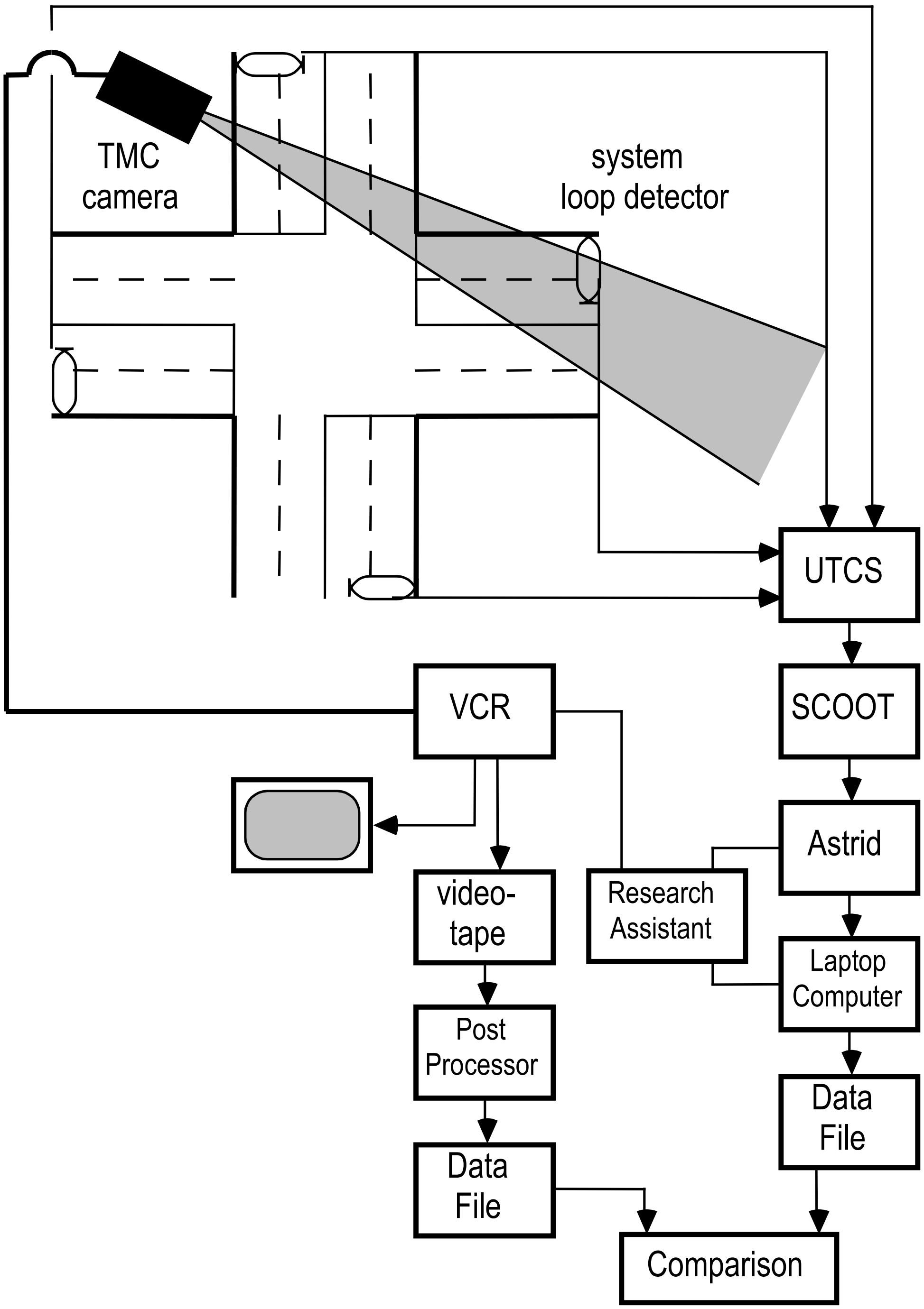


Figure 5: Data Collection Scheme for Assessing SCOOT's Representation of Traffic Conditions.

graduate research assistants, and undergraduate engineering students enrolled in CE 471: Principles of Transportation Engineering, at the University of Southern California. Delays, stops, and flows were measured just as in a standard intersection delay study. The time interval for each count is 8 seconds. Queue length was measured at the start of each green phase. The queue clearance time was measured as the time needed for all queued vehicles to pass the stop line.

1.3.4 Purging Spurious Data Associated with Communications Faults

During data collection, the graduate research assistant in the Anaheim TMC carefully compared real time traffic conditions observed via TMC cameras with the estimated values reported in SCOOT messages. A real time display of the traffic conditions estimated by SCOOT can be invoked via SCOOT's Node Fine Tuning Display (NFTD). The NFTD command reports the times at which all approaches to a given intersection begin the green phase. The NFTD also shows the queue length when an approach is green, and the associated queue clearance time. By comparing real time start-of-green times and queue clearance times reported by the SCOOT NFTD to real time video images, the graduate research assistant identified large inconsistencies at some intersections.

The graduate research assistant then referred to a list of SCOOT event driven messages, and found that these intersections were accumulating system fault messages. As a result of cumulative communication or other system faults, these intersections were unexpectedly isolated from SCOOT control. In most cases, these faults can be cleared via the XFLT command, but this requires active intervention on the part of the operator. If faults are cleared manually rather than being permitted to accumulate, the signals involved remain under SCOOT control. The number of signals slipping from SCOOT control decreased very substantially once TMC operators were notified of the need to clear faults as they occurred.

SCOOT message data associated with signals subject to cumulative communication faults are meaningless. The conditions reported in such messages diverge from conditions observed via video. As a result, seven of the ten hours of data collected could not be used because of cumulative SCOOT system errors or communications problems. In addition, there is some small indication that communication faults also sometimes temporarily affected the contents of SCOOT messages, even when faults were being actively cleared, and the signal appeared to remain under SCOOT control. Data from signals rendered suspect under this criterion were also purged. Signals that did and did not remain under SCOOT control are shown in Figure 6, along with signals subject to video surveillance.

1.4 Summary of Results

The remaining three hours of data provide a sufficiently large number of observations to draw statistically significant conclusions. These three hours of data describe conditions at the following intersection approaches, all for November 18, 1997:

1) Ball Westbound at State College and Ball,

2) State College Southbound at State College and Ball, and

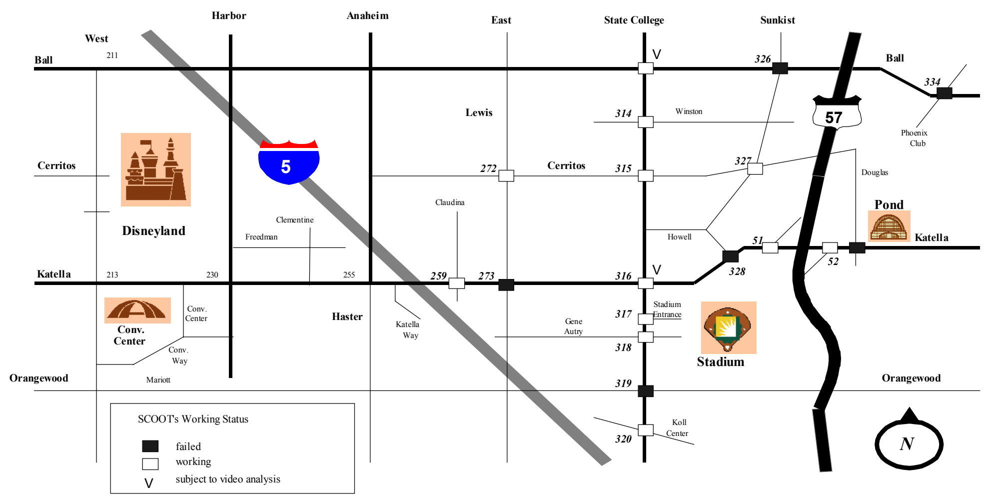


Figure 6: Observed Status of Signals Intended to be Subject to SCOOT Control.

3) Katella Eastbound at State College and Katella.

Four cases are summarized in Table 4. The three sets of videotape data and their associated SCOOT data are compared individually to control for differences across intersections, and then data for all three intersections are pooled together. Estimated correlation coefficients between the SCOOT message data and the videotape data are reported for stops, delays, flows, queue length, and queue clearance times. Estimated correlation coefficients are expected to be high if the data in the SCOOT messages reflect real traffic conditions.

The estimated correlation coefficient, r, is a well-defined numerical index describing the degree of linear association between two random variables. Estimates of simple (bivariate) correlation coefficients can range from -1.00 to +1.00. The relationship between the two variables tends toward linearity when the correlation coefficient approaches +1 or -1. An estimate of r = 1 represents a perfect positive linear relationship between two variables. An estimate of r = -1 indicates a perfect negative linear relationship. In either extreme, only one of the two variables is truly random. The second variable is merely a deterministic linear transformation of the first. An estimated correlation coefficient of r = 0 suggests that there is no linear relationship between the two variables, though a nonmonotic, nonlinear relationship may exist.

If the SCOOT system is representing traffic conditions on approaches in a completely accurate way, then the estimated correlation coefficient between the SCOOT message data and the video data will tend toward +1. However, r is a statistical estimate of a true unknown, unobserved parameter. As a statistic, it has a probability distribution. Even when the true correlation coefficient between two variables is zero, the estimated value r inevitably includes random noise that leads to an estimate different from zero. Under reasonably general conditions assumed to apply here, it is possible to determine whether an observed value r is statistically different from zero. That is, given enough data, it is

Table 4: Summary Results for Cases 1 through 4

		Case 1: Ball Westbound at State College and Ball	**Case 2: State College Southbound at State College and Ball**	**Case 3: Katella Eastbound at State College and Katella**	**Case 4: Cases 1, 2 and 3 Combined**
Date and Time		Nov 18, 1997 11:38:49-12:36:41	Nov 18, 1997 13:57:05-14:55:05	Nov 18, 1997 16:18:25-17:04:25	Nov 18, 1997 11:38:49-17:04:25
Number of Observations	**M02**	30, three of which are excluded due to communication faults	29	23	82, three of which are excluded due to communication faults
	M10 and M11	32, six of which are excluded due to communications faults	29	24, five of which are excluded due to communication faults	85, 11 of which are excluded due to communication faults
Estimated Correlation Coefficients	**Stops**	0.72	0.77	0.61	0.78
	Delay	0.83	0.46	0.59	0.65
	Flow	0.71	0.79	0.79	0.86
	Queue Length	0.70	0.52	0.68	0.76
	Queue Clearance Time	0.83	0.46	0.60	0.67
Estimated Regression Coefficient	**LPUs[a] per Vehicle**	15.3	22.52	14.66	15.6

Note: a Link Profile Units are a proprietary measure of demand internal to the SCOOT system.

possible to determine whether the difference between r and zero is large enough to conclude that the difference exists because the true value of the correlation coefficient is greater than zero. From this perspective, the original hypothesis becomes

- H_0: The true value of the correlation coefficient is zero. The inputs to SCOOT's internal MOEs and observed traffic conditions do not covary closely.
- H_1: The true value of the correlation coefficient is greater than zero. The inputs to SCOOT internal MOEs and observed traffic conditions do covary closely.

Rejecting the null hypothesis H_0 permits the null hypothesis H_1 to be accepted. Failure to reject the null hypothesis does not imply that the null is accepted. Rather, failure to reject is an inconclusive result that demonstrates nothing in a statistical sense. The alternative hypothesis is one-sided in this case, because the worst case outcome is that the values reported in the SCOOT messages have no relationship with the real world. There is no set of circumstances under which the values and reported in the SCOOT messages would be expected to move systematically with observed traffic conditions, but in the opposite direction.

The quality of the relationship observed between the video and modeled flows, stops, delays is (at least) a function of

1) the quality of the SCOOT validation process executed when the system was installed,

2) the quality of additional fine tuning done following installation,

3) the location of the detectors,

4) the noise inherent in the detectors, and

5) the quality of the video observations

In all cases, it is both qualitatively and quantitatively clear that the data provided by the SCOOT messages covaries moderately to strongly with the data extracted from video tapes. In all cases, the null hypothesis of no relationship is strongly rejected. SCOOT is successfully modeling traffic conditions on the intersection approaches we observed. The queue length and delay estimates correlation coefficients are the lowest. This is to be expected because these metrics are derivatives of the flow measures. Error propagation is at least part of the reason.

The flow correlation coefficients estimated here are lower than those compiled by compiled by Martin (1992) for the Leicester SCOOT system. SCOOT was installed in the medium sized English City of Leicester in 1989. Martin compared observed and modeled flows on the Leicester SCOOT system, Region R from 4:00 PM to 6:00 PM on May 8, 1991, and found a correlation of almost .94. He developed an SCOOT LPU calibration process that improved this value to .96.

The Anaheim correlation coefficients, while considerably lower, remain encouraging given the Anaheim installation's mid block detector locations and the considerable effort invested in fine tuning of the Leicester system. The SCOOT model's ability to predict flow and volume is good. Modeling of queues, delays and stops is less strong, but SCOOT has still managed to return estimates with substantial information content.

1.5 Detailed Results

Two Tables and 5 figures are associated with each of the 4cases summarized in Table 5. The format of these Tables are as follows.

1) Tables 5, 7, 9, and 11: SCOOT Internal Messages M02: Stops, Delays, Flows.

   Column 1 (FROM): the start time for a single observation.

   Column 2 (TO): the stop time for a single observation.

   Column 3 (INT): the time interval for a single observation.

   Column 4 (STOPS, SCOOT): the number of vehicle stops reported in SCOOT message M02, per time interval (INT).

   Column 5 (STOPS, VIDEO): the number of vehicle stops observed on video, per time interval (INT).

   Column 6 (DELAYS, SCOOT): the delay in vehicle seconds reported in SCOOT message M02, per time interval (INT).

   Column 7 (DELAYS, VIDEO): the delay in vehicle seconds observed on video, per time interval (INT).

   Column 8 (FLOWS, SCOOT): the flow in vehicles reported in SCOOT message M02, per time interval (INT).

   Column 9 (FLOWS, VIDEO): the flow in vehicles observed on video, per time interval (INT).

2) Tables 6, 8, 10, and 12: SCOOT Internal Messages M10 & M11 - Queue Lengths and Queue Clearance Time.

   Column 1 (SCOOT): the start time for green phase reported in SCOOT message M10.

   Column 2 (VIDEO): the start time for green phase observed on video.

Column 3 (DIFFERENCE):	the difference between SCOOT and video green phase times, a value always close to zero seconds.
Column 4 (SCOOT):	the length of queue in Link Profile Units (LPUs) waiting at the stop line at the beginning of the green phase, reported in SCOOT message M10.
Column 5 (VIDEO):	the length of the queue in number of vehicles observed on video.
Column 6 (SCOOT):	the queue clearance time, the time when the last queued vehicle crosses the stop line, reported in SCOOT message M11.
Column 7 (VIDEO):	the queue clearance time, the time when the last queued vehicle crosses the stop line, observed on video.

The Figures plot data from SCOOT messages against the corresponding values obtained from video tapes. Perfect agreement between these sources would place all observations on a straight, 45 degree line intersecting the origin of the plots. The reference lines appearing in the Figures appear to have varying slopes because scales on the horizontal and vertical axes varying depending on the range of the data observed. Perfect agreement is not expected: The SCOOT message values are estimates. Some noise is to be expected. Further, SCOOT reports queue lengths in LPUs, while the evaluation team observes queue lengths in terms of vehicles. LPUs is a measure of demand for service that covaries with number of vehicles in the queue, but in a dynamic way internal to SCOOT. However, if SCOOT is performing as intended, there must be a general linear relationship between the coordinates in each scatterplot. As noted above, the correlation coefficients computed in each case quantify the intensity of these relationships.

1) Figures 7, 12, 17, and 22 show scatter plots comparing number of stopped vehicles observed on video with the number of stop vehicles reported in scoot message M02.

2) Figures 8, 13, 18, and 23 show scatter plots comparing total vehicle delays observed on video with the total vehicle delays reported in scoot message M02.

3) Figures 9, 14, 19, and 24 show scatter plots comparing flow volumes delays observed on video with flow volumes reported in scoot message M02.

4) Figures 10, 15, 20, and 25 show scatter plots comparing queue lengths observed on video with queue lengths reported in scoot message M10. The plots include a simple regression estimated without an intercept term. The criterion variable is SCOOT queue length in LPUs. The explanatory variable is queue length in vehicles observed on video. The coefficient estimated as the slope of the regression line is the estimated

mean LPU value for 1 vehicle. These estimates fall within the range reported the SCOOT User Guide § 4.6.6.

5) And finally, Figures 11, 16, 21, and 26 show scatter plots comparing queue clearance times observed on video with queue lengths reported in SCOOT message M11.

The three shaded rows in Table 5 (Case 1) identify large outliers in terms of the difference between SCOOT message data and corresponding video. System fault messages associated with this data set are shown at the bottom of Table 5. A relationship exists between these faults and these outliers. For example, a system fault is reported at 12:07:24 (*l-g flt stgs B-A was 2s/b 5*) The first outlier occurs between 12:06:57 to 12:08:49. The shaded observations in Table 5 are determined similarly. These outliers are reported with the rest of data, but purged from all statistical calculations involving the data.

1.5.1 Case 1

Table 5: SCOOT Internal Message M02, Stops, Delays, and Flows; Ball Avenue Westbound at State College and Ball

November 18, 1997 11:38:49 - 12:36:41 Tape # 4

Time		Interval	Stops (Vehs/Int)		Delays (Secs / Int)		Flows (Vehs / Int)	
From	To		SCOOT	Video	SCOOT	Video	SCOOT	Video
11:38:49	11:40:49	120	20.73	20	624	480	25.27	27
11:40:49	11:42:41	112	25.23	28	1276.8	976	26.51	31
11:42:41	11:44:33	112	17.17	18	414.4	640	20.00	28
11:44:33	11:46:25	112	25.60	30	1254.4	1256	28.44	39
11:46:25	11:48:17	112	14.34	22	179.2	528	23.05	28
11:48:17	11:50:09	112	25.29	25	1153.6	1104	31.11	38
11:50:09	11:52:01	112	5.44	12	112	320	12.85	20
11:52:01	11:53:53	112	15.12	29	403.2	776	21.62	38
11:53:53	11:55:45	112	12.29	17	582.4	688	25.04	33
11:55:45	11:57:37	112	8.21	20	201.6	800	14.78	28
11:57:37	11:59:29	112	17.89	16	750.4	992	23.40	32
11:59:29	12:01:21	112	14.50	19	470.4	664	23.89	35
12:01:21	12:03:13	112	24.05	27	683.2	680	28.50	34
12:03:13	12:05:05	112	20.35	27	369.6	504	32.11	38
12:05:05	12:06:57	112	26.38	27	515.2	544	32.45	35
12:06:57	12:08:49	112	3.67	34	56	712	38.67	42
12:08:49	12:10:41	112	26.38	40	1108.8	1800	33.16	49
12:10:41	12:12:41	120	27.57	24	1080	1512	35.60	33
12:12:41	12:14:41	120	11.43	29	180	1528	42.30	36
12:14:41	12:16:41	120	31.07	37	1296	2184	36.40	42
12:16:41	12:18:41	120	25.17	33	1416	1664	33.10	48
12:18:41	12:20:41	120	18.33	16	564	472	31.27	30
12:20:41	12:22:41	120	24.57	30	960	1120	26.83	36
12:22:41	12:24:41	120	26.40	37	1224	1592	31.00	41
12:24:41	12:26:41	120	24.67	34	1080	1520	33.93	38
12:26:41	12:28:41	120	7.17	20	72	824	27.27	32
12:28:41	12:30:41	120	26.40	30	1092	1056	33.50	38
12:30:41	12:32:41	120	14.17	2	636	1024	28.10	43
12:32:41	12:34:41	120	13.90	26	468	784	36.57	41
12:34:41	12:36:41	120	21.27	29	864	1248	31.57	44

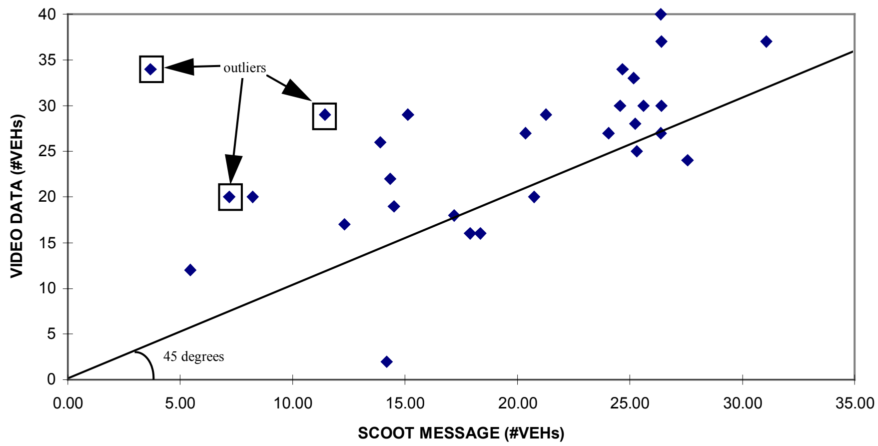
Note: 30 observations, including three outliers in terms of vehicle delay, which may be related to system faults. Correlation coefficients are calculated both with and without these outliers.

Correlation Coefficients

	W Outliers (30 obs)	W/O Outliers (27 obs)
Stops	0.52	0.72
Delay	0.70	0.83
Flow	0.66	0.71

Fault Messages Associated with these Data

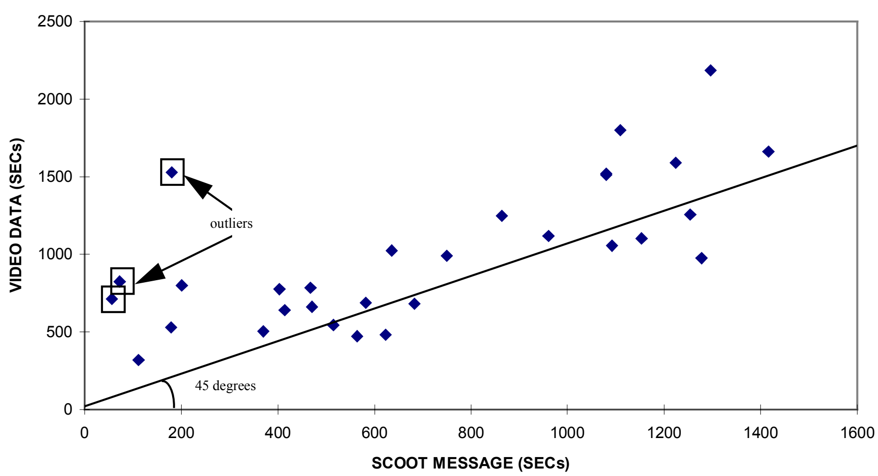
11:47:08 [0211] Min grn flt Stg C was 1 s/b 10
12:07:24 [0213] I-g flt stgs B-A was 2 s/b 5
12:22:52 [0213] I-g flt stgs A-B was 2 s/b 5
12:27:08 [0213] I-g flt stgs B-A was 0 s/b 5
12:27:09 [0213] I-g flt stgs A-B was 0 s/b 5
12:27:12 [0211] Min grn flt Stg B was 3 s/b 10



<u>Correlation Coefficient r</u>

- With Outliers: r = 0.52., • Without Outliers: r = 0.72.

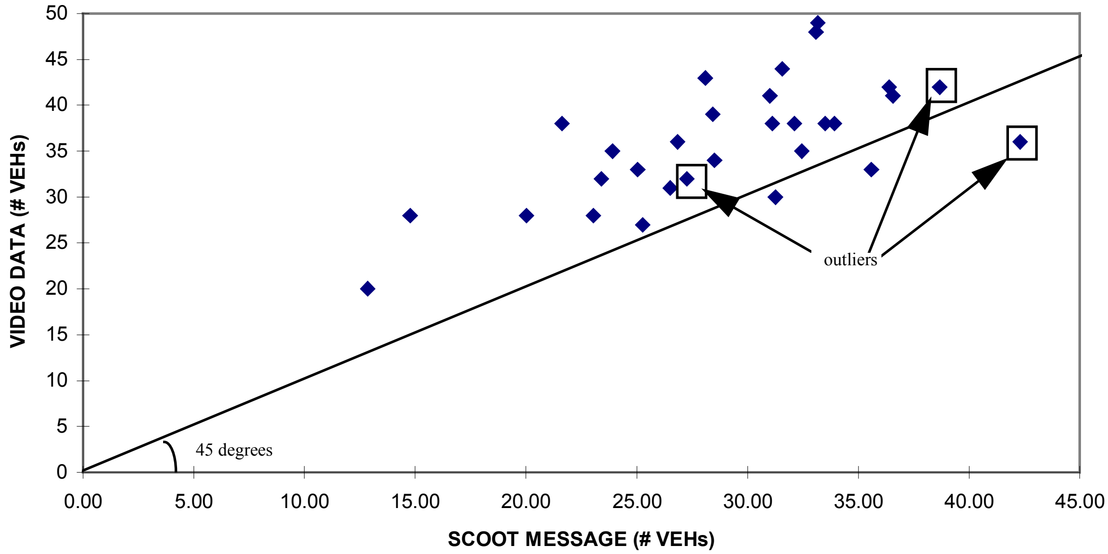
Figure 7: Number of Stopped Vehicles on Approach per SCOOT Interval, Ball Avenue Westbound at State College and Ball (Nov. 18, 11:38:49 - 12:36:41).



<u>Correlation Coefficient r</u>

- With Outliers: r = 0.70,
- Without Outliers: r = 0.83.

Figure 8: Total Vehicle Delays on Approach per SCOOT Interval, Ball Avenue Westbound at State College and Ball (Nov. 18 11:38:49 - 12:36:41).



<u>Correlation Coefficient r</u>

- With Outliers: r = 0.66,
- Without Outliers: r = 0.71.

Figure 9: Flow Volumes on Approach per SCOOT Interval, Ball Avenue Westbound at State College and Ball (Nov. 18 11:38:49 - 12:36:41).

Table 6: SCOOT Messages M10, Queue length; and M11 Queue Clearance Time; Ball Avenue Westbound at State College and Ball

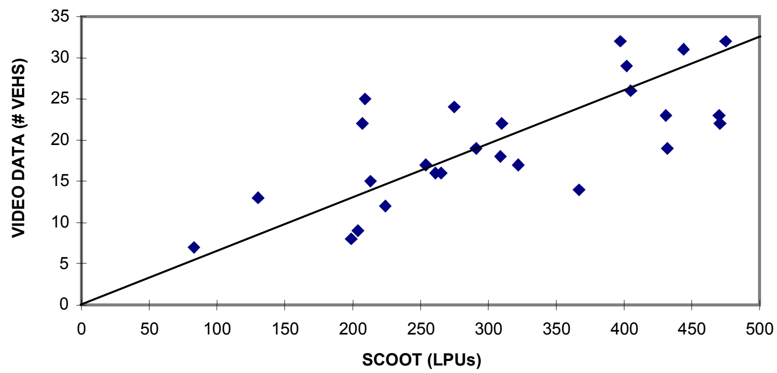
November 18, 1997 11:39:58 - 12:36:04 Tape #5

Green Start Time			Queue Length		Queue Clearance Time	
SCOOT	Video	Difference (Seconds)	SCOOT (LPUs)	Video (Vehs)	SCOOT (Seconds)	VIDEO (Seconds)
11:39:58	11:39:50	0:00:08	322	17	20	19
11:41:51	11:41:50	0:00:01	471	22	25	27
11:43:50	11:43:50	0:00:00	254	17	15	18
11:45:39	11:45:35	0:00:04	431	23	25	21
11:47:12			148			*2
11:49:23	11:49:21	0:00:02	470	23	25	28
11:51:14	11:51:13	0:00:01	83	7	6	6
11:53:03	11:53:01	0:00:02	213	15	14	21
11:54:59	11:54:57	0:00:02	204	9	12	15
11:56:55	11:56:53	0:00:02	130	13	7	19
11:58:43	11:58:43	0:00:00	265	16	17	15
12:00:35	12:00:33	0:00:02	261	16	14	26
12:02:35	12:02:33	0:00:02	310	22	23	29
12:04:27	12:04:27	0:00:00	207	22	19	35
12:06:23	12:06:21	0:00:02	275	24	25	33
12:07:27			62			*3
12:08:15	12:08:13	0:00:02	-621		0	*1
12:10:07	12:10:06	0:00:01	402	29	25	23
12:11:56	12:11:53	0:00:03	309	18	25	21
12:13:22			139			*4
12:14:00	12:13:57	0:00:03	-257		0	*1
12:15:56	12:15:55	0:00:01	397	32	25	27
12:17:52	12:17:53	-0:00:01	475	32	25	25
12:19:51	12:19:53	-0:00:02	199	8	17	11
12:22:00	12:21:53	0:00:07	367	14	23	14
12:24:00	12:23:57	0:00:03	444	31	25	26
12:25:59	12:25:57	0:00:02	405	26	24	31
12:28:08	12:28:07	0:00:01	-760		0	*1
12:30:04	12:30:01	0:00:03	432	19	25	21
12:32:07	12:32:05	0:00:02	224	12	13	15
12:34:07	12:34:05	0:00:02	209	25	13	29
12:36:04	12:36:01	0:00:03	291	19	20	18

Notes: *1: 12:08:15, 12:14:00, 12:28:08 – These queue clearance times are reported as zero because the link is faulty (*SCOOT User Guide*, § 14.2.8).
*2: 11:47:12 – This is not really a green phase. There is evidence of a link fault at 11:47:08.
*3: 12:07:27 – This is not really a green phase. There is evidence of a link fault at 12:07:24.
*4: 12:13:22 – This is not really a green phase.
There are a total of 32 total observations, 6 of which are excluded due to link faults.

Correlation Coefficients (26 Observations)

Queue Length 0.72
Queue Clearance Times 0.50

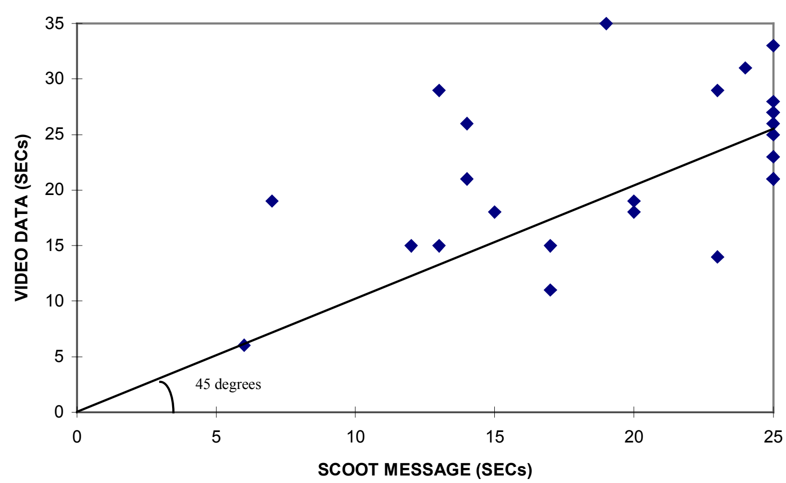


Correlation Coefficient r = 0.72.

Regression Coefficient

- The regression equation is SCOOT (LPUs) = 15.3 VIDEO (Vehs). There is no constant term.
Predictor Variable	Coefficent	St. dev.	t-ratio	p-value
VIDEO	15.2524	0.7810	19.53	0.000.

Figure 10: Queue Length, Ball Avenue Westbound at State College and Ball (Nov. 18 11:38:49 - 12:36:41).



Correlation Coefficient r = 0.50.

Figure 11: Queue Clearance Time, Ball Avenue Westbound at State College and Ball (Nov. 18 11:38:49 - 12:36:41).

1.5.2 Case 2

Table 7: SCOOT Internal Message M02, Stops, Delays, and Flows; State College Avenue Southbound at State College and Ball

November 18, 1997 13:57:05 - 14:55:0Tape #6

Time		Interval	Stops (Vehs/Int)		Delays (Secs / Int)		Flows (Vehs / Int)	
From	To		SCOOT	Video	SCOOT	Video	SCOOT	Video
13:57:05	13:59:05	120	14.93	17	600	888	19.43	23
13:59:05	14:01:05	120	18.83	19	780	944	19.40	24
14:01:05	14:03:05	120	21.23	20	1428	712	21.23	26
14:03:05	14:05:05	120	8.73	8	480	352	10.43	11
14:05:05	14:07:05	120	7.00	13	468	432	12.57	23
14:07:05	14:09:05	120	12.60	14	372	504	20.43	24
14:09:05	14:11:05	120	8.10	10	396	504	19.00	26
14:11:05	14:13:05	120	10.93	11	264	544	17.83	22
14:13:05	14:15:05	120	9.10	8	540	416	13.90	24
14:15:05	14:17:05	120	10.90	10	336	480	13.40	15
14:17:05	14:19:05	120	19.93	16	1296	656	19.93	25
14:19:05	14:21:05	120	13.83	9	1440	448	18.43	27
14:21:05	14:23:05	120	18.60	13	828	504	18.67	16
14:23:05	14:25:05	120	5.27	7	600	448	10.27	16
14:25:05	14:27:05	120	7.67	11	384	648	15.43	16
14:27:05	14:29:05	120	16.10	18	456	552	20.60	27
14:29:05	14:31:05	120	8.17	12	360	768	11.77	19
14:31:05	14:33:05	120	12.23	16	324	592	13.33	26
14:33:05	14:35:05	120	21.67	21	1212	1400	23.60	34
14:35:05	14:37:05	120	8.83	9	708	608	9.50	11
14:37:05	14:39:05	120	23.57	29	1044	744	24.00	33
14:39:05	14:41:05	120	8.23	14	444	592	11.43	15
14:41:05	14:43:05	120	10.93	6	312	760	14.43	18
14:43:05	14:45:05	120	3.93	12	96	304	10.00	15
14:45:05	14:47:05	120	20.00	14	756	680	20.77	24
14:47:05	14:49:05	120	11.23	13	324	584	14.57	28
14:49:05	14:51:05	120	21.77	24	588	760	25.00	29
14:51:05	14:53:05	120	19.10	16	984	944	21.73	32
14:53:05	14:55:05	120	6.83	15	156	272	14.50	22

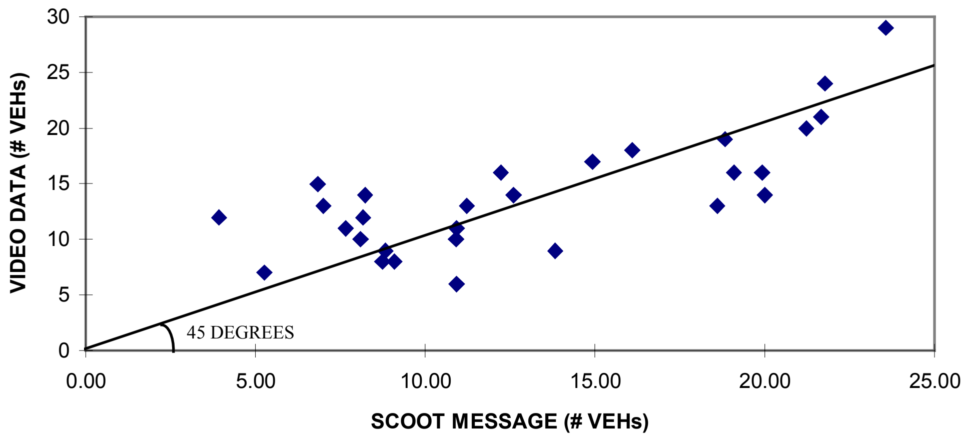
Note: 29 observations, none of which are excluded.

<u>Correlation Coefficients</u>

Stops 0.77
Delay 0.46
Flow 0.79

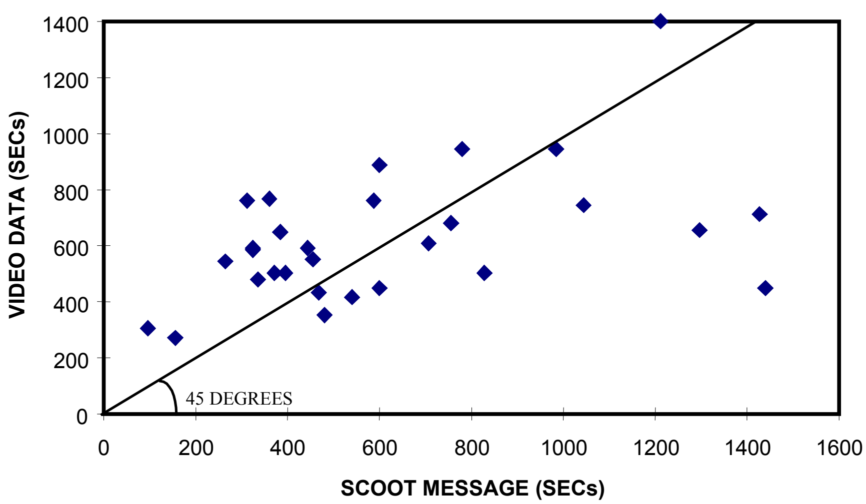
<u>Fault Messages Associated with these Data</u>

14:20:49 [0211] Min grn flt Stg D was 2 s/b 10



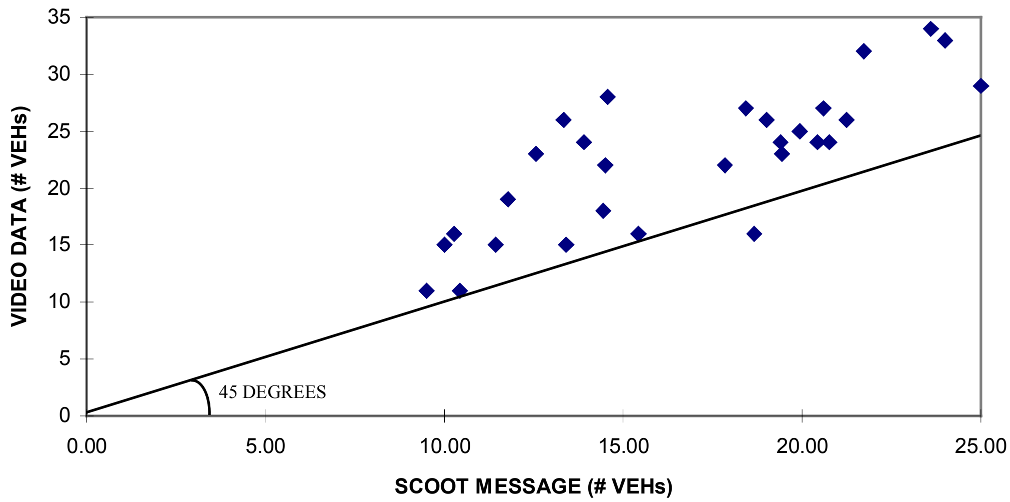
Correlation Coefficient r = 0.77.

Figure 12: Number of Stopped Vehicles on Approach per SCOOT Interval, State College Avenue Southbound at State College and Ball (Nov. 18 13:57:05 - 14:55:05).



Correlation Coefficient r = 0.46

Figure 13: Total Vehicle Delays on Approach per SCOOT Interval, State College Avenue Southbound at State College and Ball (Nov. 18 13:57:05 - 14:55:05).



Correlation Coefficient r = 0.79

Figure 14: Flow Volumes on Approach per SCOOT Interval, State College Avenue Southbound at State College and Ball (Nov. 18 13:57:05 - 14:55:05).

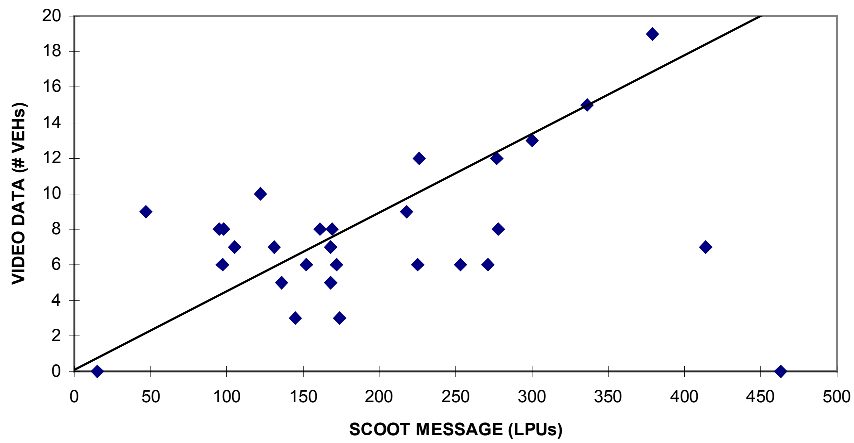
Table 8: SCOOT Messages M10, Queue length; and M11 Queue Clearance Time; State College Avenue Southbound at State College and Ball

November 18 13:57:53 - 14:54:31

Green Start Time			Queue Length		Queue Clearance Time	
SCOOT	Video	Difference (Seconds)	SCOOT (LPUs)	Video (Vehs)	SCOOT (Seconds)	VIDEO (Seconds)
13:57:53	13:57:48	0:00:05	226	12	12	14
13:59:56	13:59:48	0:00:08	300	13	17	14
14:01:59	14:01:58	0:00:01	463		-1	*1
14:03:50	14:03:48	0:00:02	161	8	8	8
14:05:59	14:05:55	0:00:04	169	8	9	9
14:08:00	14:07:58	0:00:02	168	7	13	8
14:10:04	14:10:02	0:00:02	168	5	9	4
14:11:58	14:11:52	0:00:06	105	7	6	6
14:14:01	14:14:01	0:00:00	174	3	11	3
14:16:01	14:16:02	-00:00:01	95	8	6	8
14:18:03	14:18:02	0:00:01	15.18		-1	*1
14:20:08	14:20:00	0:00:08	414	7	25	7
14:22:07	14:22:06	0:00:01	271	6	16	8
14:24:06	14:24:04	0:00:02	172	6	10	8
14:26:09	14:26:06	0:00:03	131	7	7	7
14:28:09	14:28:08	0:00:01	218	9	15	12
14:30:12	14:30:10	0:00:02	122	10	8	14
14:32:09	14:32:08	0:00:01	97	6	6	6
14:34:21	14:34:18	0:00:03	336	15	22	16
14:36:20	14:36:20	0:00:00	225	6	12	6
14:38:20	14:38:20	0:00:00	379	19	22	35
14:40:16	14:40:15	0:00:01	145	3	9	3
14:42:25	14:42:22	0:00:03	152	6	11	8
14:44:28	14:44:26	0:00:02	47	9	3	12
14:46:26	14:46:24	0:00:02	278	8	20	8
14:48:31	14:48:28	0:00:03	136	5	10	6
14:50:36	14:50:34	0:00:02	277	12	21	22
14:52:36	14:52:26	0:00:10	253	6	19	6
14:54:31	14:54:30	0:00:01	98	8	7	10

Notes: *1: 14:01:59 – The queue clearance time reported by SCOOT is –1. The queue clearance time observed from video data is 10 seconds. We assume the SCOOT report is an error code.
*1: 14:18:03 – The queue clearance time reported by SCOOT is –1. The queue clearance time observed from video data is 14 seconds. We assume the SCOOT report is an error code.
There are a total of 29 total observations, 2 of which are excluded due to link faults.

Correlation Coefficients (27 Obervations)
Queue Length 0.52
Queue Clearance Time 0.46

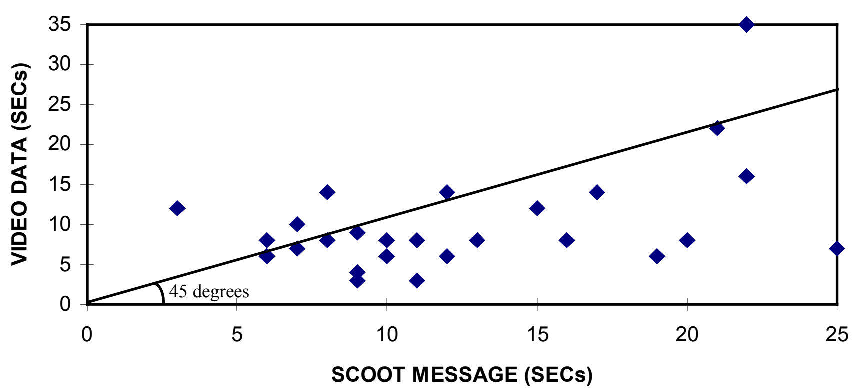


Correlation Coefficient r = 0.52.

Regression Coefficient

- The regression equation is SCOOT (LPUs) = 22.52 VIDEO (Vehs). There is no constant term.
Predictor Variable	Coefficent	St. dev.	t-ratio	p-value
VIDEO	22.524	11.86	1.899	0.000.

Figure 15: Queue Length, State College Avenue Southbound at State College and Ball (Nov. 18 13:57:53 - 14:54:31).



Correlation Coefficient r = 0.46.

Figure 16: Queue Clearance Times, State College Avenue Southbound at State College and Ball (Nov. 18 13:57:53 - 14:54:31).

1.5.3 Case 3

Table 9: SCOOT Internal Message M02, Stops, Delays, and Flows; Katella Avenue Eastbound at State College and Katella

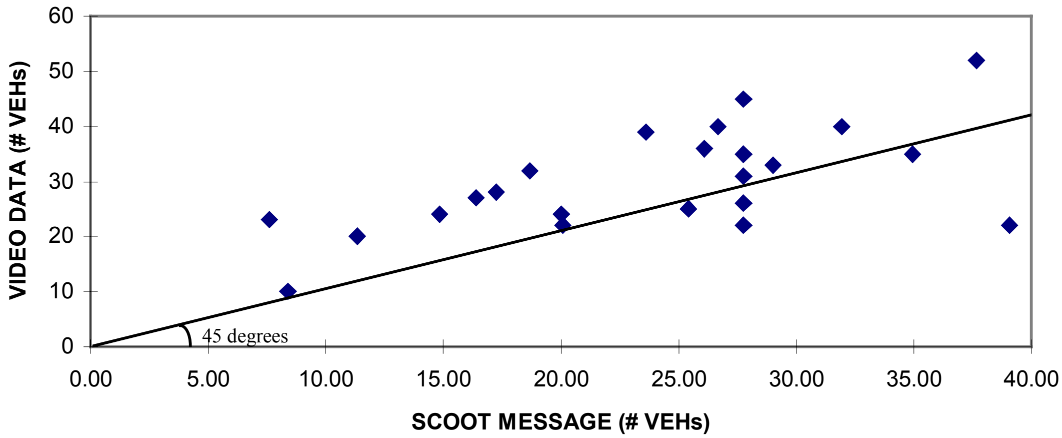
November 18, 1997 16:18:25 - 17:04:25 Tape #10

Time		Interval	Stops (Vehs/Int)		Delays (Secs / Int)		Flows (Vehs / Int)	
From	To		SCOOT	Video	SCOOT	Video	SCOOT	Video
16:18:25	16:20:25	120	25.43	25	660	880	25.67	32
16:20:25	16:22:25	120	39.07	22	516	520	40.90	54
16:22:25	16:24:25	120	27.77	31	1500	1368	35.23	40
16:24:25	16:26:25	120	27.77	22	876	1176	34.17	58
16:26:25	16:28:25	120	29.00	33	360	1040	38.57	46
16:28:25	16:30:25	120	16.40	27	540	760	22.43	37
16:30:25	16:32:25	120	23.60	39	660	864	29.67	53
16:32:25	16:34:25	120	31.93	40	1068	1016	44.07	50
16:34:25	16:36:25	120	27.77	35	1104	928	30.83	43
16:36:25	16:38:25	120	27.77	26	1176	1344	37.83	35
16:38:25	16:40:25	*120*	*20.00*	*24*	*2124*	*768*	*20.00*	30
16:40:25	16:42:25	120	26.67	40	2472	1632	26.67	61
16:42:25	16:44:25	120	14.83	24	936	1056	14.83	25
16:44:25	16:46:25	120	11.33	20	216	240	20.40	37
16:46:25	16:48:25	120	37.67	52	480	1184	64.33	75
16:48:25	16:50:25	120	20.07	22	948	904	28.33	34
16:50:25	16:52:25	120	7.60	23	408	744	17.60	30
16:52:25	16:54:25	120	27.77	45	972	1176	52.23	58
16:54:25	16:56:25	120	18.67	32	1068	976	22.90	40
16:56:25	16:58:25	120	8.40	10	636	912	12.67	23
16:58:25	17:00:25	120	26.10	36	1152	1384	28.50	45
17:00:25	17:02:25	120	17.23	28	1224	1408	27.00	46
17:02:25	17:04:25	120	34.93	35	1380	1104	35.67	39

Note: 23 observations, none of which are excluded.

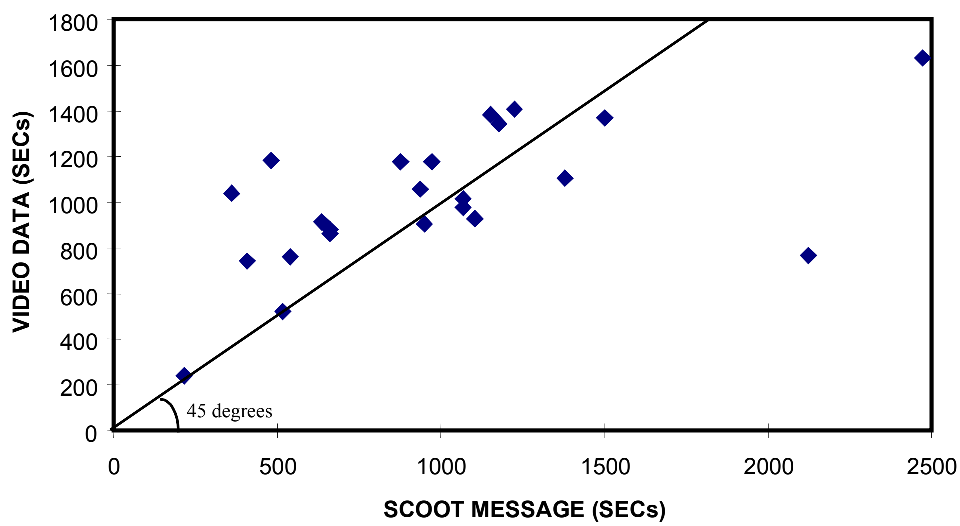
Correlation Coefficients
- Stops 0.61
- Delay 0.59
- Flow 0.79

Fault Messages Associated with these Data
16:52:08 [0213] I-g flt Stgs C-A was 0 s/b 21



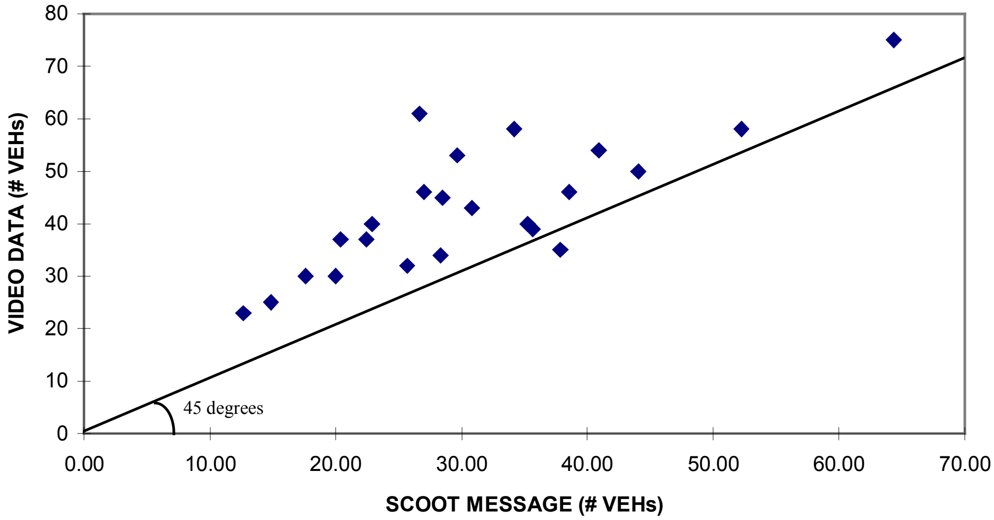
Correlation Coefficient r = 0.61.

Figure 17: Number of Stopped Vehicles on Approach per SCOOT Interval, Katella Avenue Eastbound at State College and Katella (Nov. 18 16:18:25 - 17:04:25).



Correlation Coefficient r = 0.59.

Figure 18: Total Vehicle Delays on Approach per SCOOT Interval, Katella Avenue Eastbound at State College and Katella (Nov. 18 16:18:25 - 17:04:25).



Correlation Coefficient r = 0.79.

Figure 19: Flow Volumes on Approach per SCOOT Interval, Katella Avenue Eastbound at State College and Katella (Nov. 18 16:18:25 - 17:04:25).

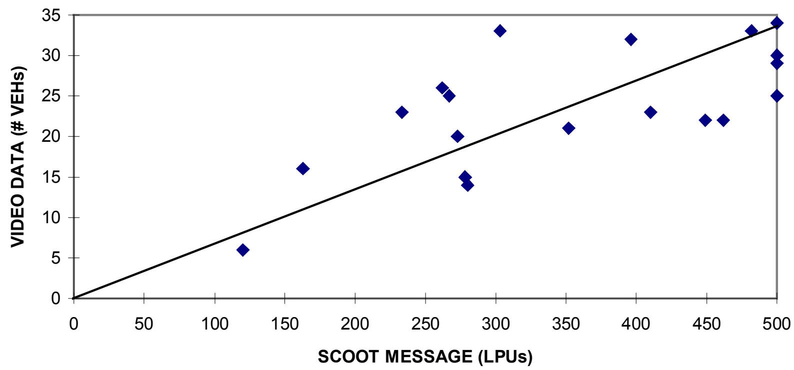
Table 10: SCOOT Messages M10, Queue length; and M11 Queue Clearance Time; Katella Avenue Eastbound at State College and Ball

November 18, 1997 16:20:07 - 17:04:47

Green Start Time			Queue Length		Queue Clearance Time	
SCOOT	Video	Difference (Seconds)	SCOOT (LPUs)	Video (Vehs)	SCOOT (Seconds)	VIDEO (Seconds)
16:20:07	16:20:06	0:00:01	262	26	25	24
16:22:01	16:21:59	0:00:02	163	16	25	14
16:24:07	16:24:03	0:00:04	449	22	25	18
16:26:01	16:26:01	0:00:00	280	14	25	12
16:28:07	16:28:05	0:00:02	233	23	16	19
16:30:10	16:30:09	0:00:01	273	20	15	18
16:32:15	16:32:12	0:00:03	303	33	25	23
16:34:14	16:34:08	0:00:06	396	32	25	28
16:36:07	16:36:06	0:00:01	462	22	25	24
16:38:19	16:38:16		500	24	-1[b]	b
16:40:13	16:40:12		500	25	-1[b]	b
16:42:23	16:42:20	0:00:03	500	29	25	20
16:44:27	16:44:25	0:00:02	267	25	24	18
16:46:26	16:46:25		-7	23	0	a
16:48:27	16:48:23	0:00:04	482	33	25	32
16:50:31	16:50:28	0:00:03	278	15	14	16
16:52:13					c	c
16:52:31	16:52:26		-154		0[a]	a
16:54:35	16:54:32	0:00:03	500	25	25	28
16:56:35	16:56:33	0:00:02	352	21	19	20
16:58:34	16:58:32	0:00:02	120	6	6	6
17:00:39	17:00:37	0:00:02	500	30	25	23
17:02:43	17:02:38	0:00:05	410	23	25	19
17:04:47	17:04:44	0:00:03	500	34	25	24

Notes: a: 16:48:26, 18:52:31 – These queue clearance times are reported as zero because the link is faulty (*SCOOT User Guide*, § 14.2.8).
b: 16:38:19 – The queue clearance time reported by SCOOT is –1. The queue clearance time observed from video data is 23 seconds. We assume the SCOOT report is an error code.
b: 16:40:13 – The queue clearance time reported by SCOOT is –1. The queue clearance time observed from video data is 34 seconds. We assume the SCOOT report is an error code.
c: 16:52:13 – This is not really a green phase. There is evidence of a link fault at 16:52:08.
There are a total of 24 total observations, 5 of which are excluded due to link faults.

Correlation Coefficients (19 Obervations)
Queue Length 0.68
Queue Clearance Time 0.60

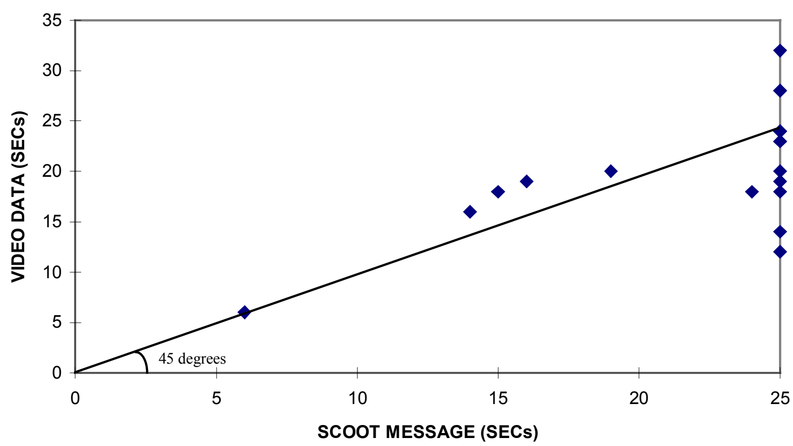


Correlation Coefficient r = 0.68.

Regression Coefficient

- The regression equation is SCOOT (LPUs) = 14.66 VIDEO (Vehs). There is no constant term.
Predictor Variable	Coefficent	St. dev.	t-ratio	p-value
VIDEO	14.6631	0.8704	16.85	0.000.

Figure 20: Queue Length, Katella Avenue Eastbound at State College and Katella (Nov. 18 16:20:07 - 17:04:44).



Correlation Coefficient r = 0.60.

Figure 21: Queue Clearance Time, Katella Avenue Eastbound at State College and Katella (Nov. 18 16:20:07 - 17:04:44).

1.5.4 Case 4

Table 11: SCOOT Internal Message M02, Stops, Delays, and Flows; All Data

November 18, 1997

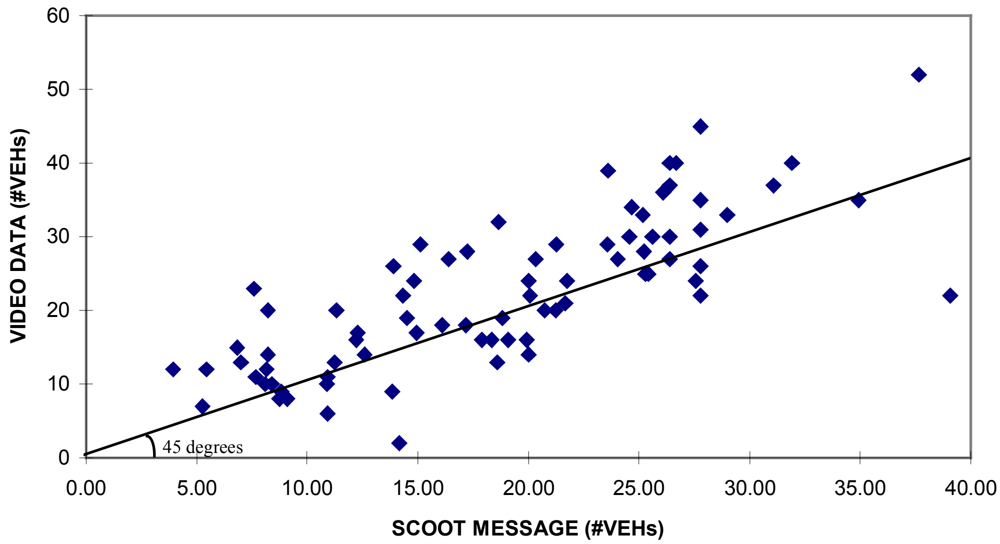
Time		Interval	Stops (Vehs/Int)		Delays (Secs / Int)		Flows (Vehs / Int)	
From	To		SCOOT	Video	SCOOT	Video	SCOOT	Video
16:18:25	16:20:25	120	25.43	25	660	880	25.67	32
16:20:25	16:22:25	120	39.07	22	516	520	40.90	54
16:22:25	16:24:25	120	27.77	31	1500	1368	35.23	40
16:24:25	16:26:25	120	27.77	22	876	1176	34.17	58
16:26:25	16:28:25	120	29.00	33	360	1040	38.57	46
16:28:25	16:30:25	120	16.40	27	540	760	22.43	37
16:30:25	16:32:25	120	23.60	39	660	864	29.67	53
16:32:25	16:34:25	120	31.93	40	1068	1016	44.07	50
16:34:25	16:36:25	120	27.77	35	1104	928	30.83	43
16:36:25	16:38:25	120	27.77	26	1176	1344	37.83	35
16:38:25	16:40:25	*120*	*20.00*	*24*	*2124*	*768*	*20.00*	30
16:40:25	16:42:25	120	26.67	40	2472	1632	26.67	61
16:42:25	16:44:25	120	14.83	24	936	1056	14.83	25
16:44:25	16:46:25	120	11.33	20	216	240	20.40	37
16:46:25	16:48:25	120	37.67	52	480	1184	64.33	75
16:48:25	16:50:25	120	20.07	22	948	904	28.33	34
16:50:25	16:52:25	120	7.60	23	408	744	17.60	30
16:52:25	16:54:25	120	27.77	45	972	1176	52.23	58
16:54:25	16:56:25	120	18.67	32	1068	976	22.90	40
16:56:25	16:58:25	120	8.40	10	636	912	12.67	23
16:58:25	17:00:25	120	26.10	36	1152	1384	28.50	45
17:00:25	17:02:25	120	17.23	28	1224	1408	27.00	46
17:02:25	17:04:25	120	34.93	35	1380	1104	35.67	39
11:38:49	11:40:49	120	20.73	20	624	480	25.27	27
11:40:49	11:42:41	112	25.23	28	1276.8	976	26.51	31
11:42:41	11:44:33	112	17.17	18	414.4	640	20.00	28
11:44:33	11:46:25	112	25.60	30	1254.4	1256	28.44	39
11:46:25	11:48:17	112	14.34	22	179.2	528	23.05	28
11:48:17	11:50:09	112	25.29	25	1153.6	1104	31.11	38
11:50:09	11:52:01	112	5.44	12	112	320	12.85	20
11:52:01	11:53:53	112	15.12	29	403.2	776	21.62	38
11:53:53	11:55:45	112	12.29	17	582.4	688	25.04	33
11:55:45	11:57:37	112	8.21	20	201.6	800	14.78	28
11:57:37	11:59:29	112	17.89	16	750.4	992	23.40	32
11:59:29	12:01:21	112	14.50	19	470.4	664	23.89	35
12:01:21	12:03:13	112	24.05	27	683.2	680	28.50	34
12:03:13	12:05:05	112	20.35	27	369.6	504	32.11	38
12:05:05	12:06:57	112	26.38	27	515.2	544	32.45	35
12:08:49	12:10:41	112	26.38	40	1108.8	1800	33.16	49

12:10:41	12:12:41	120	27.57	24	1080	1512	35.60	33
12:14:41	12:16:41	120	31.07	37	1296	2184	36.40	42
12:16:41	12:18:41	120	25.17	33	1416	1664	33.10	48
12:18:41	12:20:41	120	18.33	16	564	472	31.27	30
12:20:41	12:22:41	120	24.57	30	960	1120	26.83	36
12:22:41	12:24:41	120	26.40	37	1224	1592	31.00	41
12:24:41	12:26:41	120	24.67	34	1080	1520	33.93	38
12:28:41	12:30:41	120	26.40	30	1092	1056	33.50	38
12:30:41	12:32:41	120	14.17	2	636	1024	28.10	43
12:32:41	12:34:41	120	13.90	26	468	784	36.57	41
12:34:41	12:36:41	120	21.27	29	864	1248	31.57	44
13:57:05	13:59:05	120	14.93	17	600	888	19.43	23
13:59:05	14:01:05	120	18.83	19	780	944	19.40	24
14:01:05	14:03:05	120	21.23	20	1428	712	21.23	26
14:03:05	14:05:05	120	8.73	8	480	352	10.43	11
14:05:05	14:07:05	120	7.00	13	468	432	12.57	23
14:07:05	14:09:05	120	12.60	14	372	504	20.43	24
14:09:05	14:11:05	120	8.10	10	396	504	19.00	26
14:11:05	14:13:05	120	10.93	11	264	544	17.83	22
14:13:05	14:15:05	120	9.10	8	540	416	13.90	24
14:15:05	14:17:05	120	10.90	10	336	480	13.40	15
14:17:05	14:19:05	120	19.93	16	1296	656	19.93	25
14:19:05	14:21:05	120	13.83	9	1440	448	18.43	27
14:21:05	14:23:05	120	18.60	13	828	504	18.67	16
14:23:05	14:25:05	120	5.27	7	600	448	10.27	16
14:25:05	14:27:05	120	7.67	11	384	648	15.43	16
14:27:05	14:29:05	120	16.10	18	456	552	20.60	27
14:29:05	14:31:05	120	8.17	12	360	768	11.77	19
14:31:05	14:33:05	120	12.23	16	324	592	13.33	26
14:33:05	14:35:05	120	21.67	21	1212	1400	23.60	34
14:35:05	14:37:05	120	8.83	9	708	608	9.50	11
14:37:05	14:39:05	120	23.57	29	1044	744	24.00	33
14:39:05	14:41:05	120	8.23	14	444	592	11.43	15
14:41:05	14:43:05	120	10.93	6	312	760	14.43	18
14:43:05	14:45:05	120	3.93	12	96	304	10.00	15
14:45:05	14:47:05	120	20.00	14	756	680	20.77	24
14:47:05	14:49:05	120	11.23	13	324	584	14.57	28
14:49:05	14:51:05	120	21.77	24	588	760	25.00	29
14:51:05	14:53:05	120	19.10	16	984	944	21.73	32
14:53:05	14:55:05	120	6.83	15	156	272	14.50	22

Note: 79 observations.

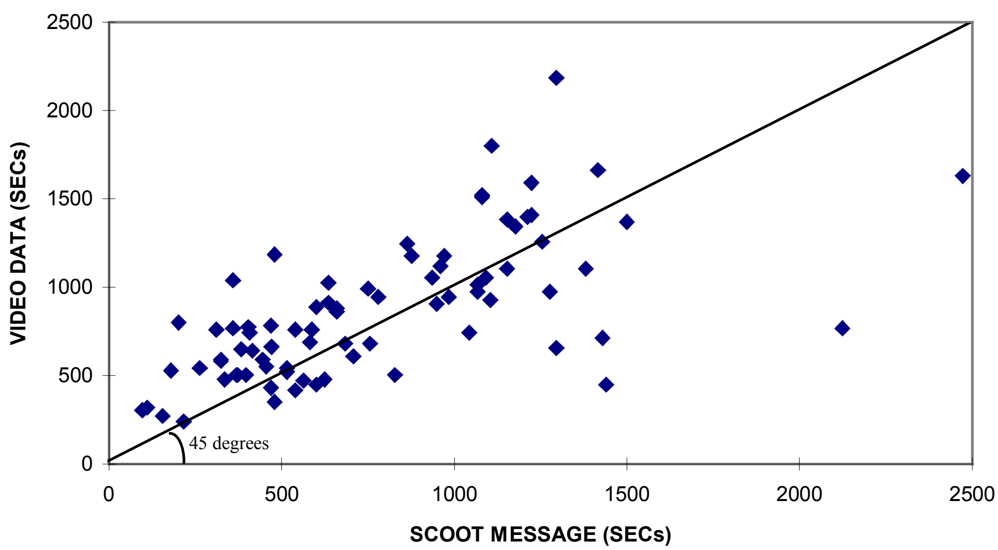
Correlation Coefficients

Stops 0.78
Delay 0.65
Flow 0.86



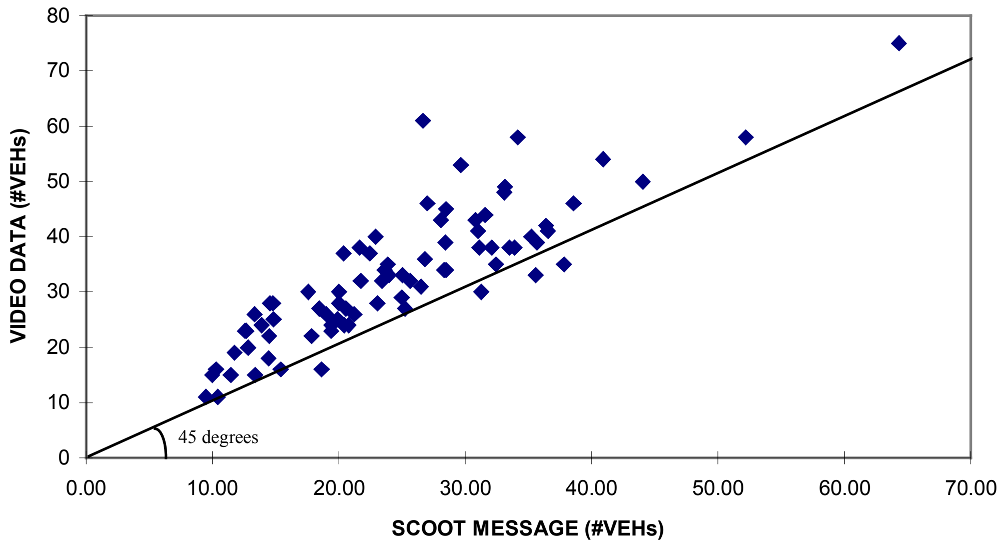
<u>Correlation Coefficient r</u> = 0.78.

Figure 22: Number of Stopped Vehicles on Approach per SCOOT Interval, All Data. (Nov. 18).



<u>Correlation Coefficient r</u> = 0.65.

Figure 23: Total Vehicle Delays on Approach per SCOOT Interval, All Data (Nov. 18).



<u>Correlation Coefficient r</u> = 0.86.

Figure 24: Flow Volumes on Approach per SCOOT Interval, All Data (Nov. 18).

Table 12: SCOOT Messages M10, Queue length; and M11 Queue Clearance Time; All Data

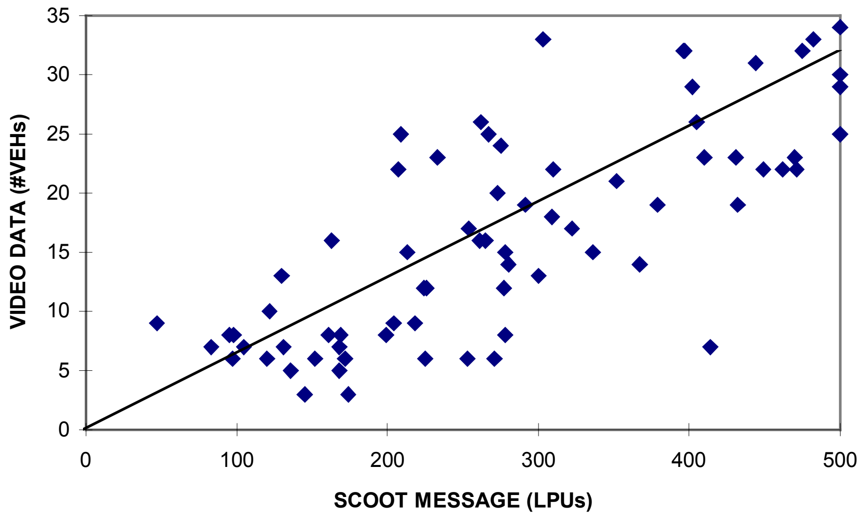
Green Start Time			Queue Length		Queue Clearance Time	
SCOOT	Video	Difference (Seconds)	SCOOT (LPUs)	Video (Vehs)	SCOOT (Seconds)	VIDEO (Seconds)
16:20:07	16:20:06	0:00:01	262	26	25	24
16:22:01	16:21:59	0:00:02	163	16	25	14
16:24:07	16:24:03	0:00:04	449	22	25	18
16:26:01	16:26:01	0:00:00	280	14	25	12
16:28:07	16:28:05	0:00:02	233	23	16	19
16:30:10	16:30:09	0:00:01	273	20	15	18
16:32:15	16:32:12	0:00:03	303	33	25	23
16:34:14	16:34:08	0:00:06	396	32	25	28
16:36:07	16:36:06	0:00:01	462	22	25	24
16:42:23	16:42:20	0:00:03	500	29	25	20
16:44:27	16:44:25	0:00:02	267	25	24	18
16:48:27	16:48:23	0:00:04	482	33	25	32
16:50:31	16:50:28	0:00:03	278	15	14	16
16:54:35	16:54:32	0:00:03	500	25	25	28
16:56:35	16:56:33	0:00:02	352	21	19	20
16:58:34	16:58:32	0:00:02	120	6	6	6
17:00:39	17:00:37	0:00:02	500	30	25	23
17:02:43	17:02:38	0:00:05	410	23	25	19
17:04:47	17:04:44	0:00:03	500	34	25	24
11:39:58	11:39:50	0:00:08	322	17	20	19
11:41:51	11:41:50	0:00:01	471	22	25	27
11:43:50	11:43:50	0:00:00	254	17	15	18
11:45:39	11:45:35	0:00:04	431	23	25	21
11:49:23	11:49:21	0:00:02	470	23	25	28
11:51:14	11:51:13	0:00:01	83	7	6	6
11:53:03	11:53:01	0:00:02	213	15	14	21
11:54:59	11:54:57	0:00:02	204	9	12	15
11:56:55	11:56:53	0:00:02	130	13	7	19
11:58:43	11:58:43	0:00:00	265	16	17	15
12:00:35	12:00:33	0:00:02	261	16	14	26
12:02:35	12:02:33	0:00:02	310	22	23	29
12:04:27	12:04:27	0:00:00	207	22	19	35
12:06:23	12:06:21	0:00:02	275	24	25	33
12:10:07	12:10:06	0:00:01	402	29	25	23
12:11:56	12:11:53	0:00:03	309	18	25	21
12:15:56	12:15:55	0:00:01	397	32	25	27
12:17:52	12:17:53	-0:00:01	475	32	25	25
12:19:51	12:19:53	-0:00:02	199	8	17	11
12:22:00	12:21:53	0:00:07	367	14	23	14
12:24:00	12:23:57	0:00:03	444	31	25	26
12:25:59	12:25:57	0:00:02	405	26	24	31
12:30:04	12:30:01	0:00:03	432	19	25	21
12:32:07	12:32:05	0:00:02	224	12	13	15

12:34:07	12:34:05	0:00:02	209	25	13	29
12:36:04	12:36:01	0:00:03	291	19	20	18
13:57:53	13:57:48	0:00:05	226	12	12	14
13:59:56	13:59:48	0:00:08	300	13	17	14
14:03:50	14:03:48	0:00:02	161	8	8	8
14:05:59	14:05:55	0:00:04	169	8	9	9
14:08:00	14:07:58	0:00:02	168	7	13	8
14:10:04	14:10:02	0:00:02	168	5	9	4
14:11:58	14:11:52	0:00:06	105	7	6	6
14:14:01	14:14:01	0:00:00	174	3	11	3
14:16:01	14:16:02	-00:00:01	95	8	6	8
14:20:08	14:20:00	0:00:08	414	7	25	7
14:22:07	14:22:06	0:00:01	271	6	16	8
14:24:06	14:24:04	0:00:02	172	6	10	8
14:26:09	14:26:06	0:00:03	131	7	7	7
14:28:09	14:28:08	0:00:01	218	9	15	12
14:30:12	14:30:10	0:00:02	122	10	8	14
14:32:09	14:32:08	0:00:01	97	6	6	6
14:34:21	14:34:18	0:00:03	336	15	22	16
14:36:20	14:36:20	0:00:00	225	6	12	6
14:38:20	14:38:20	0:00:00	379	19	22	35
14:40:16	14:40:15	0:00:01	145	3	9	3
14:42:25	14:42:22	0:00:03	152	6	11	8
14:44:28	14:44:26	0:00:02	47	9	3	12
14:46:26	14:46:24	0:00:02	278	8	20	8
14:48:31	14:48:28	0:00:03	136	5	10	6
14:50:36	14:50:34	0:00:02	277	12	21	22
14:52:36	14:52:26	0:00:10	253	6	19	6
14:54:31	14:54:30	0:00:01	98	8	7	10

Note: 72 observations.

<u>Correlation Coefficients</u>

Queue Length	0.76
Queue Clearance Times	0.67

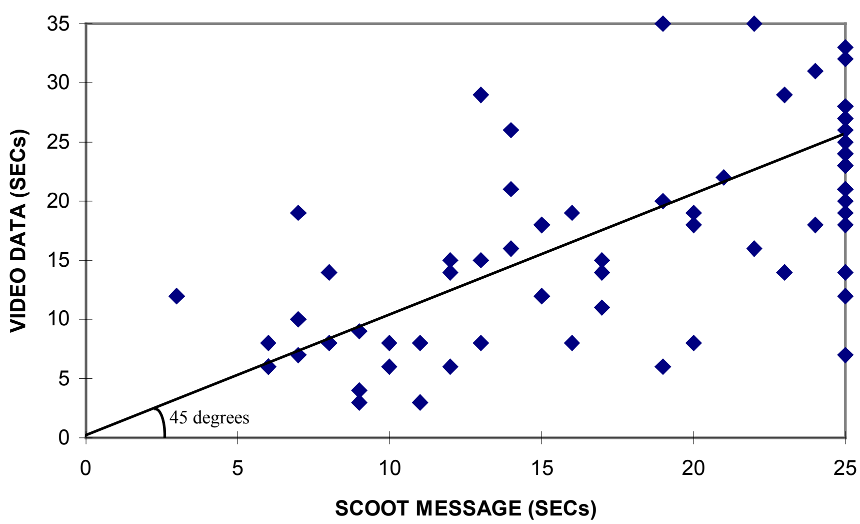


Correlation Coefficient r = 0.76.

Regression Coefficient

- The regression equation is SCOOT (LPUs) = 15.59 VIDEO (Vehs). There is no constant term.
- Predictor Variable Coefficent St. dev. t-ratio p
  VIDEO 15.5909 0.6006 25.96 0.000.

Figure 25: Queue Length, All Data (Nov. 18).



Correlation Coefficient r = 0.67.

Figure 26: Queue Clearance Time, All Data (Nov. 18).

2. TRAFFIC PERFORMANCE UNDER SCOOT

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Research Assistants Steve Mattingly, Ph.D. Candidate, and James Roldan, Department of Civil Engineering, University of California at Irvine.

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This section primarily addresses the third evaluation goal, to determine if SCOOT can indeed provide improvements given Anaheim's existing geometry and level of detectorization.

2.1 Summary of the Traffic Performance Evaluation Procedure

Signalized intersections in the FOT area are indicated in Figure 1, and listed in Table 13. SCOOT control subareas are identified in Figure 27.

2.1.1 Establishing a Baseline

The baseline for the evaluation was Anaheim's UTCS fixed-time system. The Anaheim system also included enhanced offline optimization tools consistent with a 1.5 generation control (GC) system; however, these 1.5 GC tools were not used in real-time due to computing constraints. Further, the City of Anaheim chose to not use 1.5 GC to update any of their timing plans prior to the evaluation. The City of Anaheim updated their timing plans during the FETSIM project approximately seven years before the SCOOT evaluation was conducted. Since the conclusion of the FETSIM project, the City has made some small adjustments to individual intersections based on citizen complaints and engineering judgement.

The evaluation team assumed that the City of Anaheim would notify them of any changes in the baseline conditions before data collection efforts began, and that all timing plans to remain unchanged during the entire data collection period. The City of Anaheim appears to have complied with these requests.

2.1.2 Collaboration with the Anaheim Transportation Management Center

Evaluating the SCOOT implementation required a comprehensive inventory of activities in the Anaheim TMC. As noted in the previous section, a USC graduate research

Table 13: Signalized Intersections in the FOT Area

Intersection No.	E-W	N-S	Event Site	Arterial Approaches	Upstream Detectors
334	Ball	Ph.Club	Arrowhead Pond	4	0
326	Ball	Sunkist		4	4
313	Ball	State College		4	4
314	Winston	State College		4	2 NS
327	Cerritos	Sunkist	Arrowhead Pond	4	4
315	Cerritos	State College	Arrowhead Pond	4	4
330	Katella	Douglass	Arrowhead Pond / Edison Intl. Field	4	4
52	Katella	SR-57 NB	Arrowhead Pond / Edison Intl. Field	3	2 EW
51	Katella	SR-57 SB	Arrowhead Pond / Edison Intl. Field	3	2 EW
328	Katella	Howell	Arrowhead Pond / Edison Intl. Field	4	2 EW
316	Katella	State College	Arrowhead Pond / Edison Intl. Field	4	4
317	Stadium.Entr	State College	Edison Intl. Field	3	2 NS
318	Gene.Autry	State College	Edison Intl. Field	4	0
319	Orangewood	State College	Edison Intl. Field	4	4
320	Koll Center	State College	Edison Intl. Field	4	0
272	Cerritos	Lewis	Interstate-5	4	4
273	Katella	Lewis	Interstate-5	4	2 EW
259	Katella	Claudina	Interstate-5	4	2 EW

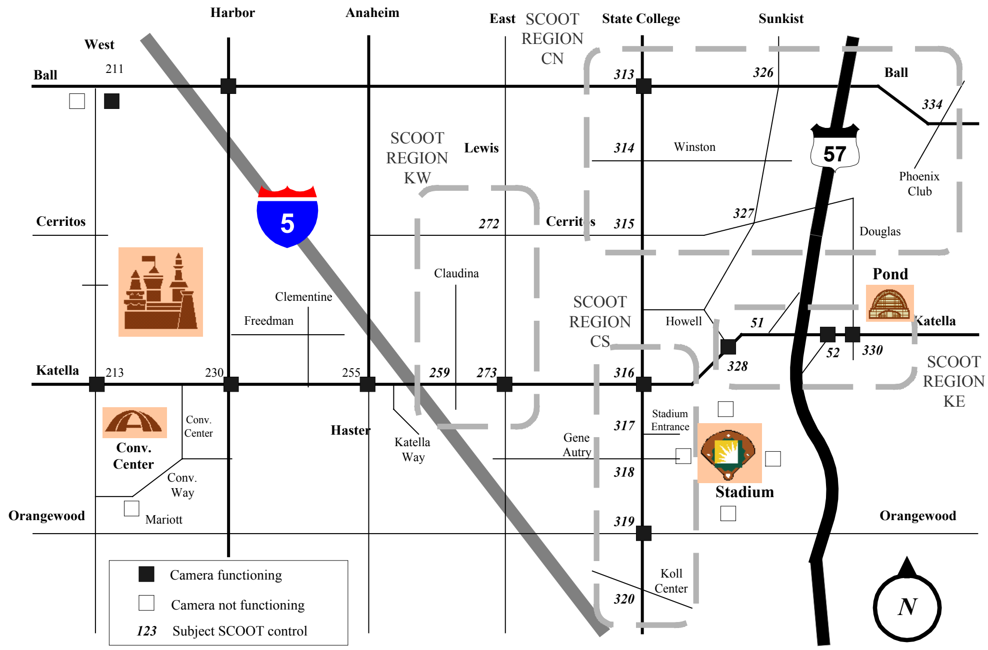


Figure 27: Signals Designated to be Subject to SCOOT Control, and SCOOT Control Subareas.

assistant was employed in the Anaheim TMC as an intern prior to and during the data collection phase of the evaluation. The graduate research assistant completed an inventory of the Anaheim TMC operator tasks prior to the implementation of SCOOT, helped develop a questionnaire concerning the quality of the SCOOT/TMC operator interface, and completed an inventory of the TMC operator tasks after the implementation of SCOOT.

2.1.3 Evaluation Dimensions

The evaluation includes comparisons of before SCOOT flows and after SCOOT flows across different dimensions. These are

1) PM peak (3:30 PM to 7 PM) versus evening off-peak (7 PM to 10:30 PM) states,

2) special event versus nonevent states, and

3) experimental group versus control group states.

The control dimension denotes the best available level of UTCS 1.0 Generation Control. The control network for floating car studies was selected to be as close to the SCOOT study area as possible, so that any unanticipated, systematic, exogenous, before-SCOOT-to-after-SCOOT, week-to-week, or day-to-day variations in travel demand in the two networks could be identified and; if necessary, subtracted from SCOOT treatment effects. The control area was one long block away from the SCOOT study area, had similar network characteristics, and had similar traffic during the evening off-peak period. This control net included the intersections of La Palma / State College, South Street / State College, South Street / Sunkist, Lincoln / Sunkist, and Lincoln / State College. The control area intersections are shown in Figure 1.

It is important to evaluate SCOOT during both peak and off-peak periods because it is likely that SCOOT is able to achieve different levels of coordination and delay reduction across this dimension. The evaluation examines the PM peak because the special events at the Anaheim Pond all occur on weekday evenings. Most of the special event traffic mixes with PM peak traffic volumes to create more significant effects. The comparisons necessary to evaluate SCOOT performance required collection of network field data. It is important to compare data for similar collection periods when comparing special event and nonevent traffic. Figure 28 shows the dimensions of the field test for the intersections subject to SCOOT control.

2.1.4 Selecting Intersections

The evaluation team selected six intersections in the SCOOT network and 1 or more intersections from 3 of the 4 SCOOT subareas appearing in Figure 27. The intersections included 2 arterial-to-arterial intersections,

1) Katella/St. College and St. College/Ball,

three collector-to-arterial intersections,

2) Katella/Howell, Ball/Sunkist, and St. College/Cerritos,

and one collector-to-collector intersection,

3) Cerritos/Sunkist.

2.1.5 Defining Field Data Collection Scenarios

The field study for the performance evaluation of SCOOT included the twelve scenarios summarized in Table 14**.** The study was conducted over ten days on the dates shown in Table 15. These include five before SCOOT dates, and five after SCOOT dates. Off-peak and Peak period performance studies were all completed on the same dates, in the evenings. The evaluation team held two data collection sessions at each intersection every night during the study period. One session occurred during the PM peak and one occurred during the evening off-peak.

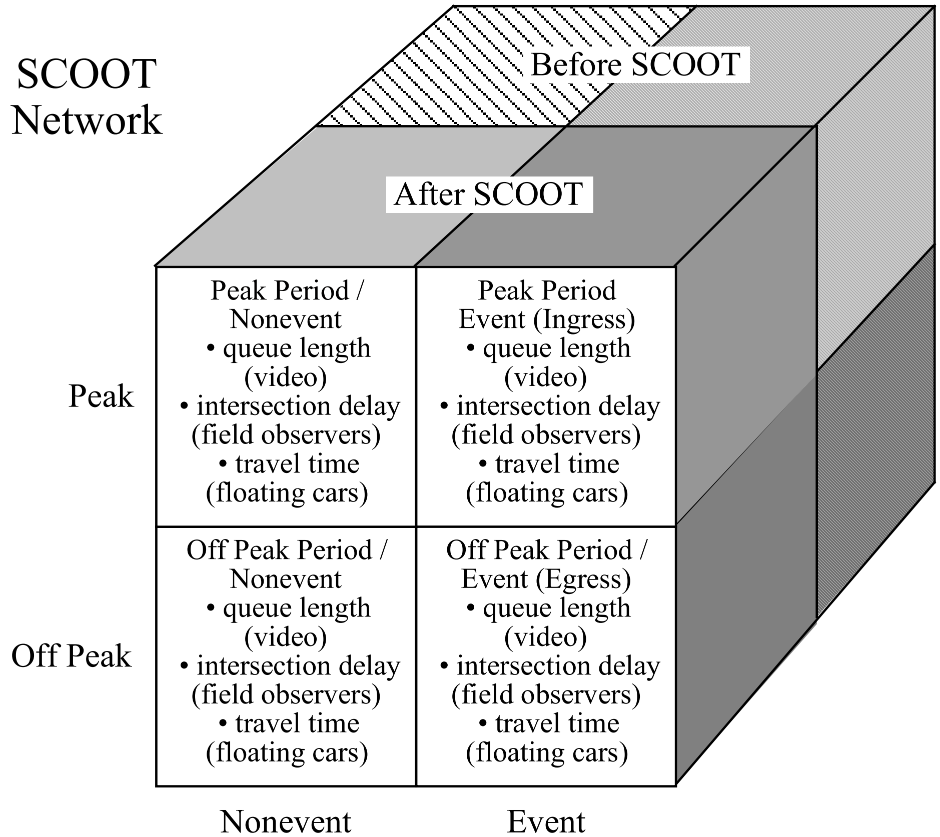


Figure 28: The Field Study Dimensions.

2.2 Floating Car Travel Time Studies

A travel time study determines the time required to traverse a specific route. A typical travel time study uses a test vehicle driven over a street section in a series of test runs. Such floating car data provides a measure of vehicle hours and miles traveled through subareas of the network, including queue delays, stop delays, turn delays, and moving times.

2.2.1 Approach

The evaluation team used a floating car study that maximized the data collected realtive to available collection resources. Floating car study teams consisted of a driver and an observer/navigator/recorder. Teams drove at the speed of the average traffic flow. The driver tried to float in the traffic stream passing as many vehicles as pass the test car. The observer started his or her stopwatch at the beginning of each run, and recorded the arrival time at various control points along the route. Additionally, the observer used the stopwatch split function to record the length of individual stopped-time delays. The time, location, and the cause of these delays were recorded.

Table 14: Data Collection Scenarios for the SCOOT Field Study

Traffic Conditions	SCOOT Status
PM Peak Period	Installed, not operating, recording data
Evening Off-Peak Period	Installed, not operating, recording data
Special Event Peak Period	Installed, not operating, recording data
Special Event Access Period	Installed, not operating, recording data
Special Event Off-Peak Period	Installed, not operating, recording data
Special Events Egress Period	Installed, not operating, recording data
PM Peak Period	Installed, operating, controlling
Evening Off-peak Period	Installed, operating, controlling
Special Event Peak Period	Installed, operating, controlling
Special Event Entrance Period	Installed, operating, controlling
Special Event Off-Peak Period	Installed, operating, controlling
Special Events Egress Period	Installed, operating, controlling

Table 15: Data Collection Dates for the SCOOT Field Study[a]

Tuesday No Event	Wednesday[b] Anaheim Pond Event
Before (SCOOT) Study	
October 14, 1997 15:30 – 18:30, PM Peak 18:30 – 22:30, Evening Off-Peak	October 15, 1997, 17:00 – 23:00
October 21, 1997 15:30 – 18:30, PM Peak 18:30 – 22:30, Evening Off-Peal	October 22, 1997, 17:00 – 23:00
October 28, 1997 15:30 – 18:30, PM Peak 18:30 – 22:30, Evening Off-Peak	
After (SCOOT) Study	
November 4, 1997 15:30 – 18:30, PM Peak 18:30 – 22:30, Evening Off-Peak	
November 11, 1997 15:30 – 18:30, PM Peak 18:30 – 22:30, Eveing Off-Peak	November 12, 1997, 17:00 – 23:00
November 18, 1997 15:30 – 18:30, PM Peak 18:30 – 22:30	November 19, 1997, 17:00 – 23:00

Notes: a. Control data were collected concurrent with data collected from the study area.
b. No PM peak distinction on these dates since volumes are primarily affected by special event.

The basic unit of observation in the floating car studies is time between control points. Each route includes multiple control points. This increases the number of available observations from which to draw variance estimates. Comparing conditions before and after deployment of SCOOT provides, at a minimum, an opportunity to identify changes in average travel times. If SCOOT functions in a systematic way, some portion of differences observed across before and after SCOOT conditions is necessarily due to differences in volumes. Some is due to systematic differences in other conditions that could not be fully anticipated but which can be identified by data from the control routes. Some is due to SCOOT, and some is due to noise. Our goal is to identify and separate these influences on floating car travel times.

2.2.2 Floating Car Study Logistics

The drivers used their own cars. Only drivers with legal insurance coverage participated in the study. They signed a standard waiver to absolve the University of California at Irvine, the University of Southern California and the evaluation team from liability in the event of accident.

Cars were deployed to assure coverage of key intersections where traffic conditions are representative and video resources were available. Floating cars were used during ingress to and egress from events, and during nonevent conditions.

1) Team size: 2, including one driver and one observer/navigator/recorder

2) Number of teams: 5, including 1 team for control net studies.

3) Routes:

- Team 1: Back-and-forth Route 1.

  Start on State College from North of Ball and drive South past Katella and Koll Center. Return North on State College past Ball. Repeat.

  Expected run time: 4-7 minutes without special events, 4-10 minutes during special events.

- Team 2: Back-and-forth Route 2.

  Start on Katella from west of State College and drive East past the Anaheim Pond and Douglass. Return West past State College. Repeat.

  Expected run time: 2-5 minutes without special events, and 3-15 minutes during special events.

- Team 3: Circular Route 1.

  Start on Ball Street from West of State College. Turn right on State College and proceed South until Cerritos,. Turn left and drive East. Turn right on southbound Sunkist. Turn left on Howell. Turn right on Westbound Katella. Turn right on Northbound State College. Turn right on Eastbound Ball. Drive past Sunkist and return on Westbound Ball. Turn left on Southbound State College. Turn right on

Westbound Katella. Turn right on Northbound Lewis. Turn right on Westbound Ball.

Expected run time 14-22 minutes.

- Team 4: Circular Route 2.

  Reverse the direction of circular route 1.

- Team 5: Control Net Route.

  Start on Eastbound La Palma from West of State College. Turn right on Southbound State College. Turn left on Eastbound South Street. Turn left on Northbound Sunkist. Turn left on Westbound Lincoln. Turn right on Northbound State College. Turn left on Westbound La Palma. Turn around and return.

  Expected run time: 8 to 14 minutes.

2.3 Intersection Delay Studies

The objective of this portion of the test was measurement of queue lengths, total vehicle delay, and flows on intersection approaches. The evaluation team used hand-held electronic counters to monitor all vehicles stopped on intersection approaches, and to complete volume counts of all vehicles passing through the intersection on each approach. The delay study data collection included of two components,

1) a team consisting of two people doing volume counts, and

2) a team consisting of four people doing intersection delay counts.

2.3.1 Intersection Volume Counts

At each intersection, 2 members of the delay study team were responsible for counting the volume for each study interval, usually 50 minutes. The first person was positioned at the Northwest corner, and the second at the Southeast corner. The Northwest counter was responsible for all movements on the Eastbound and Southbound approaches. The Southeast counter was responsible for all movements on the Westbound and Northbound approaches. Volume counts were done using electronic JAMAR count boards. The JAMAR counters stored data in one minute intervals. The boards were downloaded (almost) daily by the evaluation team.

2.3.2 Intersection Delay Counts

In addition to the two volume counters, each intersection team included four delay counters. A delay counter stood at each approach counting vehicle delays. The delay counters recorded a numerical snapshot of the queue on the approach every 15 seconds.

Delay counters performed their counts during 10 minute study periods followed by 2 minute breaks, recording their data on standard count sheets. The evaluation team compiled this data and entered it into Excel spreadsheets.

2.4 Field Data Collection Problems and Constraints

The evaluation team encountered several SCOOT related problems during the after SCOOT study.

2.4.1 Problems Not Related to the Peformance of SCOOT

On November 12, a special event day, an accident occurred on California Interstate 5 between State College and Katella. As a result of this accident, the entire network became saturated with traffic diverted from I-5. In addition, several small accidents occurred at other locations in the network during this time period. The traffic traveling southbound on State College became jammed from signal operations in the City of Santa Ana, and the jam extended back into the SCOOT network to locations North of Orangewood.

Rain problems occurred only once. Rain fell in the City of Anaheim on November 19. As a result, the evaluation team suspended data collection efforts from 8:00 PM until 10:00 PM. Data collection resumed in time to gather data on event egress, but the team had to eliminate four off-peak special event intersections from the study.

In general, the floating car teams seemed to have little difficulty after solving the problems associated with not being able to read a stopwatch at night. The teams used small flashlights or the map lights in their cars to provide the illumination needed to create records. During the after SCOOT study, one lane was blocked on one floating car route between Koll Center and Orangewood due to utility work. One of the floating car teams received two tickets from the Anaheim police for running red lights. After the second ticket, the driver was released from the study.

2.4.2 Problems Related to the Performance of SCOOT

Overall, problems reduced the available intersection data by about 50%, and completely eliminated some intersections from the non-event portion of the investigation. For the first three days of data collection after SCOOT operation began, SCOOT control was set to terminate at 7:30 PM. Why SCOOT was configured to cease control at this time is unclear. Since this was unexpected, unannounced, and not identified until after data collection had begun, this reduced the amount of off-peak data collected by the evaluation team.

Even more problematic, some SCOOT signals tended to accumulate communication faults throughout the after SCOOT period. Six intersections accumulated so many faults that SCOOT switched these signals to free operation, isolating them from SCOOT control. This occurred without announcement. Unlike the previous problem, this outcome was not a matter of a(n unannounced) system setting defined as part of Siemens' SCOOT configuration. The accumulation of communication faults was unanticipated by all parties. As described in Section 1.3.4, this shift from SCOOT control to free operation was eventually identified by the USC graduate research assistant's comparison of the start-of-green times and queue clearance times reported by SCOOT's Node Fine Tuning Display to real time video images recorded in the Anaheim TMC. When the graduate research assistant identified inconsistent results, he referred to a list of SCOOT event driven messages, and found that these intersections were accumulating system fault messages. Once this discovery was made, the faults could be cleared, and, with constant attention from a TMC operator, the signals could be maintained under SCOOT control. Unfortunately, neither the evaluation team nor City of Anaheim personnel could determine when these changes occurred for the period prior to the discovery of system fault messages. As a result, the evaluation team decided to eliminate the use of all data from these six intersections prior to attempts to clear accumulated communication faults.

Finally, the SCOOT logs recorded additional periods during which SCOOT went off-line and signals scheduled for SCOOT control reverted to free operation. All of these problems could have been remedied if the City of Anaheim had acquired more experience with the SCOOT system before the evaluation began.

2.4.3 Resulting Constraints on Intersection Delay Study Data Reduction and Analysis

As noted in Section 2.1.5, the field study took place over a period of ten days. Each day, two intersection teams covered a total of 12 intersections, usually at 50 minute intervals. Given the number of days and intersections, the data reduction process needed to post process and combine the data's volume and delay components was very time intensive.

After each day of data collection, a member of the evaluation team (usually) downloaded the intersection volume counts from the electronic JAMAR counters to PC's using the Petra software program. The Petra count files were then exported into an Excel spreadsheet. The spreadsheet consisted of movement counts for all approaches, as well as approach totals. All counts were recorded in one minute intervals.

The delay count sheet data were also imported into formatted spreadsheets. These spreadsheets were electronic copies of the sheets the team members used for recording the delay counts. Each sheet had a series of the pages that recorded delays in 15 second intervals for 10 minute periods.

After inputting this data, the volume counts were added to the delay count spreadsheets. Since the field study used one minute intervals for both the delay and volume counts, these data matched together easily. Matching volume counts with delay counts makes it possible to complete delay analysis, including the calculation of delay per vehicle, total stopped vehicles, % changes, and other quantities.

However, combining the volume counts and the delay counts to calculate delay per vehicle requires coordination between the volume counts and delay counts. The two teams needed to start and stop their counts at the same time. Unfortunately, this field coordination step was incomplete. As the data reduction/analysis took place, this lack of coordination became a significant hindrance. Problems included the following.

1) Start/Stop Discrepancies: The two volume counters at the Northwest and Southeast intersection corners sometimes failed to communicate when starting and stopping counts. As a result, some sections of data (up to ten minutes per period at some intersections) were of no use because the intersection analysis required simultaneous data for all approaches. In addition to the lack of coordination between the volume counters, volume counters sometimes failed to communicate with delay counters, and delay counters sometimes failed to communicate with each other. This resulted in some additional data loss because intersection delay analysis requires both volume counts and corresponding delay data.

2) Time Discrepancies: Some field team members failed to make sure that all field clocks, including JAMAR clocks and delay counter clocks, were synchronized. Consequently, if field team members did not communicate start and stop times, the evaluation team was sometimes unable to use the times recorded from unsynchronized clocks. This led to a further data loss.

3) Extensive Breaks: As the analysis process continued, some of the field personnel became fatigued. Some of the delay counters took more than the instructed two minute break between counts. The reduced the number of delay counts that could be matched with volume data, which was continuously recorded. When combined with start/stop discrepancies, these long breaks greatly reduced the useful data set.

These were all relatively simple errors that could have been avoided with better coordination between field team members. Fortunately, the evaluation team had pursued an over-sampling strategy, substituting addition data recorders for field supervisors, and the remaining data was sufficient to perform an adequate analysis.

In addition to the field errors listed above, the evaluation team needed to establish a better data storage protocol in the earliest phases of the field study. Data was not always downloaded from JAMAR boards the same evening it was collected. The evaluation team also needed to more closely review the data as it was being collected. By doing so, some of the field errors could have been identified and problems resolved before errors propagated further. For future reference, the field evaluation teams should include a full-time data entry member at work from the beginning of the field study.

2.5 Field Study Data Analysis

The data from the field study is extensive, but the results from the statistical analysis are very uneven across the various study dimensions for the different intersections. This makes it difficult to draw general conclusions. However several insights can be extracted from the various graphs and tables provided below. The intersection delay study data and the floating car study data are examined separately.

2.5.1 Intersection Delay Analysis

The averaged delay results are available in the graphs in Figures 29 through 52, and Tables 16 through 45. The graphs show the delay patterns over time during each study period. These normally consist of 4 to 8 different delay values. The graphs and tables are organized in groups of 5, with results for the 4 individual intersection approaches appearing first, followed by the overall intersection delay results. Graphs are not provided for all the cases, because most do not provide much insight into the results. This is due to uneven and often drastic delay variations over time. However, tables giving averaged delay for the various study dimensions shown in the matrix in Figure 28 are provided for all intersections. The aggregate data for the PM peak, evening off-peak, event, and non-event cases shown in the tables are statistically significant.

The results of the intersection delay analysis are as follows.

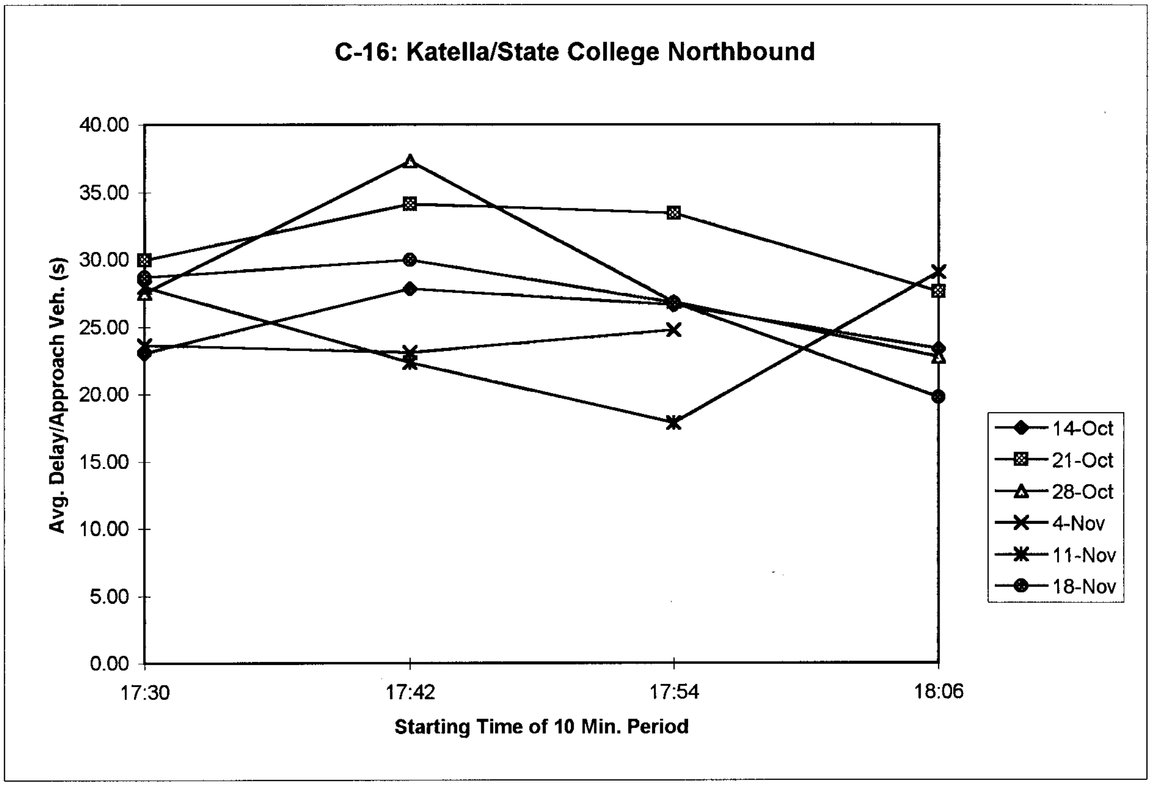
1) The SCOOT system generally performs better under off-peak conditions than under peak conditions. This is borne out by the results in Table 25 for the medium-volume State-College/Ball intersection, in Table 35 for the low-volume Cerritos/Sunkist intersection, and in Table 40 for the high-volume Katella/Howell intersection under special events. For those cases in which SCOOT performed worse than the baseline control system, the performance loss was less under off-peak conditions than it was under peak conditions.

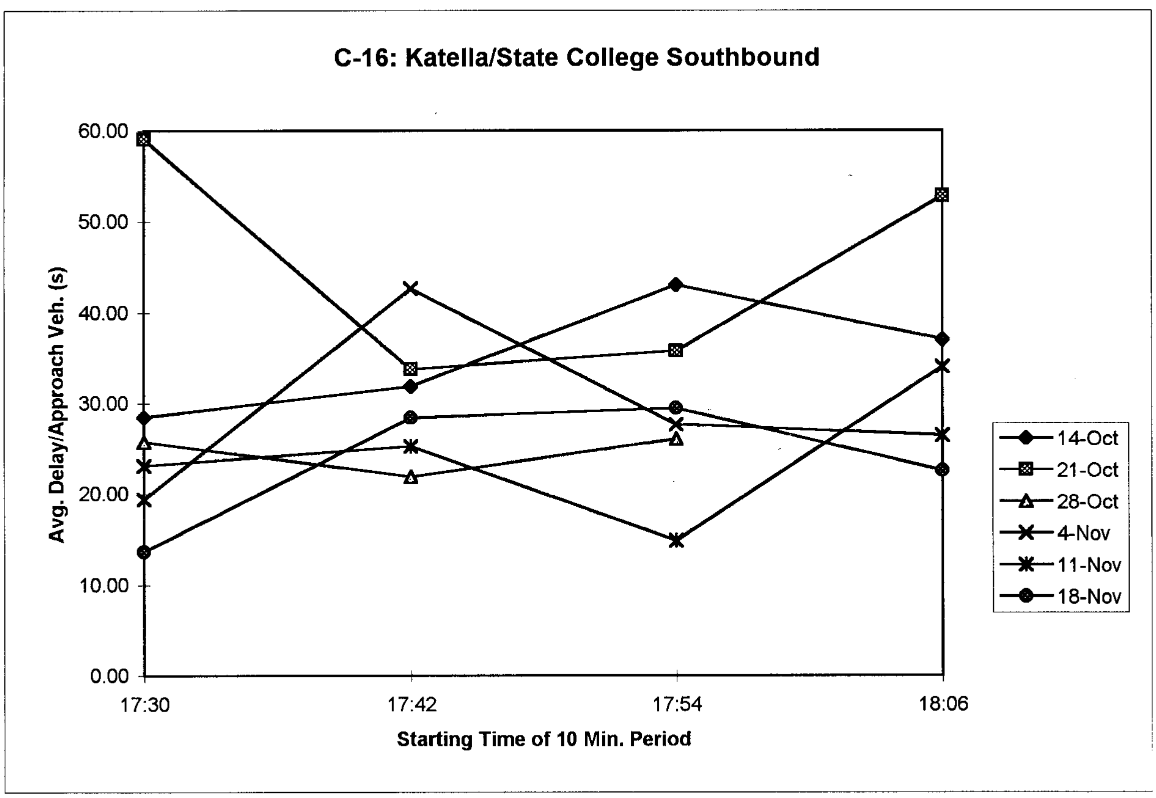
2) The relative performance of SCOOT in comparison to the baseline system improves under special-event conditions compared to non-event conditions for smaller volume intersections. The reverse occurred for some higher-volume intersections.

    - Tables 19 (State-College/Katella), 25 (State-College/Ball), 30 (State-College/ Cerritos) and 35 (Cerritos/Sunkist) all show that delays associated with SCOOT were worse relative to the baseline system under special event conditions. If the data from the heavily congested I-5 accident case is excluded, SCOOT delays were generally not more than 10% higher than the baseline delays. At some intersections SCOOT performed better under nonevent conditions than the baseline system. This delay reduction disappeared under event conditions.

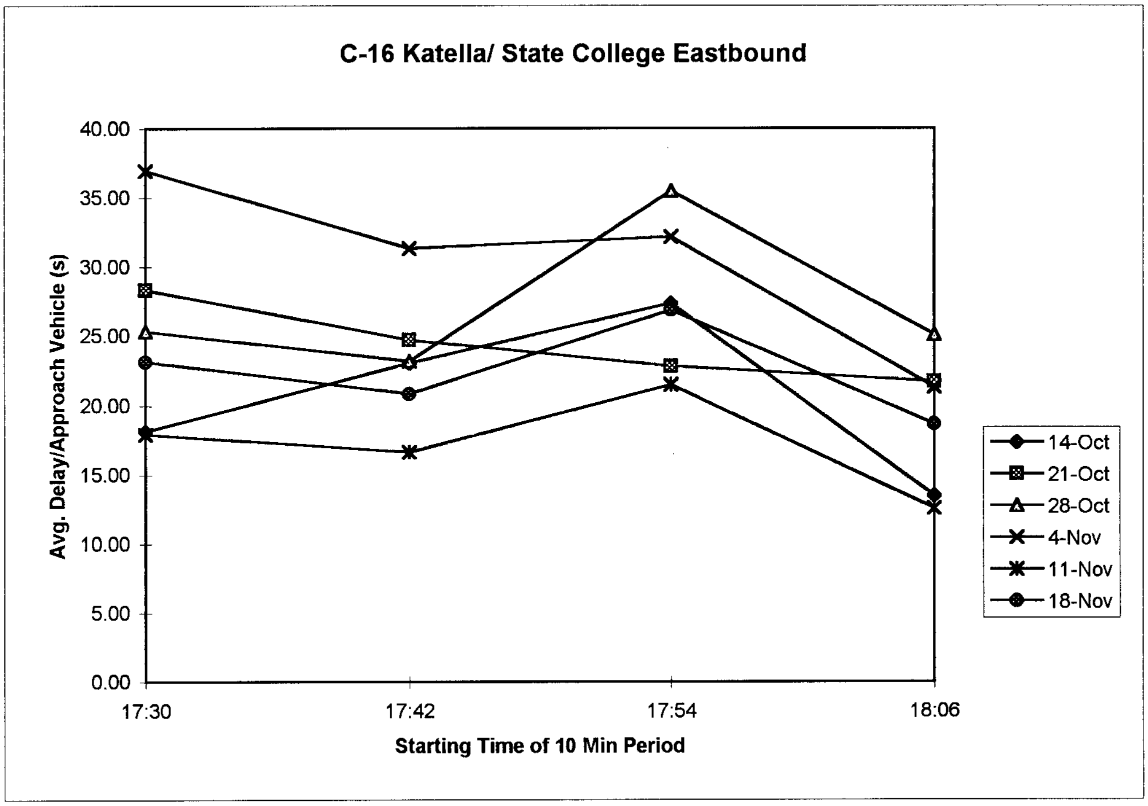
    - Table 30 shows substantial increases in nonevent delays at Cerritos/State-College under SCOOT compared to the baseline, but the difference in delays improved by about 30% under special event conditions. This indicates SCOOT is able to handle special events better at a medium volume intersection, especially if directional flows are present.

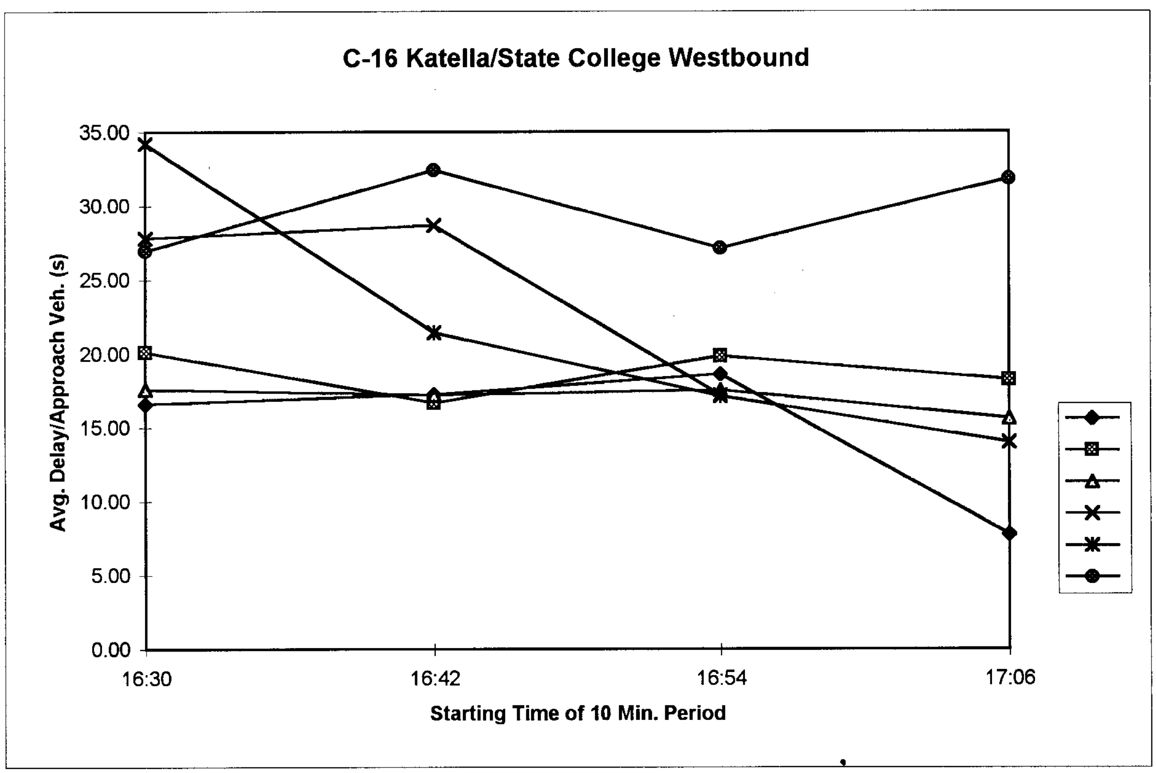
3) SCOOT performed very well at two intersections subject to heavy exit traffic from special events. This is perhaps the most promising finding from the intersection delay studies. Both Table 35 (Cerritos/Sunkist) and Table 40 (Katella/Howell) show that the intersections performed up to 20 to 40% better than the baseline system under the sudden exit of traffic from the special event location during off-peak periods (i.e.,





Figures 29 & 30: High Volume, Katella & State College. No Events (N- & S-bound).





Figures 31 & 32: High Volume, Katella & State College. No Events (E- & W-bound).

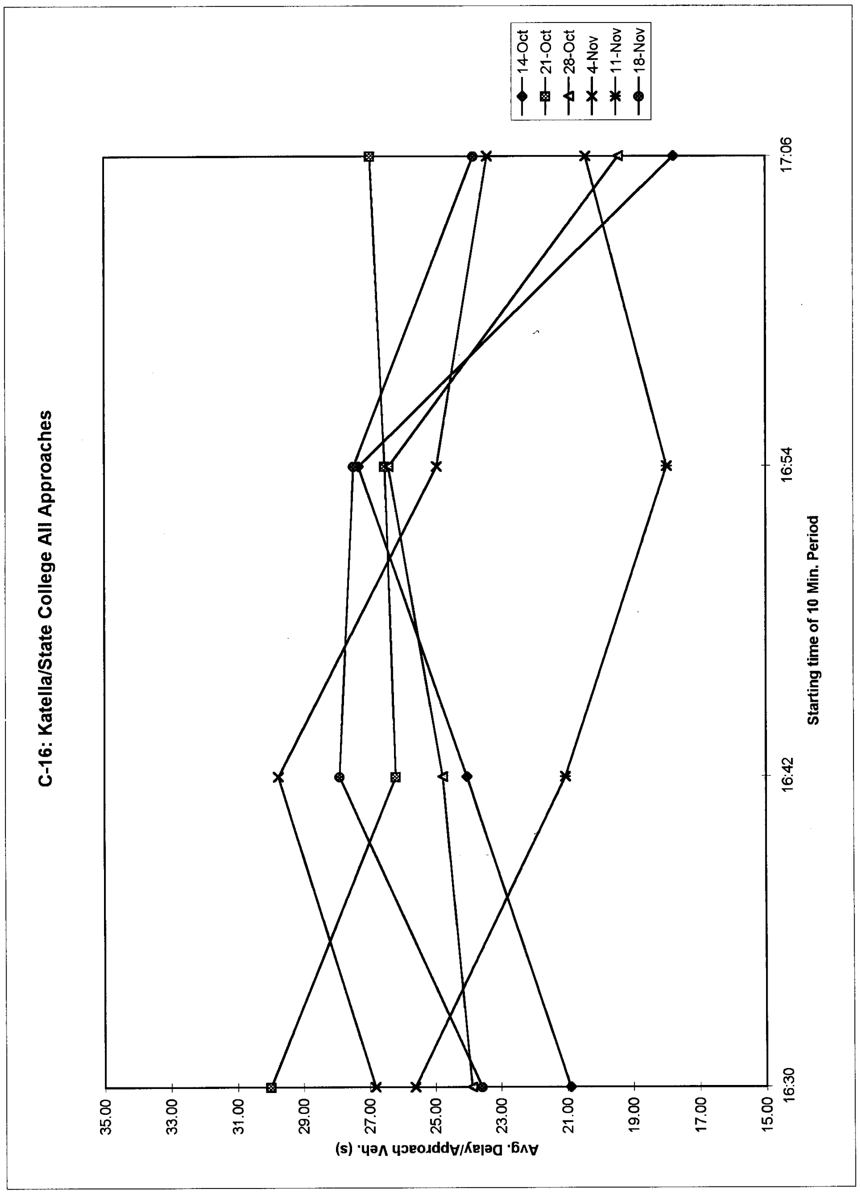
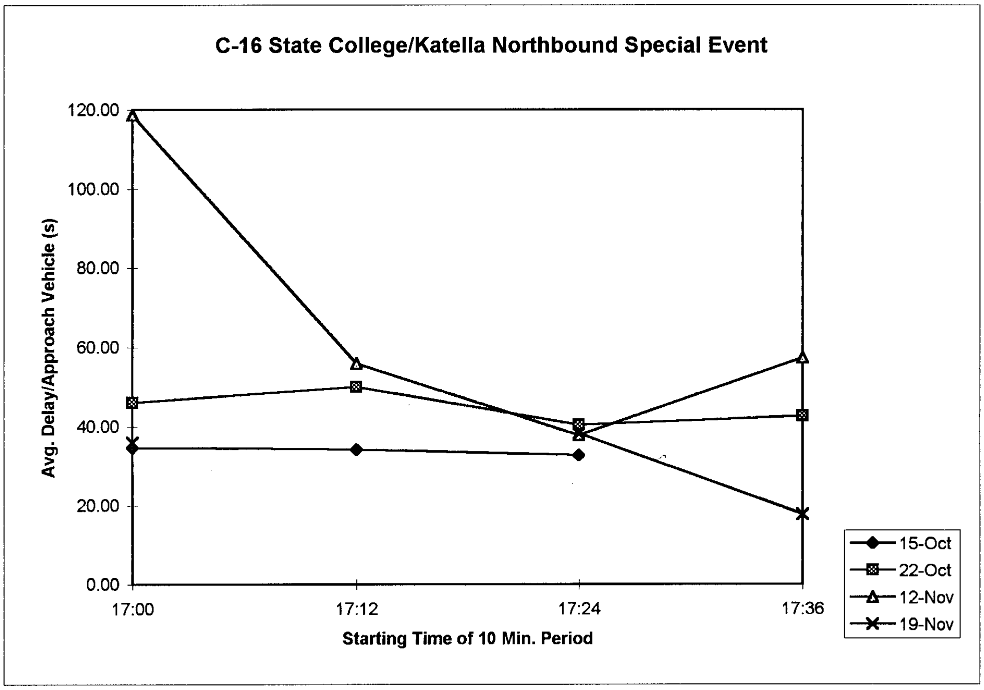
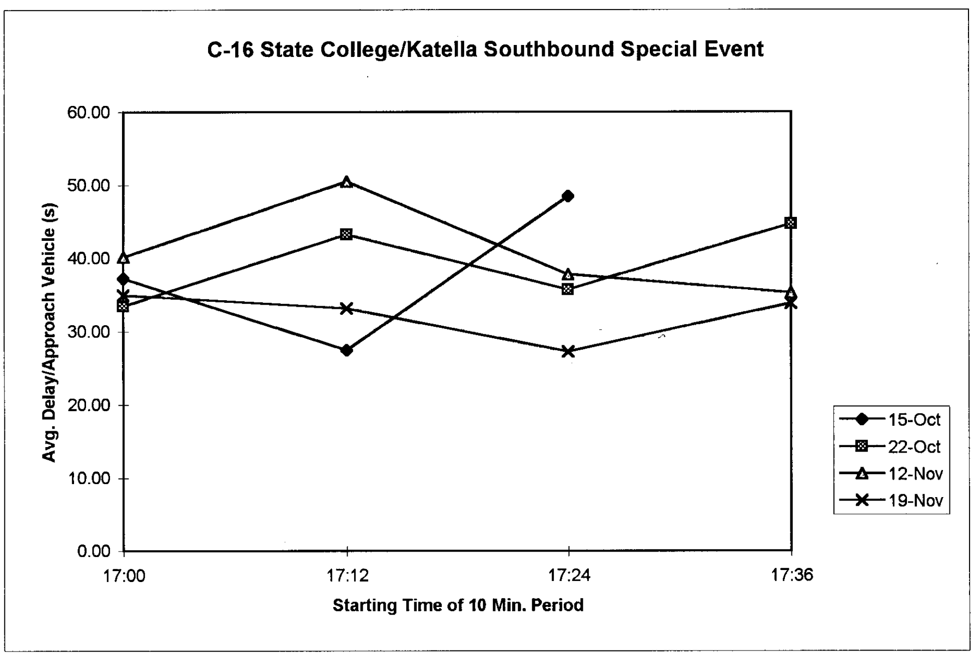
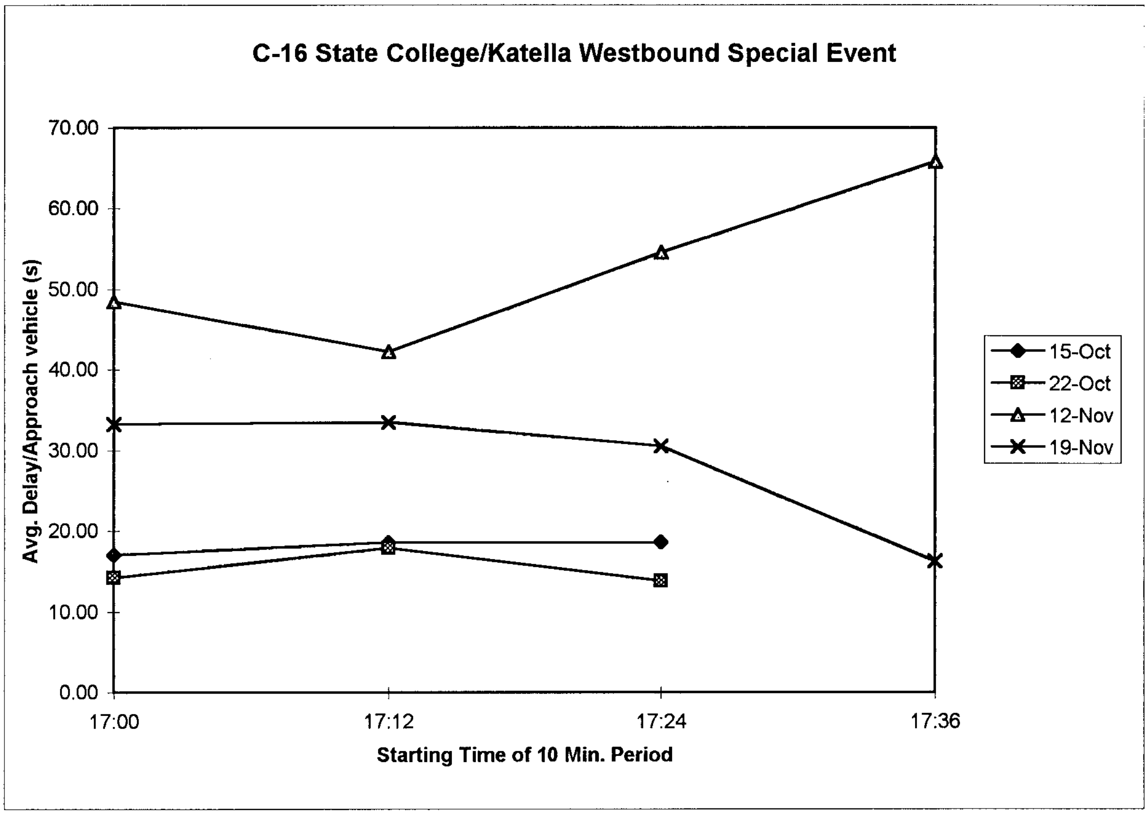


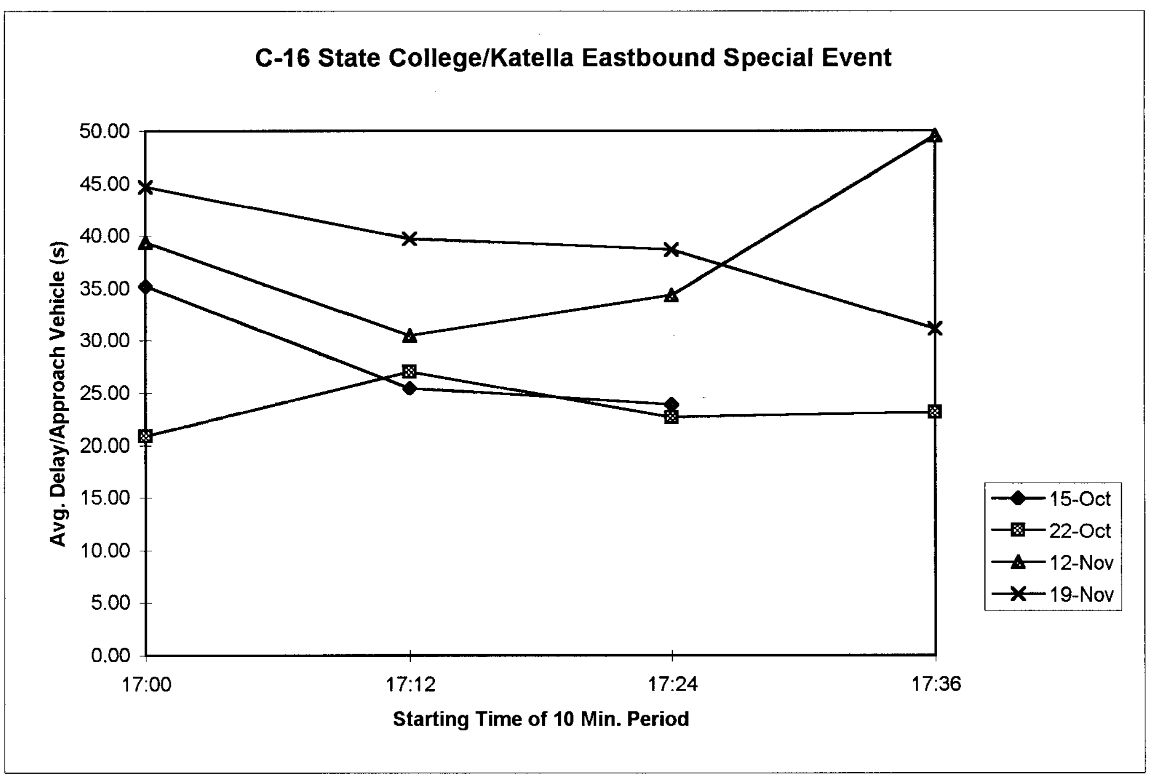
Figure 33: High Volume, Katella & State College. No Events (All Approaches).





Figures 34 & 35: High Volume, Katella & St. College. Special Events (N- & S-bound).





Figures 36 & 37: High Volume, Katella & St. College. Special Events (W- & E-bound).

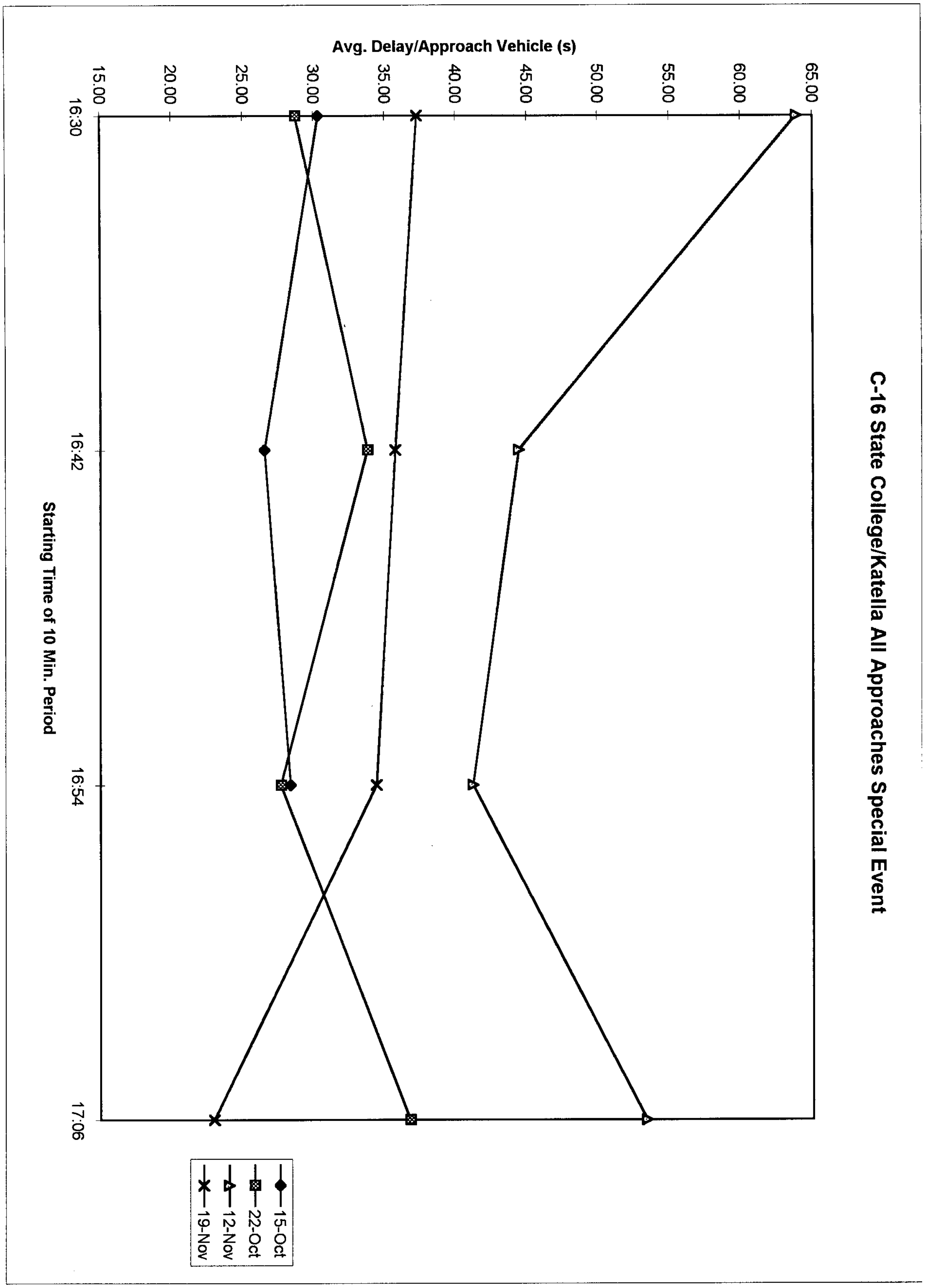
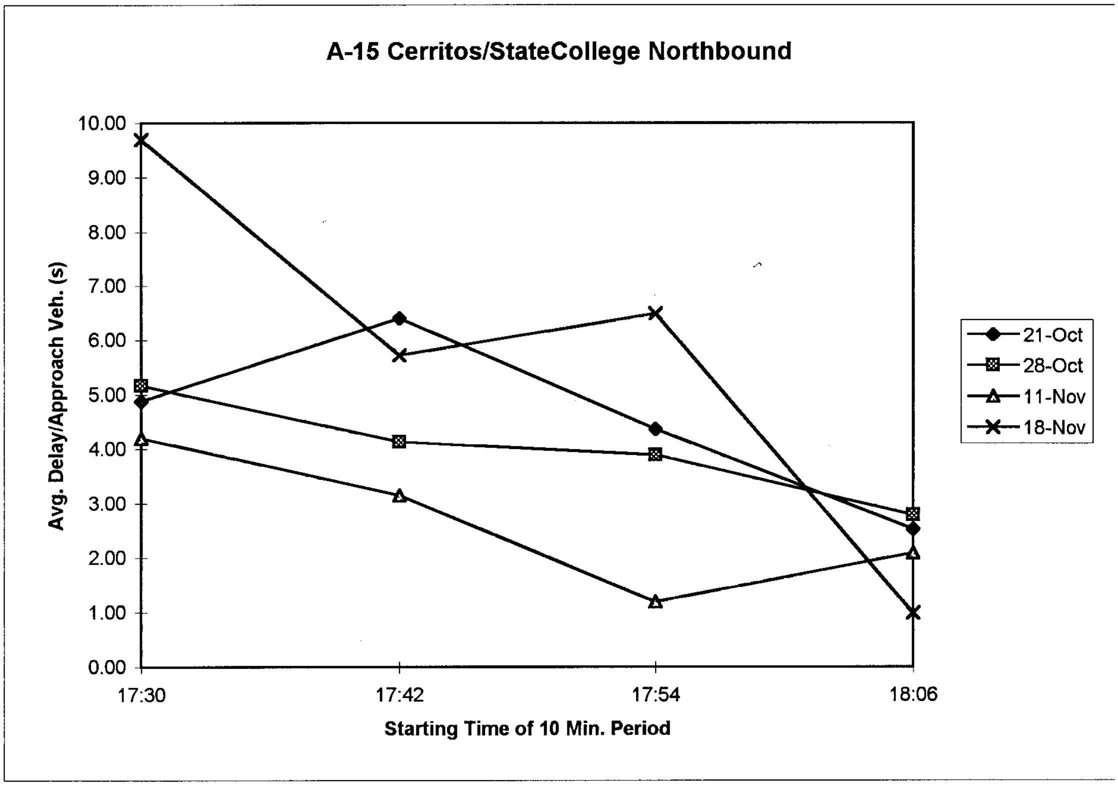
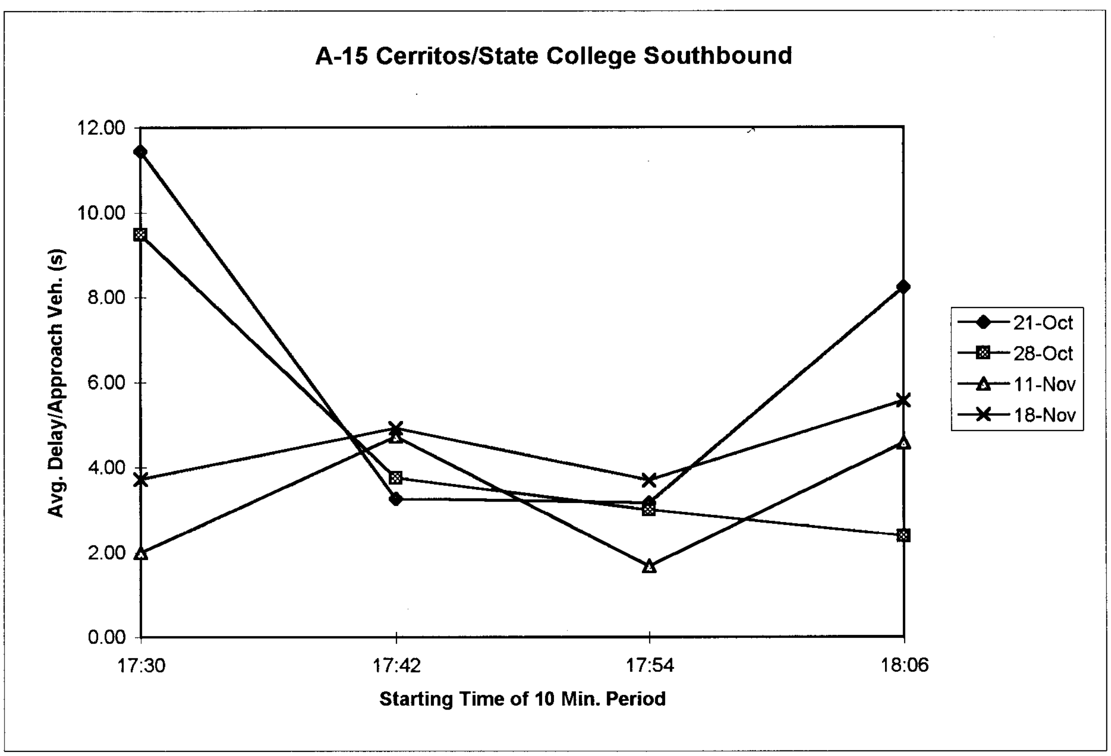
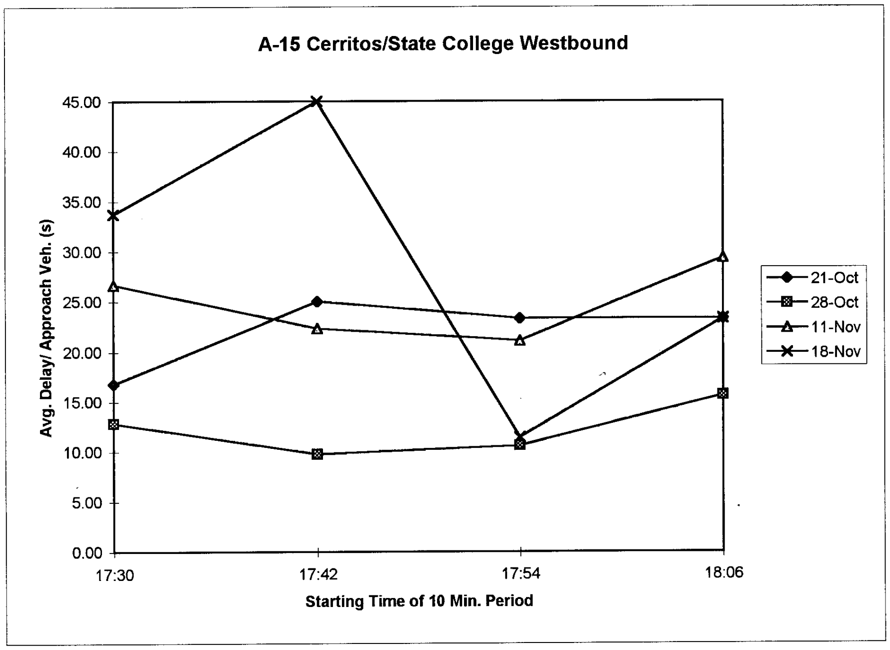


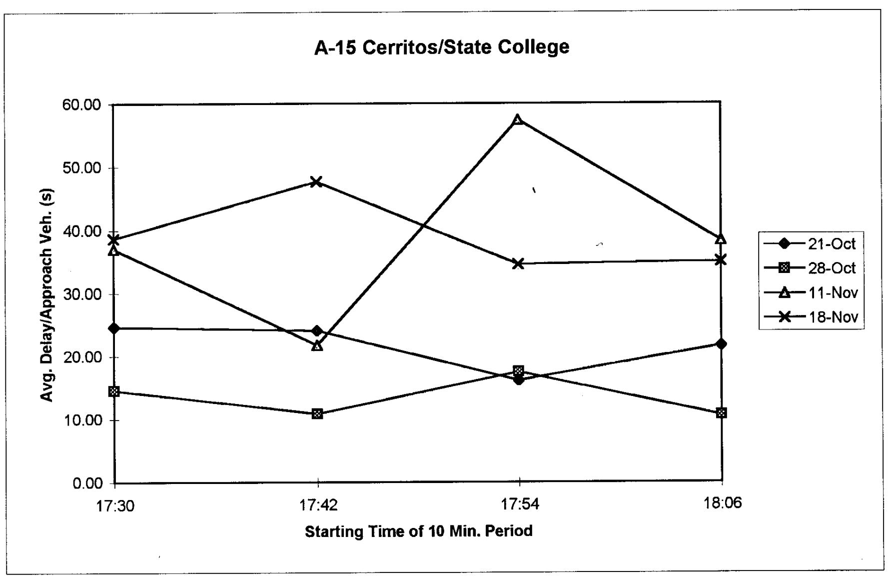
Figure 38: High Volume, Katella & State College. Special Events (All Approaches).





Figures 39 & 40: Medium Volume, Cerritos & State College (N- & S-bound).





Figures 41 & 42: Medium Volume, Cerritos & State College (W-& E-bound).

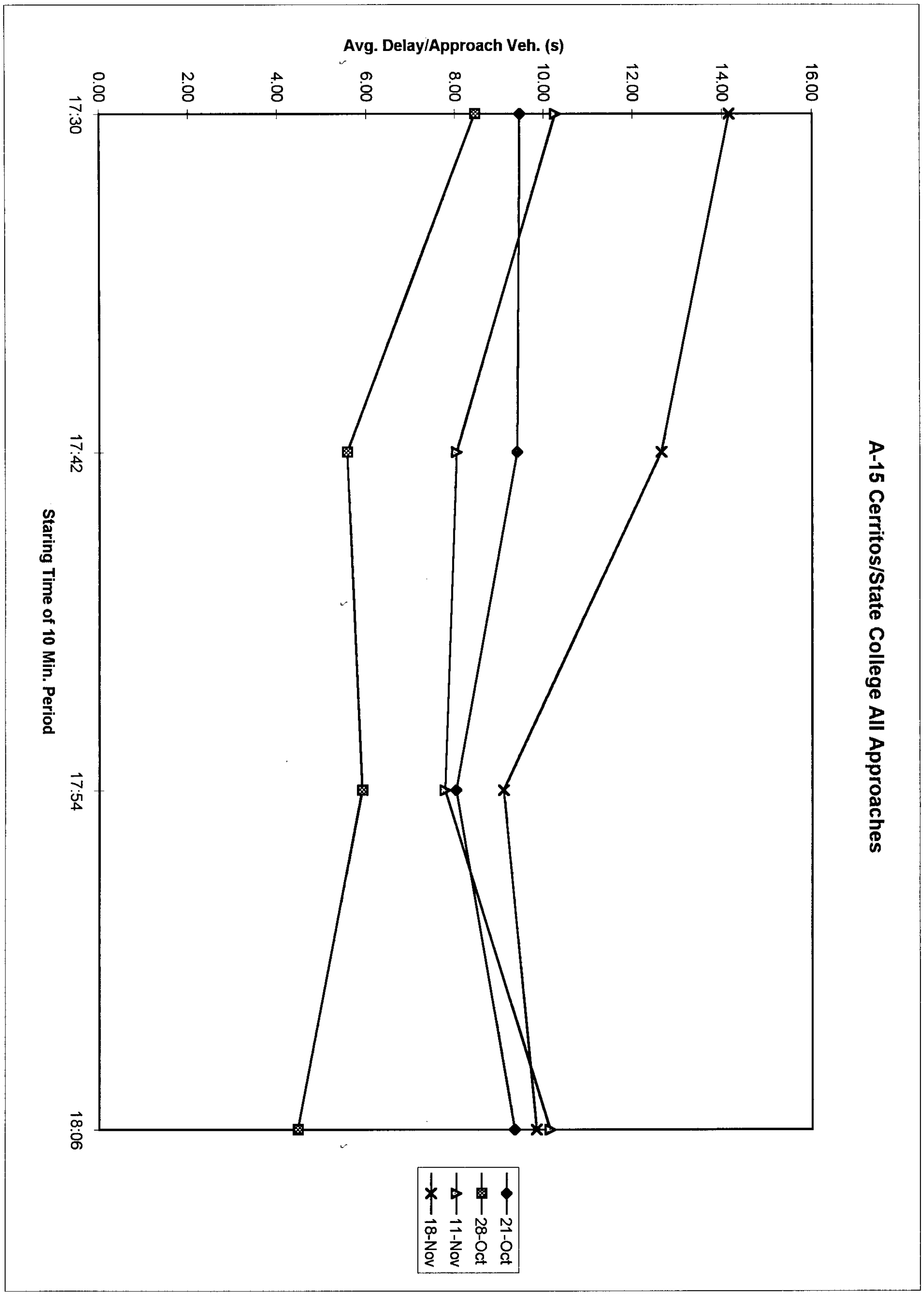
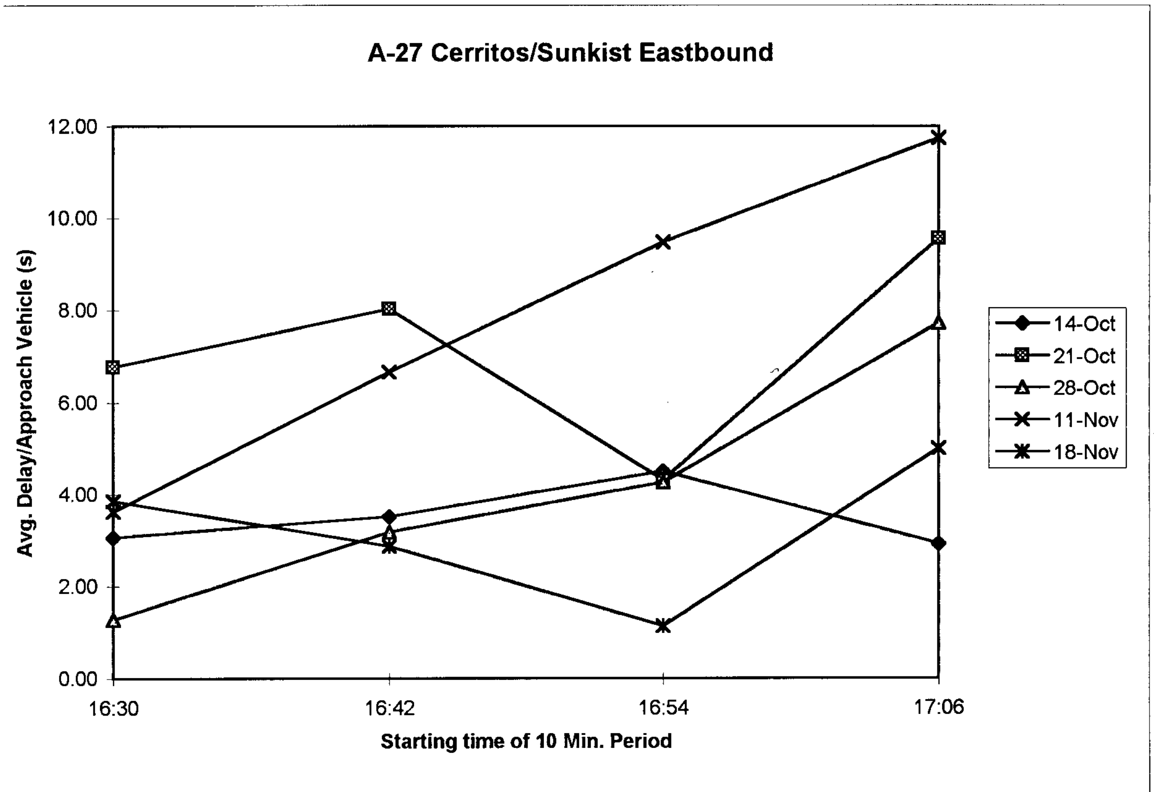
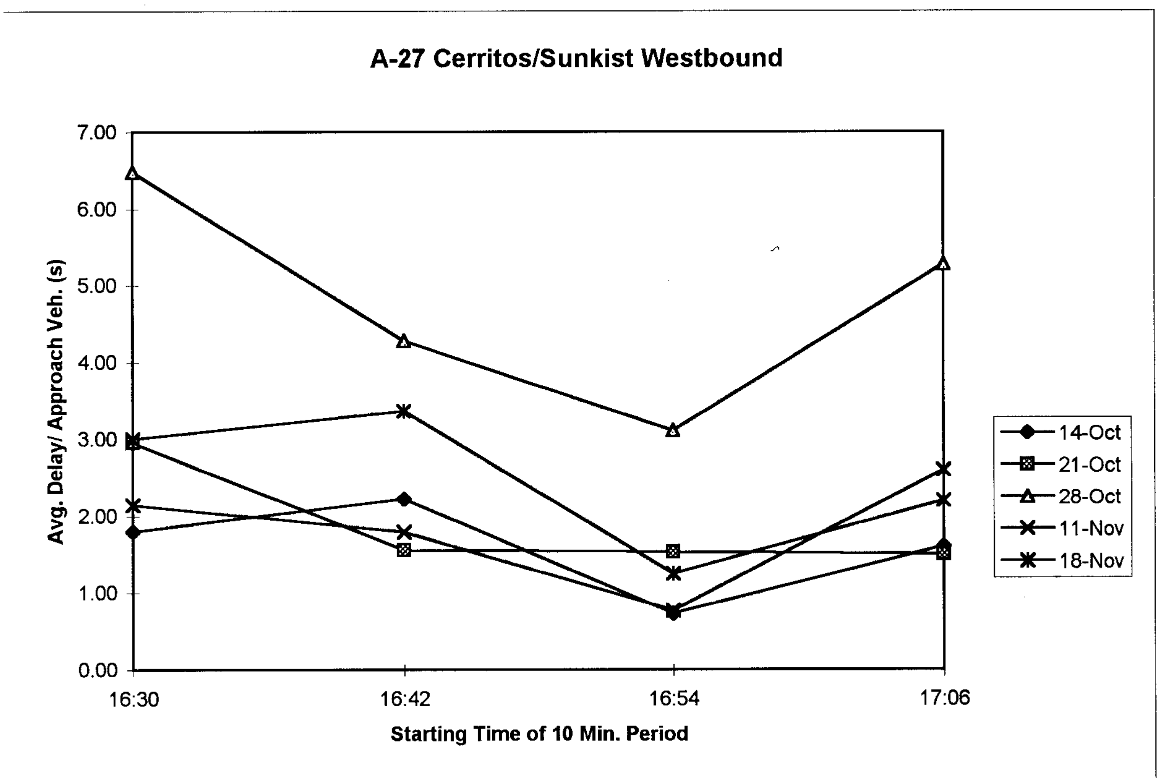
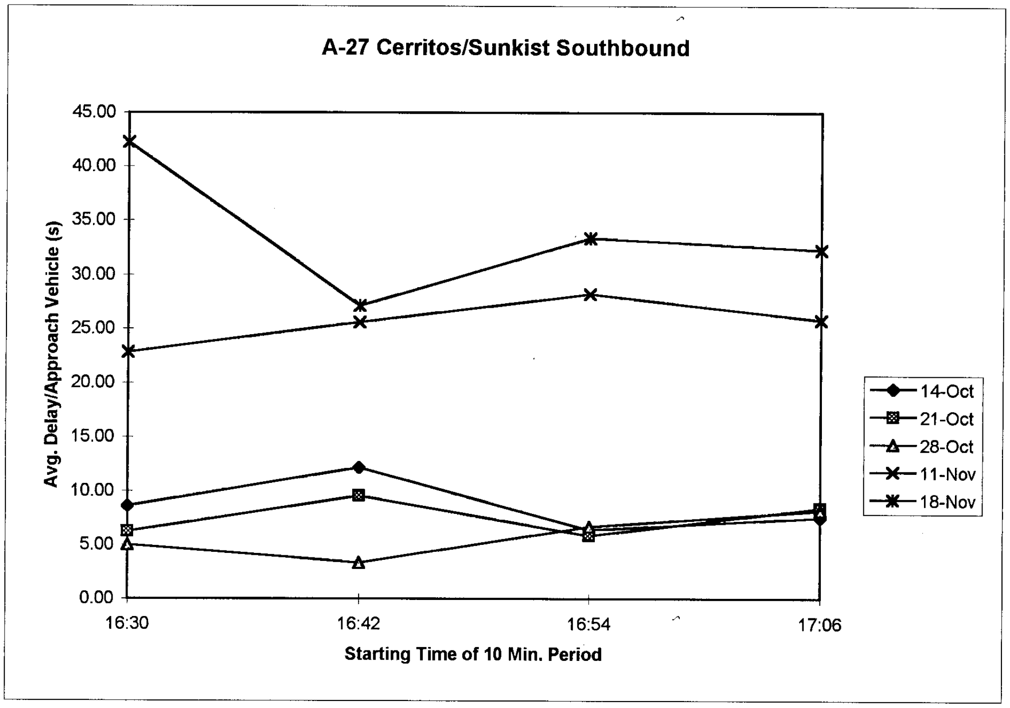


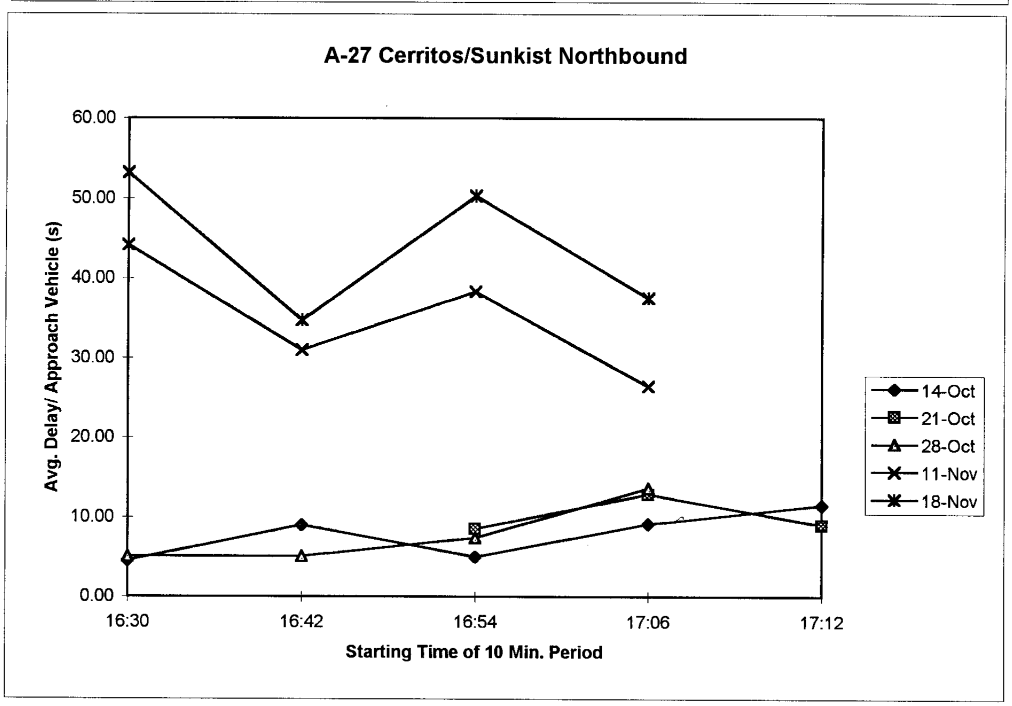
Figure 43: Medium Volume, Cerritos & State College (All Approaches).





Figures 44 & 45: Low Volume, Cerritos/Sunkist (E- & W-bound).





Figures 46 & 47: Low Volume, Cerritos & Sunkist (S- & N-bound).

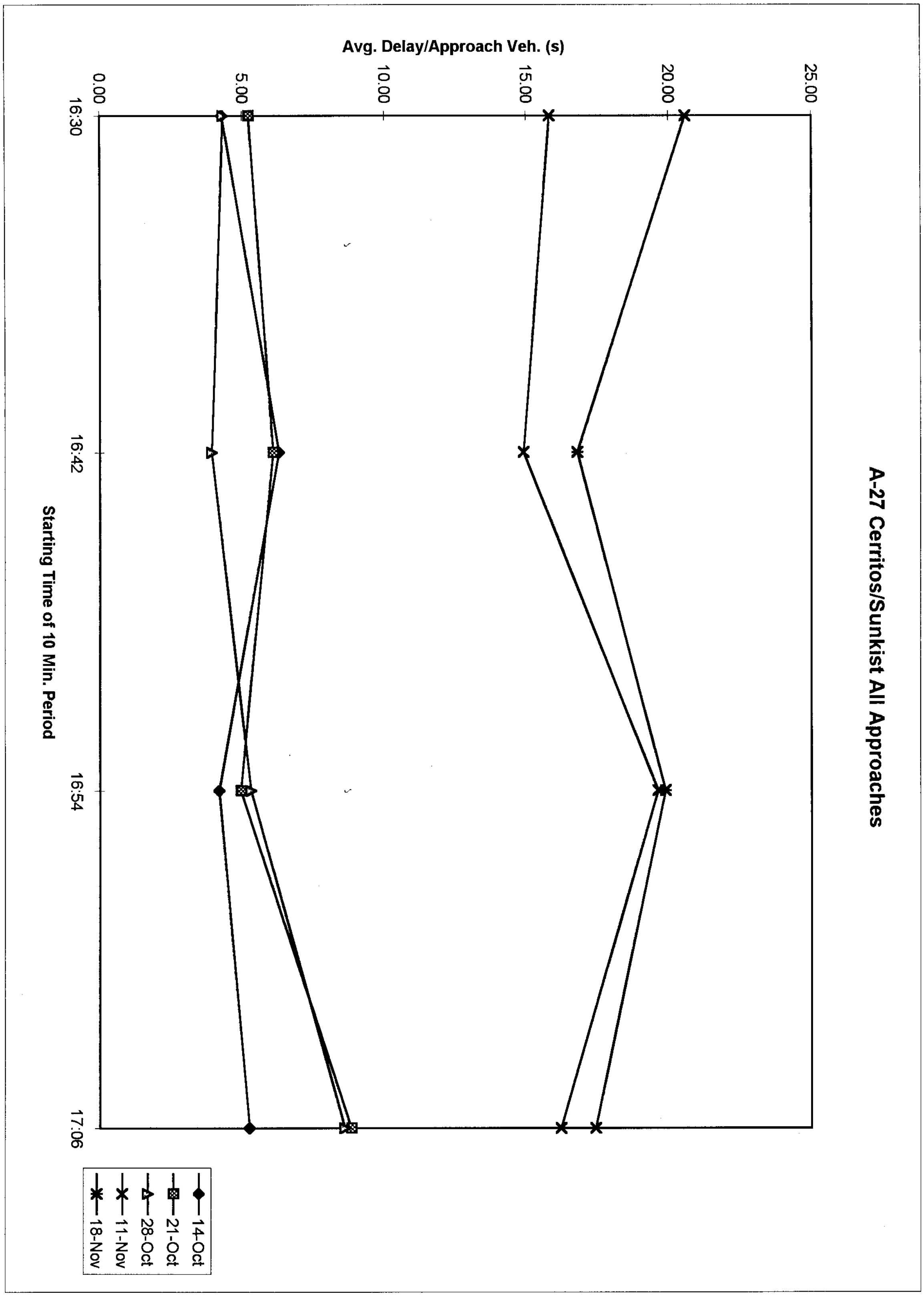
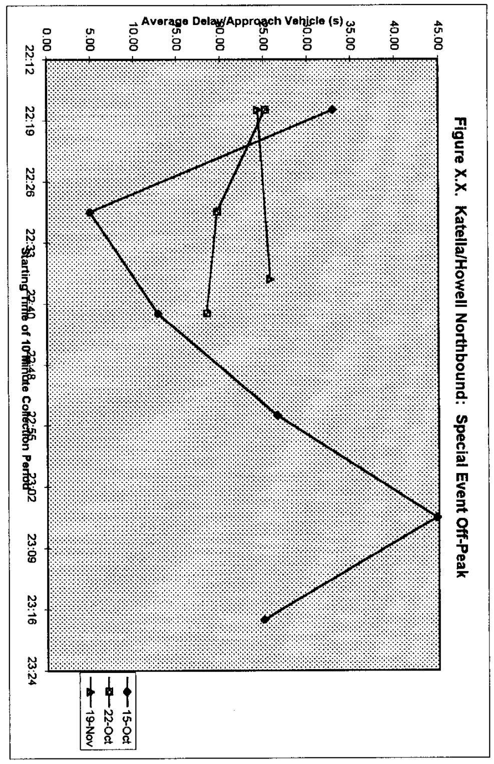
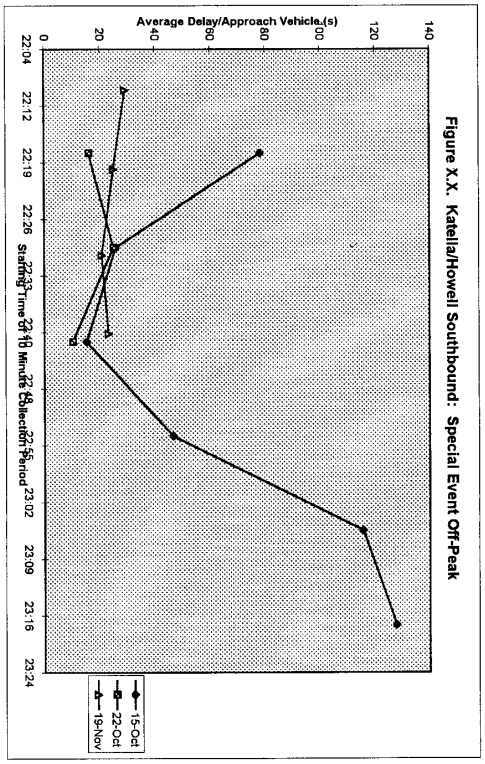
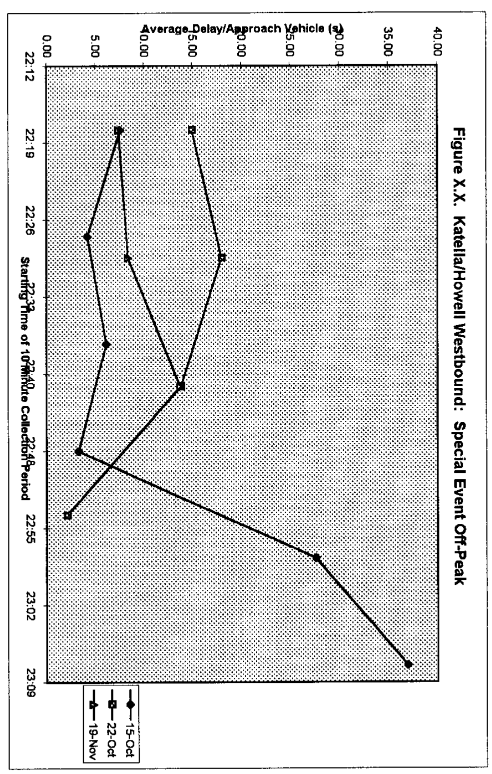
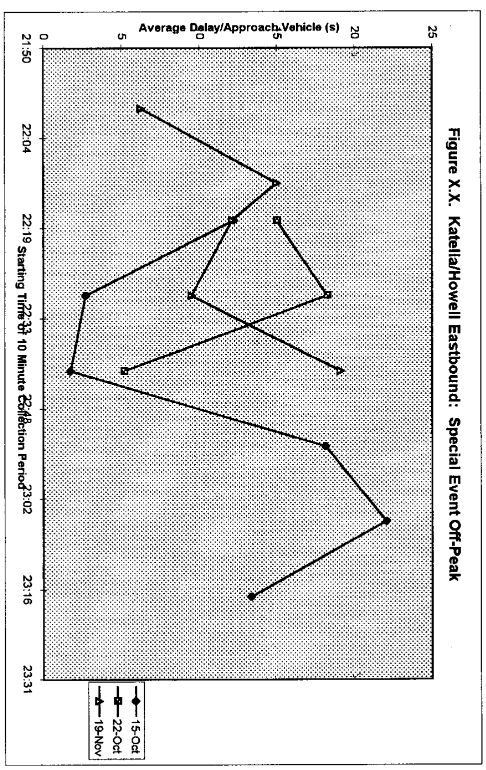


Figure 48: Low Volume, Cerritos & Sunkist (All Approaches).









Figures 49-52: Off-Peak, Special Event. Katella & Howell (Near Event Location).

Table 16. Katella and State College, Northbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	496	Number of Samples	393
Total Delay (Hrs.)	17.59	Total Delay (Hrs.)	13.45
Avg. Delay/Approach Volume (Sec.)	28.89	Avg. Delay/Approach Volume (Sec.)	27.68
Percent Error	2.61%	Percent Error	3.26%
		Percentage Change	-4.20%
		t-Score	2.03
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	239	Number of Samples	80
Total Delay (Hrs.)	2.28	Total Delay (Hrs.)	0.58
Avg. Delay/Approach Volume (Sec.)	19.57	Avg. Delay/Approach Volume (Sec.)	18.00
Percent Error	1.16%	Percent Error	2.10%
		Percentage Change	-8.03%
		t-Score	
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	256
Total Delay (Hrs.)	21.20	Total Delay (Hrs.)	29.01
Avg. Delay/Approach Volume (Sec.)	40.52	Avg. Delay/Approach Volume (Sec.)	56.64
Percent Error	3.76%	Percent Error	5.62%
		Percentage Change	39.79%
		t-Score	-8.95
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	96
Total Delay (Hrs.)	21.20	Total Delay (Hrs.)	5.23
Avg. Delay/Approach Volume (Sec.)	40.52	Avg. Delay/Approach Volume (Sec.)	33.64
Percent Error	3.76%	Percent Error	7.55%
		Percentage Change	-16.97%
		t-Score	4.55

Table 17. Katella and State College, Southbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	485	Number of Samples	416
Total Delay (Hrs.)	13.65	Total Delay (Hrs.)	7.98
Avg. Delay/Approach Volume (Sec.)	33.52	Avg. Delay/Approach Volume (Sec.)	24.69
Percent Error	1.73%	Percent Error	1.86%
		Percentage Change	-26.35%
		t-Score	23.42
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	239	Number of Samples	80
Total Delay (Hrs.)	1.26	Total Delay (Hrs.)	0.76
Avg. Delay/Approach Volume (Sec.)	20.22	Avg. Delay/Approach Volume (Sec.)	33.70
Percent Error	1.08%	Percent Error	1.26%
		Percentage Change	66.66%
		t-Score	-55.35
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	324
Total Delay (Hrs.)	10.29	Total Delay (Hrs.)	14.81
Avg. Delay/Approach Volume (Sec.)	37.61	Avg. Delay/Approach Volume (Sec.)	37.66
Percent Error	2.37%	Percent Error	3.18%
		Percentage Change	0.12%
		t-Score	-0.06
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	148
Total Delay (Hrs.)	10.29	Total Delay (Hrs.)	5.03
Avg. Delay/Approach Volume (Sec.)	37.61	Avg. Delay/Approach Volume (Sec.)	32.36
Percent Error	2.37%	Percent Error	3.58%
		Percentage Change	-13.98%
		t-Score	7.05

Table 18: Katella and State College, Eastbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	482	Number of Samples	401
Total Delay (Hrs.)	15.12	Total Delay (Hrs.)	13.31
Avg. Delay/Approach Volume (Sec.)	24.19	Avg. Delay/Approach Volume (Sec.)	23.78
Percent Error	3.13%	Percent Error	3.69%
		Percentage Change	-1.72%
		t-Score	0.71
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	240	Number of Samples	80
Total Delay (Hrs.)	1.28	Total Delay (Hrs.)	0.47
Avg. Delay/Approach Volume (Sec.)	12.13	Avg. Delay/Approach Volume (Sec.)	11.77
Percent Error	2.28%	Percent Error	3.28%
		Percentage Change	-2.93%
		t-Score	1.47
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	332
Total Delay (Hrs.)	11.23	Total Delay (Hrs.)	25.01
Avg. Delay/Approach Volume (Sec.)	25.58	Avg. Delay/Approach Volume (Sec.)	38.12
Percent Error	4.46%	Percent Error	4.35%
		Percentage Change	49.01%
		t-Score	-12.21
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	160
Total Delay (Hrs.)	11.23	Total Delay (Hrs.)	11.30
Avg. Delay/Approach Volume (Sec.)	25.58	Avg. Delay/Approach Volume (Sec.)	38.36
Percent Error	4.46%	Percent Error	6.25%
		Percentage Change	49.95%
		t-Score	-9.43

Table 19: Katella and State College, Westbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	479	Number of Samples	424
Total Delay (Hrs.)	11.90	Total Delay (Hrs.)	17.27
Avg. Delay/Approach Volume (Sec.)	17.04	Avg. Delay/Approach Volume (Sec.)	29.14
Percent Error	3.52%	Percent Error	3.34%
		Percentage Change	71.02%
		t-Score	-20.76
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	372	Number of Samples	80
Total Delay (Hrs.)	1.89	Total Delay (Hrs.)	0.30
Avg. Delay/Approach Volume (Sec.)	11.23	Avg. Delay/Approach Volume (Sec.)	7.10
Percent Error	2.03%	Percent Error	4.50%
		Percentage Change	-36.78%
		t-Score	20.61
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	240	Number of Samples	320
Total Delay (Hrs.)	7.30	Total Delay (Hrs.)	28.81
Avg. Delay/Approach Volume (Sec.)	16.68	Avg. Delay/Approach Volume (Sec.)	42.18
Percent Error	5.20%	Percent Error	5.02%
		Percentage Change	152.82 %
		t-Score	-21.85
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	240	Number of Samples	160
Total Delay (Hrs.)	7.30	Total Delay (Hrs.)	9.80
Avg. Delay/Approach Volume (Sec.)	16.68	Avg. Delay/Approach Volume (Sec.)	30.40
Percent Error	5.20%	Percent Error	6.21%
		Percentage Change	82.21%
		t-Score	-12.94

Table 20: Katella and State College, All Approaches

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1942	Number of Samples	1457
Total Delay (Hrs.)	58.26	Total Delay (Hrs.)	52.00
Avg. Delay/Approach Volume (Sec.)	24.90	Avg. Delay/Approach Volume (Sec.)	26.51
Percent Error	1.37%	Percent Error	1.75%
		Percentage Change	6.46%
		t-Score	-5.47
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	955	Number of Samples	320
Total Delay (Hrs.)	4.82	Total Delay (Hrs.)	2.10
Avg. Delay/Approach Volume (Sec.)	13.85	Avg. Delay/Approach Volume (Sec.)	15.43
Percent Error	0.84%	Percent Error	1.27%
		Percentage Change	11.40%
		t-Score	-13.56
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1080	Number of Samples	1232
Total Delay (Hrs.)	50.03	Total Delay (Hrs.)	97.65
Avg. Delay/Approach Volume (Sec.)	29.89	Avg. Delay/Approach Volume (Sec.)	43.50
Percent Error	2.10%	Percent Error	2.44%
		Percentage Change	45.53%
		t-Score	-21.65
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	1080	Number of Samples	564
Total Delay (Hrs.)	50.03	Total Delay (Hrs.)	31.38
Avg. Delay/Approach Volume (Sec.)	29.89	Avg. Delay/Approach Volume (Sec.)	33.80
Percent Error	2.10%	Percent Error	3.10%
		Percentage Change	13.07%
		t-Score	-6.26

Table 21: Ball and State College, Northbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	468	Number of Samples	160
Total Delay (Hrs.)	52.74	Total Delay (Hrs.)	21.79
Avg. Delay/Approach Volume (Sec.)	59.87	Avg. Delay/Approach Volume (Sec.)	85.46
Percent Error	2.91%	Percent Error	3.21%
		Percentage Change	42.73%
		t-Score	-15.43
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	381	Number of Samples	120
Total Delay (Hrs.)	8.72	Total Delay (Hrs.)	1.00
Avg. Delay/Approach Volume (Sec.)	29.35	Avg. Delay/Approach Volume (Sec.)	26.98
Percent Error	0.62%	Percent Error	1.47%
		Percentage Change	-8.10%
		t-Score	10.70
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	234	Number of Samples	203
Total Delay (Hrs.)	25.08	Total Delay (Hrs.)	25.56
Avg. Delay/Approach Volume (Sec.)	58.06	Avg. Delay/Approach Volume (Sec.)	71.16
Percent Error	4.22%	Percent Error	3.69%
		Percentage Change	22.56%
		t-Score	-7.16
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	234	Number of Samples	136
Total Delay (Hrs.)	25.08	Total Delay (Hrs.)	18.96
Avg. Delay/Approach Volume (Sec.)	58.06	Avg. Delay/Approach Volume (Sec.)	78.99
Percent Error	4.22%	Percent Error	4.14%
		Percentage Change	36.03%
		t-Score	-10.04

Table 22: Ball and State College, Southbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	522	Number of Samples	160
Total Delay (Hrs.)	20.58	Total Delay (Hrs.)	7.95
Avg. Delay/Approach Volume (Sec.)	41.82	Avg. Delay/Approach Volume (Sec.)	53.90
Percent Error	1.57%	Percent Error	2.14%
		Percentage Change	28.87%
		t-Score	-17.83
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	383	Number of Samples	100
Total Delay (Hrs.)	9.08	Total Delay (Hrs.)	0.95
Avg. Delay/Approach Volume (Sec.)	31.72	Avg. Delay/Approach Volume (Sec.)	26.40
Percent Error	0.56%	Percent Error	1.63%
		Percentage Change	-16.78%
		t-Score	22.39
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	243	Number of Samples	300
Total Delay (Hrs.)	8.80	Total Delay (Hrs.)	15.13
Avg. Delay/Approach Volume (Sec.)	34.83	Avg. Delay/Approach Volume (Sec.)	47.96
Percent Error	2.66%	Percent Error	1.70%
		Percentage Change	37.67%
		t-Score	-20.84
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	243	Number of Samples	180
Total Delay (Hrs.)	8.80	Total Delay (Hrs.)	8.81
Avg. Delay/Approach Volume (Sec.)	34.83	Avg. Delay/Approach Volume (Sec.)	48.96
Percent Error	2.66%	Percent Error	1.91%
		Percentage Change	40.54%
		t-Score	-21.04

Table 23: Ball and State College, Eastbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	660	Number of Samples	160
Total Delay (Hrs.)	36.86	Total Delay (Hrs.)	8.88
Avg. Delay/Approach Volume (Sec.)	45.91	Avg. Delay/Approach Volume (Sec.)	34.33
Percent Error	3.46%	Percent Error	6.40%
		Percentage Change	-25.22%
		t-Score	8.38
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	362	Number of Samples	120
Total Delay (Hrs.)	9.65	Total Delay (Hrs.)	0.91
Avg. Delay/Approach Volume (Sec.)	29.38	Avg. Delay/Approach Volume (Sec.)	14.73
Percent Error	1.10%	Percent Error	29.8%
		Percentage Change	-49.86%
		t-Score	52.72
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	242	Number of Samples	313
Total Delay (Hrs.)	13.92	Total Delay (Hrs.)	30.93
Avg. Delay/Approach Volume (Sec.)	36.42	Avg. Delay/Approach Volume (Sec.)	59.07
Percent Error	4.61%	Percent Error	3.16%
		Percentage Change	62.18%
		t-Score	-17.68
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	242	Number of Samples	152
Total Delay (Hrs.)	13.92	Total Delay (Hrs.)	9.79
Avg. Delay/Approach Volume (Sec.)	36.42	Avg. Delay/Approach Volume (Sec.)	38.95
Percent Error	4.61%	Percent Error	4.90%
		Percentage Change	6.95%
		t-Score	-1.95

Table 24: Ball and State College, Westbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	502	Number of Samples	160
Total Delay (Hrs.)	24.48	Total Delay (Hrs.)	4.97
Avg. Delay/Approach Volume (Sec.)	35.88	Avg. Delay/Approach Volume (Sec.)	21.20
Percent Error	2.98%	Percent Error	5.89%
		Percentage Change	-40.91%
		t-Score	17.50
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	374	Number of Samples	140
Total Delay (Hrs.)	9.86	Total Delay (Hrs.)	1.16
Avg. Delay/Approach Volume (Sec.)	29.80	Avg. Delay/Approach Volume (Sec.)	15.92
Percent Error	0.98%	Percent Error	2.52%
		Percentage Change	-46.59%
		t-Score	54.88
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	239	Number of Samples	294
Total Delay (Hrs.)	14.29	Total Delay (Hrs.)	25.13
Avg. Delay/Approach Volume (Sec.)	41.41	Avg. Delay/Approach Volume (Sec.)	47.26
Percent Error	3.86%	Percent Error	4.37%
		Percentage Change	14.11%
		t-Score	-4.39
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	239	Number of Samples	160
Total Delay (Hrs.)	14.29	Total Delay (Hrs.)	8.20
Avg. Delay/Approach Volume (Sec.)	41.41	Avg. Delay/Approach Volume (Sec.)	30.18
Percent Error	3.86%	Percent Error	5.23%
		Percentage Change	-27.11%
		t-Score	9.8

Table 25: Ball and State College, All Approaches

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	2152	Number of Samples	643
Total Delay (Hrs.)	134.6 5	Total Delay (Hrs.)	43.59
Avg. Delay/Approach Volume (Sec.)	47.12	Avg. Delay/Approach Volume (Sec.)	48.68
Percent Error	1.56%	Percent Error	2.62%
		Percentage Change	3.31%
		t-Score	-2.08
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	2152	Number of Samples	484
Total Delay (Hrs.)	37.30	Total Delay (Hrs.)	4.02
Avg. Delay/Approach Volume (Sec.)	30.02	Avg. Delay/Approach Volume (Sec.)	19.36
Percent Error	2.44%	Percent Error	1.07%
		Percentage Change	-35.53%
		t-Score	27.44
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	958	Number of Samples	1110
Total Delay (Hrs.)	62.08	Total Delay (Hrs.)	96.75
Avg. Delay/Approach Volume (Sec.)	43.98	Avg. Delay/Approach Volume (Sec.)	55.92
Percent Error	2.18%	Percent Error	1.78%
		Percentage Change	27.16%
		t-Score	-16.92
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	958	Number of Samples	628
Total Delay (Hrs.)	62.08	Total Delay (Hrs.)	45.76
Avg. Delay/Approach Volume (Sec.)	43.98	Avg. Delay/Approach Volume (Sec.)	48.53
Percent Error	2.18%	Percent Error	2.42%
		Percentage Change	10.34%
		t-Score	-5.88

Table 26: Cerritos and State College, Northbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	320	Number of Samples	320
Total Delay (Hrs.)	2.10	Total Delay (Hrs.)	2.01
Avg. Delay/Approach Volume (Sec.)	4.38	Avg. Delay/Approach Volume (Sec.)	4.71
Percent Error	6.88%	Percent Error	9.17%
		Percentage Change	7.55%
		t-Score	-1.23
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	890	Number of Samples	388
Total Delay (Hrs.)	0.96	Total Delay (Hrs.)	0.25
Avg. Delay/Approach Volume (Sec.)	3.24	Avg. Delay/Approach Volume (Sec.)	1.74
Percent Error	2.22%	Percent Error	4.41%
		Percentage Change	-46.24%
		t-Score	27.92
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	260
Total Delay (Hrs.)	2.27	Total Delay (Hrs.)	2.03
Avg. Delay/Approach Volume (Sec.)	7.83	Avg. Delay/Approach Volume (Sec.)	6.29
Percent Error	5.79%	Percent Error	8.85%
		Percentage Change	-19.65%
		t-Score	4.20
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	100
Total Delay (Hrs.)	2.27	Total Delay (Hrs.)	0.16
Avg. Delay/Approach Volume (Sec.)	7.83	Avg. Delay/Approach Volume (Sec.)	1.62
Percent Error	5.79%	Percent Error	11.51%
		Percentage Change	-79.32%
		t-Score	24.85

Table 27: Cerritos and State College, Southbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	344	Number of Samples	321
Total Delay (Hrs.)	0.61	Total Delay (Hrs.)	0.95
Avg. Delay/Approach Volume (Sec.)	4.46	Avg. Delay/Approach Volume (Sec.)	3.97
Percent Error	5.17%	Percent Error	5.24%
		Percentage Change	-11.11%
		t-Score	3.13
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	809	Number of Samples	360
Total Delay (Hrs.)	0.45	Total Delay (Hrs.)	0.22
Avg. Delay/Approach Volume (Sec.)	2.24	Avg. Delay/Approach Volume (Sec.)	1.99
Percent Error	2.10%	Percent Error	3.02%
		Percentage Change	-11.26%
		t-Score	6.48
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	344
Total Delay (Hrs.)	0.83	Total Delay (Hrs.)	0.70
Avg. Delay/Approach Volume (Sec.)	4.28	Avg. Delay/Approach Volume (Sec.)	3.01
Percent Error	5.31%	Percent Error	4.66%
		Percentage Change	-29.73%
		t-Score	9.34
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	160
Total Delay (Hrs.)	0.83	Total Delay (Hrs.)	0.21
Avg. Delay/Approach Volume (Sec.)	4.28	Avg. Delay/Approach Volume (Sec.)	2.70
Percent Error	5.31%	Percent Error	4.74%
		Percentage Change	-36.96%
		t-Score	11.88

Table 28: Cerritos and State College, Eastbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	344	Number of Samples	320
Total Delay (Hrs.)	2.25	Total Delay (Hrs.)	3.97
Avg. Delay/Approach Volume (Sec.)	17.34	Avg. Delay/Approach Volume (Sec.)	37.23
Percent Error	1.24%	Percent Error	1.03%
		Percentage Change	114.69%
		t-Score	-88.74
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	829	Number of Samples	400
Total Delay (Hrs.)	1.57	Total Delay (Hrs.)	1.94
Avg. Delay/Approach Volume (Sec.)	11.40	Avg. Delay/Approach Volume (Sec.)	29.25
Percent Error	0.55%	Percent Error	0.56%
		Percentage Change	156.52%
		t-Score	-200.42
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	320
Total Delay (Hrs.)	2.58	Total Delay (Hrs.)	4.05
Avg. Delay/Approach Volume (Sec.)	23.69	Avg. Delay/Approach Volume (Sec.)	30.79
Percent Error	1.19%	Percent Error	1.28%
		Percentage Change	30.00%
		t-Score	-28.71
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	160
Total Delay (Hrs.)	2.58	Total Delay (Hrs.)	1.80
Avg. Delay/Approach Volume (Sec.)	23.69	Avg. Delay/Approach Volume (Sec.)	32.08
Percent Error	1.19%	Percent Error	1.54%
		Percentage Change	35.43%
		t-Score	-28.93

Table 29: Cerritos and State College, Westbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	320	Number of Samples	321
Total Delay (Hrs.)	1.54	Total Delay (Hrs.)	1.95
Avg. Delay/Approach Volume (Sec.)	16.23	Avg. Delay/Approach Volume (Sec.)	24.81
Percent Error	1.10%	Percent Error	0.94%
		Percentage Change	52.86%
		t-Score	-57.44
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	834	Number of Samples	425
Total Delay (Hrs.)	0.56	Total Delay (Hrs.)	0.35
Avg. Delay/Approach Volume (Sec.)	12.13	Avg. Delay/Approach Volume (Sec.)	15.95
Percent Error	0.26%	Percent Error	0.36%
		Percentage Change	31.53
		t-Score	-115.27
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	316
Total Delay (Hrs.)	1.09	Total Delay (Hrs.)	1.70
Avg. Delay/Approach Volume (Sec.)	18.71	Avg. Delay/Approach Volume (Sec.)	41.82
Percent Error	0.85%	Percent Error	0.46%
		Percentage Change	123.44%
		t-Score	-181.22
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	280	Number of Samples	160
Total Delay (Hrs.)	1.09	Total Delay (Hrs.)	1.04
Avg. Delay/Approach Volume (Sec.)	18.71	Avg. Delay/Approach Volume (Sec.)	44.12
Percent Error	0.85%	Percent Error	0.71%
		Percentage Change	135.74%
		t-Score	-141.87

Table 30: Cerritos and State College, All Approaches

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1328	Number of Samples	1282
Total Delay (Hrs.)	6.51	Total Delay (Hrs.)	8.88
Avg. Delay/Approach Volume (Sec.)	7.73	Avg. Delay/Approach Volume (Sec.)	10.43
Percent Error	1.53%	Percent Error	1.63%
		Percentage Change	34.85%
		t-Score	-25.47
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	3362	Number of Samples	1573
Total Delay (Hrs.)	3.55	Total Delay (Hrs.)	2.76
Avg. Delay/Approach Volume (Sec.)	5.19	Avg. Delay/Approach Volume (Sec.)	8.06
Percent Error	0.55%	Percent Error	0.69%
		Percentage Change	55.19%
		t-Score	-89.84
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1120	Number of Samples	1240
Total Delay (Hrs.)	6.77	Total Delay (Hrs.)	8.48
Avg. Delay/Approach Volume (Sec.)	10.39	Avg. Delay/Approach Volume (Sec.)	11.67
Percent Error	1.49%	Percent Error	1.50%
		Percentage Change	12.29%
		t-Score	-10.70
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	1120	Number of Samples	580
Total Delay (Hrs.)	6.77	Total Delay (Hrs.)	3.21
Avg. Delay/Approach Volume (Sec.)	10.39	Avg. Delay/Approach Volume (Sec.)	12.60
Percent Error	1.49%	Percent Error	1.48%
		Percentage Change	21.17%
		t-Score	-17.80

Table 31: Cerritos and Sunkist, Northbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	434	Number of Samples	330
Total Delay (Hrs.)	1.41	Total Delay (Hrs.)	4.35
Avg. Delay/Approach Volume (Sec.)	8.37	Avg. Delay/Approach Volume (Sec.)	38.51
Percent Error	1.68%	Percent Error	0.87%
		Percentage Change	360.34%
		t-Score	-162.00
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	772	Number of Samples	399
Total Delay (Hrs.)	0.08	Total Delay (Hrs.)	0.36
Avg. Delay/Approach Volume (Sec.)	3.65	Avg. Delay/Approach Volume (Sec.)	20.48
Percent Error	0.33%	Percent Error	0.33%
		Percentage Change	461.20%
		t-Score	-483.02
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	217
Total Delay (Hrs.)	0.35	Total Delay (Hrs.)	0.33
Avg. Delay/Approach Volume (Sec.)	8.85	Avg. Delay/Approach Volume (Sec.)	13.19
Percent Error	0.85%	Percent Error	0.99%
		Percentage Change	48.93%
		t-Score	-36.34
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	97
Total Delay (Hrs.)	0.35	Total Delay (Hrs.)	0.09
Avg. Delay/Approach Volume (Sec.)	8.85	Avg. Delay/Approach Volume (Sec.)	9.55
Percent Error	0.85%	Percent Error	1.39%
		Percentage Change	7.81%
		t-Score	-8.91
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	463	Number of Samples	160
Total Delay (Hrs.)	3.74	Total Delay (Hrs.)	1.08
Avg. Delay/Approach Volume (Sec.)	91.63	Avg. Delay/Approach Volume (Sec.)	65.85
Percent Error	0.41%	Percent Error	0.45%
		Percentage Change	-28.14%
		t-Score	104.67

Table 32: Cerritos and Sunkist, Southbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	533	Number of Samples	320
Total Delay (Hrs.)	1.10	Total Delay (Hrs.)	2.96
Avg. Delay/Approach Volume (Sec.)	7.21	Avg. Delay/Approach Volume (Sec.)	29.67
Percent Error	1.16%	Percent Error	0.86%
		Percentage Change	311.22%
		t-Score	
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	820	Number of Samples	401
Total Delay (Hrs.)	0.63	Total Delay (Hrs.)	1.08
Avg. Delay/Approach Volume (Sec.)	11.42	Avg. Delay/Approach Volume (Sec.)	38.70
Percent Error	0.32%	Percent Error	0.22%
		Percentage Change	238.84%
		t-Score	-569.84
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	281
Total Delay (Hrs.)	6.89	Total Delay (Hrs.)	12.32
Avg. Delay/Approach Volume (Sec.)	32.90	Avg. Delay/Approach Volume (Sec.)	63.71
Percent Error	1.93%	Percent Error	1.70%
		Percentage Change	93.61%
		t-Score	-48.10
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	160
Total Delay (Hrs.)	6.89	Total Delay (Hrs.)	5.60
Avg. Delay/Approach Volume (Sec.)	32.90	Avg. Delay/Approach Volume (Sec.)	57.44
Percent Error	1.93%	Percent Error	2.13%
		Percentage Change	74.55%
		t-Score	-34.90
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	320	Number of Samples	221
Total Delay (Hrs.)	0.91	Total Delay (Hrs.)	0.41
Avg. Delay/Approach Volume (Sec.)	51.09	Avg. Delay/Approach Volume (Sec.)	42.43
Percent Error	0.24%	Percent Error	0.24%
		Percentage Change	-16.96%
		t-Score	106.76

Table 33: Cerritos and Sunkist, Eastbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	497	Number of Samples	346
Total Delay (Hrs.)	1.08	Total Delay (Hrs.)	0.80
Avg. Delay/Approach Volume (Sec.)	5.02	Avg. Delay/Approach Volume (Sec.)	5.34
Percent Error	2.34%	Percent Error	3.42%
		Percentage Change	6.45%
		t-Score	-2.92
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	821	Number of Samples	400
Total Delay (Hrs.)	0.09	Total Delay (Hrs.)	0.04
Avg. Delay/Approach Volume (Sec.)	1.17	Avg. Delay/Approach Volume (Sec.)	1.01
Percent Error	1.53%	Percent Error	1.92%
		Percentage Change	13.39%
		t-Score	11.62
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	267
Total Delay (Hrs.)	1.29	Total Delay (Hrs.)	0.55
Avg. Delay/Approach Volume (Sec.)	8.86	Avg. Delay/Approach Volume (Sec.)	4.46
Percent Error	1.89%	Percent Error	3.58%
		Percentage Change	-49.69%
		t-Score	37.27
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	160
Total Delay (Hrs.)	1.29	Total Delay (Hrs.)	0.32
Avg. Delay/Approach Volume (Sec.)	8.86	Avg. Delay/Approach Volume (Sec.)	4.65
Percent Error	1.89%	Percent Error	4.40%
		Percentage Change	-47.47%
		t-Score	31.13
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	457	Number of Samples	156
Total Delay (Hrs.)	2.06	Total Delay (Hrs.)	0.30
Avg. Delay/Approach Volume (Sec.)	67.98	Avg. Delay/Approach Volume (Sec.)	29.59
Percent Error	0.26%	Percent Error	0.70%
		Percentage Change	-56.47%
		t-Score	275.49

Table 34: Cerritos and Sunkist, Westbound Approach

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	504	Number of Samples	370
Total Delay (Hrs.)	0.45	Total Delay (Hrs.)	0.25
Avg. Delay/Approach Volume (Sec.)	2.70	Avg. Delay/Approach Volume (Sec.)	2.24
Percent Error	2.07%	Percent Error	3.22
		Percentage Change	-17.09%
		t-Score	
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	772	Number of Samples	399
Total Delay (Hrs.)	0.08	Total Delay (Hrs.)	0.01
Avg. Delay/Approach Volume (Sec.)	2.75	Avg. Delay/Approach Volume (Sec.)	0.68
Percent Error	0.46%	Percent Error	1.02%
		Percentage Change	-75.23%
		t-Score	278.78
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	440	Number of Samples	281
Total Delay (Hrs.)	0.30	Total Delay (Hrs.)	0.14
Avg. Delay/Approach Volume (Sec.)	8.00	Avg. Delay/Approach Volume (Sec.)	5.05
Percent Error	0.53%	Percent Error	1.00%
		Percentage Change	-36.88%
		t-Score	88.04
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	440	Number of Samples	160
Total Delay (Hrs.)	0.30	Total Delay (Hrs.)	0.05
Avg. Delay/Approach Volume (Sec.)	8.00	Avg. Delay/Approach Volume (Sec.)	2.90
Percent Error	0.53%	Percent Error	1.75%
		Percentage Change	-63.71%
		t-Score	151.23
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	449	Number of Samples	176
Total Delay (Hrs.)	4.39	Total Delay (Hrs.)	4.43
Avg. Delay/Approach Volume (Sec.)	7.81	Avg. Delay/Approach Volume (Sec.)	9.94
Percent Error	8.85%	Percent Error	16.37%
		Percentage Change	27.36%
		t-Score	-2.37

Table 35: Cerritos and Sunkist, All Approaches

Non-Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1968	Number of Samples	1366
Total Delay (Hrs.)	1.86	Total Delay (Hrs.)	4.60
Avg. Delay/Approach Volume (Sec.)	5.54	Avg. Delay/Approach Volume (Sec.)	20.65
Percent Error	0.93%	Percent Error	0.63%
		Percentage Change	272.93%
		t-Score	
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	3185	Number of Samples	1599
Total Delay (Hrs.)	0.88	Total Delay (Hrs.)	1.48
Avg. Delay/Approach Volume (Sec.)	4.76	Avg. Delay/Approach Volume (Sec.)	15.04
Percent Error	0.24%	Percent Error	0.21%
		Percentage Change	216.13%
		t-Score	-607.03
Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1640	Number of Samples	1046
Total Delay (Hrs.)	8.84	Total Delay (Hrs.)	13.34
Avg. Delay/Approach Volume (Sec.)	20.42	Avg. Delay/Approach Volume (Sec.)	36.13
Percent Error	0.88%	Percent Error	1.12%
		Percentage Change	76.92%
		t-Score	-69.68
PM Peak Results: No I-5 Incident			
Before SCOOT		**After SCOOT**	
Number of Samples	1640	Number of Samples	579
Total Delay (Hrs.)	8.84	Total Delay (Hrs.)	6.05
Avg. Delay/Approach Volume (Sec.)	20.42	Avg. Delay/Approach Volume (Sec.)	31.54
Percent Error	0.88%	Percent Error	1.44%
		Percentage Change	54.46%
		t-Score	-44.57
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1689	Number of Samples	713
Total Delay (Hrs.)	11.10	Total Delay (Hrs.)	6.22
Avg. Delay/Approach Volume (Sec.)	17.05	Avg. Delay/Approach Volume (Sec.)	12.92
Percent Error	1.29%	Percent Error	3.43%
		Percentage Change	-24.20%
		t-Score	16.35

Table 36: Katella and Howell, Northbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	357	Number of Samples	228
Total Delay (Hrs.)	1.02	Total Delay (Hrs.)	0.52
Avg. Delay/Approach Volume (Sec.)	22.59	Avg. Delay/Approach Volume (Sec.)	23.25
Percent Error	0.55%	Percent Error	0.40%
		Percentage Change	2.91%
		t-Score	-8.32
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	360	Number of Samples	80
Total Delay (Hrs.)	2.18	Total Delay (Hrs.)	0.68
Avg. Delay/Approach Volume (Sec.)	28.12	Avg. Delay/Approach Volume (Sec.)	25.21
Percent Error	1.14%	Percent Error	1.97%
		Percentage Change	-10.36%
		t-Score	9.65

Table 37: Katella and Howell, Southbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	404	Number of Samples	232
Total Delay (Hrs.)	6.05	Total Delay (Hrs.)	1.59
Avg. Delay/Approach Volume (Sec.)	43.24	Avg. Delay/Approach Volume (Sec.)	46.97
Percent Error	0.46%	Percent Error	0.45%
		Percentage Change	8.61%
		t-Score	-25.22
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	160
Total Delay (Hrs.)	14.75	Total Delay (Hrs.)	4.02
Avg. Delay/Approach Volume (Sec.)	57.48	Avg. Delay/Approach Volume (Sec.)	24.96
Percent Error	2.49%	Percent Error	3.71%
		Percentage Change	-56.58%
		t-Score	37.36

Table 38: Katella and Howell, Eastbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	320	Number of Samples	213
Total Delay (Hrs.)	7.76	Total Delay (Hrs.)	2.47
Avg. Delay/Approach Volume (Sec.)	20.30	Avg. Delay/Approach Volume (Sec.)	11.84
Percent Error	4.85%	Percent Error	6.00%
		Percentage Change	-41.65%
		t-Score	13.60
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	400	Number of Samples	184
Total Delay (Hrs.)	2.80	Total Delay (Hrs.)	1.40
Avg. Delay/Approach Volume (Sec.)	13.83	Avg. Delay/Approach Volume (Sec.)	9.39
Percent Error	2.61%	Percent Error	3.91%
		Percentage Change	-18.21%
		t-Score	8.64

Table 39: Katella and Howell, Westbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	372	Number of Samples	220
Total Delay (Hrs.)	3.66	Total Delay (Hrs.)	2.17
Avg. Delay/Approach Volume (Sec.)	11.77	Avg. Delay/Approach Volume (Sec.)	16.88
Percent Error	3.16%	Percent Error	2.88%
		Percentage Change	43.45%
		t-Score	-16.38%
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	380	Number of Samples	148
Total Delay (Hrs.)	5.39	Total Delay (Hrs.)	1.53
Avg. Delay/Approach Volume (Sec.)	17.10	Avg. Delay/Approach Volume (Sec.)	12.25
Percent Error	4.79%	Percent Error	4.66%
		Percentage Change	-28.35%
		t-Score	9.51

Table 40: Katella and Howell, All Approaches

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1453	Number of Samples	893
Total Delay (Hrs.)	18.49	Total Delay (Hrs.)	6.75
Avg. Delay/Approach Volume (Sec.)	21.06	Avg. Delay/Approach Volume (Sec.)	17.16
Percent Error	1.26%	Percent Error	1.32%
		Percentage Change	-18.49%
		t-Score	21.92
Evening Off-Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1540	Number of Samples	572
Total Delay (Hrs.)	25.12	Total Delay (Hrs.)	7.63
Avg. Delay/Approach Volume (Sec.)	29.50	Avg. Delay/Approach Volume (Sec.)	17.47
Percent Error	1.58%	Percent Error	2.09%
		Percentage Change	-40.77%
		t-Score	39.87

Table 41: Ball and Sunkist, Northbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	397	Number of Samples	120
Total Delay (Hrs.)	5.16	Total Delay (Hrs.)	2.15
Avg. Delay/Approach Volume (Sec.)	26.93	Avg. Delay/Approach Volume (Sec.)	26.11
Percent Error	1.40%	Percent Error	3.00%
		Percentage Change	-3.06%
		t-Score	1.86

Table 42: Ball and Sunkist, Southbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	380	Number of Samples	136
Total Delay (Hrs.)	5.36	Total Delay (Hrs.)	1.77
Avg. Delay/Approach Volume (Sec.)	25.65	Avg. Delay/Approach Volume (Sec.)	32.78
Percent Error	1.42%	Percent Error	1.81%
		Percentage Change	27.80%
		t-Score	-20.83

Table 43. Ball and Sunkist, Eastbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	361	Number of Samples	112
Total Delay (Hrs.)	15.45	Total Delay (Hrs.)	2.06
Avg. Delay/Approach Volume (Sec.)	26.63	Avg. Delay/Approach Volume (Sec.)	15.00
Percent Error	3.96%	Percent Error	4.85%
		Percentage Change	-43.68%
		t-Score	17.80

Table 44: Ball and Sunkist, Westbound Approach

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	361	Number of Samples	120
Total Delay (Hrs.)	17.56	Total Delay (Hrs.)	6.68
Avg. Delay/Approach Volume (Sec.)	23.87	Avg. Delay/Approach Volume (Sec.)	27.78
Percent Error	4.63%	Percent Error	7.64%
		Percentage Change	16.39%
		t-Score	-3.20

Table 45: Ball and Sunkist, All Approaches

Special Event			
PM Peak Results			
Before SCOOT		**After SCOOT**	
Number of Samples	1499	Number of Samples	488
Total Delay (Hrs.)	5.16	Total Delay (Hrs.)	2.15
Avg. Delay/Approach Volume (Sec.)	26.93	Avg. Delay/Approach Volume (Sec.)	26.11
Percent Error	1.63%	Percent Error	2.72%
		Percentage Change	-3.06%
		t-Score	1.93

traffic leaving after the NHL hockey game). This is a good indication that SCOOT's capacity to adapt to a sudden change in traffic conditions offers advantages relative to the baseline system. The baseline system is set for relatively lower volumes at these intersections.

4) Evidence from the PM peak periods is insufficient evidence to show that SCOOT provides either significantly better or significantly worse control than the baseline system. The SCOOT system provides lower delays compared to the baseline system in some cases, and higher delays in other cases. In most cases, the delays associated with the SCOOT system and the delays associated with the baseline system are comparable.

   - We attribute the few cases where SCOOT performed noticeably worse than the baseline system to the special circumstances and problems associated with the deployment. Tables 16 through 20 for the high volume Katella/State-College intersection demonstrates this aspect of the results. The SCOOT delays were lower than the baseline delays on 3 of the 4 approaches by values between 4 and 8%. But, the overall delay for this intersection was higher than for the baseline case, because one approach was showing a delay increase up to 60% in the PM peak period. Subsequent consultation with Siemens and Siemens' examination of the parameter settings revealed that the parameters were clearly not ideal. This problem could and likely would have been avoided if there was more time available for the deployment, if communications faults between traffic signal controllers and the TMC had occurred less frequently (i.e., if Anaheim's physical plant had been in better condition), and/or if the TMC staff had been trained to adjust the SCOOT intersection parameters themselves.

   - The low-volume intersection at Cerritos/Sunkist described in Table 35 produced strikingly high SCOOT delays. Further examination revealed that the reason is the inclusion of this intersection as part of the SCOOT system. The volumes were very low at this intersection. Siemens indicated that this intersection would normally not be subjected to SCOOT control. Including it in the SCOOT control area would force use of a common signal cycle length that is not appropriate for the intersection, thus causing long delays. However, inclusion of the intersection was required as part the deployment. Increases in the delays at this intersection with respect to the baseline are mitigated when volumes increase under special event conditions.

5) In the cases where SCOOT intersection delays increased relative to the baseline system the increase was rarely more than 10%. In cases where SCOOT performed better than the baseline system, the benefits were normally under 5%. This is a very encouraging result, even a surprising result. The deployment problems identified above produced a substandard implementation of the SCOOT system. The SCOOT system, despite this substandard implementation, did not cause any unacceptably high delays, did not cause any catastrophic problems in the Anaheim network, and still did

reduce delay at some intersections. Only the two cases identified above, use of the wrong parameter settings for an approach at the State College/Katella intersection and the inappropriate inclusion of a very small-volume intersection in the system, produced increases in delay large enough to be considered unacceptable.

Further insights into the traffic performance under SCOOT are derived from the floating car study results.

2.5.2 Floating Car Analysis

Tables 46, 47 and 48 show the summary statistics for the floating car studies. These tables focus on average total travel times, average running time, and average stopped time, respectively, for the seven routes on which floating car data was collected. Floating car routes are described in section 2.2.2. Route 2 and Route 2b refer to the back and forth directions on Katella Street that lead to the Arrowhead Pond. Routes 1 and 1b refer to the back and forth directions on State College running across Katella. And, Routes 3 and 4 are circular routes that take the vehicle across various parts of the network. Route 3 has substantially more left-turns than Route 4.

Times measured on floating car routes provide a more accurate measure of the comprehensive conditions experienced during a trip through the network than can be identified at individual intersections. Considerable information is available in terms of the daily profiles of travel time variations on these routes. However, the focus here is to provide overall, summary conclusions at the aggregate level. Conclusions based on disaggregate data are more likely to be spurious. Results shown in Tables 46 through 48 are summarized as follows.

2.5.2.1 Summary Results

1) Travel times on selected routes showed the effect of directional settings in SCOOT. The back and forth directions that had different travel times under the baseline system showed similar travel times under SCOOT in one case. A second case showed the reverse, with nearly identical baseline times diverging under SCOOT. Table 46 shows this for Route 1 and Route 2. The back and forth directions of Route 1 show a 15% difference under baseline control for special event conditions. This difference is reduced to less than 3% difference under SCOOT control. The same table also shows that Route 2 has almost identical travel times in both directions under baseline control for special event conditions. This difference is increased to over 15% under SCOOT. Since Routes 2 and 2b (Katella) lead to and away from the Arrowhead Pond. This difference indicates that the baseline signal plan set for the special events is performing better than SCOOT. SCOOT does not have different plan periods and settings for special events. SCOOT reduces special event travel time in one direction and increases it in the other.

2) The route travel times under SCOOT show reductions under 10% in some cases and increases under 15% in others. On the more circuitous, longer routes covering more of the network, SCOOT showed travel time reductions of up to about 2% and

Table 46: Average Travel Times on the Floating Car Routes

Route	Before SCOOT					After SCOOT				
	Special Event		No Special Event			Special Event		No Special Event		
	Day 2	Day 4	Day 1	Day 3	Day 5	Day 8	Day 10	Day 6	Day 7	Day 9
R1	3.742	3.930	3.947	3.985	4.002	4.397	4.197	4.164	4.122	4.080
	Avg. = 3.836		Avg. = 3.978			Avg. = 4.297		Avg. = 4.122		
						% Chg. = 12.02		% Chg. = 3.62		
R1-b	4.669	3.995	4.085	4.171	4.452	4.181	4.201	4.522	4.175	4.206
	Avg. = 4.332		Avg. = 4.236			Avg. = 4.191		Avg. = 4.301		
						% Chg. = 12.02		% Chg. = 3.62		
R2	4.227	3.575	3.251	2.766	3.108	3.831	3.462	3.061	3.051	3.267
	Avg. = 3.901		Avg. = 3.042			Avg. = 3.647		Avg. = 3.126		
						% Chg. = - 6.52		% Chg. = 2.78		
R2-b	4.267	3.547	3.182	2.996	3.028	4.426	4.487	3.449	3.117	3.457
	Avg. = 3.907		Avg. = 3.069			Avg. = 4.457		Avg. = 3.341		
						% Chg. = 14.06		% Chg. = 8.87		
R3	17.324	15.152	15.131	15.999	15.230	16.236	17.389	13.627	15.830	16.030
	Avg. = 16.238		Avg. = 15.453			Avg. = 16.813		Avg. = 15.162		
						% Chg. = 3.54		% Chg. = -1.88		
R4	9.054	8.750	8.687	8.878	8.009	9.284	9.642	8.445	9.131	9.210
	Avg. = 8.902		Avg. = 8.525			Avg. = 9.463		Avg. = 8.929		
						% Chg. = 6.30		% Chg. = 4.74		
R5	10.831	11.517	9.069	11.208	9.981	11.317	7.907	10.811	10.167	8.161
	Avg. = 11.174		Avg. = 10.086			Avg. = 9.612		Avg. = 9.713		
						% Chg. = -13.98		% Chg. = -3.70		

Table 47: Average Running Times on the Floating Car Routes

Route	Before SCOOT					After SCOOT				
	Special Event		No Special Event			Special Event		No Special Event		
	Day 2	Day 4	Day 1	Day 3	Day 5	Day 8	Day 10	Day 6	Day 7	Day 9
R1	2.688	2.681	2.682	2.717	2.676	2.709	2.832	2.834	2.818	2.722
	Avg. = 2.685		Avg. = 2.692			Avg. = 2.771		Avg. = 2.791		
						% Chg. = 3.20		% Chg. = 3.70		
R1-b	3.088	2.860	2.929	2.694	2.877	2.860	3.012	2.858	3.253	2.899
	Avg. = 2.974		Avg. = 2.833			Avg. = 2.936		Avg. = 3.003		
						% Chg. = -1.28		% Chg. = 6.00		
R2	3.064	2.342	2.456	2.246	2.319	2.815	2.535	2.502	2.259	2.496
	Avg. = 2.686		Avg. = 2.363			Avg. = 3.245		Avg. = 2.339		
						% Chg. = - 1.04		% Chg. = 3.36		
R2-b	3.115	2.256	2.511	2.302	2.277	3.476	3.013	2.598	2.117	2.301
	Avg. = 2.686		Avg. = 2.363			Avg. = 3.245		Avg. = 2.339		
						% Chg. = -1.28		% Chg. = 6.00		
R3	10.280	10.437	10.317	9.627	9.352	9.618	9.555	9.962	10.406	10.355
	Avg. = 10.359		Avg. = 9.965			Avg. = 9.587		Avg. = 10.151		
						% Chg. = -7.45		% Chg. = 3.95		
R4	7.186	6.545	6.594	6.825	6.634	7.188	6.904	6.379	6.781	6.402
	Avg. = 6.866		Avg. = 6.684			Avg. = 7.046		Avg. = 6.521		
						% Chg. = 2.63		% Chg. = -2.45		
R5	5.456	6.167	5.306	5.317	5.189	6.086	5.676	5.417	5.339	5.467
	Avg. = 5.812		Avg. = 5.271			Avg. = 5.881		Avg. = 5.408		
						% Chg. = 1.20		% Chg. = 2.60		

Table 48: Average Stopped Times on the Floating Car Routes

Route	Before SCOOT					After SCOOT				
	Special Event		No Special Event			Special Event		No Special Event		
	Day 2	Day 4	Day 1	Day 3	Day 5	Day 8	Day 10	Day 6	Day 7	Day 9
R1	1.079	1.249	1.265	1.269	1.326	1.688	1.365	1.330	1.304	1.358
	Avg. = 1.164		Avg. = 1.287			Avg. = 1.527		Avg. = 1.331		
						% Chg. = 31.14		% Chg. = 3.42		
R1-b	1.582	1.135	1.556	1.486	1.575	1.321	1.189	1.676	0.988	1.307
	Avg. = 1.359		Avg. = 1.539			Avg. = 1.255		Avg. = 1.324		
						% Chg. = -7.62		% Chg. = -13.99		
R2	1.163	1.233	0.795	0.520	0.792	1.016	0.927	0.559	0.792	0.770
	Avg. = 1.198		Avg. = 0.702			Avg. = 0.972		Avg. = 0.707		
						% Chg. = - 18.91		% Chg. = 0.68		
R2-b	1.097	1.290	0.671	0.694	0.752	0.950	1.474	0.852	1.001	1.157
	Avg. = 1.194		Avg. = 0.706			Avg. = 1.212		Avg. = 1.003		
						% Chg. = 1.55		% Chg. = 42.18		
R3	7.048	4.714	4.813	6.322	5.879	6.618	7.778	3.935	5.423	5.675
	Avg. = 5.881		Avg. = 5.671			Avg. = 7.198		Avg. = 5.011		
						% Chg. = 22.39		% Chg. = -11.64		
R4	1.874	2.208	2.124	2.122	1.375	2.100	2.737	2.084	2.772	2.812
	Avg. = 2.041		Avg. = 1.874			Avg. = 2.419		Avg. = 2.556		
						% Chg. = 18.50		% Chg. = 36.42		
R5	5.375	5.350	3.764	5.892	4.792	5.231	2.231	5.417	5.339	2.693
	Avg. = 5.363		Avg. = 4.816			Avg. = 3.731		Avg. = 4.305		
						% Chg. = -30.42		% Chg. = -10.60		

increases of up to about 6%. The relative performance against the baseline system was better under nonevent conditions than under special event conditions.

2.5.2.2 Floating Car Route Time Profiles

In this section, we provide the travel time profiles on the six floating car study routes. The graphs 53 through 64 show for each of the six routes the travel time, stopped time and running time profiles. Two graphs are provided for each route; one for the no event days and one for the special event days. While the individual graphs do not necessarily show conclusive observations due to paucity of data points (many more days would be needed, necessitating considerably more expenses in data collection) to make conclusive observations for each route, but taken in totality, these profiles corroborate the earlier conclusion from the summary tables. The primary conclusion would be that the travel time, stopped time and running times did not show substantial differences between the "before" case and the "after" case. That implies that even a less-than-ideal SCOOT implementation was capable of at least performing as well as the existing control system.

The variations and the cases of larger delays are largely due to demand variations, and they seem to occur both with the existing system (see Figure 63 for Route 3, Day 2) and with the SCOOT system (see Fig 54 for route 1, Day 8). These demand-related drastic variations (mostly in travel time) appear to be the primary reason for most of the percentage changes reported in the summary tables of the previous sub-section. In fact the graphs show similar variations and time profiles in general, for most cases. No further statistical studies were attempted on this data to read more into them, as it would appear not to extract any more causal conclusions, but would rather result in spurious conclusions from the data.

A closer look reveals that the stopped time profiles for the SCOOT system are, on average, marginally below those of the existing system for the no-event days (see Figures 53, 55, 57, 59, 61, 63). On the other hand, for special event days the stopped time profiles for SCOOT are, on average, marginally above those of the existing system (see Figures 54, 56, 58, 60, 62, and 64). The running time profiles are, on average, identical between the systems, except for a couple of cases where demand variations caused congestion (Fig 63 and 64). Thus the variations in the total travel time roughly follow the variations in stooped times, other than in the couple of days of demand-related congestion.

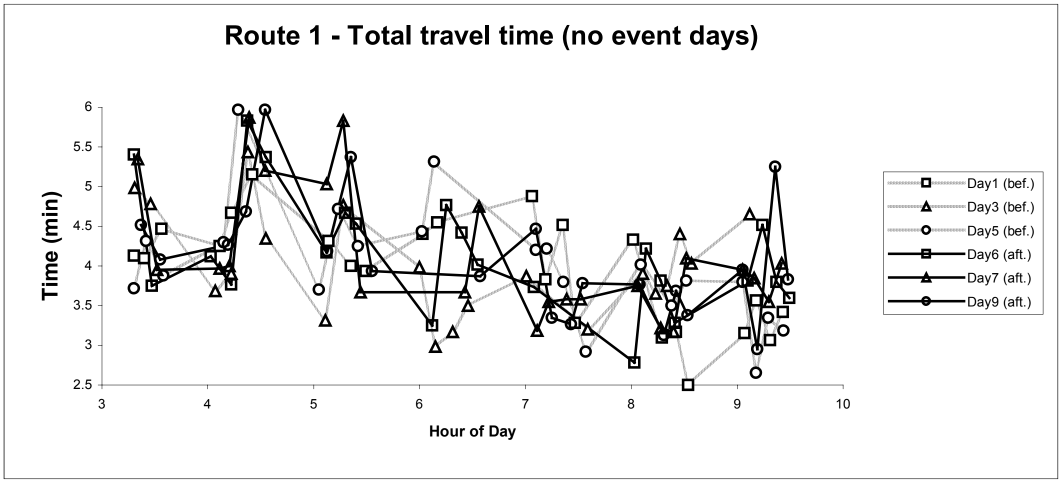
2.5.2.3 Two-Fluid Model Analysis

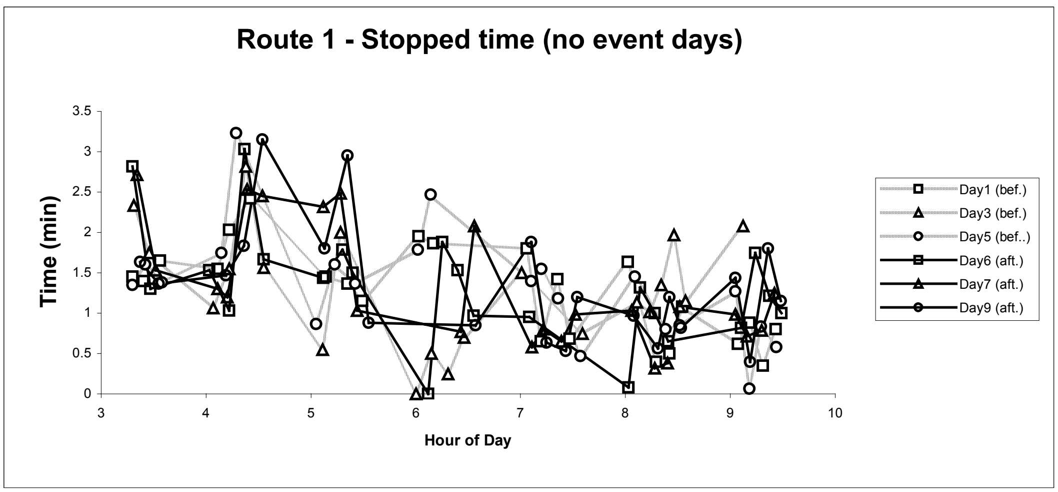
The final part of the analysis is based on the Two-fluid theory for network traffic quality. Recent literature on Network-level Traffic Flow Theory provides a starting point on evaluating the quality of traffic in urban arterial networks. The approach that will be used here is based on the "Two-Fluid Theory" (Herman et al., 1979,1985; Ardekani et al., 1985,1987; Jayakrishnan et al., 1990). The "Two-Fluids" refer to the stopped and running traffic here. It has been shown with data from several cities in the US and abroad (Albuquerque, Detroit, Dallas and San Antonio in the USA; Mexico City and Matamoros in Mexico, London in the UK, Melbourne in Australia) that the stopped and running portions of travel times are related as follows:

$$Ts = T^{1/(n+1)} - Tm \bullet T^{n/(n+1)} \qquad \textbf{(2)}$$

$$T = Ts + Tr \qquad \textbf{(3)}$$

where, T = average total travel time (min/mile),
Ts = average stopped portion of travel time (min/mile),
Tr = average running portion of travel time (min/mile),





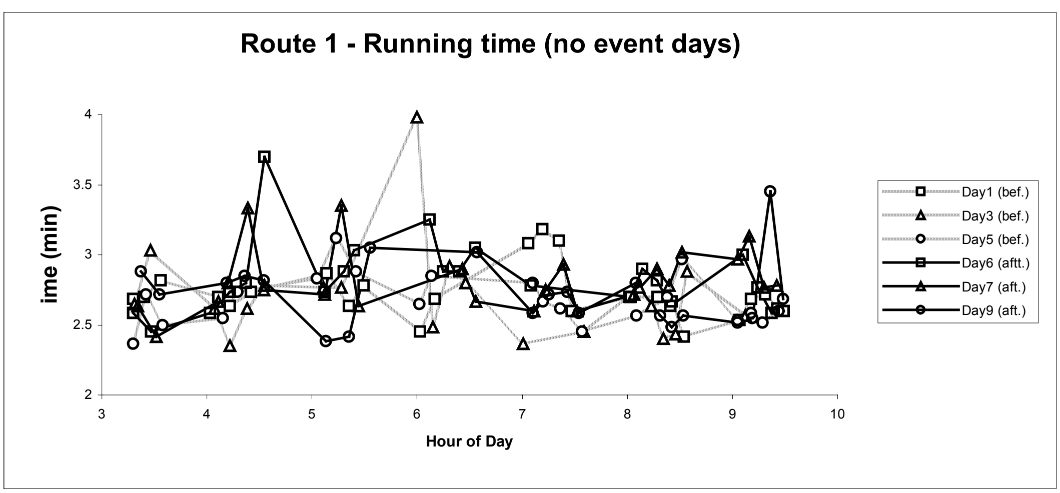
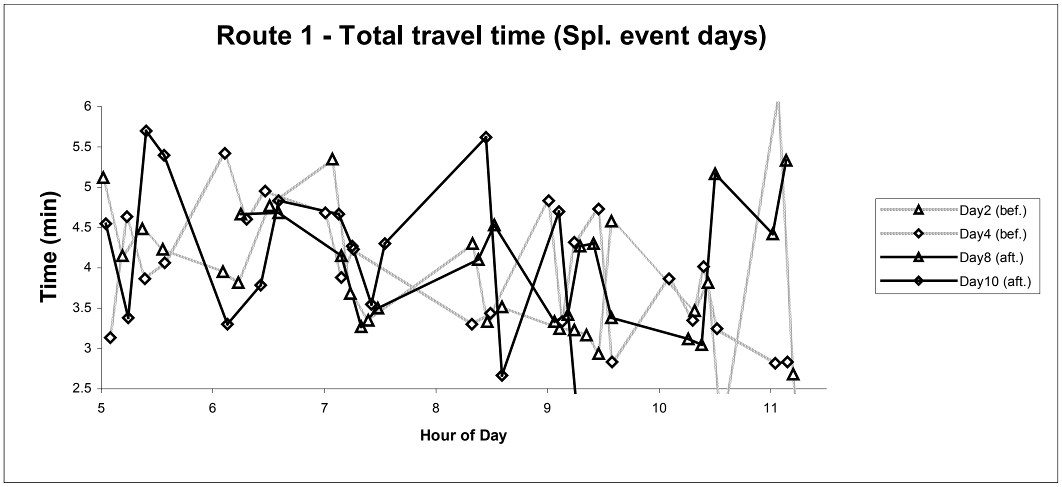
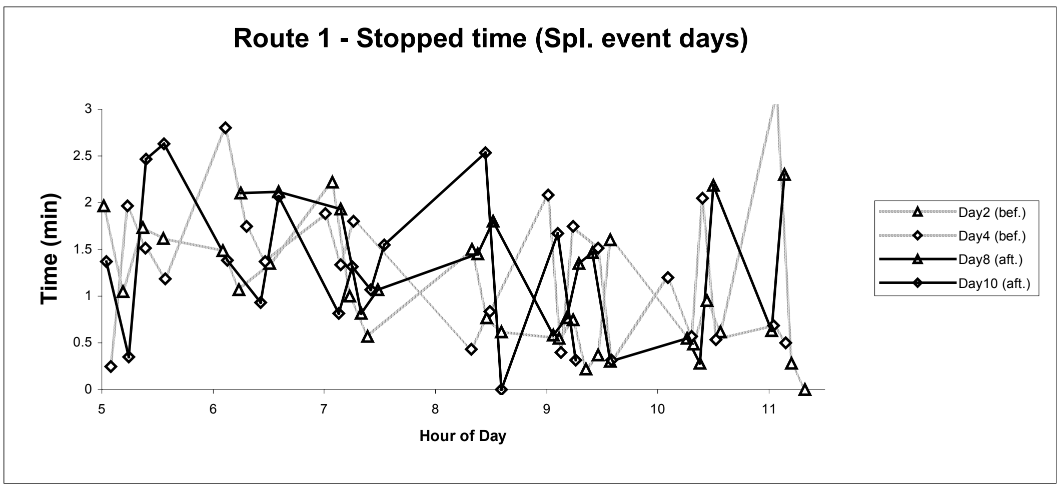


Figure 53: Floating Car Results on Route 1, No Events (Gray Lines – Before, Black Lines – After).





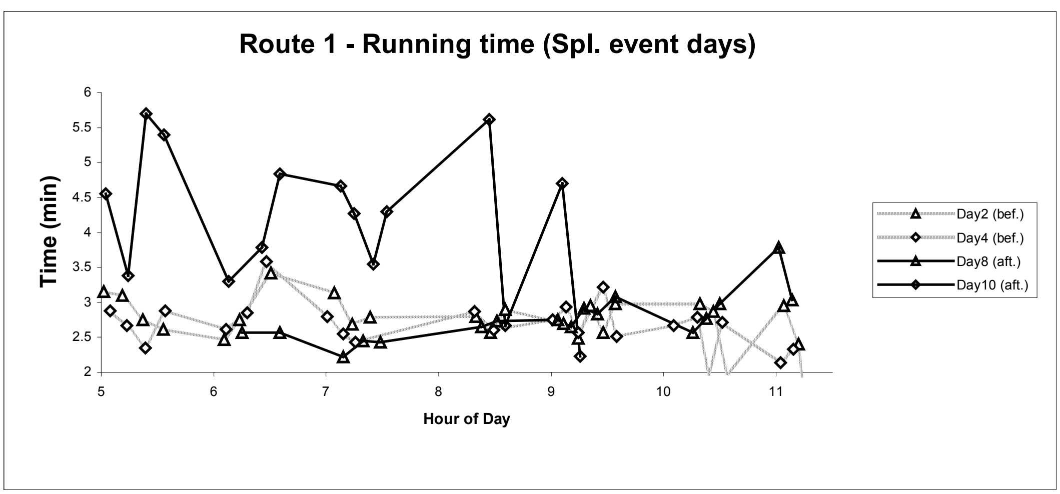
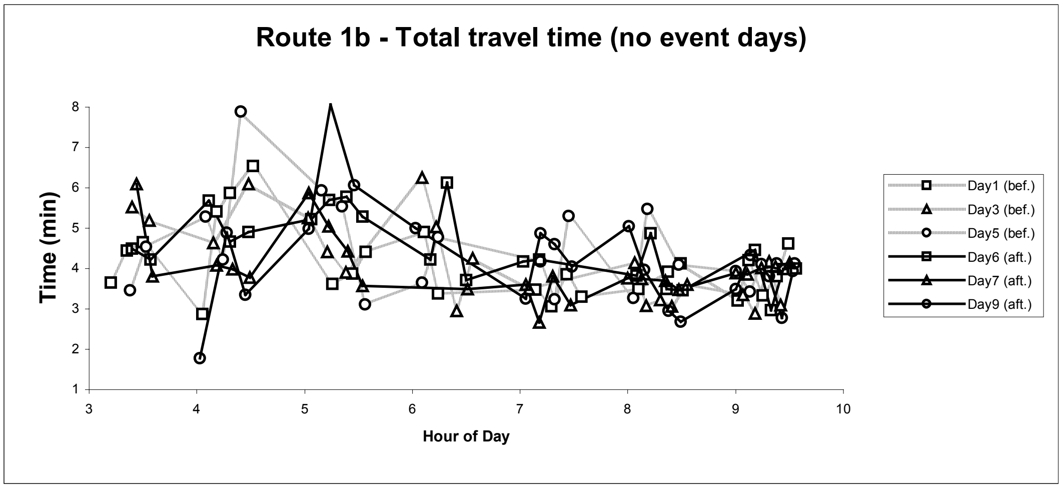
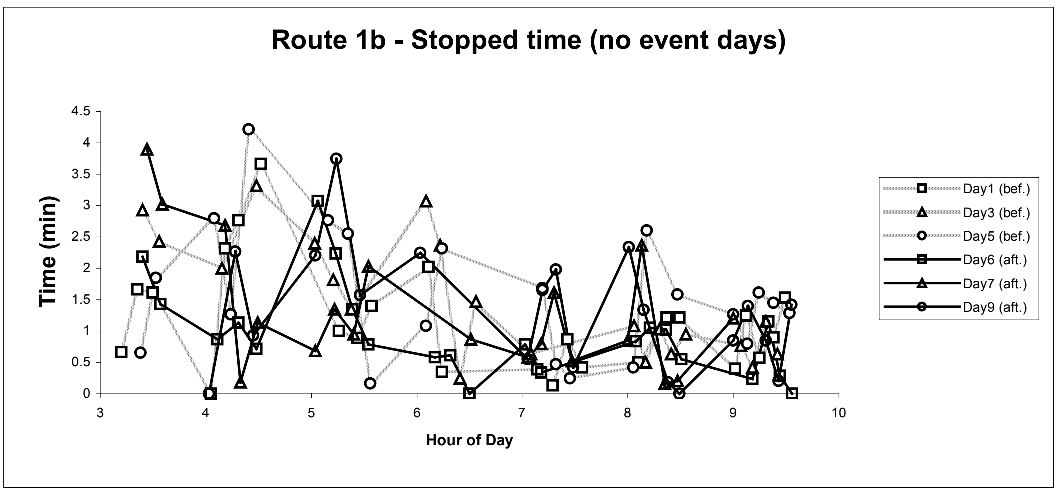


Figure 54: Floating Car Results – Route 1, Events (Gray Lines – Before, Black Lines – After).





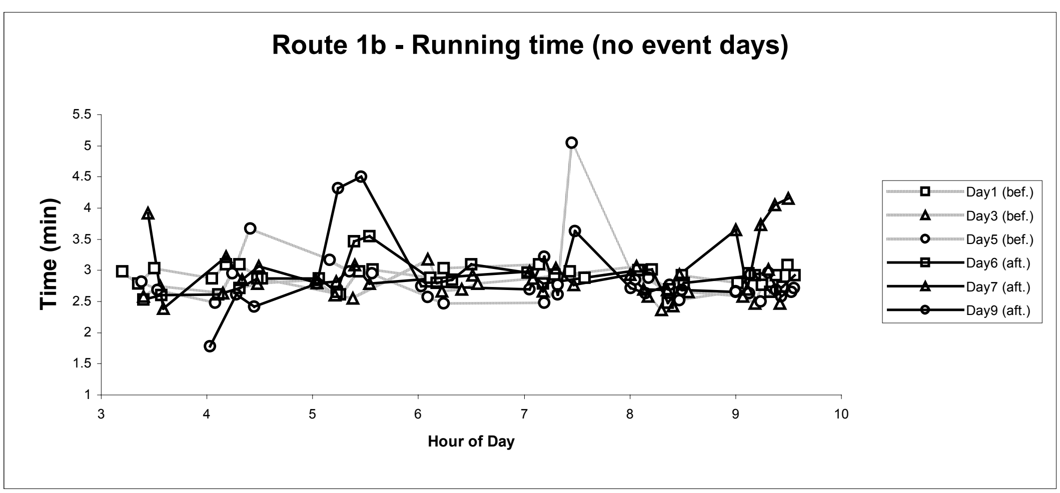
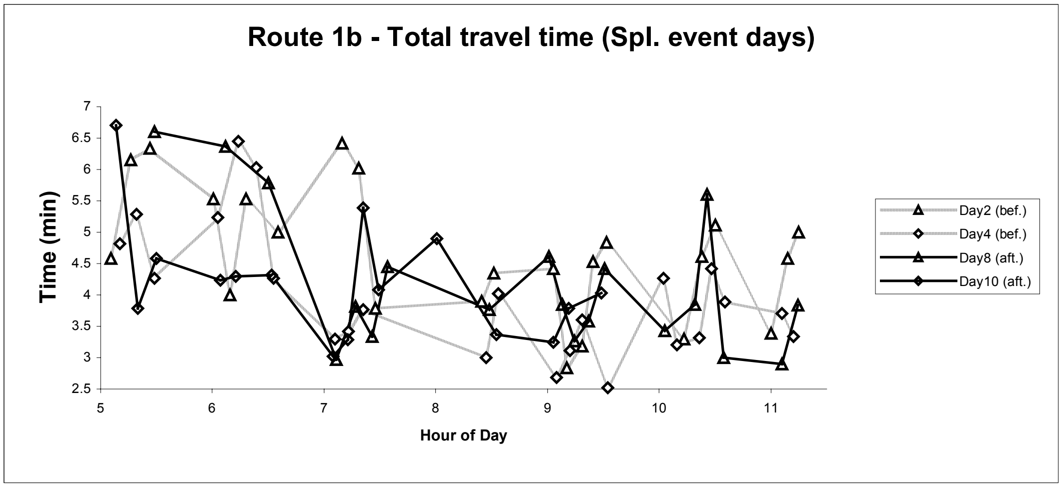
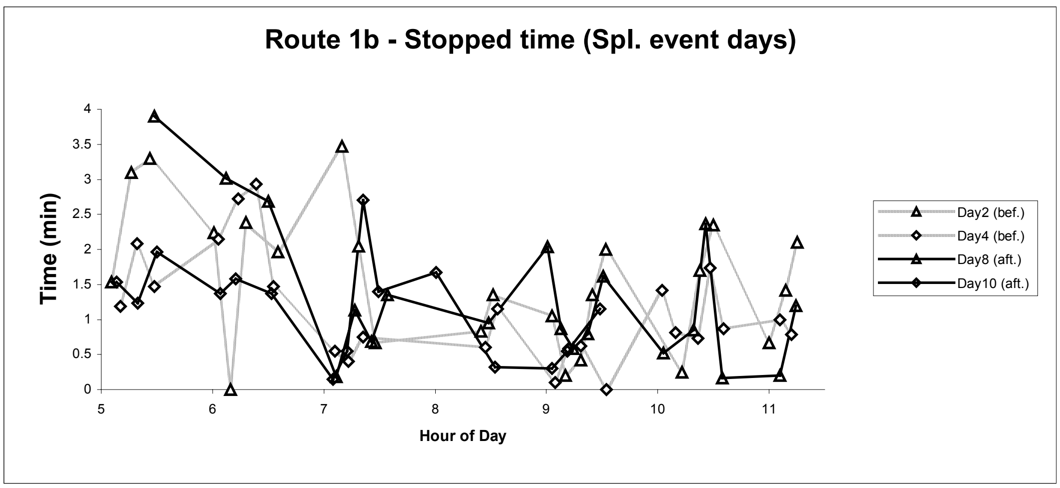


Figure 55: Floating Car Results – Route 1b, No Events (Gray Lines – Before, Black Lines – After).





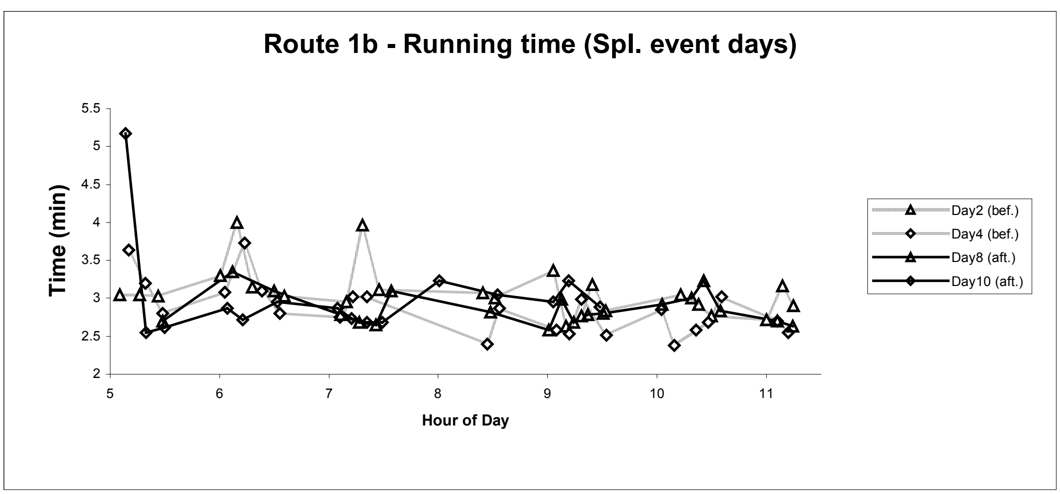
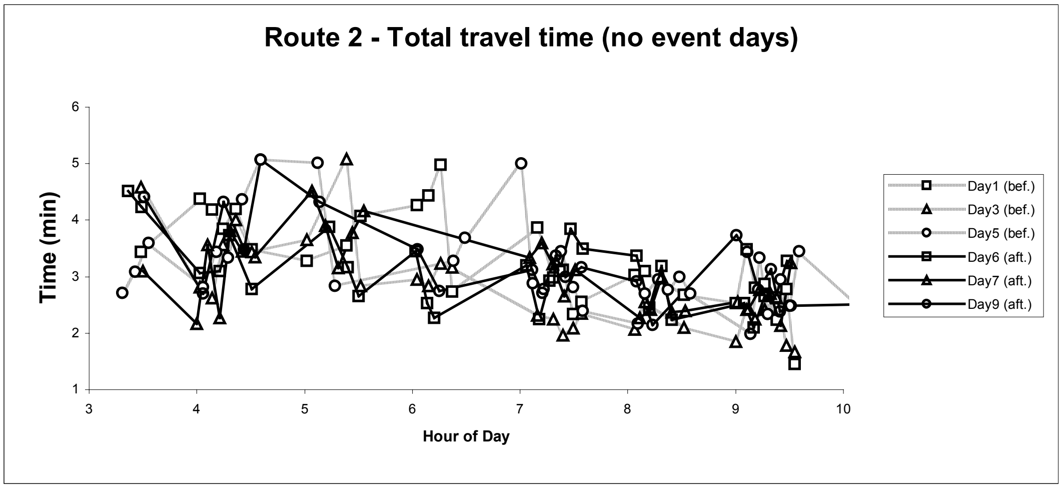
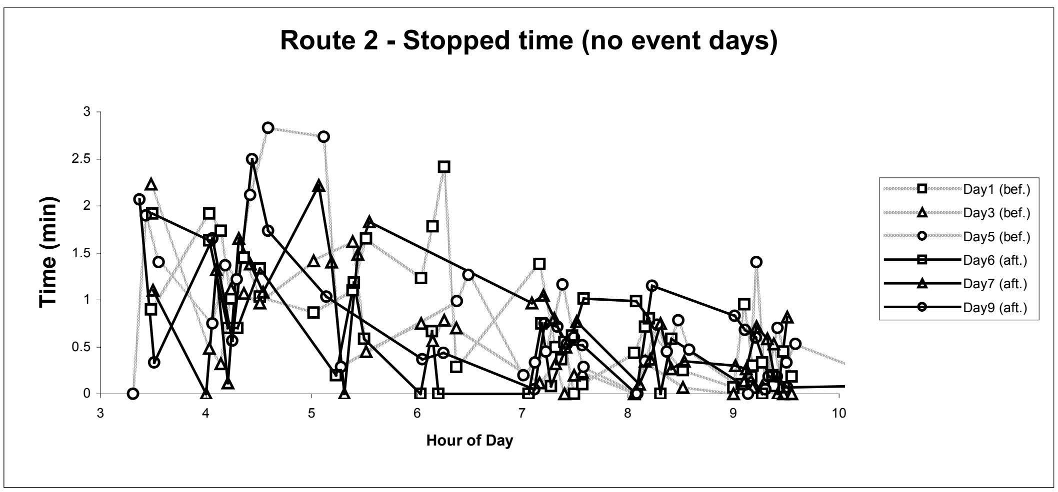


Figure 56: Floating Car Results – Route 1b, Events (Gray Lines – Before, Black Lines – After).





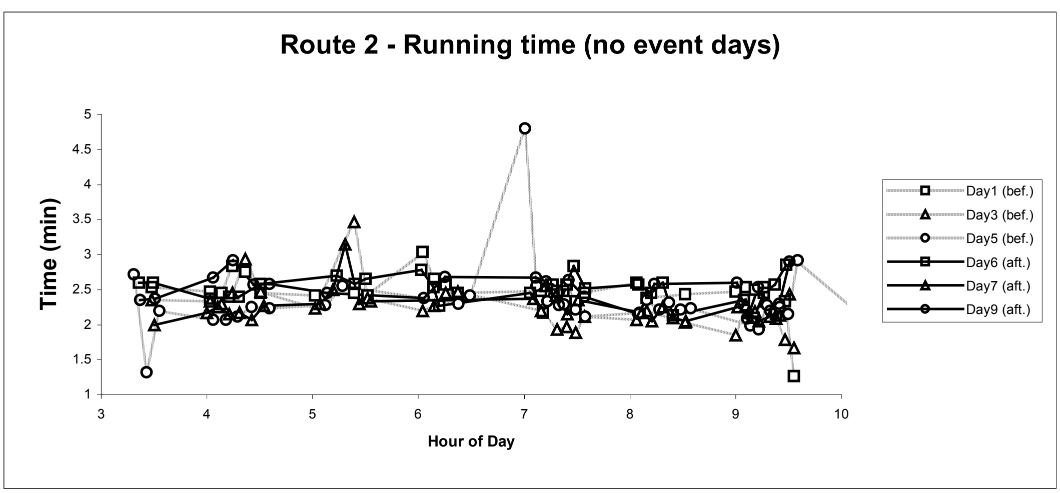
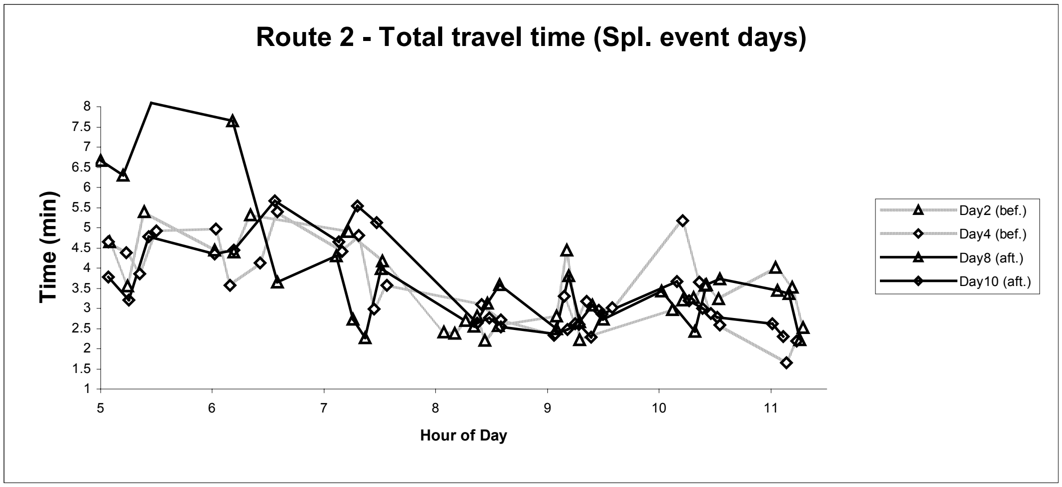
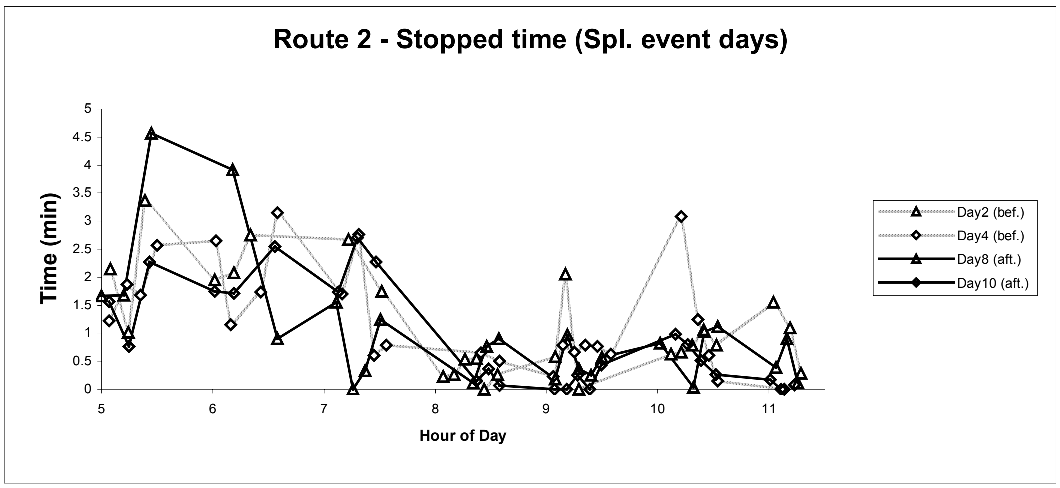


Figure 57: Floating Car Results – Route 2, No Events (Gray Lines – Before, Black Lines – After).





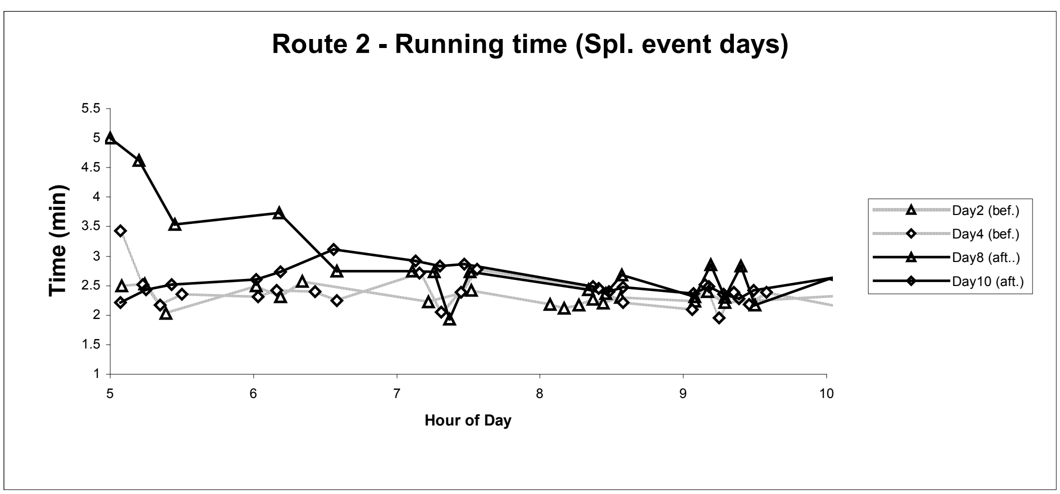
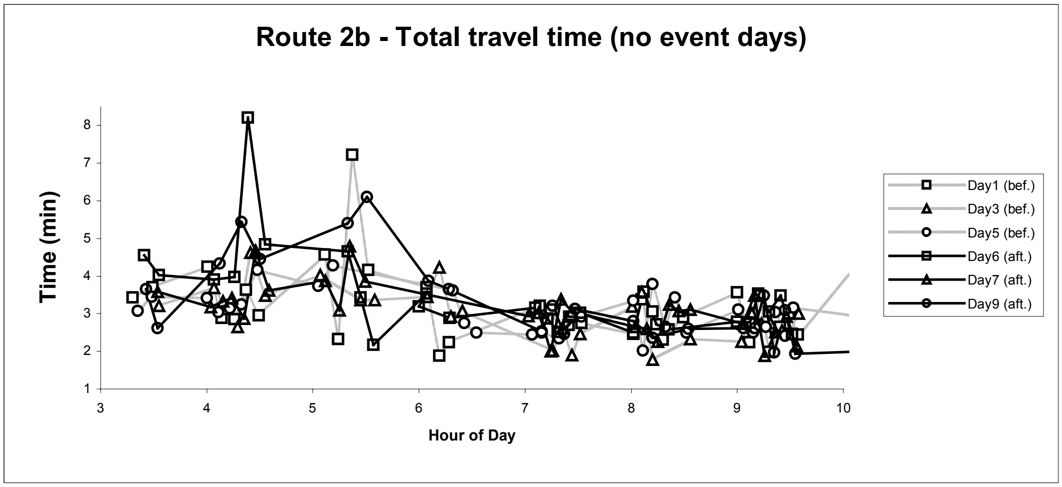
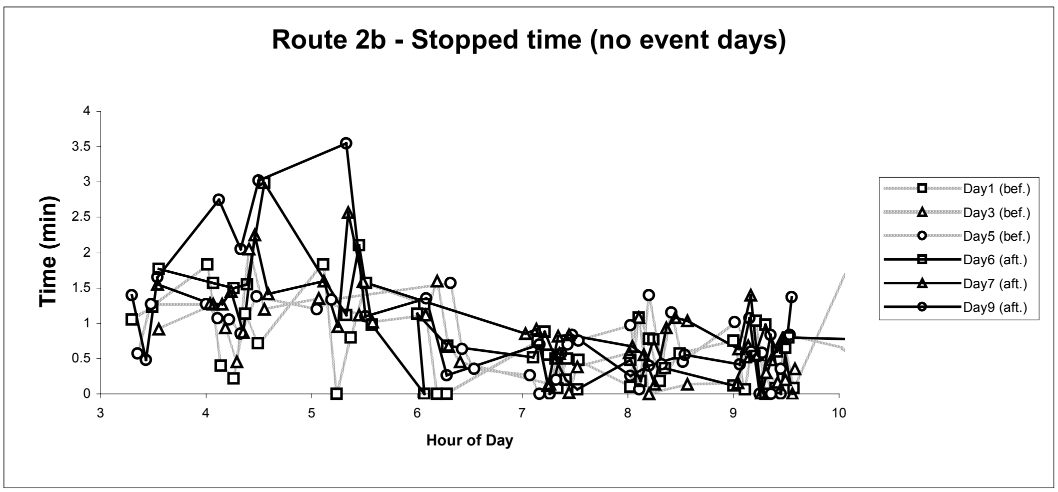


Figure 58: Floating Car Results – Route 2, Events (Gray Lines – Before, Black Lines – After).





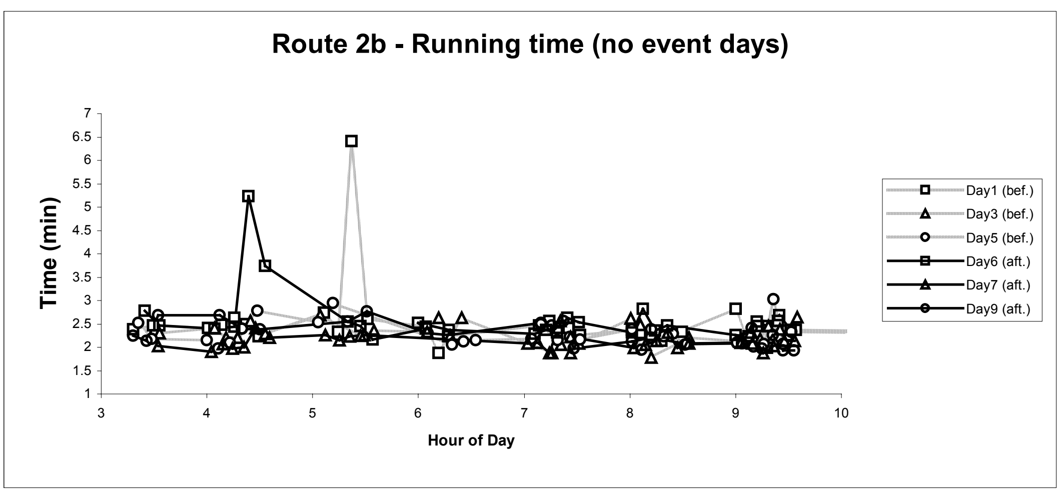
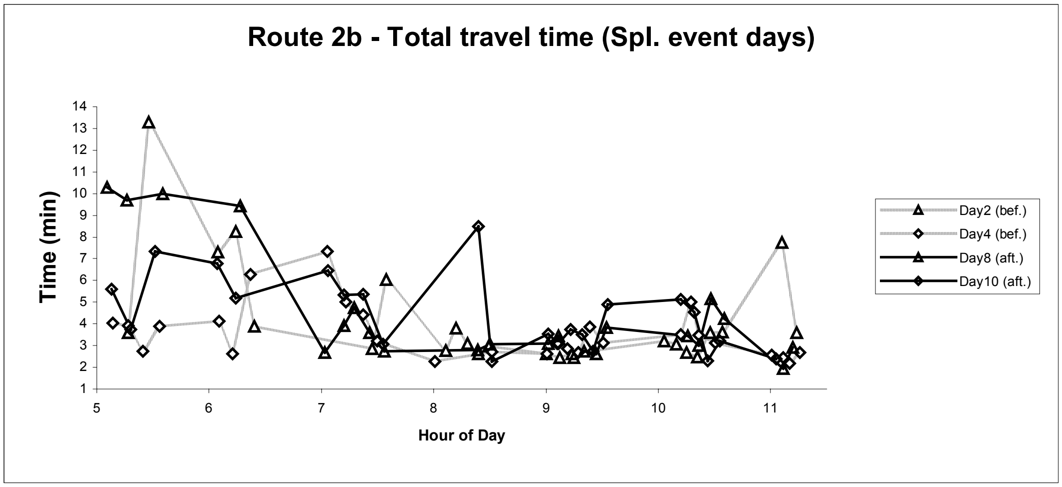
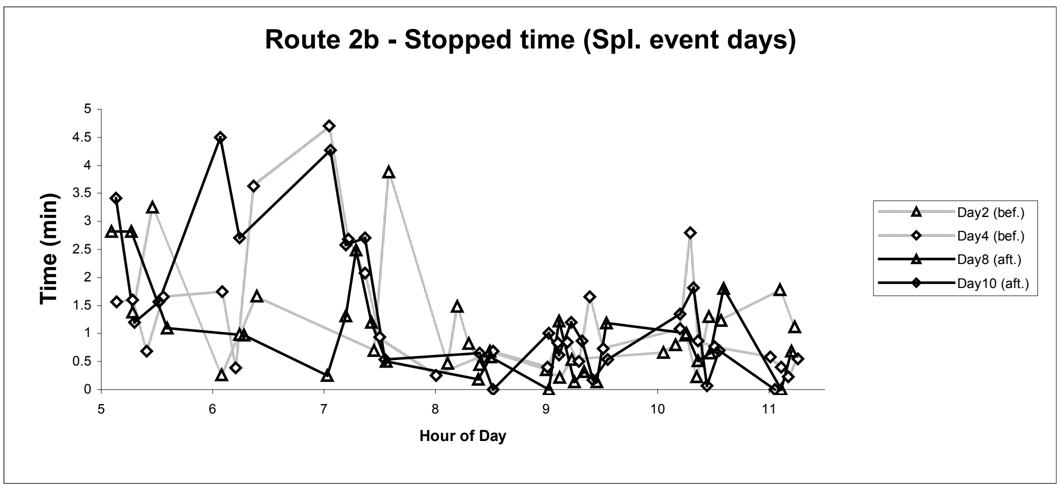


Figure 59: Floating Car Results – Route 2b, No Events (Gray lines – Before, Black Lines – After).





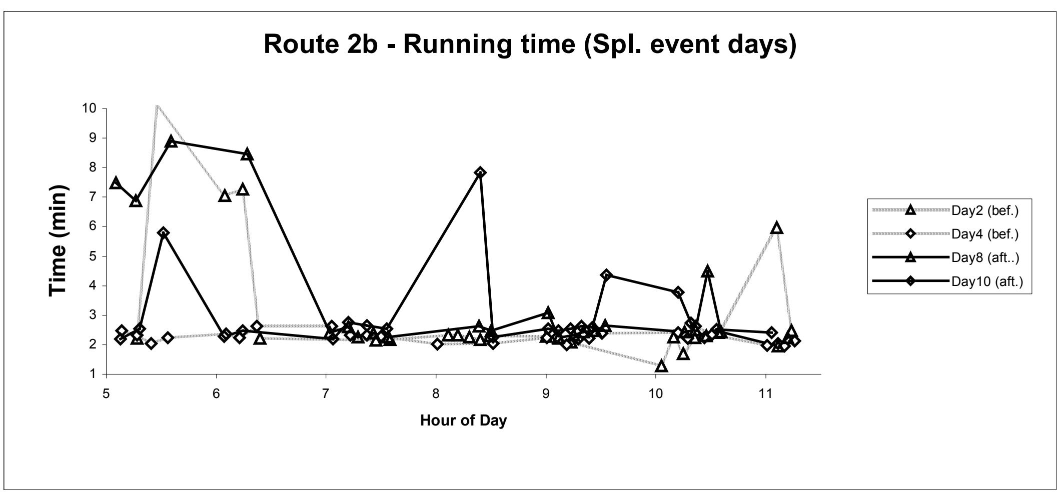
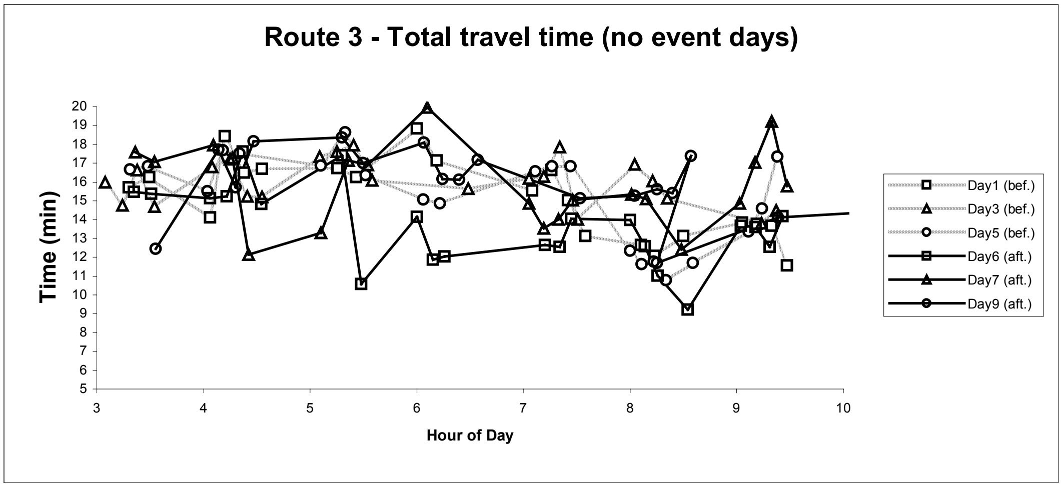
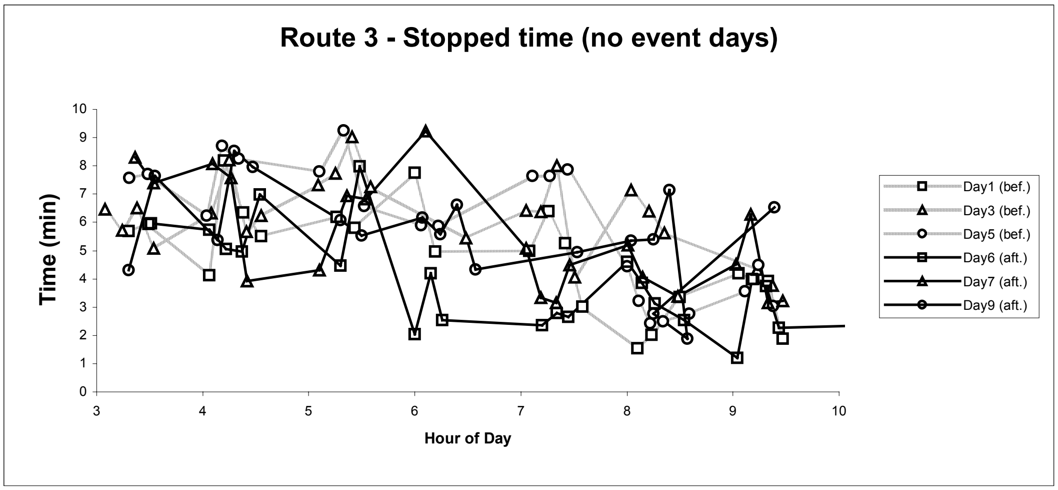


Figure 60: Floating Car Results – Route 2b, Events (Gray Lines – Before, Black Lines – After).





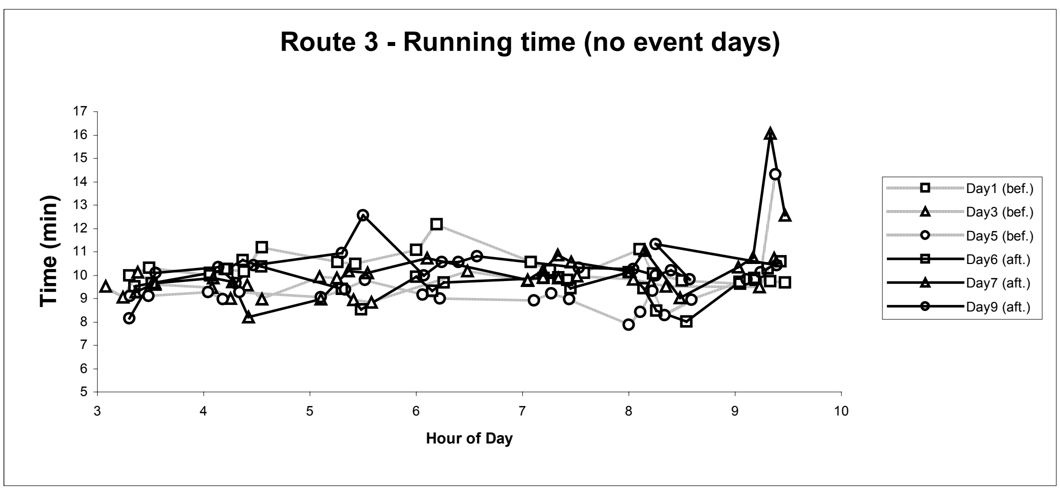
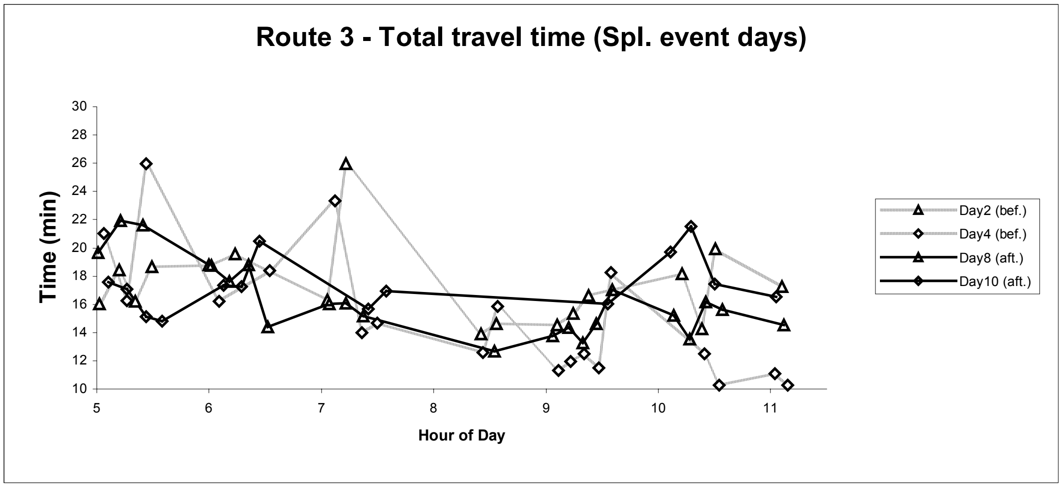
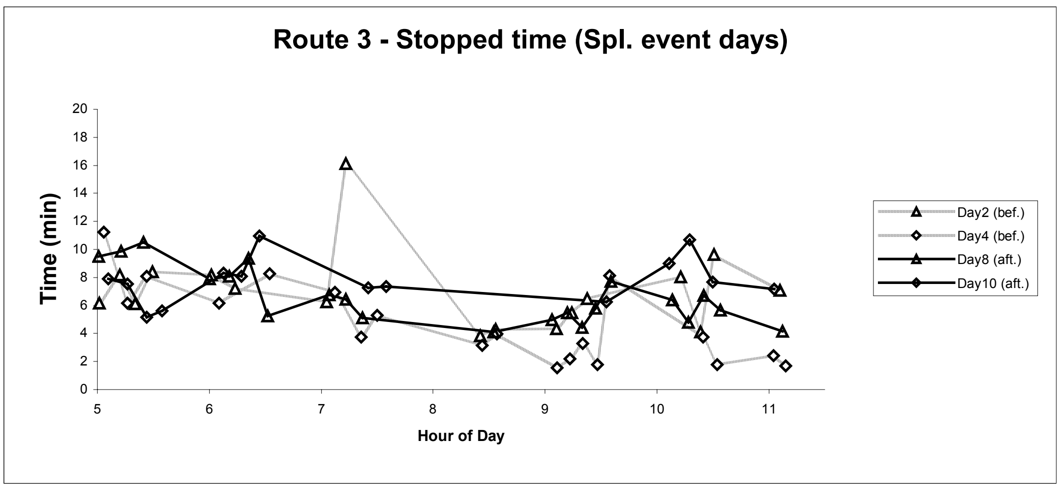


Figure 61: Floating Car Results – Route 3, No Events (Gray Lines – Before, Black Lines – After).





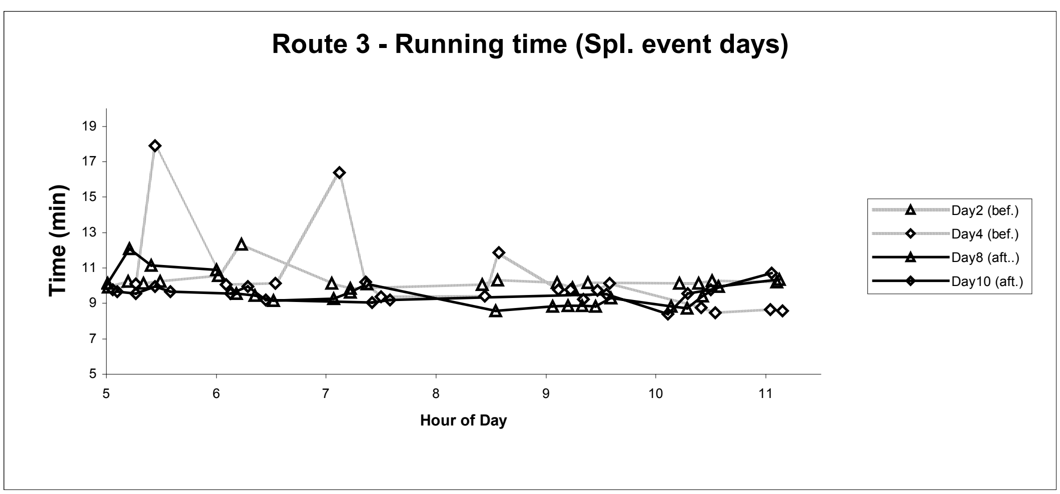
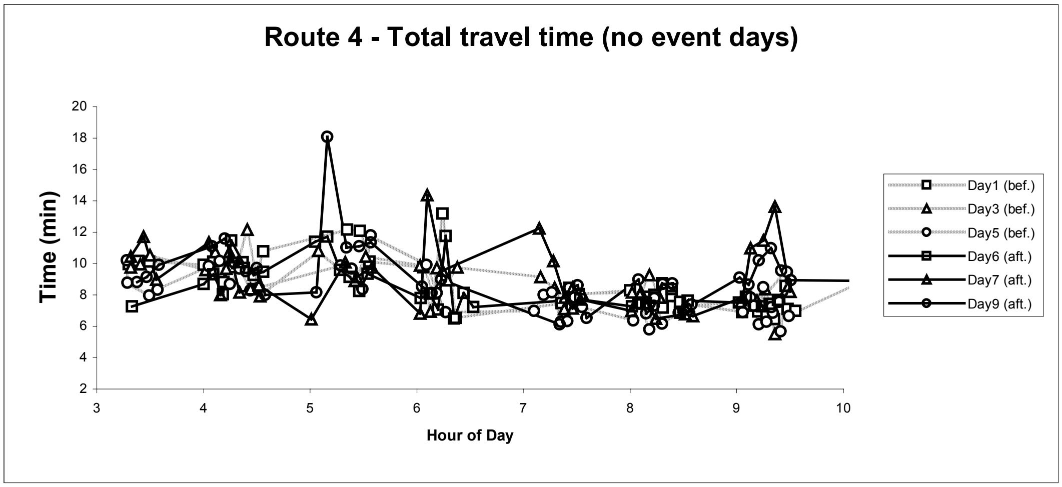
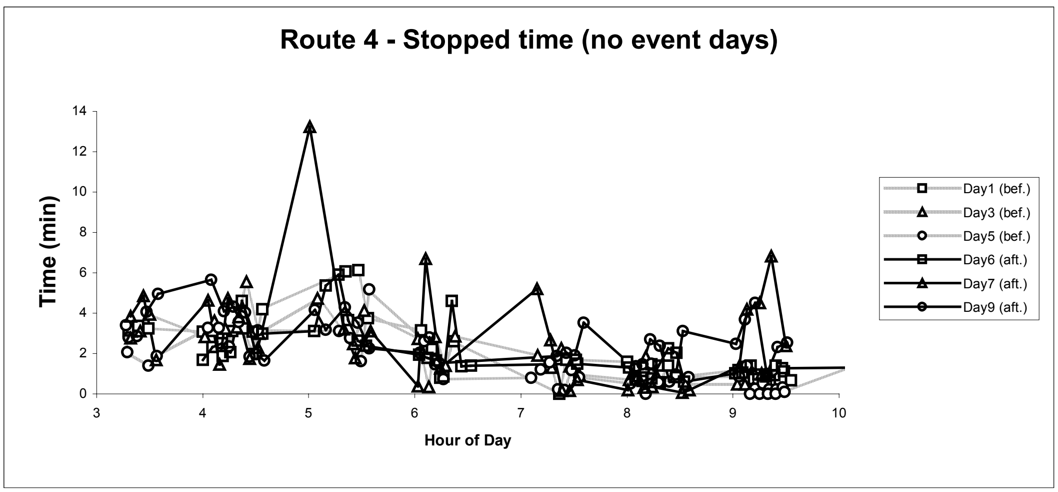


Figure 62: Floating Car Results – Route 3, Events (Gray Lines – Before, Black Lines – After).





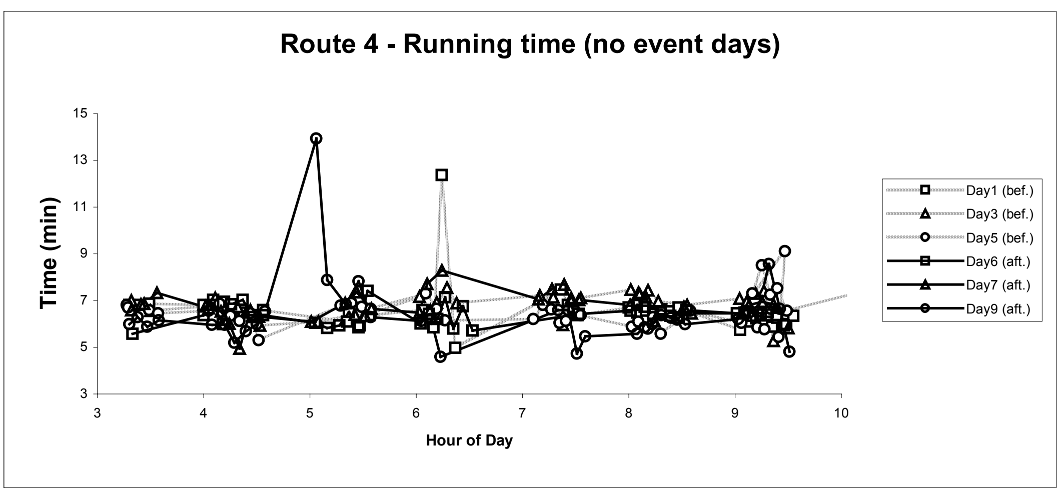
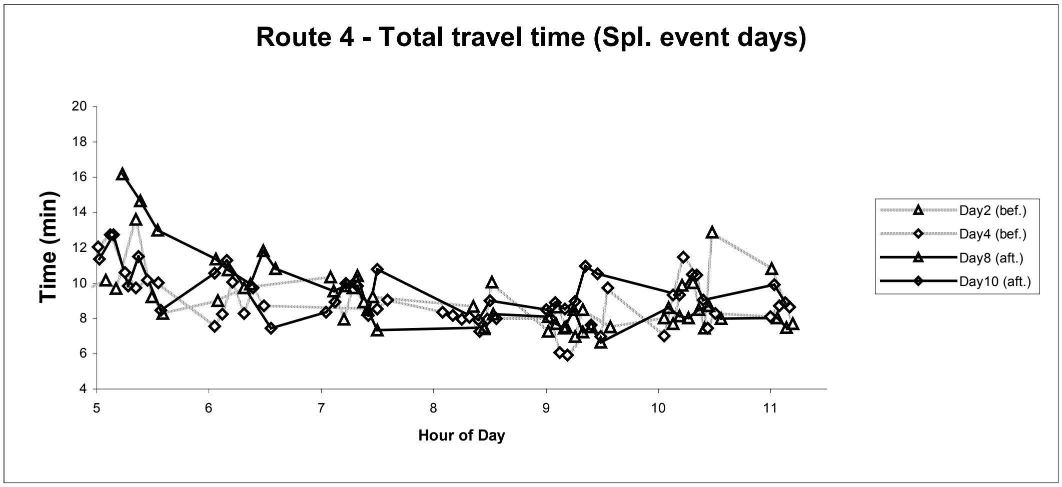
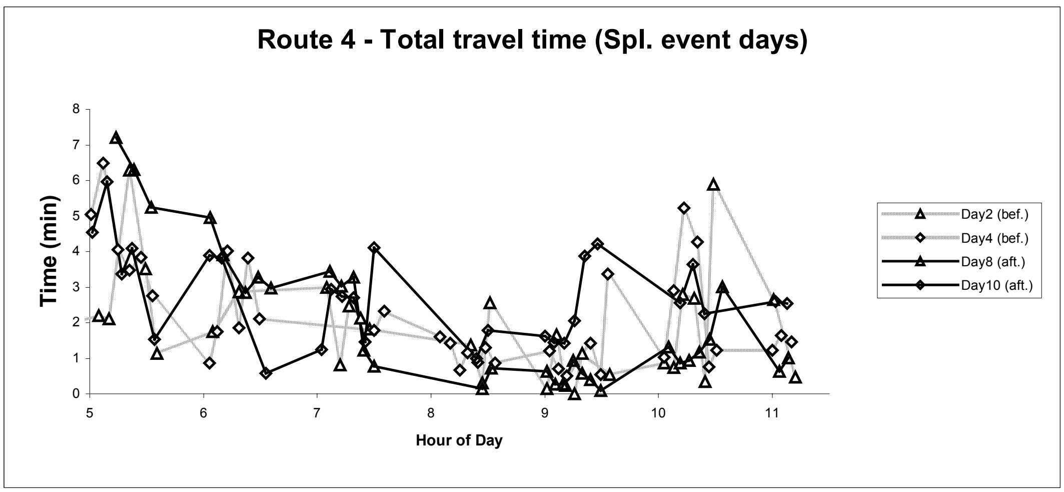


Figure 63: Floating Car Results – Route 4, No Events (Gray Lines – Before, Black Lines – After).





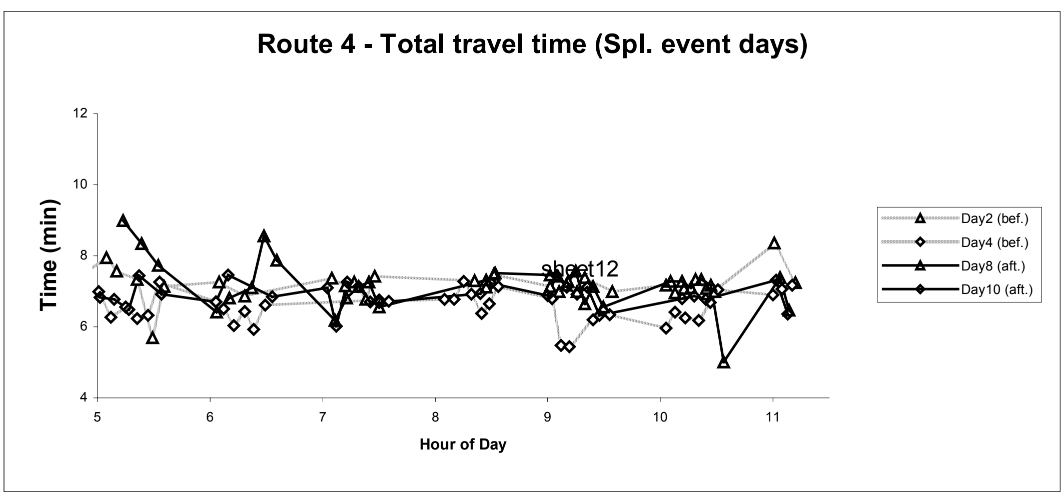


Figure 64: Floating Car Results – Route 4, Events (Gray lines – Before, Black Lines – After).

Tm = a parameter (equal to average minimum trip time, min/mile) capturing the travel time under the best of conditions, and

n = parameter capturing rate of worsening of traffic conditions as traffic volume increases.

The network level averages of the *Ts* and *Tr* variables are available from floating car study results. The two parameters (*n* and *Tm*) can be estimated using a simple log-linear regression. These two estimated parameters can be used to evaluate how well the control configuration performs under low volume conditions, as well as to study how well the control system preserves the traffic quality, as the flows increase. As such, a comparison between the parameters allows us to make some conclusions across a spectrum of conditions rather than at definite volume levels, etc. The model thus helps to reduce the dimensionality of the comparison matrix and helps us tackle the fact that a traffic control system has varying performance over a continuum of conditions rather than at one specific condition.

Figures 65 through 68 show the scatter plots used for finding the regression equations fitting the above two-fluid model to the Anaheim FOT network. Note that the scatter, even with log-transformation is rather substantial around the regression equations. This is not unusual in two-fluid studies, but is particularly pronounced here, due to the smaller size of the network and the rather disparate driving times and conditions on the six routes used for the study. Also, one could discern some patterns in the scatter resulting from there being six distinct route's data in the scatter. This is rather unusual in two-fluid studies, and a random driving pattern would have resulted in less correlation. It was decided for the purpose of this study that it would not be useful to disaggregate the data across the routes and examine them separately. Instead, the pooled data was used to find an overall conclusion, which as we find show only minimal difference in the traffic quality.

The final comparisons are between the regression equations and the estimated parameter values for n and Tm as shown in Figure 69. The most important observation is perhaps that the curves are all somewhat similar, which means that the changes caused by the SCOOT system was not substantial, and neither was it making the conditions worse. It should also be noted that the curves show that both the baseline system and SCOOT show much better performance than the traffic control systems in other cities where such Two-fluid models were calibrated (as reported in the published literature referred above.

In the no event conditions, the SCOOT system reduced the *Tm* from 1.45 min/miles to 1.38 min/mile and increased the *n* from 0.64 to 0.82. In the case of special events, SCOOT increased the *Tm* from 1.20 min/mile to 1.48 min/mile but decreased the *n* from 1.24 to 0.86. While the changes in *Tm* (effectively the limiting travel times in the least congested conditions) are easier to understand, *n* is a parameter that is not straight-forward, as it refers to the worsening of the performance as the congestion increases. The worsening of SCOOT from a slightly better low-congestion performance in no-event conditions is somewhat sharper than that of the baseline system. Conversely, the worsening of the

SCOOT system from a slightly worse low-congestion performance is somewhat less sharp than that by the baseline system. These conclusions should be understood in the context of

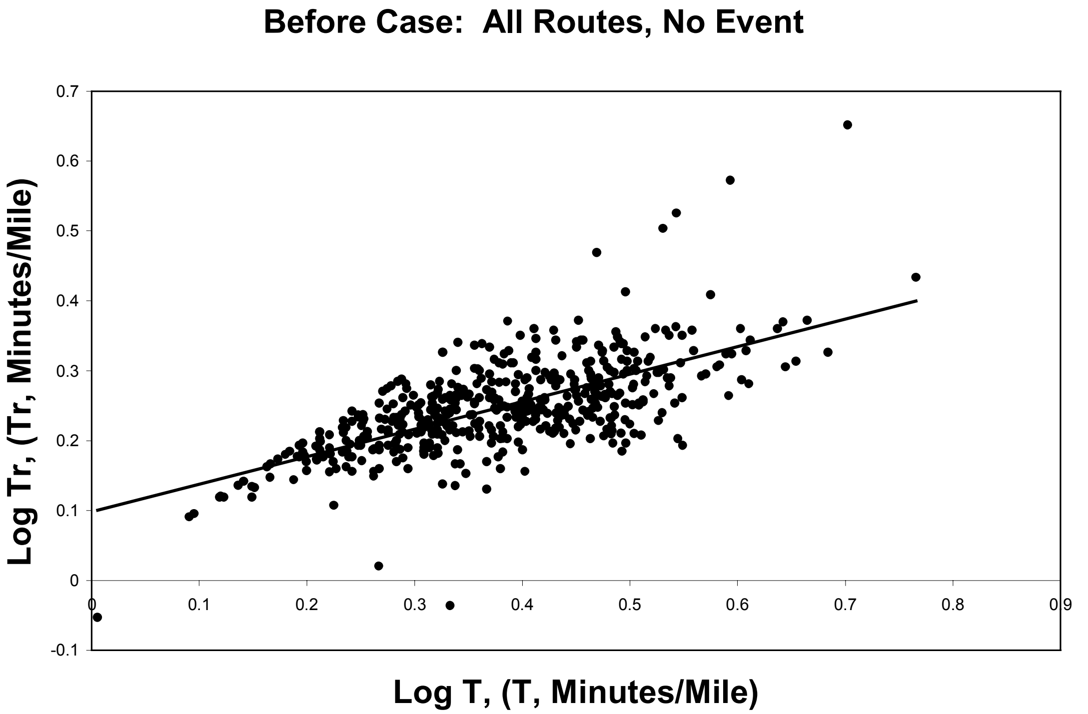


Figure 65: Log-Regression Scatter Plot for the Two-Fluid model (Before Case, All routes, No Event).

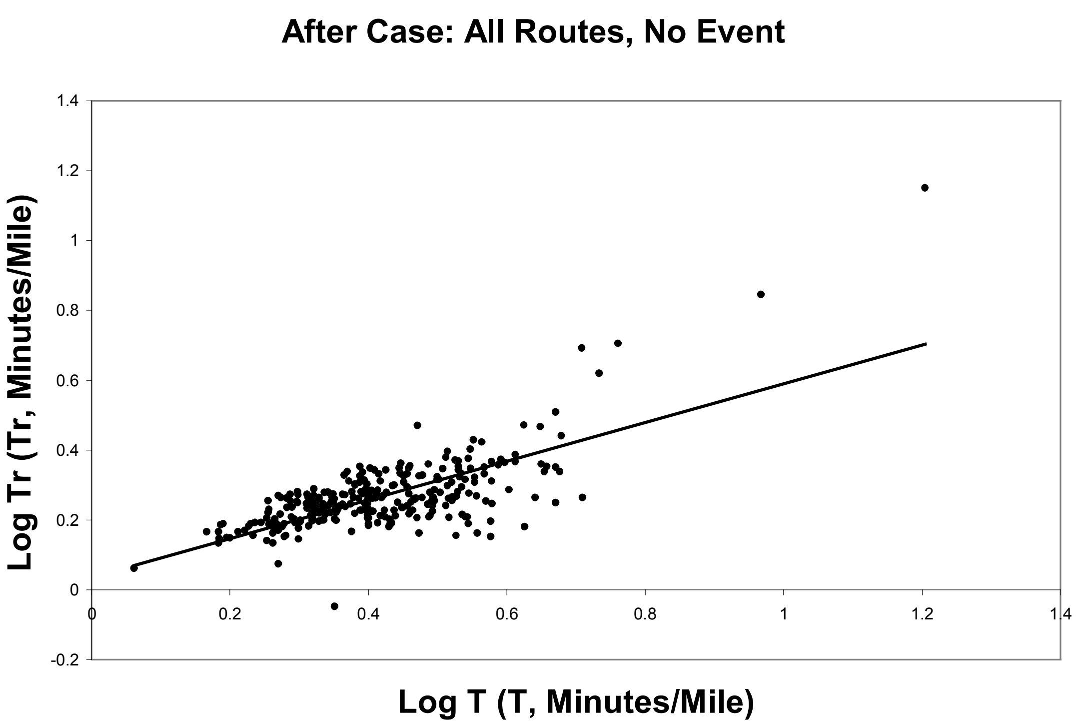


Figure 66: Log-Regression Scatter Plot for the Two-Fluid Model (After Case, All Routes, No Events).

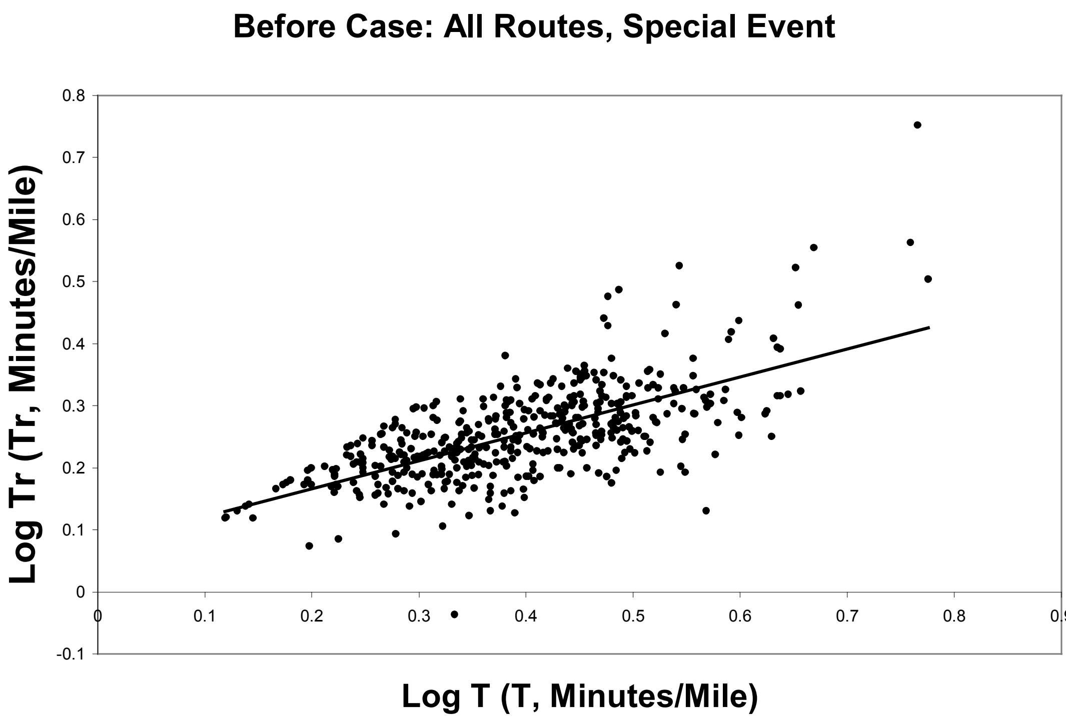


Figure 67: Log-Regression Scatter Plot for the Two-Fluid Model (Before Case, All Routes, Special Events).

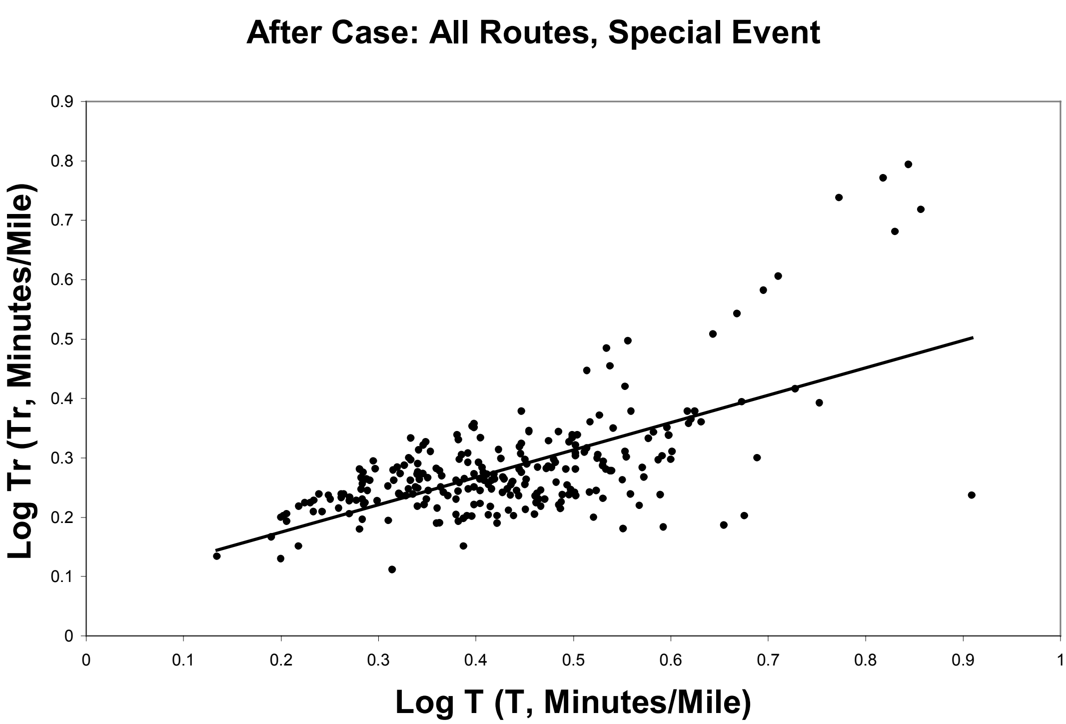


Figure 68: Log-Regression Scatter Plot for the Two-Fluid model (After Case, All Routes, Special Events).

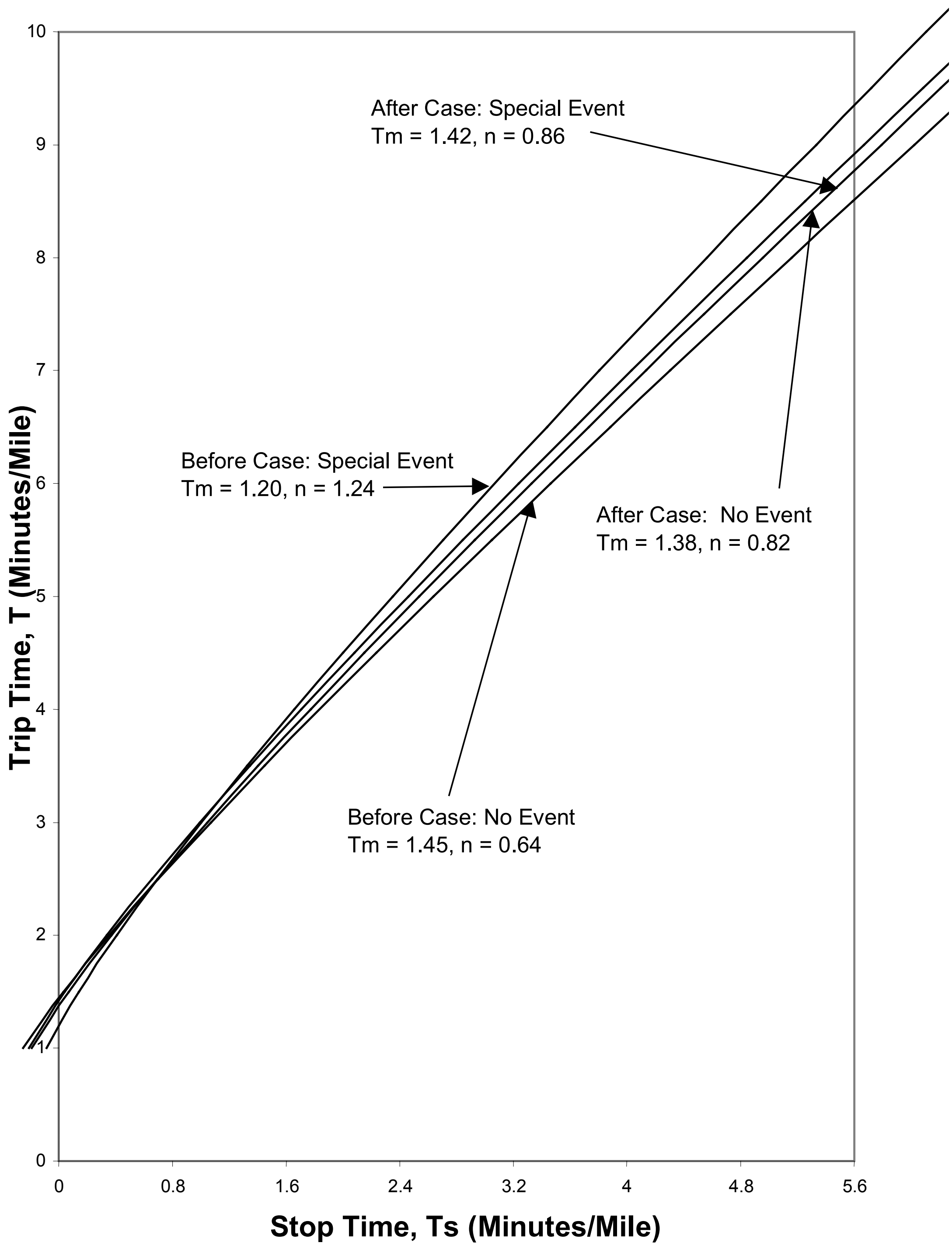


Figure 69: Final Regression Curve Comparison Between Different Two-Fluid Model Cases: Trip Time vs. Stop Time for the Anaheim FOT Network.

both systems showing rather close performance anyway, however. The observation from intersection delay studies and summary floating car results discussed earlier that SCOOT still performed better under no event cases seems to be borne out by these results too.

2.6 Some Final Comments About Traffic Performance Under SCOOT

SCOOT amply demonstrated that it can operate in a network with non-ideal detectorization and communication, and control traffic in a manner that does not cause substantial or otherwise unacceptable increases in intersection delays and route travel times. In the case of two intersections near the special event location, the SCOOT delays were substantially lower than under the baseline system during the sudden traffic egress periods. This points to SCOOT's ability to make adaptive adjustments. The Anaheim deployment did not, however, show the kind of benefits shown by more standard implementations of SCOOT around the world. This is expected, given the combination of anticipated and unanticipated conditions associated with the field operational test, and given that the Anaheim performance comparisons were made against a baseline system that is considered nearly state-of-the-art in US practice.

A proper comparison with an ideally detectorized SCOOT network in Anaheim would have proved very useful, but SCOOT is already accepted as a traffic control system with proven benefits demonstrated at other installations. Consequently, an ideal installation was not attempted in this FOT, though the installation was not intended to be quite as non-ideal as it ultimately proved to be. In addition to the constraints associated with use of mid-block loop detectors, SCOOT's capabilities were not fully reflected in the Anaheim installation due to

1) accumulated communications faults leading to unexpected isolation of signals from SCOOT control,

2) scheduled but unannounced termination of SCOOT control,

3) and the minimal time spent in fine-tuning the SCOOT system parameters.

The absence of fine-tuning was driven by the project deadlines, and by the City of Anaheim TMC staff not being fully trained to make these adjustments before the field study was conducted. This is unfortunate, because fine tuning is important. When the SCOOT system was installed in the City of Leicester, the initial global controls were so poorly configured for Leicester that in most areas, traffic moved less efficiently under SCOOT (Gillam and Withill, 1990). Training was needed to enable the Leicester users to understand and customize SCOOT default settings. The system installed in Leicester was a pre 2.3 version, and many of the default parameters have since been improved, so the Anaheim and Leicester results are only loosely comparable. Further, the Siemens reports its Windows interface on a newly coded C language platform has eradicated many of SCOOT's earlier problems.

Delays remained acceptable under SCOOT and no serious traffic problems arose. This indicates SCOOT is a system worth pursuing in Anaheim and other US cities, though the unanticipated conditions of the test make it impossible to address the key question of whether SCOOT should be implemented with existing mid-block detectors. Foregoing SCOOT's standard upstream detector installation provides some savings, but how these compare to the potential long term disadvantage of operating a sub-optimal SCOOT system remains unclear. Further studies on SCOOT implementation in a more elaborate network with less peaking and fewer special event characteristics than Anaheim may prove beneficial.

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APPENDIX: Sample of Data Downloaded From SCOOT

```
     EXTRACT n20111a  PRO /DW:FR  /TS:7  /TE:11
/O:EXTRACT.OUT  /D:FLOW

     Fr 19-Sep-1997  12:24:23

             Satart  End      Flow Flow Flow Flow Flow
     Site    Day  Time Time    Mean Stdev   Max  Min  Count
             hh:mm hh:mm  veh/h   veh/h   veh/h   veh/h
     -------------------------------------------------------
            n20111a  lpu factor   17.0  lpu/veh  (default)
     n20111a MO 07:00   07:15      83 4  97 75 30
     n20111a MO 07:15   07:30      117  7  143   105  30
     n20111a MO 07:30   07:45      139  4  141   127  31
     n20111a MO 07:45   08:00      186  9  196   146  30
     n20111a MO 08:00   08:15      221  6  227   202  28
     n20111a MO 08:15   08:30      206  23 325   228  27
     n20111a MO 08:30   08:45      407  36 421   352  27
     n20111a MO 08:45   09:00      312  10 313   321  26
     n20111a MO 09:00   09:15      292  11 328   308  27
     n20111a MO 09:15   09:30      276  8  279   283  28
     n20111a MO 09:30   09:45      281  11 300   246  27
     n20111a MO 09:45   10:00      336  21 355   275  29
     n20111a MO 10:00   10:15      296  24 324   276  30
     n20111a MO 10:15   10:30      372  32 319   259  30
     n20111a MO 10:30   10:45      361  25 404   254  29
     n20111a MO 10:45   11:00      371  23 398   206  27
```