

ANAHEIM ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST: TECHNICAL EVALUATION OF SCOOT

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This paper provides a technical evaluation of the traffic control element of the Anaheim Advanced Traffic Control System Field Operations Test (FOT), sponsored by the US Department of Transportation. The primary objective for this FOT was the evaluation of adaptive traffic signal control technologies, including the Split Cycle and Offset Optimization Technique (SCOOT) for intersection signal control. The SCOOT evaluation was defined relative to existing, first generation Urban Traffic Control System (UTCS)-based control using standard US field detectorization. This US geometry is not the detector configuration normally used with SCOOT.

SCOOT was implemented with some degree of success, though technical problems limited SCOOT performance. Anaheim's existing communication and controller systems contributed major deployment limitations since they were less adequate than anticipated. SCOOT remains in use in selected areas, with plans for system expansion.

Keywords: Urban transportation, Traffic management, Intelligent transportation systems, Traffic control devices, Computer aided operations, Field tests, Evaluation. Other Keywords: SCOOT, ATMS

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1. INTRODUCTION

An evaluation of the systems deployed in the City of Anaheim for the federally-sponsored *Anaheim Advanced Traffic Control System Field Operations Test* (FOT) was conducted by California Partnership for Advanced Transit and Highway (PATH) researchers from fall 1994 through spring 1998. The FOT involved an integrated Advanced Transportation Management System (ATMS) that extends the capabilities of Anaheim's existing arterial traffic management systems. The FOT was conducted by a consortium consisting of the California Department of Transportation (Caltrans), the City of Anaheim (lead), and Odetics, Inc., a private sector provider of advanced technology systems. 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 [1].

1.1. Context of the FOT

The City of Anaheim has a population of 300,000 and 150,000 jobs within a land area of nearly fifty square miles. Anaheim Convention Center, Disneyland, Arrowhead Pond of Anaheim, Edison International Field of Anaheim, and 15,000 hotel/motel rooms are all located within a three square mile area of the City. These event centers have a combined maximum attendance potential of 200,000 visitors, most of whom travel by car.

Delay at signalized intersections connected by short network links is a significant problem. Speeds and travel times are dominated by queue delay at intersections. Further, Anaheim's arterial street system is often impacted in unpredictable ways by ongoing construction at event centers.

The FOT project proposal anticipated that the use of SCOOT (Split Cycle Offset Optimization Technique) would increase the efficiency of urban traffic control operations by

allowing the control system to adapt to real-time traffic conditions. The overarching objectives of the strategies implemented in Anaheim are to decrease the total vehicle hours traveled for any constant number of vehicle miles traveled, and to achieve this in an institutionally acceptable and efficient manner. See McNally, et. al. [2] for a detailed evaluation of the FOT's institutional aspects.

1.2. SCOOT Overview

The core of the Anaheim Field Operation Test (FOT) traffic control element is the real time integration of the SCOOT 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.

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.

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 in Oxnard, CA shortly before the Field Operational Test [3].

Siemens Traffic Controls Ltd., the UK arm of Siemens' Worldwide Traffic Control Systems Group, installed SCOOT version 3.1 in the City of Anaheim. The City of Anaheim uses SCOOT on the portion of their network near Arrowhead Pond and Edison Field. A nearby portion of the Anaheim network served as a control area for the evaluation. Figure 1 displays the SCOOT test area. The experimental control portion of the network is the area North of the SCOOT region. The control area remained under Urban Traffic Control System (UTCS) first generation control throughout the evaluation.

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 on intersection approaches. This criterion is expressed in terms of a Performance Index (*PI*) that is used to compare alternative courses of action. The *PI* consists of a weighted sum of the delay and the number of stops at the intersections in the study area.

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

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 ,

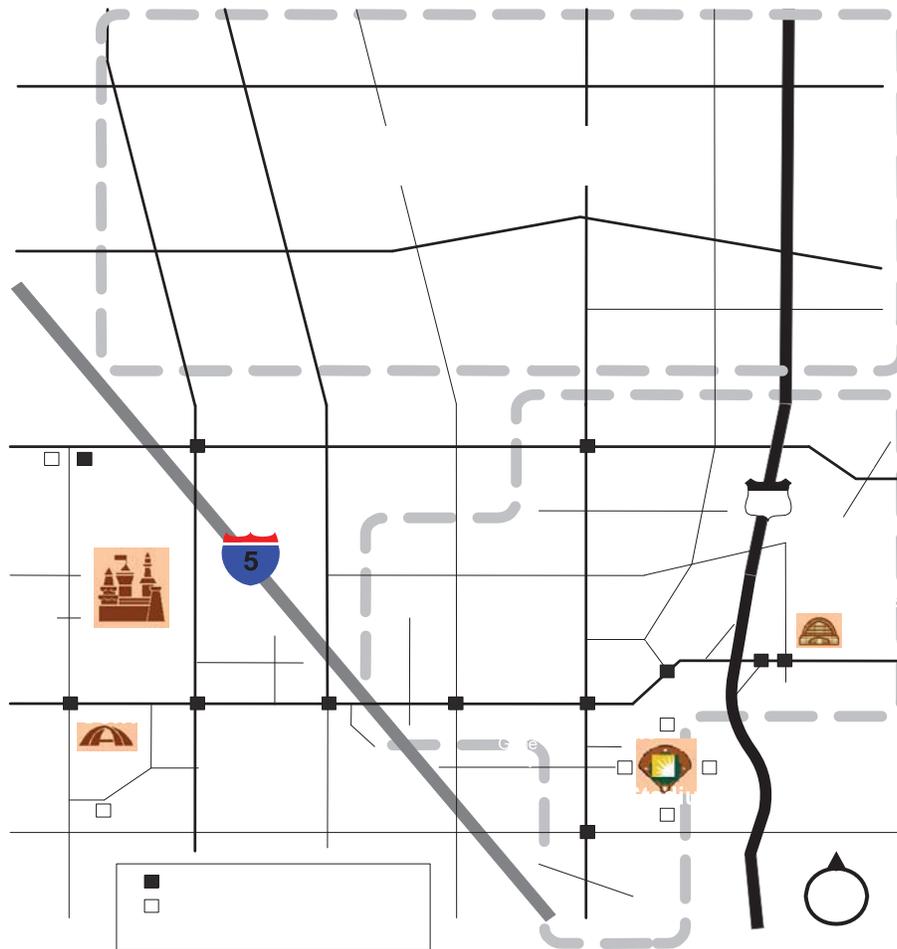


FIGURE 1 Map of the Anaheim Field Operational Test and evaluation control areas.

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. SCOOT also allows users to specify performance objectives such as journey time improvement, and reductions in delay and stops.

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

the locations of induction loop detectors embedded in the pavement of intersection approaches, signal phase order, and a variety of other parameters to simulate traffic conditions in the form of Cyclic Flow Profiles (CFP). Collectively, these data are used to predict the flows, lengths of traffic queues, delays, and stops on each link downstream from detectors.

SCOOT requires upstream detectors, typically placed just downstream of the preceding intersection. In addition, the system may require additional detectors when there is a high flow source or sink in a mid-block position. These upstream detectors give advance information about approaching vehicle platoons. Vehicles recorded at the upstream detector progress along the link according to a cruise time modified to account for 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. Detected platoons are dispersed using Robertson's [4] platoon dispersion algorithm to provide approximate flow rates at the downstream stop line.

The detector data stored in the SCOOT computer reveal the variation in demand during each cycle. SCOOT's Split, Cycle and Offset Optimizers (locally) optimize signal timing by searching for improvements in terms of the CFP across each subarea. The split optimizer operates intersection by intersection. The offset optimizer operates on upstream and downstream intersection clusters, evaluating the advisability of altering the cycle offset at each 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 subareas, usually consisting of three to four intersections, by plus or minus four seconds. SCOOT typically makes

about 10,000 decisions per hour for every 100 intersections in the system. All decisions are made by the central computer [5].

2. SCOOT EVALUATION

The technical objective of evaluating network performance is to identify constraints on implementation, and to quantify improvements to the maximum extent possible. Changes in network performance resulting from the implementation of SCOOT were measured in terms of surveillance information provided by the system, and from more limited field observations such as floating car studies and intersection delay studies. This assesses the changes in queue delays and travel times during normal and special event traffic conditions. Table I lists the objectives of the SCOOT technical evaluation and the data sources used to address each.

The benefits derived from traditional SCOOT detectorization schemes are documented and accepted, but SCOOT's effectiveness with Anaheim's existing or similar US detector

TABLE I SCOOT technical evaluation data collection requirements

Technical evaluation objective (1)	Data source (2)
Assess the changes in queue and travel times during normal conditions	Floating-car Study Intersection Delay Study
Assess the changes in queue and travel times during special event conditions	Floating-car Study Intersection Delay Study
Assess the quality of SCOOT's internal representation of traffic conditions	SCOOT Message Data, and Video
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

configurations was unknown prior to the FOT. Anaheim's existing system detectors are located approximately mid-block, about 250 ft. upstream of the intersection being controlled. However, SCOOT usually relies on detectors that are located at the upstream end of the link. See Figure 2. This field operational test integrated SCOOT into the existing Anaheim infrastructure to determine its effectiveness with nonstandard detector locations and to evaluate its transferability to other existing systems. There was no certainty that the existing infrastructure would provide optimal (or even acceptable) results, though Siemens personnel calibrating the Anaheim SCOOT installation reported that SCOOT's global control settings were adjusted to account for the nonstandard location of loop detectors. Unfortunately, Siemens could make no details available for the evaluation.

A complete technical evaluation of the constraints associated with using mid-block or other nonstandard detector information to supply SCOOT with information about upstream

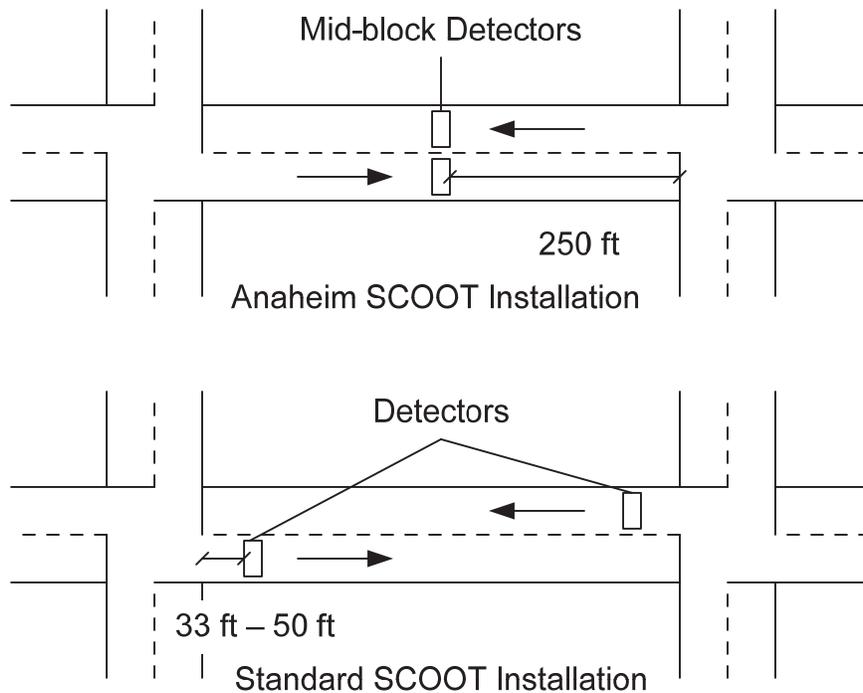


FIGURE 2 Anaheim and standard SCOOT loop detector locations.

demand would require that some test intersections be subject to redundant loop installations. This would require installing upstream loops at some intersections in a standard SCOOT configuration in addition to existing mid-block detectors, and then examining SCOOT's performance against both detector configurations. This would permit the impact of nonstandard detectorization to be separated from the improvements provided by SCOOT control. Unfortunately, resource constraints precluded 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.

The quality of SCOOT's internal representation of real traffic conditions on intersection approaches is fundamentally important to SCOOT's ability to optimize signal timings. The quality of SCOOT's performance is necessarily constrained by the system's ability to represent traffic conditions at intersections. If SCOOT is able to model traffic conditions accurately, then it may also be able to improve these conditions.

It is impossible for SCOOT to meet sufficient conditions for improvements unless these necessary conditions have been met. However, necessary conditions might be met even if sufficient conditions are not. Under such circumstances, SCOOT does not provide traffic improvements, but has the potential to do so if aspects of the SCOOT installation are changed. However, if necessary conditions are not met, SCOOT cannot provide traffic improvements. See Table II.

TABLE II Technical evaluation outcomes in terms of necessary and sufficient conditions for SCOOT improvements in traffic flows

	Necessary Conditions Unmet (1)	Necessary Conditions Met (2)
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	Any apparent improvements in traffic conditions are spurious, and cannot be attributed to SCOOT	SCOOT did provide improvements in traffic conditions.

2.1. Necessary Conditions: SCOOT's Internal Representation of Traffic Flow

2.1.1. Data Requirements

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

- = one from the SCOOT model, provided by downloading message reports from the SCOOT system regarding how SCOOT assesses the real traffic conditions of the road network [6, p. 115-120], and
- = another consisting of empirical field observations, provided by post-processing video tapes of conditions on approaches to intersections subject to SCOOT control.

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. 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 [6,§ 4.6.6]. Message M11 gives the time required to discharge the M10 queue in seconds by approach. This is reported as the time when the last queued vehicle crosses the stop line.

SCOOT estimates of stops, delays, and flows can be compared with values drawn from an intersection delay study. SCOOT estimates of queue length and queue clearance time can be compared with conditions recorded on videotape. Videotapes of traffic flows provide more detailed information about traffic conditions, queue length, and queue delay at a given intersection than either floating cars studies or real time intersection delay studies.

2.1.2. Data Collection Sequence

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. 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. Fourteen closed-circuit television (CCTV) 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. The evaluation team used the Anaheim TMC cameras to collect ten hours of videotape records of traffic conditions on intersection approaches while simultaneously downloading corresponding SCOOT model messages. The data describing traffic conditions had to be obtained by post-processing the videotapes manually. A summary of this synchronized data collection scheme appears in Figure 3.

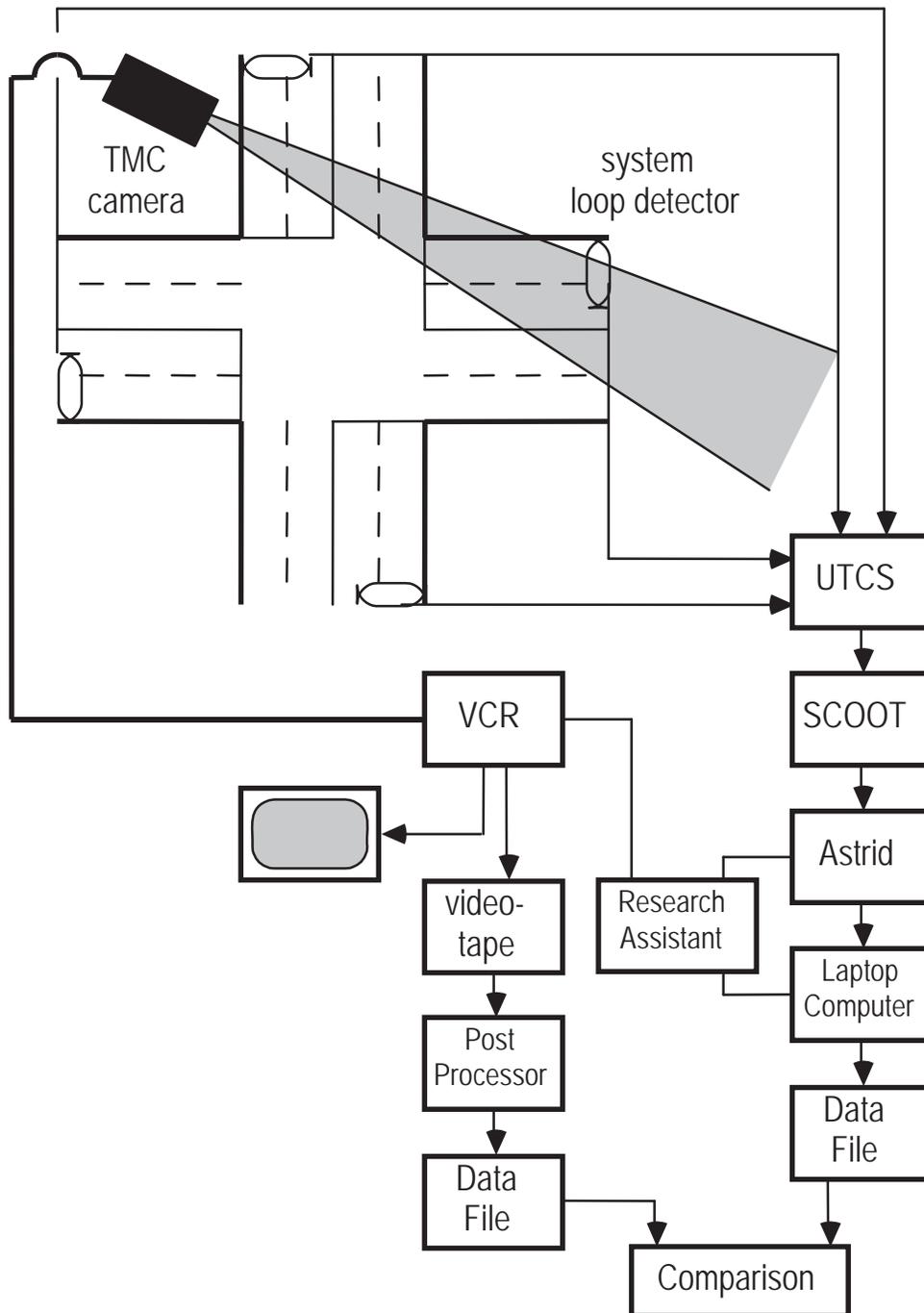


FIGURE 3 Data collection scheme for assessing SCOOT's representation of traffic conditions [7].

2.1.3. Summary of Model Quality Results

Seven of the ten hours of SCOOT model message data collected could not be used because cumulative SCOOT system errors or communications faults were unexpectedly isolating some intersections from SCOOT control. In most cases, cumulative communication and other system faults can be cleared via active intervention on the part of the TMC operator. If faults are cleared manually rather than being permitted to accumulate, the signals involved remain under SCOOT control.

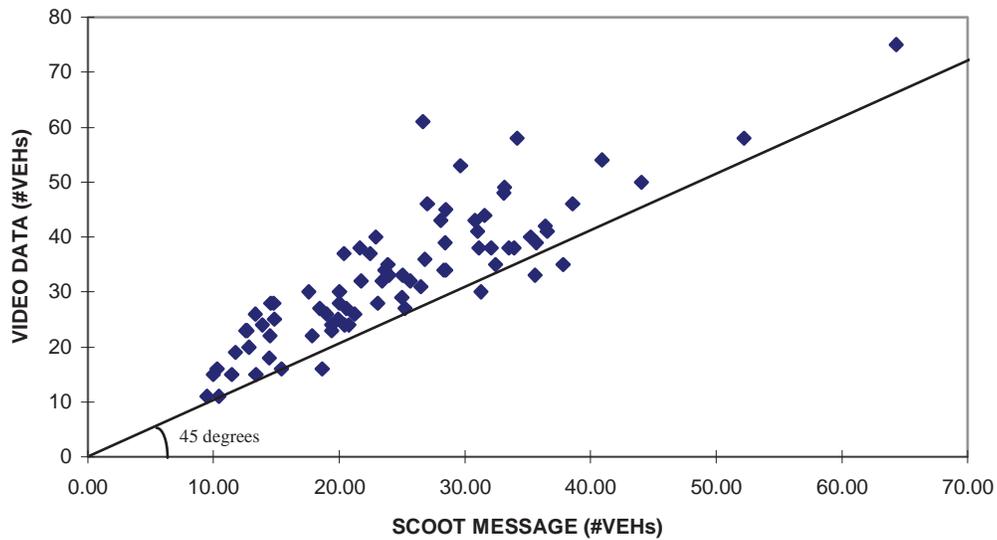
The remaining three hours of data provide sufficient observations from which to draw statistically significant conclusions about the quality of SCOOT's internal representation of traffic. These three hours of data describe conditions at the approaches to three intersections on November 18, 1997. Table III compares the three sets of videotape data and their associated SCOOT data to control for differences across intersections. Data for all three intersections are also pooled to form an aggregate estimate. Estimated coefficients of determination r^2 between the SCOOT message data and the videotape data are reported for stops, delays, flows, queue length, and queue clearance times. If the SCOOT system is representing traffic conditions on approaches in a very accurate way, then the estimated coefficient of determination r^2 between the SCOOT message data and the video data will tend toward unity.

In the aggregate, observed flows and flows reported in SCOOT system messages return an estimated coefficient of determination (r^2) of 0.740. See Figure 4. Coefficients for other traffic indicators are lower. This is expected, because these other measures are derived from flow measures, and these additional modeling steps needed to derive these other measures are

TABLE III Summary results for Cases 1 through 3, and aggregated

		Case 1: Ball West- bound at State College and Ball (1)	Case 2: State College Southbound at State College and Ball (2)	Case 3: Katella East- bound at State College and Katella (3)	Cases 1, 2 and 3 Pooled (4)
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 by SCOOT Model Mes- sage Type	M02 ¹	30, 3 of which are excluded due to com- munication faults	29	23	82, 3 of which are excluded due to com- munication faults
	M10 ² and M11 ³	32, 6 of which are excluded due to com- munications faults	29	24, 5 of which are excluded due to com- munication faults	85, 11 of which are excluded due to com- munication faults
Estimated Coefficients of Determin- ation r^2	Stops	0.518	0.593	0.372	0.608
	Delay	0.689	0.212	0.348	0.423
	Flow	0.504	0.624	0.624	0.740
	Queue Length	0.490	0.270	0.462	0.578
	Queue Clearance Time	0.689	0.212	0.360	0.449
Estimated Regression Coefficient	LPU ⁴ per Vehicle	15.3	22.52	14.66	15.6

- Note:
1. Message M02 provides approach information on stops, delays, and flows.
 2. Message M10 reports queue lengths by approach at the start of the green phase.
 3. Message M11 gives the time required to discharge the M10 queue in seconds by approach.
 4. Link Profile Units are a proprietary measure of demand internal to the SCOOT system.
 5. All estimates r^2 are strongly statistically significant.



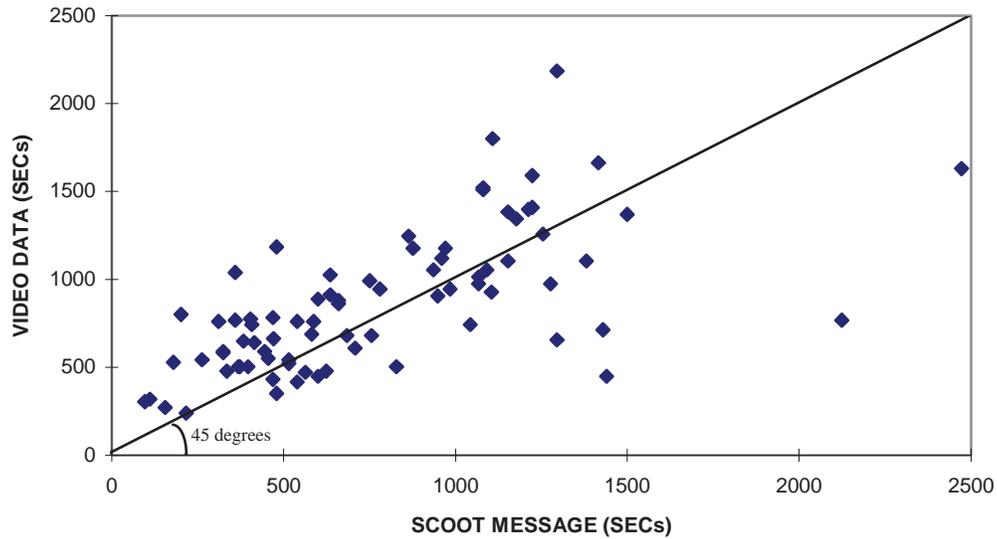
Coefficient of Determination $r^2 = 0.740$

FIGURE 4 Flow Volumes on Approach per SCOOT Interval, All Data (Nov. 18, 1997).

likely to introduce additional error into the values appearing in SCOOT messages. In the aggregate, the estimated coefficient of determination between observed and SCOOT measures of intersection delay was 0.423. See Figure 5. This was the lowest pooled estimate obtained. Approach delay is more difficult to compute from video observations than the other quantities. The estimated coefficients of determination for observed stops, queue length, and queue clearance times fall between these bounds. Estimates for individual intersections are based on smaller samples, and have more variance than these aggregate values, producing some estimates above and below the aggregate interval.

The quality of the observed fit between the video and modeled flows, stops, delays is, at minimum, a function of

- = the quality of the SCOOT validation process executed when the system was installed,



Coefficient of Determination $r^2 = 0.423$

FIGURE 5 Total vehicle delays on approach per SCOOT interval, all data (Nov. 18, 1997).

- = the quality of additional fine tuning done following installation,
- = the location of the detectors,
- = the noise inherent in the detectors, and
- = 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 videotapes. In all cases, the null hypothesis of no relationship is strongly rejected. SCOOT is successfully returning estimates that have substantial information content, but the flow coefficients of determination estimated here are lower than those compiled by Martin [8] for the Leicester SCOOT system. SCOOT was installed in the medium sized English City of Leicester in 1989 [9]. 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 an estimated correlation r of almost .94 ($r^2 = .884$). He developed an SCOOT LPU calibration process that improved this value of r to .96 ($r^2 = .922$).

The Anaheim coefficients of determination, while considerably lower than those obtained by Martin, remain encouraging given the Anaheim installation's mid block detector locations and the very substantial effort invested in fine-tuning of the Leicester system. Much less effort was invested in the Anaheim installation. The lower coefficients observed in Anaheim are most likely a result of nonstandard detector locations. Improvements could be generated either by changing the locations of detectors, or by further adjusting SCOOT's global control settings to try and better compensate for the effect of nonstandard detector locations.

2.2. Sufficient Conditions: Traffic Performance Under SCOOT

Traffic performance evaluation under SCOOT focuses on delays at SCOOT intersections, as well as running times, stop times, and total times on selected floating car routes in the SCOOT network. The evaluation team adopted a standard before-and-after evaluation format. Measurements were taken of traffic conditions in the PM-peak and evening off-peak during special events and during non-event traffic conditions with without SCOOT and with SCOOT.

2.2.1. Field Observations

Delay measurement teams were posted at intersections and travel time measurement teams drove floating cars across five routes. Ten observation periods in mid October, 1997 were selected for the before study of existing Urban Traffic Control System (UTCS) control, and ten subsequent

observation periods in mid November, 1997 were selected for the after study under SCOOT operation.

Unfortunately, resource limitations prevented round-the-clock measurements at all intersections. Intersection delays were calculated by counting the stopped cars during short sampling intervals, accumulating totals, and multiplying by the duration of the sampling interval. The delays were not disaggregated for each turning movement. Instead, 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. Observed times were aggregated and averaged for each route for each observation day.

2.2.2. Field Data Collection Problems and Constraints

The evaluation team encountered several problems during the after SCOOT study. On November 12, a special event day, an accident occurred on Interstate 5, which caused the entire network to become saturated with diverted traffic throughout the peak period. In addition, several small accidents occurred at several other locations in the network during this time period as a result of the abnormal congestion. 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. Fortunately, rain only affected data collection efforts during a single off-peak special event period, and posed no other problems during the other nine data collection days.

Overall, problems reduced the available intersection data by about fifty percent, and completely eliminated some intersections from the non-event portion of the investigation. Further, for the first three days of data collection for SCOOT operations, SCOOT control

inexplicably terminated at 7:30 PM. Since this was unexpected, 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” 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 an unannounced system setting defined as part of Siemens' SCOOT configuration. The accumulation of communication faults was a result of problems with the Anaheim infrastructure, and was unanticipated by all both the project team and the evaluation team. Once this problem was discovered, 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 the six affected intersections collected prior to attempts to clear accumulated communication faults.

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

2.2.3. Summary of Traffic Performance Results

Results provided by the intersection delay analysis are mixed, and include the following sometimes contradictory results.

- The SCOOT system generally performed better under off-peak conditions than under peak conditions.
- The relative performance of SCOOT in comparison to the baseline system improves under special-event conditions compared to nonevent conditions for low volume intersections, although the reverse occurred for some high volume intersections.
- SCOOT performed very well at two intersections subject to heavy egress traffic from the special event locations, pointing to SCOOT's capacity to make adaptive adjustments.
- The SCOOT system produced lower intersection delays than the baseline system in some cases, and higher delays in others. SCOOT increased delays more frequently than it decreased delays, but there is insufficient evidence to show that this SCOOT installation performs significantly worse or better than the baseline system during peak-periods.
- In cases where SCOOT performed worse than the baseline system with respect to intersection delays, the increase in delay was rarely more than ten percent. In cases where SCOOT performed better, improvements were normally less than five percent.
- SCOOT and baseline system delays are comparable in most cases. In the cases where SCOOT performed worst, special circumstances associated with the project contributed to this result. These circumstances include non-ideal parameter settings, and the inclusion of low volume intersections that probably should not have been subject to SCOOT control. Forcing a common signal cycle length that is not appropriate for the intersection can cause excessive delays.

- = The SCOOT system, despite the substandard implementation and ongoing communication faults, did not produce any instances of unacceptably higher intersection delays, and did not cause any major problems in the system.

Results derived from the travel time analysis include the following.

- = Travel times on selected routes showed the effect of directional settings in the baseline system and SCOOT. The back and forth directional routes, which had different travel times under the baseline system, showed similar travel times under SCOOT in one case, and the reverse in another case.
- = Route travel times under SCOOT showed reductions of less than 10 percent in some cases, and increases of less than 15 percent in others. On the more circuitous, longer routes covering more of the network, SCOOT showed travel time reductions of as much as 2 percent, and increases of as much as 6 percent. SCOOT's performance relative to the baseline system was better under event conditions than under nonevent conditions.

3. CONCLUSIONS

3.1. SCOOT Deployment and Performance

SCOOT can operate in a network with nonstandard detectorization, and control traffic without causing substantial increases in intersection delays and route travel times. SCOOT was implemented in Anaheim with some degree of success, but SCOOT did not show the level of benefits demonstrated by standard implementations elsewhere. This is understandable, considering that the SCOOT performance comparisons were made against a baseline system that is considered state-of-the-art in US practice. In addition, technical and institutional problems limited SCOOT's

expected performance. Siemens and the City of Anaheim spent minimal time fine-tuning the SCOOT parameters. Training for City TMC staff was incomplete. Communication and controller systems, while sufficient to support UTCS control, were still of lower quality than anticipated or needed. Further, the City completed no acceptance test prior to evaluation of the system. Many of these outcomes were driven by responses to project deadlines. Problems were exacerbated by staff changes affecting project management, and by delays due to contractual disputes.

In summary, SCOOT's ability to at least partially model traffic conditions based on nonstandard detector locations, the fact that traffic conditions remained acceptable under SCOOT, and that no serious traffic problems arose, all suggest that SCOOT is a system worth pursuing in Anaheim and other US cities.

3.2. Institutional Assessment and Lessons Learned

The evaluation plan for this FOT was consistent with Federal guidelines for the FOT program [10], but proved to be of limited use. McNally, *et al.* [2, 10] provide a detailed institutional assessment of the Anaheim FOT that identifies critical institutional problems expected to inhibit the implementation of advanced transportation management strategies. These problems also constrained the evaluation team and the scope of the technical evaluation. The firms and agencies involved in the FOT cooperated with the evaluation team to the extent that project resources permitted, but the project budgets included no provisions for extensive collaboration with the evaluation team. Consequently, the project partners viewed the evaluation as a separate activity that was subject to an increasingly large set of constraints as partners made project and technology choices during the course of the FOT.

The Anaheim FOT included many such adjustments. The firms and agencies involved failed to anticipate many implementation costs, and participant costs continued to climb as the project experienced delays. Continuity in the project management position might have prevented the unanticipated delay costs. Participants recognized that the City must change its existing maintenance policies to operate the new control system properly. However, the City staff believed that the project failed to adequately plan for the operations, maintenance, and training needs of the new system. A breakdown in project management that occurred between the SCOOT contract award and contract signing nearly proved to be fatal stumbling block.

Anaheim committed to SCOOT well in advance of applying to the FOT program for funding. Despite the assumption of responsibilities by other staff and partners, a decided lack of City experience and authority existed during SCOOT implementation. Siemens dismissed the significance of implementing SCOOT without detectors in standard SCOOT locations, but only because SCOOT's inability to control the offsets except with the sync phase and unreliable field data communications represented larger areas of concern. A draft operating policy, which included full SCOOT use except during special events, was implemented only at the end of the evaluation period, thus, no evaluation of operations under that policy was possible.

As in many ITS projects, this FOT project required a champion to rise to challenge and save the project from the extended delays that afflicted it. The replacement project manager from the City met this need with a highly proactive strategy. When the project concluded, many technical concerns with SCOOT persisted, including operator acceptance, training, and SCOOT operational problems. Improved and increased training seemed to be the best strategy for alleviating these concerns.

3.3 Current Status of SCOOT in the City of Anaheim

The City continues to use SCOOT at times, but they still have not committed to its use full-time. However, they continue to expand the system when possible by installing new SCOOT detectors. Siemens returned to Anaheim following the PATH evaluation to address problems identified during the course of the evaluation. The City subsequently improved the SCOOT system by installing a Digital Equipment Corporation (DEC, now Hewlett-Packard) Alpha workstation as an upgrade to the original 1997 technology. The City remains committed to improving its traffic signal control system, and reports that SCOOT will continue to play a role in these improvements.

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LIST OF FIGURES

FIGURE 1 Map of the Anaheim Field Operational Test and evaluation control areas.

FIGURE 2 Anaheim and conventional SCOOT loop detector locations.

FIGURE 3 Data collection scheme for assessing SCOOT's representation of traffic conditions [7].

FIGURE 4 Flow Volumes on Approach per SCOOT Interval, All Data (Nov. 18, 1997).

FIGURE 5 Total vehicle delays on approach per SCOOT interval, all data (Nov. 18, 1997).

LIST OF TABLES

TABLE I SCOOT technical evaluation data collection requirements

TABLE II Technical evaluation outcomes in terms of necessary and sufficient conditions for
SCOOT improvements in traffic flows

TABLE III Summary results for Cases 1 through 3, and aggregated

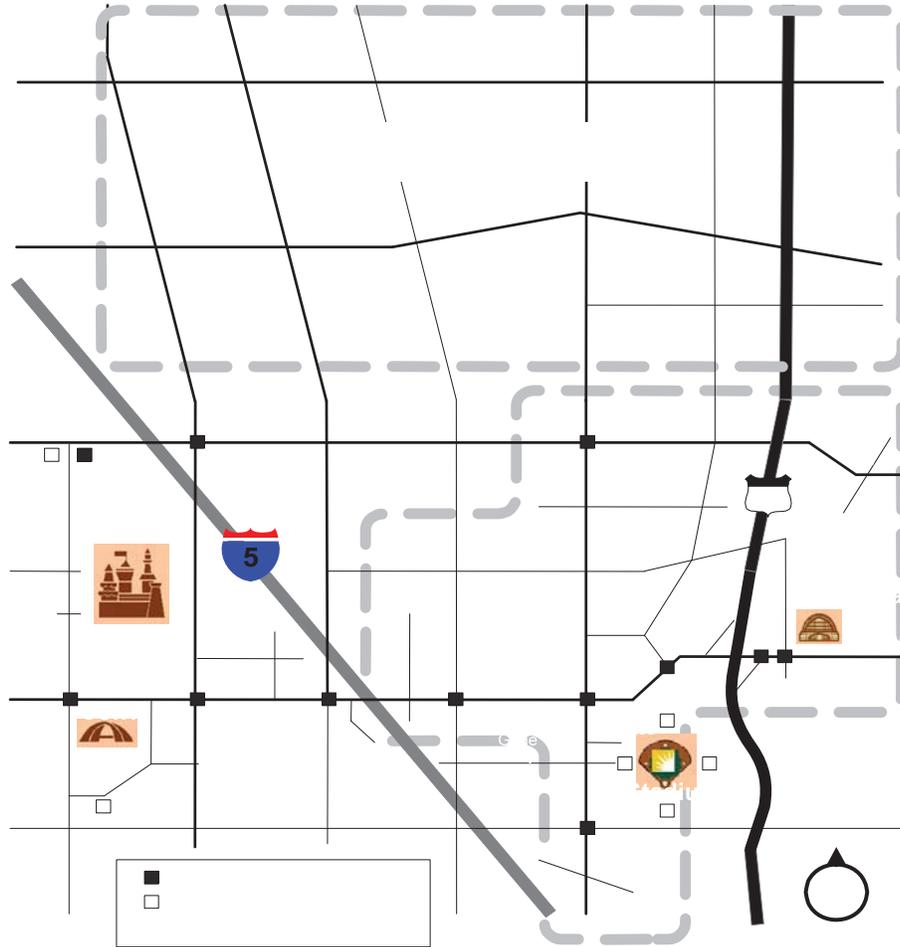


FIGURE 1 Map of the Anaheim Field Operational Test and evaluation control areas.

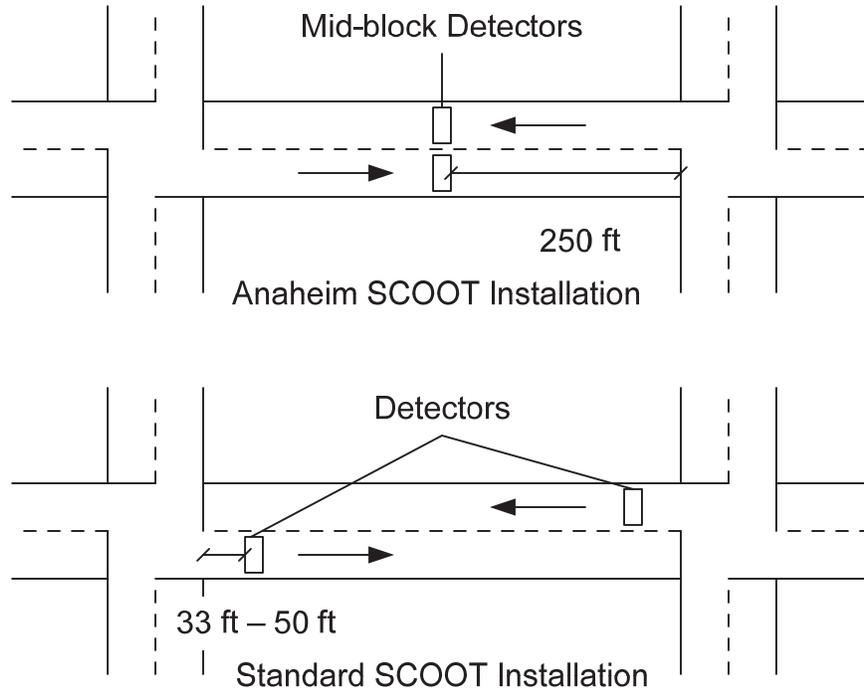


FIGURE 2 Anaheim and standard SCOOT loop detector locations.

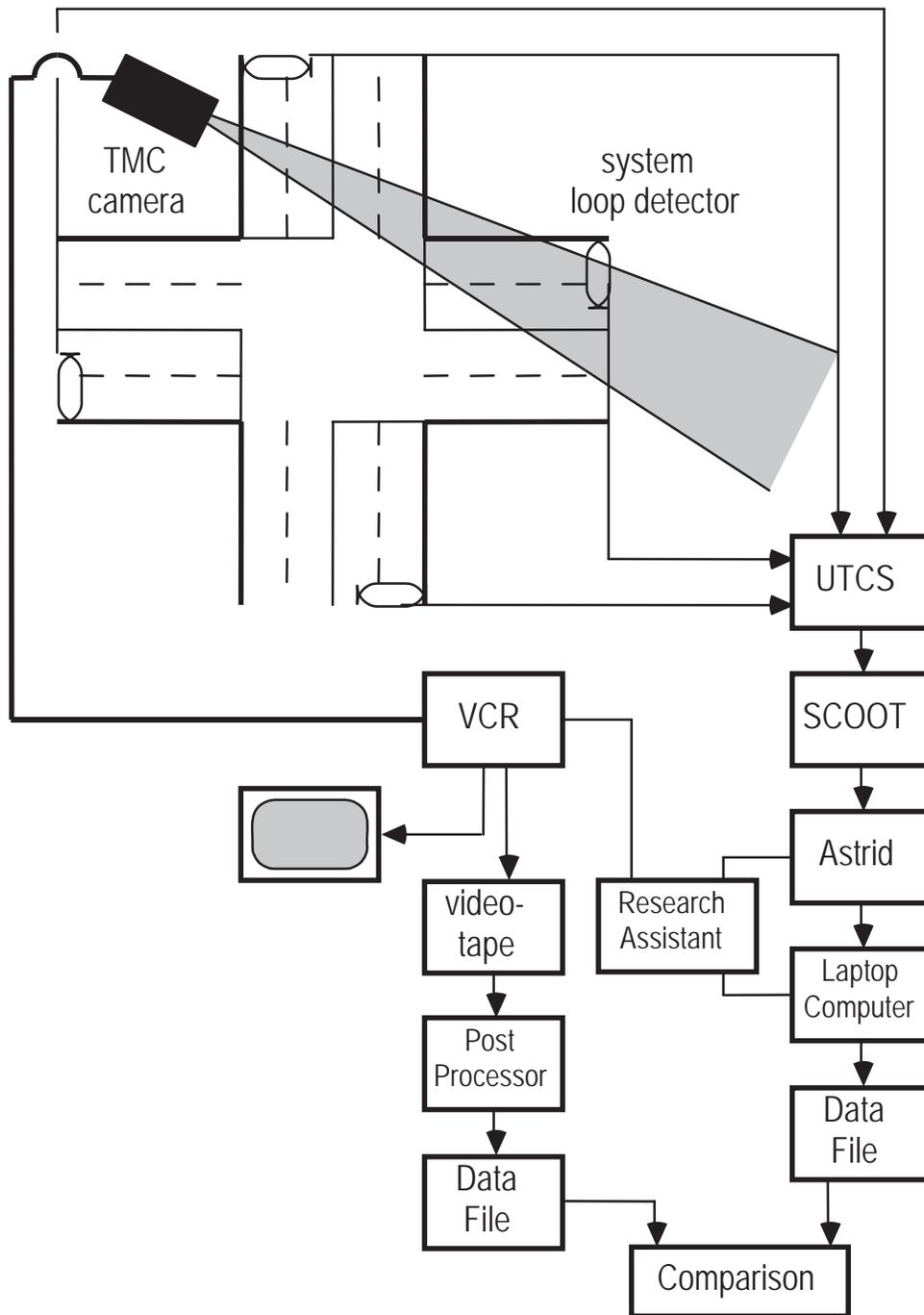
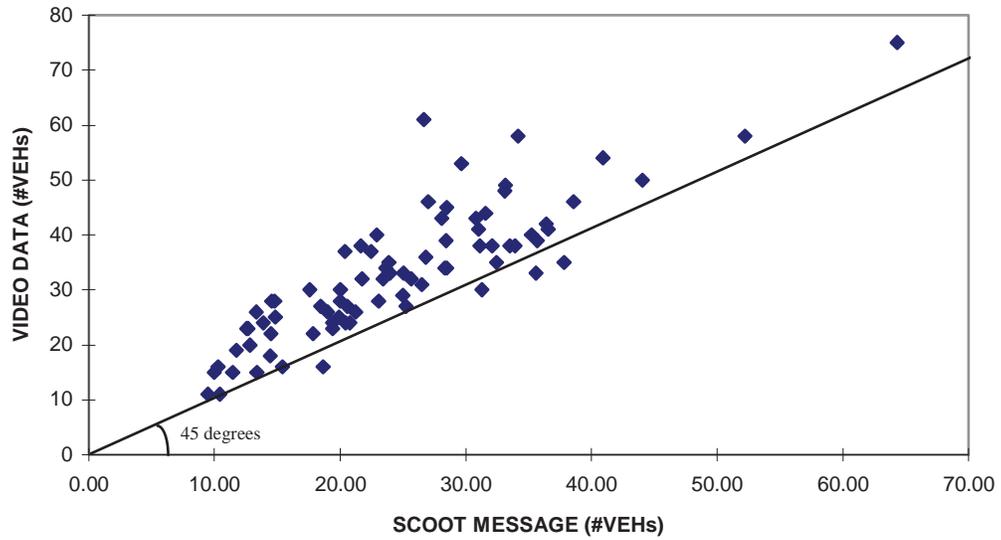
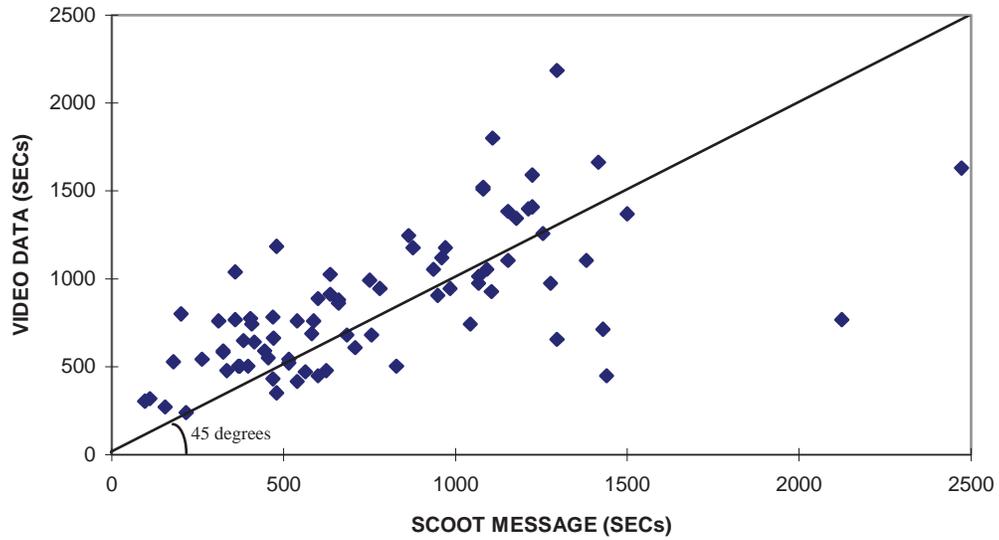


FIGURE 3 Data collection scheme for assessing SCOOT's representation of traffic conditions[7].



Coefficient of Determination $r^2 = 0.740$

FIGURE 4 Flow Volumes on Approach per SCOOT Interval, All Data (Nov. 18, 1997).



Coefficient of Determination $r^2 = 0.423$

FIGURE 5. Total vehicle delays on approach per SCOOT interval, all data (Nov. 18, 1997).

TABLE I SCOOT technical evaluation data collection requirements

Technical evaluation objective (1)	Data source (2)
Assess the changes in queue and travel times during normal conditions	Floating-car Study Intersection Delay Study
Assess the changes in queue and travel times during special event conditions	Floating-car Study Intersection Delay Study
Assess the quality of SCOOT’s internal representation of traffic conditions	SCOOT Message Data, and Video
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

TABLE II Technical evaluation outcomes in terms of necessary and sufficient conditions for SCOOT improvements in traffic flows

	Necessary Conditions Unmet (1)	Necessary Conditions Met (2)
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.

TABLE III Summary results for Cases 1 through 3, and aggregated

		Case 1: Ball West- bound at State College and Ball (1)	Case 2: State College Southbound at State College and Ball (2)	Case 3: Katella East- bound at State College and Katella (3)	Cases 1, 2 and 3 Pooled (4)
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 by SCOOT Model Mes- sage Type	M02 ¹	30, 3 of which are excluded due to com- munication faults	29	23	82, 3 of which are excluded due to com- munication faults
	M10 ² and M11 ³	32, 6 of which are excluded due to com- munications faults	29	24, 5 of which are excluded due to com- munication faults	85, 11 of which are excluded due to com- munication faults
Estimated Coefficients of Determin- ation r^2	Stops	0.518	0.593	0.372	0.608
	Delay	0.689	0.212	0.348	0.423
	Flow	0.504	0.624	0.624	0.740
	Queue Length	0.490	0.270	0.462	0.578
	Queue Clearance Time	0.689	0.212	0.360	0.449
Estimated Regression Coefficient	LPU ⁴ per Vehicle	15.3	22.52	14.66	15.6

- Note:
1. Message M02 provides approach information on stops, delays, and flows.
 2. Message M10 reports queue lengths by approach at the start of the green phase.
 3. Message M11 gives the time required to discharge the M10 queue in seconds by approach.
 4. Link Profile Units are a proprietary measure of demand internal to the SCOOT system.