Title

Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test: Final Report Task B; Assessment of Institutional Issues

Authors

McNally, M.G.
Moore, James E., II
MacCarley, C. Arthur
et al.

Publication Date

1999-07-01

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

Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test: Final Report Task B; Assessment of Institutional Issues

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

California PATH Research Report
UCB-ITS-PRR-99-27

This work was performed as part of the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration.

Report for RTA 65V313 Task Order 4

July 1999

ISSN 1055-1425

EVALUATION OF THE ANAHEIM ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST

FINAL REPORT

Task B: Assessment of Institutional Issues

University Evaluators

M.G. McNally
University of California, Irvine

James E. Moore, II
University of Southern California

C.Arthur MacCarley
California Polytechnic State University, San Luis Obispo

R.Jayakrishnan
University of California, Irvine

Research Assistants

Steve Mattingly and James Roldan
University of California, Irvine

Hsi-Hwa Hu and Seongkil Cho
University of Southern California

July 1999

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EVALUATION OF THE ANAHEIM ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST

Task B: Assessment of Institutional Issues

ACKNOWLEDGEMENTS

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 B report, Evaluation of Institutional Issues, are Michael G. McNally and Stephen P. Mattingly; significant contributions, however, were made my all members of the Evaluation Team. The primary authors of the Task A report, Evaluation of SCOOT Performance, were James E. Moore, II and R. Jayakrishnan. 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, in particular, 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 or Caltrans.

EVALUATION OF THE ANAHEIM ADVANCED TRAFFIC CONTROL SYSTEM FIELD OPERATIONAL TEST

Task B: Assessment of Institutional Issues

ABSTRACT

This report provides an overview of the technical and institutional issues associated with the evaluation of the federally-sponsored *Anaheim Advanced Traffic Control System Field Operations 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 which limited SCOOT performance included less than anticipated quality of existing communication and controller systems; 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 Task B of the three part evaluation project. Separate reports summarize Task A and C, performance evaluations of the advanced traffic control technologies and the advanced Video Traffic Detection Systems, respectively.

Key Words: FOT, adaptive control, institutional issues, VTDS

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 as part of the Intelligent Vehicle Highway System Field Operational Test Program. The FOT involves an integrated Advanced Transportation Management System 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 mid-block 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, a video traffic detection system (VTDS), was planned as a low cost alternative to existing VTDS technology. It's performance would be measured by it's capability to replace inductance loop detectors currently utilized.

Project evaluation comprised three tasks: (A) performance assessment of the traffic control technologies, (B) assessment of institutional issues, and (C) evaluation of the VTDS. Only Task B is summarized herein; see the separate task reports and the consolidated Executive Summary documents for further information.

Evaluation Task B: **Assessment of Institutional Issues**

Lead Evaluator: MG McNally, University of California, Irvine

Context

This evaluation project is of particular interest not only for its potential to assess the effectiveness of applications of advanced traffic control technologies but also to assess the relative role of institutional issues. Such issues may be categorized in at least two related ways: by the nature of the issue (such as project administration) and by stage in project deployment (baseline, implementation, operations, maintenance, and transferability). A comprehensive assessment of these five major stages of the operational test was approached via two primary evaluation techniques: a systematic "fly-on-the-wall" review of the FOT in terms of institutional catalysts and constraints, and a series of comprehensive interviews of all key project participants. The question of interest was through what structure and methods the technologies in question can be applied so that their effectiveness is neither reduced nor confounded by institutional limitations relative to the programming, implementation, and operations of such technologies.

The institutional evaluation proceeded in parallel with the technical evaluation, however, the former was process-centered versus the effectiveness orientation of the technical evaluation. The five evaluation stages and the associated evaluation goals (which incorporated twenty specific objectives) were:

1. Establish Baseline Institutional Status
2. Assess Institutional Issues in System Implementation
3. Assess Institutional Issues in System Operations
4. Assess Project Transferability
5. Assess Project Maintainability

Field Observation

Data required for the evaluation of institutional issues are substantively qualitative, and as such, may often be somewhat subjective. To minimize bias in the interpretation of the data, data was gathered from alternative sources to see if some consensus, if not still subjective conclusions, could be drawn. The first source of data came via direct observation of project participants, primarily at formal project meetings but also informally over the duration of the project. Formal meetings were documented in meeting minutes which were independently recorded and shared by the Project Manager and by members of the evaluation team. There was a substantial amount of other documentation, associated with both the FOT (proposals, technical memoranda, hardware and software documentation, etc.) and with prior related work in the City. All key project participants were interviewed to gain their opinions on the progress of the FOT and on the relative role of various institutional issues. The interviews were structured around a series of questions addressing anticipated institutional issues. Separate formats were utilized depending on the level of involvement of the interview subject.

Institutional Evaluation Results

The administration of this project proved to be much more time consuming than anticipated, despite fairly extensive prior City experience with complex, multi-agency projects. This was due in part to a lack of precedence in developing legal agreements, and the necessary review and approval delays of city attorneys and councils. Initially scheduled to be completed within 12 months, it was not possible to commence the technical field study until almost 36 months after the evaluation contract was approved.

1. Baseline Findings

   Anaheim had committed to both SCOOT and 1.5GC well in advance of applying for the FOT program. The FOT project represented an opportunity for the City to obtain federal funds in support of their traffic control system. The 1.5GC system may have been included in the FOT to provide additional funds to resolve its operational status. VTDS was brought into the project, in part, as an example of a public-private partnership, rather than as a necessary part of the package. Despite Anaheim's experience in deploying advanced traffic technologies, their baseline timing plans were somewhat dated as were their field controllers and the associated communication systems.

2. System Implementation

   SCOOT: Project delays, attributed to contractual matters and project management issues, began when a SCOOT contractor (Siemens) was selected. There were institutional ramifications of incorporating a new technology into an existing control system, although most of these issues were technically-based. Coordination between the City and Siemens was significantly impacted by the vacancy in the Principal Traffic Engineer position. Despite assumption of responsibilities by other partners, there was a decided lack of City experience and authority during the SCOOT implementation. A Siemens representative dismissed the significance of implementing SCOOT without detectors in standard locations but only because other factors represented a greater concern. SCOOT's inability to fully control offsets and field data communications which were less reliable than anticipated and limited the resultant field performance.

1.5GC: Despite having an earlier version of 1.5GC in house, the FOT Partners were unable to develop and implement a version of 1.5GC that met the functional requirements originally proposed. Technical problems prevented true "man-in-the-loop" implementation and the system was not used to update baseline parameters.

VTDS: There were no institutional problems associated with the VTDS implementation. The proposed functionality was reduced to presence detection only during the project.

3. System Operations
A draft operating policy, which included full SCOOT usage except during special events, was implemented only at the end of the evaluation period, thus, no evaluation of operations under that policy was possible. Development of this policy was late due to delays in SCOOT implementation, limited operator training, and very limited operational experience prior to the evaluation period. Having SCOOT implemented in parallel to the existing UTCS-system may have further delayed SCOOT training and operations by impeding operator learning and acceptance.

4. Project Transferability
It is difficult to establish to what degree advanced technologies which are not primarily off-the-shelf products can be transferred to other locations. This project, however, suggests that, in the case of systems such as the Odetic's VTDS and 1.5GC, products that are not widely deployed are essentially still in the research and development process and can encounter significant delays, cost overruns, changes in product specifications, and unsuccessful implementation. Final deployment is dependent on partner commitment (a modified VTDS was eventually deployed in the City). The institutional lessons learned are themselves transferable. Institutional issues were considered to be critical project limitations, more so than technical limitations per se (lack of knowledge of technical limitations appears more critical than the limitations themselves).

5. Project Maintainability
Potentially significant costs may compromise project maintainability, costs including TMC and field hardware and software maintenance. The City will have to devote more time to training to continue to operate SCOOT effectively. In the months following the evaluation phase, SCOOT was being utilized to a limited extent within the project area. A modified version of the VTDS was deployed in the construction area neighboring the new Disney theme park. No additional technical evaluations have been completed.

Evaluation Conclusions Relative to Institutional Issues

Two broad conclusions can be drawn. First, the technologies implemented enjoyed some limited success. Second, given these results, institutional and technical factors were identified which were critical in defining this performance. In this sense, the project was successful, although without more extensive observations under normal operating conditions, it would be premature to advise extended implementation in the City or elsewhere. Therefore, no recommendation can be made at this time relative to potential success in transferring the technologies. It is also difficult to fully assess system maintainability issues, due to the field test orientation of the project and the limited observation of system operations. It is estimated, however, that fairly significant increases in traffic management costs would be realized if SCOOT operations were to be expanded. Technical problems were judged as somewhat expected for a project of this scale. Institutional issues associated with project management and contractual matters were judged as unexpected and critical influences on the project. While they were ultimately resolved, their presence nearly terminated the project prior to final implementation.

Evaluation of the Anaheim
Advanced Traffic Control System Field Operational Test

Task B: INSTITUTIONAL ISSUES

Principal Authors:
M.G.McNally and S.P.Mattingly

1. INTRODUCTION

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 evaluation is consistent with provisions of IVHS FOT program, and the Intermodal Surface Transportation Efficiency Act of 1991, which requires that all Field Operational Test include an independent evaluation component.

1.1 Independent Evaluation

The subject 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 planned implementation area comprises major employment and residential concentrations and includes such major event locations as *Disneyland*, *the Anaheim Convention Center*, *Edison International Field of Anaheim*, and *the Arrowhead Pond of Anaheim* (note that the study area was significantly reduced in scale prior to implementation and evaluation). The subject FOT is distinguished by two key technical features: arterial traffic control supervised by SCOOT (Split Cycle and Offset Optimization Technique) and by a 1.5GC (Generation Control) system, and a VTDS (Video Traffic Detection System) developed by Odetics for automated detection of metrics required for optimal traffic management on arterials. The evaluation entailed both a technical performance assessment and a comprehensive institutional analysis.

1.2 Institutional Perspective

To achieve the FOT objective of adaptive arterial traffic control necessitates the identification, evaluation, and resolution of a wide variety of institutional barriers to successful project completion. While both federal and state policy are firmly supportive of the rapid deployment of new technologies in Advanced Transportation Management Systems, the actual implementation involves the integration of diverse technologies from a variety of competing vendors in local environments with little if any experience with such technologies. This suggests that a variety of learning curves must be traced, as the players deal with the technical issues, and necessarily, the institutional issues, of implementation. The focus of the assessment is to identify under what structure ATMS strategies can be deployed so that their effectiveness is neither reduced nor confounded by limitations posed by institutional issues. The scope of potential institutional issues is necessarily quite wide.

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 involves 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).

1.3 Report Organization

This evaluation report summarizes the institutional evaluation (Task B) of the three part evaluation effort. Separate reports present the technical evaluations of the advanced traffic control technologies (Task A) and the advanced Video Traffic Detection Systems (Task C), respectively.

To properly position the assessment and interpretation of institutional issues associated with the Anaheim Field Operational Test (Anaheim FOT), the evaluation approach is necessarily quite broad, incorporating elements of the technical evaluation (including a summary of the technologies deployed as well as those existent in Anaheim prior to the FOT) with a broad assessment of institutional issues in technology deployment. Section 2 presents a rather extensive background of the FOT project, which presents the evolution of the project from prior work establishing the Anaheim Traffic Management Center as one of the first TMCs in the country. The institutional structure for the Anaheim TMC and that of the FOT project are presented. An overview of the federal FOT program is also presented as are brief summaries of other contemporaneous FOTs in California.

Section 3 presents an overview of Anaheim's integrated traffic control system and descriptions of the technologies planned for implementation. It also describes the initial and final study areas. This section is intended to provide a context for the institutional assessment; technical details and technical evaluation results for the control systems and for VTDS are presented in the Task B and Task C final reports, respectively.

Sections 4 and 5 present the institutional evaluation. The general approach and an overview of prospective institutional issues open section 4, followed by an historical summary of events defining the progress of the FOT, including a comprehensive event time line. The first of two primary evaluation approaches is then presented, involving a systematic "fly-on-the-wall" review of the FOT in terms of institutional catalysts and constraints. This review is organized in five stages depicting the development of the operational test: baseline system, implementation, operations, maintainability, and transferability. Each sections considers objectives associated with each stage, including objectives which were defined both *a priori* and *a posteriori*. Section 4 concludes with an insider's summary and interpretation of TMC operations by a student member of the evaluation team who worked in the Anaheim TMC during the last half of the evaluation period. Section 5 summarizes the second primary evaluation approach involving comprehensive interviews of all key project participants. Section 6 concludes this report and presents key findings of this evaluation.

2. PROJECT BACKGROUND

The City of Anaheim has achieved an impressive track record in the application of advanced technologies to address their pressing transportation problems. Over the past decade, the City has planned and actively pursued participation and funding from county, state, and federal agencies to leverage local funds for the installation of increasing sophisticated elements of an comprehensive traffic management system. The fact that the technologies associated with the Anaheim FOT project were identified years before the FOT program began exemplifies the pro-active perspective that characterizes the City. There are many institutional factors which have contributed and continue to contribute to this perspective. JHK and Associates (1992) identified the following issues as critical to successful project implementation while establishing the TMC:

(a) incremental implementation allowing confidence and experience to grow with the system
(b) direct agency participation with commitment of sufficient and enthusiastic staff
(c) planning flexibility, given overall direction, to adjust to changing funding sources, evolving plans of other agencies, and new technologies, providing new opportunities
(d) interagency cooperation as a positive approach to problem prevention and solving
(e) risk taking to move forward by accepting some risk to gain opportunities
(f) leveraging local funding with active pursuit by lead agency

2.1 Development of the Anaheim Traffic Management System

Over the last four decades, the City of Anaheim (and the rest of Orange County) has experienced tremendous growth, far exceeding the City's initial expectations (for details, see JHK, 1992). Since the opening of Disneyland in 1955, the impact of special activity generators began to dominate traffic planning in the City. Together with *Anaheim Stadium* (now *Edison International Field of Anaheim*), the *Anaheim Convention Center*, and *the Arrowhead Pond of Anaheim*, the City has a core of four major special generators at the heart of a dense employment/residential area in the midst of heavily utilized regional freeway corridors. In 1986, a strategic planning process "identified transportation management solutions for the reduction of traffic congestion throughout the area as the top priority" (JHK, 1992). The City adopted an underlying philosophy of applying advanced but proven techniques of surveillance, control, and integrated response to address local, event-based, and regional traffic demands in the City.

The City recognized that the state-of-the-art was evolving rapidly and that external funding was necessary to leverage local dollars, thus, an incremental overall approach was taken. An initial focus on an advanced signal control system and changeable message signs gradually evolved into the Anaheim Traffic Management System (TMS) comprising a state-of-the-art traffic management center (TMC), a UTCS Enhanced central control system, changeable message signs (CMS), highway advisory radio (HAR), closed circuit television (CCTV) surveillance, and other

ATMS options. The system developed in an explicitly multi-jurisdictional fashion, being closely coordinated with other City agencies, including the Anaheim Police Department, with Caltrans and local municipalities, with county, state, and federal agencies, and with the University of California, Irvine for research and evaluation purposes. The City was named an FHWA demonstration site for advanced integrated traffic management systems and the TMC became operational in November 1988.

2.2 FETSIM and the Katella Avenue Study

The 1992 implementation report (JHK, 1992) indicated that the City had already identified a role for advanced detection and control technologies and, if fact, was already planning the integration of video imaging processing techniques for arterial detection, advanced traffic control (via 1.5GC), and SCOOT. The implementation of 1.5GC was identified as underway, apparently adapting similar software from the Los Angeles ATSAC system. Current signal timing plans were largely developed via participation in the State of California FETSIM (Fuel Efficient Traffic SIgnal Maintenance) program. Between 1986 and 1993, the City had five proposals funded to re-time a total of 249 intersections using TRANSYT-7F (Skabardonis, 1994). In 1991, as part of a study of inter-jurisdictional signal coordination (Recker *et al.*, 1992), traffic signals on Katella Avenue, including many of those in the FOT implementation area, were re-timed, also using TRANSYT-7F. Significant improvement was identified over the timing plans generated in the 1986 FETSIM project (the results of that study were similarly improved with respect to the timing plans in use prior to 1986). These results are consistent with analyses of numerous FETSIM studies state-wide which suggested that a general range of improvement in several measures of effectiveness was expected; this suggests that timing plans stray from the optimal over time. No formal study of timing plans has occurred in the study area since 1991, although City engineers observed traffic performance at most study intersections and made manual adjustments in the field. To what degree the baseline timing plans can be considered near-optimal is unknown. This, of course, would in large measure define potential improvement with either 1.5GC or SCOOT.

2.3 Evolution of the Anaheim FOT Proposal

The federal *IVHS Field Operational Test Program*, a component of the 1991 ISTEA legislation, was formally announced in May 1992 (Federal Register, 1992a), with the call for participation following in July 1992 (Federal Register, 1992b). With Anaheim's continuing interest in advanced transportation technologies and Caltrans state-wide policy placing the state in the forefront of Intelligent Transportation Systems (ITS, then IVHS) deployment, the development of the proposal for the Anaheim FOT proceeded rapidly. Most partners and technologies had already been identified in the on-going development of Anaheim's integrated transportation management system. The initial FOT proposal (Caltrans *et al.*, 1992) was submitted to the Federal Highway Administration (FHWA) in October 1992; it was selected for funding in the FOT program for fiscal year 1993.

Two additional documents were reviewed. In May of 1993, a Memorandum of Understanding for county-wide deployment was signed, with Anaheim as a signatory. And in June 1993, a final FOT proposal was completed with a comprehensive listing of work tasks, deliverables, preliminary budgets, and responsible parties identified by work tasks. These documents are reviewed in the next three sections.

2.3.1 Initial Proposal (October 1992)

The initial proposal in October 1992 built upon the backbone provided by the existing Anaheim Traffic Management System (TMS). The FOT involves three separate technical elements. A 1.5 Generation Control (1.5GC) System was planned as the first element. The second element focused on the selection and implementation of an adaptive, second generation control system, SCOOT. The final element involved the integration of a Video Traffic Detection System (VTDS). These elements were planned for implementation and testing in the Katella Avenue corridor near the City's major event generators.

The 1.5GC system would simplify the current process of collecting input data and producing time-of-day plans. Ultimately, the City plans to use 1.5GC as a management tool that measures the effectiveness of different control strategies. The SCOOT system would require greater effort to implement due to vendor selection and system design. The SCOOT System would also automate data collection and automatically optimize signal timing plans based on real-time conditions. The City of Anaheim planned to use 1.5GC to evaluate SCOOT results.

The VTDS would perform traffic counts at the stop bars of each intersection approach.

Currently, the City can not determine traffic turning movement counts automatically using presence-mode inductive-loop sensors; however, the VTDS was planned to supply this data. Since optimal detector sensor placement for SCOOT is unknown, the VTDS would allow for adjustable placement to improve SCOOT operations. The system should operate in various lighting conditions such as during bright daylight, night time, dawn, dusk, and lighting strikes, and should function in different weather conditions, including rain, fog, and high wind. Finally, the system should be able to handle the City's varied traffic conditions (congested, quiescent, and normal traffic, at intersections and on freeways).

The primary FOT objective was expressed as:

_ Evaluate the performance of SCOOT against fixed-time plans and 1.5GC methods in a controlled American urban environment. This includes: the resource demands in setting-up SCOOT, the modifications of the model to suit the local operating conditions, and transferability to other American cities.

Issues that this FOT hoped to address included:

_ The potential of advanced traffic signal control techniques to accommodate major traffic transients arising from freeway diversion and/or ATIS recommendations.

_ The integration of advanced signal control techniques with ATIS operations, both in terms of special event management information systems and the application of expert systems used to manage/operate the ATIS elements.

_ A general evaluation of the advanced control method under varying traffic conditions, particularly those arising in conjunction with ATIS recommendations.

_ A comparison of the methods against existing control techniques.

_ Documentation and standardization of the implementation to assist in transferability.

As an implementation site, the FOT partners initially selected the portion of Katella Avenue between West Street and Douglass Road for several reasons:

_ It is a major arterial representing a facility commonly found in the United States.

_ It is under the control of the Anaheim TMS. This UTCS-Enhanced system provides the necessary control system for the evaluation because the TMS can collect the required real-time traffic data and support other traffic control methodologies.

_ Katella Avenue experiences unpredictable and highly variable conditions due to the proximity of the Anaheim Stadium and Disneyland facilities. Events at these facilities will provide realistic scenarios for assessing SCOOT's adaptive capabilities.

_ The City of Anaheim has an experienced staff manning the Traffic Management Center (TMC) which houses the TMS. The staff applies special event management techniques in the area; therefore, they seem prepared to support the evaluation.

Anticipated results included:

_ 1.5GC will prove to be an effective management tool that can be used by other agencies to identify trends in traffic flow patterns and to adjust timing plans that minimize traffic delay. The partners expect 1.5GC to reduce delay time by ten percent.

_ The partners anticipate that this FOT will identify an effective procedure for implementing an adaptive signal control system into an existing signal control system through software integration.

_ The partners expect the VTDS to prove itself as a robust, accurate system for detection of vehicle presence and determining vehicle counts.

_ The UK Transport and Road Research Laboratory (TRRL) has evaluated SCOOT relative to fixed-time plan systems and found reductions in delay of up to 25 percent.

The partners expect these technologies to produce significant benefits if other agencies implement these technologies. Through the use of area-wide surveillance and detection, Anaheim plans to optimize its traffic control strategies from a system-wide perspective in real-time. If these technologies significantly reduce congestion as expected, travel times will decrease, roadway capacity will increase, air pollution will decrease, highway safety will improve and energy consumption will decrease. Anaheim hopes to use SCOOT during special event scenarios to improve traffic conditions and minimize operator intervention. The partners expect to determine the processes associated with installing, operating, and maintaining a

SCOOT system.

The following roles were defined for each participant. The City of Anaheim assumed overall responsibility for project management; JHK/Transcore, as the City's system manager, was charged with integration and deployment of the 1.5GC System; Odetics was charged with completing the VTDS operational test; Caltrans was identified as a member of the project management team (in addition to its role as a funding intermediary between FHWA and the City), and PATH (Partners for Advanced Transit and Highways at the University of California, Berkeley) assumed responsibility for administrating the evaluation tests. The SCOOT provider was to be selected via competitive bid.

2.3.2 Memorandum of Understanding (May 1993)

The Memorandum of Understanding (MOU) served the purpose of facilitating and supporting the development and implementation of an Intelligent Transportation System (ITS) Program in Orange County by coordinating the activities and efforts of Caltrans District 12, the California Highway Patrol (CHP), the Orange County Transportation Authority (OCTA), and the Cities of Irvine and Anaheim. The MOU stated that the signatory agencies intended to jointly develop an ITS program for Orange County, including participation in the ITS Corridors Program, the FOT Program, and the California Advanced Testbed Program. Additionally, they agreed to form a management board that would take responsibility for the joint and cooperative implementation of ITS efforts in the County. The Board was charged with the overall management of the effort and the implementation of public-private partnerships involving ITS projects. As part of the MOU, each agency accepted specific responsibilities in the successful development of an ITS program for Orange County; these included:

<u>Caltrans</u>

- Responsibility for the construction, maintenance, and operation of freeway projects throughout the State of California.
- Joint responsibility with the CHP to operate Caltrans' Orange County TMC.
- Providing project management of any ITS projects on freeways or state highways.
- Providing the focus for collection and dissemination of traffic condition information during operational testing phases.

<u>CHP</u>

_ Monitoring motorist activities on all highways, county roads, and select expressways in the Orange County area.
_ Joint responsibility with the Caltrans to operate the Orange County TMC where they provided staffing and access to roadway incident information through enforcement communication systems, such as radio communication with patrol vehicles, and information from the Emergency 911 and Motorist Call Box Systems.
_ Providing services that included roadway surveillance, general assistance to motorists, traffic enforcement, traffic accident investigation, and commercial vehicle safety inspection programs.
_ Providing expertise in incident reporting, communications, and roadway conditions assessment.

FHWA
_ Providing a national focus for the FOT Program and other federally assisted ITS projects.
_ Coordinating proposed activities with related activities across the nation.
_ Ensuring the independent evaluation of the FOT Program and other federally assisted ITS projects as part of the national ITS plan.
_ Providing the funding for the FOT Program and other federally assisted ITS projects through the execution of individual Cooperative Agreements with Caltrans.

FTA
_ Providing a national focus for public transportation related activities of the FOT Program and other federally assisted ITS projects.
_ Coordinating these projects with other related activities across the nation.
_ Possibly providing funding fot ITS projects.

Caltrans
Headquarters
_ Administrating and coordinating the ITS Corridors Program and its compatibility and potential for statewide deployment.
_ Providing the overall direction of statewide agenda involving advanced transportation management and information systems for research and development.

OCTA
_ Transportation planning, programming, and coordination in Orange County.
_ Serving as overall coordinator of ITS efforts within the County.
_ Ensuring that ITS projects remained consistent with the Orange County ITS Master Plan and the 2020 Transportation Vision.

_ Serving as the lead agency for transit related projects and other regional transportation projects that relate to ITS.
_ Coordinating ITS funding opportunities, and program funding for ITS related projects

Anaheim
_ The planning, construction, operation and maintenance of its streets.
_ Operation of the Anaheim TMC.
_ Providing project management for any ITS activities on its street network.

Irvine
_ Operation of the City of Irvine's ITRAC (Irvine Traffic Control Center).
_ Providing project management for any ITS activities on its street network.

PATH
_ The lead role in the evaluation of FOTs.

2.3.3 Final Proposal (June 1993)

The final proposal in June 1993 detailed the project work plan, identifying tasks and responsible parties as well as covering changes to the overall schedule and budget. The overall budget increased relative to the first proposal, with over thirty percent of the increase for the project management budget and another thirty percent into the evaluation effort (the later due in part from uncertainty associated with the execution of the evaluation effort). The three technical elements, 1.5GC, SCOOT, and VTDS, accounted for 10, 20, and 5 percent of the overall budget increase. The most relevant numbers are the final project expenditures, which totalled $1,360,491, with a federal contribution of $886,187, a state contribution of $444,885, and $29,419 of City funds.

The following summarizes project objectives, deliverables, preliminary budgets, and responsible parties by work tasks as identified in the final FOT proposal.

Task 0: Project Management
Objective: Maintaining project schedule and accounting
Deliverable: Monthly and quarterly reports
Budget: $84,719 ($0 of which is from matching sources)

Agency/firm: City of Anaheim

Task 1: 1.5GC Modifications
Budget: $52,576 ($20,000 of which is a local match)
Agency/firm: City of Anaheim via their system manger JHK/Transcore

Design
Objective: To determine what modifications need to be made to 1.5GC so that a comparison can be made with the signals under the SCOOT network
Deliverable: 1.5GC/SCOOT interface design document

1.5GC Modifications
Objective: Modify 1.5GC to operate concurrently as an analysis tool
Deliverable: 1.5GC software modifications and documentation

The FOT plans to compare SCOOT's on-line changes with timing derived using available tools in 1.5GC to assess the SCOOT plan using 1.5GC performance measurements.

Task 2: 1.5GC Calibration and Test
Objective: Develop a set of requirements to calibrate 1.5GC so that a comparison can be made with SCOOT and calibrate 1.5GC for the test network.
Deliverable: 1.5GC calibration report will define and document the calibrated data set
Budget: $13,528 ($0 of which is from matching sources)
Agency/firm: City of Anaheim via their system manger JHK/Transcore

Task 3: SCOOT System Manager Services
Budget: $145,716 ($0 of which is from matching sources)
Agency/firm: City of Anaheim via their system manager JHK/Transcore

Interfacing SCOOT with the existing traffic management system and 1.5GC
Objective: Determine the requirements to interface SCOOT to the Anaheim TMS
Deliverable: Technical memorandum detailing the necessary modifications for interfacing SCOOT with the existing TMS
Preparation and solicitation of proposals
Objective: Prepare and solicit proposals for SCOOT
Deliverable: Detailed RFP and vendor list

Selection of preferred vendor

Objective: To select the best vendor for this project
Deliverable: List of selection criteria and recommendation of preferred vendor

Modifications of the Anaheim Traffic Management System
Objective: To adapt the TMS to use SCOOT
Deliverable: Technical memorandum identifying the modifications to the existing TMS

Integration (Installation)
Objective: To install and integrate all necessary elements of this test project
Deliverable: Technical memorandum detailing the process of integration

Acceptance testing
Objective: To perform all necessary tests to confirm system performance
Deliverable: Completed acceptance test schedule

Task 4: SCOOT Vendor Services
Objective: To supply and install SCOOT version 2.4 capability on the Anaheim TMS
Deliverable: Functioning SCOOT system
Budget: $457,208 (all of which is from a Caltrans match)
Agency/firm: SCOOT provider (Siemens not specified in the proposal)

Task 5: SCOOT Calibration
Objective: Calibration of SCOOT to best operate the system
Deliverable: Technical memorandum detailing the calibration process
Budget: $12,792 (all of which is from a Caltrans match)
Agency/firm: SCOOT provider (Siemens not specified in the proposal)

Task 6: Develop VTDS Field Test Plan
Budget: $59,055 ($0 of which is from matching sources)

Perform Site Analysis of Anaheim Intersection
Objective: Site analysis of Anaheim intersection
Deliverable: Site analysis memorandum
Agency/firm: City of Anaheim, Odetics, JHK, and CSC

The proposal specified the Harbor & Katella intersection as the VTDS test site.

Develop Field Test Plan and Support Evaluation Test Plan
Objective: Develop field test plan and support development of the evaluation test plan for VTDS tests
Deliverable: Field test plan
Agency/firm: City of Anaheim and Odetics

Prepare Video Camera Subsystem Installation Plans
Objective: Prepare video camera subsystem installation plans
Deliverable: Video camera subsystem installation plan
Agency/firm: JHK (detailed design for all equipment, cable and conduit)

Prepare Communications System Installation Plans
Objective: Prepare communications system installation plans
Deliverable: Communications equipment installation plan
Agency/firm: JHK

Task 7: VTDS User Interface Development
Objective: Develop a user interface for the VTDS and produce an operations manual
Deliverable: User operations manual
Budget: $432,176 ($373,500 of which is from an Odetics match)
Agency/firm: Odetics

Task 8: Communications Equipment Procurement and Installation
Budget: $280,293 ($0 of which is from matching sources)

Prepare Equipment Specifications and Select Equipment
Objective: Prepare equipment specifications and select equipment
Deliverable: Equipment specifications and selection
Install and Integrate Video-camera Subsystem
Objective: Mount, install, and integrate the camera subsystems
Deliverable: Technical memorandum
Agency/firm: CSC

Install and Integrate Communications System

Objective: Integrate the communications system
Deliverable: Memorandum verifying inspection and integration of communications system
Agency/firm: JHK

Task 9: Mobile Lab Integration
Objective: Make any necessary modifications to the Odetics mobile lab to accommodate the remote tests in adverse weather conditions
Deliverable: Memorandum describing any modifications
Budget: $274,238 ($251,000 of which is from an Odetics match)
Agency/firm: Odetics

Task 10: VTDS Test
Objective: Perform operational tests of the VTDS
Deliverable: Test report
Budget: $188,386 ($0 of which is from matching sources)
Agency/firm: Odetics

Odetics tested the VTDS under various types of conditions. The video signals will be sent to the Anaheim TMC and to Odetics for processing

Task 11: Evaluation
Budget: $90,839 ($75,000 of which is from FHWA research funds)
Agency/firm: PATH

Design of Evaluation Methods and Criteria
Objective: To define evaluation methodologies
Deliverable: Technical memorandum detailing the evaluation aspects of the FOT

SCOOT Performance
Objective: To evaluate the performance of SCOOT
Deliverable: Technical memo detailing the evaluation of SCOOT performance

Assessment of SCOOT Calibration Techniques
Objective: To calibrate the SCOOT model
Deliverable: Technical memorandum documenting the calibration aspects of SCOOT implementation

Determine Modifications to the SCOOT Model
Objective: To modify the SCOOT model to represent U.S. traffic and driver behavior
Deliverable: Technical memorandum identifying such changes

Transferability of SCOOT during the Implementation Process
Objective: To document the transferability of SCOOT's implementation process
Deliverable: Technical memorandum addressing the transferability issues

The evaluation must completely document the implementation process. This effort should focus on: communication and data requirements, detector placement, use of the SCOOT system displays, etc.

Video Traffic Detection System
Objective: Optimization of detector placement through use of VTDS
Deliverable: Technical memorandum detailing the findings of this evaluation

Perform VTDS Evaluation Tests
Objective: Perform tests to evaluate VTDS performance
Deliverable: Memorandum detailing the evaluation test results

Task 12: Deployment Plan
Objective: Determine deployment potential in U.S.
Deliverable: Discussion papers - deployment of (a) 1.5GC, (b) SCOOT, (c) VTDS
Budget: $109,501 ($55,000 of which is from FHWA research funds)
Agency/firm: City of Anaheim with input from Odetics, JHK, R.L.French, Automatic/Eagle, Caltrans, and FHWA

Task 13: Final Report
Objective: Document project results for distribution
Deliverable: Final report
Budget: $70,120 ($40,000 of which is from FHWA research funds)
Agency/firm: PATH

2.4 A Proposal for an Independent Evaluation

Negotiations between federal and state DOTs defined the funding stream for the California FOT projects and designated PATH at the University of California, Berkeley as the FOT evaluator. PATH then solicited independent parties to serve as formal evaluators. The initial evaluation team was selected and approved in July 1993 and involved faculty and researchers from three academic institutions in southern California who together had extensive experience with adaptive traffic control (including SCOOT), VTDS, institutional issues, and system evaluation, with a track record of participation in local and regional transportation projects. The final evaluation team proposal was approved and work underway, after substantial contractual delay, by the end of 1994. The first evaluation team task was to develop and submit a formal Evaluation Plan which specified evaluation hypotheses, methodology, and data; this document, first submitted in mid-1995, would be revised numerous times in response to the changing schedule and deliverables of FOT partners. The evaluation plan developed was responsive to federal guidelines (USDOT, 1993) developed by Mitre (aka, the Mitre Guidelines), although a good deal of discussion addressed the appropriateness of those general guidelines relative to standard federal contracting guidelines, to the Volpe guidelines developed for the Federal Transit Administration, and the requirements of an independent and unbiased evaluation. These discussions were compounded by the development of an Evaluation Oversight Charter, based on a similar document developed as part of the TravInfo FOT in the Bay Area.

2.5 California's Role in the Federal FOT Program

The State of California has taken a pro-active role in the Federal FOT program, and was awarded several of the initial field operational tests. This section provides a brief overview of each of these projects. Only the Irvine FOT is considered to have technologies similar to those being implemented in Anaheim, however, preliminary assessment suggests that the institutional issues associated with some of these project have much in common. These issues will be addressed with the Irvine FOT institutional evaluation.

2.5.1 The Irvine Integrated Ramp Meter / Adaptive Signal Control

The Irvine FOT is one of several federally-funded ITS implementation projects in the area of adaptive control, and perhaps the only one that attempts to integrate adaptive freeway ramp metering and arterial adaptive signal control. This FOT's project objective was to "integrate and coordinate a centrally controlled freeway ramp meter system with an arterial traffic management system" (Irvine FOT Proposal, 1994). The full FOT implementation involves a highly congested corridor through a rapidly growing employment center. The study area for arterial control implementation is characterized by an incompletely developed, non-grid arterial network overlaying two diverging freeways set in an exclusively non-residential sector of the city. The

FOT involves the continued development of an Advanced Transportation Management / Information System (ATMIS) in two overlapping jurisdictions, with the Caltrans District 12 TMC managing the freeway system and the City of Irvine's ITRAC controlling the arterial system. The FOT extends the capabilities of existing freeway and arterial traffic management systems in the defined corridor. Its key features are the integration and real-time control of current and evolving traffic operations technologies to achieve some degree of integrated control of the freeway and neighboring arterial networks in the defined FOT area.

FOT partners plan to demonstrate the effectiveness of collaborative efforts between transportation agencies in improving overall corridor traffic flow. The planned traffic control in the Irvine FOT comprises the real-time integration of:

- **MIST** (**M**anagement **I**nformation **S**ystem for **T**ransportation), a data manager/supervisor for operations and control of the arterial network which enables interaction between freeway and arterial operation control technologies

- **OPAC** (**O**ptimal **P**olicies for **A**rterial **C**ontrol), an adaptive optimization algorithm for local intersections in the Irvine arterial network

- **D12 ATMS** (Caltrans **D**istrict **12** **A**dvanced **T**ransportation **M**anagement **S**ystem), an operator decision support system (ODSS) and data manager for operations and control of the Orange County freeway network (including the FOT and Testbed areas) which enables interaction between freeway and arterial operation control technologies

- **SWARM** (**S**ystem-**W**ide **A**daptive **R**amp **M**etering System) adaptive optimization algorithms for local and system ramp metering

This FOT has been significantly delayed and has not entered the field evaluation as of July 1998.

2.5.2 Mobile Surveillance

To support testing and evaluation within the Testbed, portable video image processing (VIP) systems and a supporting wireless communications infrastructure based on Spread Spectrum Radio (SSR) technology have been developed and deployed under the federal Mobile Video Surveillance/Communications (MVSC) Field Operational Test Project. Each VIP sensor node is capable of generating vehicle count, speed, occupancy, density, and queuing data. Additional data on estimated vehicle length and digitized video imaging may also be available from each

VIP system. The architecture of this system is designed to permit both applied research as well as additional operational capability. The MVSC provides capabilities in the following areas:

1. Performance improvement in traffic flow resulting from closed-loop, centralized, control of on-ramp meters in freeway construction zones where magnetic loop detectors have been severed.
2. Flexibility of a video image processing system as an accurate, reliable, and cost-effective alternative to traditional in-pavement loop detectors.
3. A transportable ramp metering system that employs spread spectrum radio technology to link the controller to a central computer and a transportable video image processing system in place of magnetic loop detectors.

The targeted applications of the MVSC units include the use of a machine vision (or VIP) as a replacement of in-pavement loop systems, temporarily rendered inoperative, for determination of traffic parameters, and the wireless transmission of closed circuit television surveillance video and traffic data from mobile remote sites to designated TMCs. The Video Image Processing Surveillance System consists of both fixed and transportable installations, and there are two types of transportable systems: Surveillance Trailer systems and Ramp Metering Trailer systems. The additional surveillance and control functions provided by this mobile system offer a unique opportunity to study and evaluate the impacts of ITS projects on the management of traffic. In addition to allowing for individual operating agencies to focus their surveillance functions on particular "hot spots", the system also can greatly facilitate the sharing of traffic information on a regional basis to better coordinate inter-jurisdictional management of traffic. The system currently consists of six Surveillance Trailers and three Ramp Metering Trailers. This system is available for deployment under a wide variety of conditions that either call for more-focused surveillance (e.g., special event traffic) or for temporary surveillance and control in locations where such capability is interrupted (e.g., during construction).

2.5.3 San Diego SMART Call Box

Currently, California has about 15,500 call boxes installed in twenty-six of the state's fifty-eight counties, which covers 6,300 miles of highway. The call boxes are a stand-alone units: each box uses battery power with a solar charging panel, a cellular transceiver and a microprocessor for control. This FOT replaces a box's existing controller card with a "smarter" card. After this swap, the boxes provide ITS services, such as performing traffic counts, detecting incidents, monitoring weather conditions, and hosting slow-scan closed circuit television cameras.

The partners for this project included San Diego's Service Authority for Freeway Emergencies (SAFE), Caltrans, the CHP, GTE, and US Commlink. TeleTran Tek Services managed the project, and San Diego State University served as the independent evaluator for PATH. The FOT lasted 27 months and ended on June 30, 1996.

The evaluation wanted to determine whether the modified call boxes could provide ITS functions in a cost-effective manner. Additionally, the evaluators examined the institutional issues that might affect a fully deployed system.

2.5.4 Spread Spectrum Network Radio

This test addressed the goal of reducing the cost of hardwiring Los Angeles' expanding ATSAC traffic system. This test used a communication network for advanced urban traffic control systems based on radio rather than hardwired links. The partners involved in this project included Los Angeles Department of Transportation (LADOT), and JHK and Associates. Hughes Aircraft Company worked as a subcontractor for JHK. The University of Southern California served as the project's independent evaluators for PATH. The project began in September 1994 and was completed in 1997.

2.5.5 TravInfo

This FOT attempted to test the impacts of comprehensive, real-time information about the current conditions in the nine-county Bay Area's surface transportation system. Specifically, its ability to increase the use of public transit and ridesharing services. The Metropolitan Transportation Commission (MTC) operated TravInfo as a public/private partnership, and PATH served as the independent evaluators. Metro Networks, a private consultant selected by MTC, supervised TravInfo's testing and installation. Testing began in May 1996 and the FOT was expected to be completed in 1998.

2.5.6 TransCal - Interregional Traveler Information System

The TransCal FOT showcased emerging capabilities in computing, communications, and consumer electronics that improved the quality of traveler information. TRW Inc. developed the TransCal system as a interregional traveler information system (IRTIS) that integrated road, traffic, transit, weather, and value-added traveler services data. The University of California at Davis served as the independent evaluators for this FOT.

2.5.7 Other Related FOT Projects

Several early FOT projects have been completed and reports documenting institutional issues associated with these projects were useful in drawing conclusions relative to Anaheim. The FOT projects reviewed included ADVANCE, Advantage I-75, HELP/Crescent, TRANSCOM/TRANSMIT, TravTek, and Westchester County Commuter Central (see SAIC, 1994), and FAST-TRAC, Guidestar, Houston Smart Commuter, SaFIRES, SmarTraveler, and TravelAid (see Blythe and DeBlasio, 1995). The Joint Programs Office report to Congress (FHWA, 1996) categorizes all operational tests by broad focus and enabling technologies; few FOTs are similar to the Anaheim project in this regard. A second SCOOT implementation is underway in Minneapolis (AUSCI project) but involves a downtown grid and extensive detectorization via a VTDS (Autoscope). FAST-TRAC and a second FOT (unidentified except for the name ICTM) have implemented SCATS, an adaptive control scheme quite different in design than SCOOT. Finally, as described in a prior section, the Irvine FOT is implementing OPAC, an adaptive control system focused on individual intersection optimization (note the evaluation team for the Irvine project is that for Anaheim, thus, the Final Report for Irvine will provide comparisons to the Anaheim project). Despite the limited number of comparable projects, institutional issues have been found to be shared by many of the above projects.

2.6 Institutional Structure

The institutional structure defining the administration of the FOT, while easy to present in terms of a management hierarchy, is difficult to interpret in terms of evolving responsibilities and level of participation. The former are presented here, while comments on the effective performance of the administrative structure are provided in the institutional analyses which follow. Figure 1 presents the operation hierarchy for the City of Anaheim Traffic Engineering & Operations. Figure 2 presents the proposed administrative structure for the FOT project itself.

2.7 Coordination of Evaluation Projects

In Fall 1995, Booz-Allen & Hamilton Inc. (BAH), FHWA's FOT evaluation support consultant, held Operational Test workshops in McLean, Virginia. The Anaheim project manager and two evaluators attended this workshop which presented BAH's guidelines for a successful FOT. The workshop hoped to provide guidance and to supply attendees with an impression of how their tests fit into the national program. The workshop opened with an explanation of the National ITS Program, including the evolution of the ITS Program, the Operational Test Program, and the Evaluation Process. The workshop also focused on the Operational Test Evaluation Development Process, concentrating on the development process and expected products. The workshop also presented brief overviews of all FOT projects.

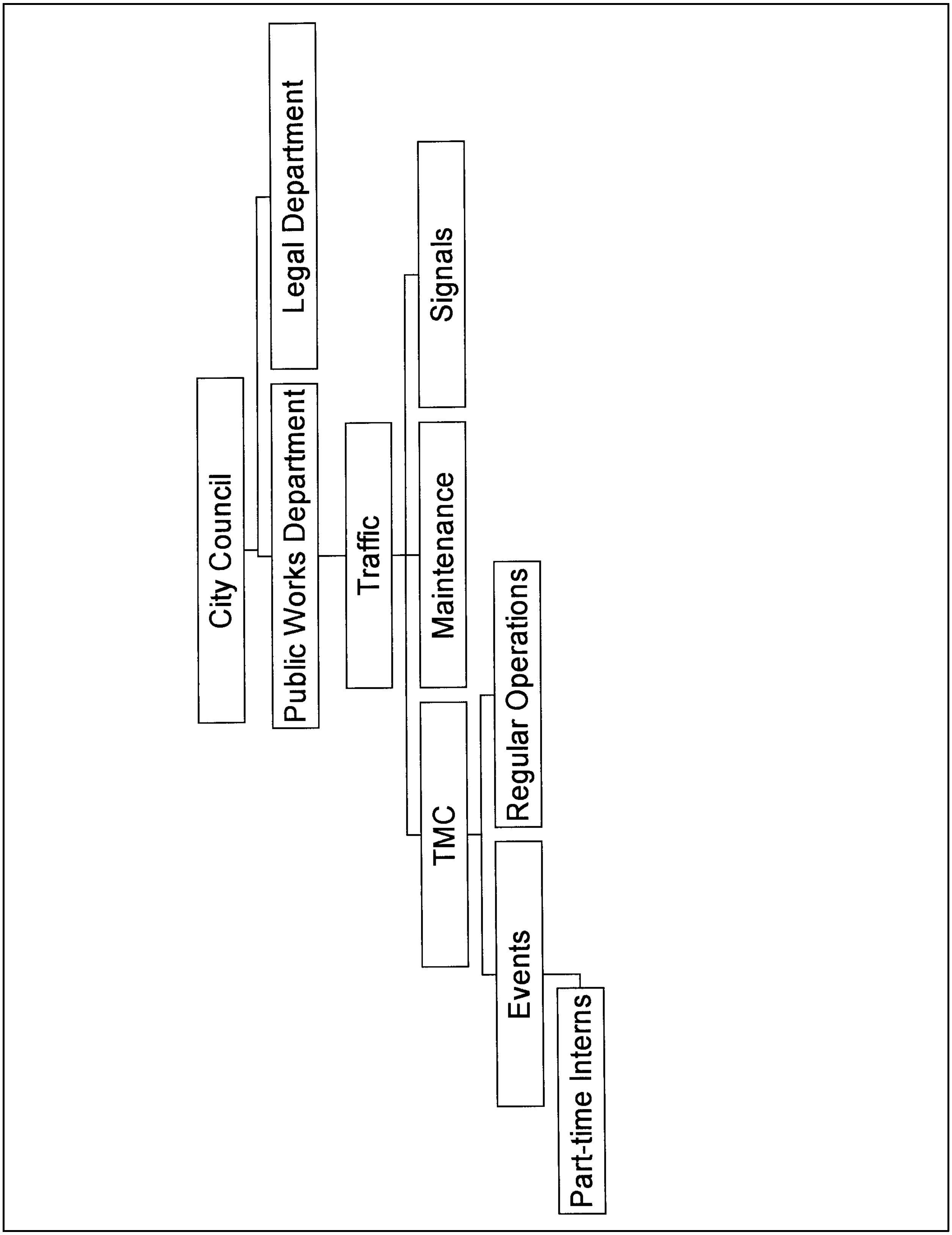

Figure 2.1 Anaheim City Traffic Administrative Structure

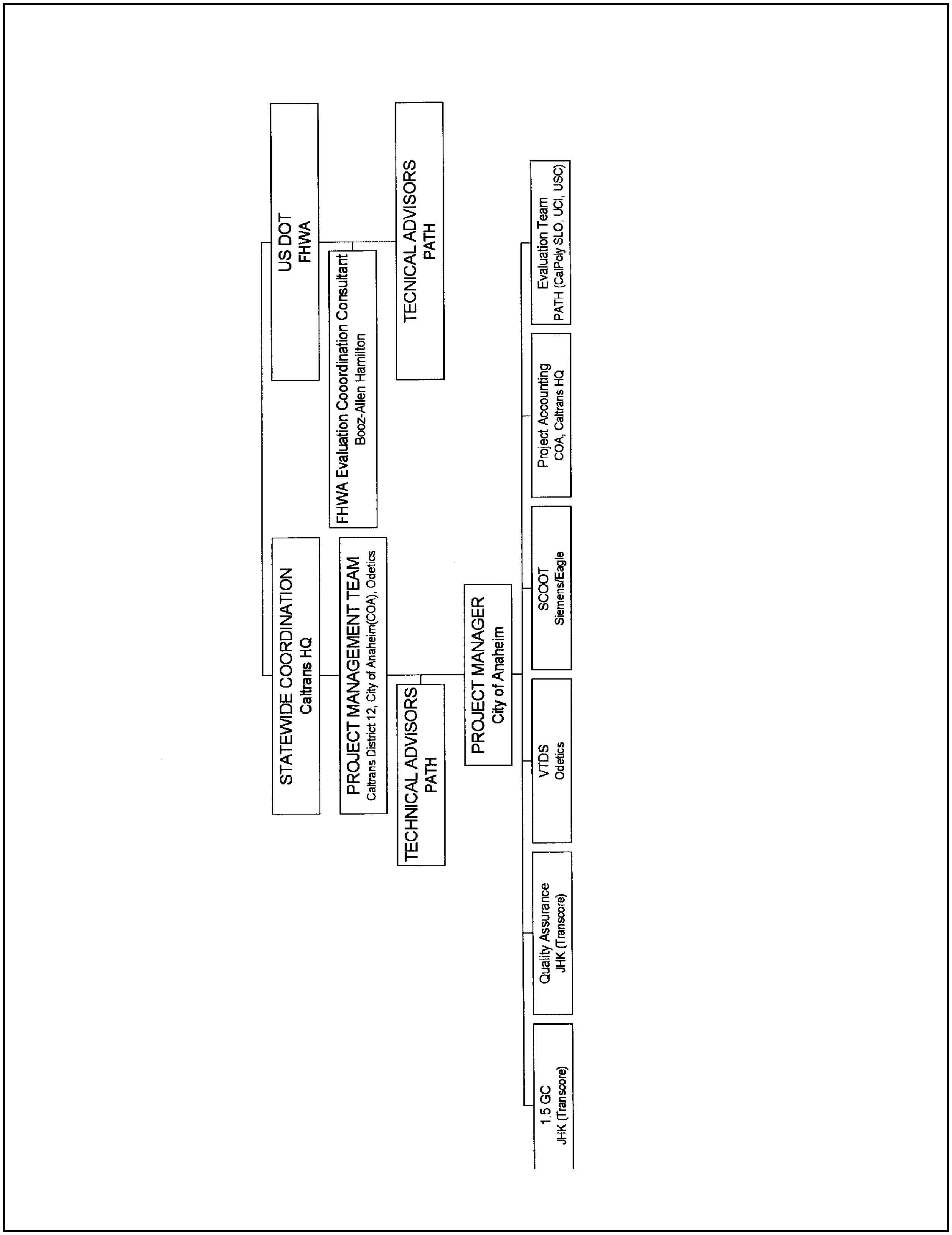

Figure 2.2 Anaheim FOT Project Administrative Structure

3. OVERVIEW OF ANAHEIM FOT TECHNOLOGIES

The development of the overall Anaheim integrated transportation management system was evolving toward adaptive control since the City's TMC was first established. With significant international success (see Martin and Hockaday, 1995), but only limited domestic application, SCOOT was considered an ideal candidate for traffic control. The City was particularly interested in effective control for the varying traffic demands associated with the many special events occurring within the city. The City envisioned an intermediate step between their first generation (1.0GC) UTCS control system and plans for second generation control (2.0GC) with SCOOT. This link was 1.5GC, planned as, effectively, a man-in-the-loop control system which would automatically generate and evaluate alternative signal timing plans, but require operator intervention to implement. The third planned system, the VTDS, also evolved from the variable traffic patterns observed in the city, and the inability to insure the uninterrupted flow of required field data to the control system due to construction and other activities which deactivated conventional loop detectors installed in pavements. Video traffic detection systems existed, but were sufficiently expensive to preclude their widespread application in the city. When a low-cost alternative was presented, it became the third technology in the FOT proposal. Following summaries of the existing control system, overviews of SCOOT and 1.5GC are provided, as well as a very brief summary of VTDS. More comprehensive reviews of these technologies are provided in the Task A (SCOOT and 1.5GC) and Task C (VTDS) final reports, respectively.

3.1 Anaheim's Current Control System

The existing first generation Urban Traffic Control System (UTCS) is centrally controlled and was implemented when the TMC was established in 1987. Additional technologies, including CCTV, CMS, and HAR, have been incorporated into TMC operations over the past decade. The City selected UTCS Enhanced software, a component of which provides Critical Intersection Control which allows for modification of timing plans at heavily congested locations but which requires advance system detectors. These detectors are located further upstream than for normal actuated control and became a key system component when planning for actuated control began.

The City of Anaheim implemented its integrated Traffic Management System (TMS) on November 17, 1988, as a Federal Demonstration Project; a focus of the Anaheim system is its capabilities to control traffic associated with special events (see JHK, 1992). The city handles recurring traffic conditions through a time-of-day schedule. Primarily, the City developed these timing plans under the Caltrans FETSIM program which utilized TRANSYT-7F for pre-identified sub-networks with similar traffic characteristics.

3.1.1 UTCS

The Urban Traffic Control System (UTCS) is the designation for a research project established by the office of Research of the Federal Highway Administration in the early 1970's to provide computer-supervised control of some 200 intersections in Washington DC. The principal objective of the project was to develop software for advanced signal control strategies to improve traffic operations in urban areas.

The UTCS research project on control strategies has been divided into three generations of traffic control techniques, usually referred to as 1.0GC, 2.0GC, and 3.0GC (ITE, 1985). These techniques are briefly described below.

a. First Generation control, or 1.0GC, consists of traffic signal timing plans developed off-line, based on historical traffic patterns.

b. Second generation control, or 2.0GC, involves real-time production and implementation of plans through on-line techniques, based on surveillance data gathered from vehicle detectors and from predicted traffic volumes.

c. The third generation concept, or 3.0GC, is envisioned to implement and evaluate a fully traffic-responsive, on-line control system. To achieve this, signal timing parameters must be changed continuously in response to real-time measurements of traffic variables.

When Anaheim began to design their TMS in 1986, UTCS Extended software was initially recommended over the Enhanced version. The Enhanced system required significantly greater computing power, utilized a somewhat unwieldy command language (OIL - Operator Interface Language), and had seen only limited application (Los Angeles and San Diego were the only two agencies using the Enhanced software while many were using the Extended version). However, one year into the project, significant improvements in the Enhanced Version were made that addressed the City's concerns and they changed to the Enhanced software. A component of the Enhanced version provides Critical Intersection Control (CIC) which allows for modification of timing plans at heavily congested locations but which requires advance system detectors. These detectors are located further upstream than for normal actuated control and became a key system component when planning for actuated control began. The major functional components comprising the Enhanced 1-GC software are described below:

a. Detector telemetry processing. Processing detector inputs to compute vehicle occupancy and perform reasonableness checks to assure that the computations of measures of effectiveness do not include inputs from malfunctioning detectors, automatically dropping failed detectors and returning functional detectors to the on-line mode of operation.

b. Measures of effectiveness algorithms. Vehicle occupancy and data defining the occurrence times are processed by these algorithms to provide traffic volume, speed, occupancy, stops, delays, queue length, demand per signal cycle, and congestion.

c. Communications processing. A modular communications software package provides for compatibility with different types of communications hardware.

d. Manual plan selection. This function permits an operator to select any signal timing plan for one or more controllers. In responding to this type of operator's request, the software performs data validity checks and then implements the selected plan.

e. Time-of-day/day-of-week operation. This operation identifies specific timing plan schedules for specific times of day, specific days of week, and for special events.

f. Traffic responsive operation. Input data from vehicle detectors is used to select a timing plan from a library of stored plans.

g. Critical Intersection Control (CIC). The CIC function is used at an individual intersection when it is properly instrumented with vehicle detectors and one or more of the intersection approach volumes exceeds a specified input threshold value.

3.1.2 Anaheim TMC

Currently, Anaheim's TMC provides for real-time monitoring and control capabilities, utilizing first generation control capabilities of UTCS Enhanced. The City handles recurring traffic conditions through a time-of-day schedule with as many as six different timing plans; in the Disneyland and Stadium areas this total may reach 28 plans. Primarily, the city developed these timing plans using funds provided by the Caltrans FETSIM (Fuel Efficient Traffic SIgnal

Management Program) program. This program utilized TRANSYT-7F for pre-identified sub-networks with similar traffic characteristics and assigns a common cycle length for these sections. More recently, the City has fine-tuned the timing plans throughout the city by further dividing the sections into clusters of adjacent intersections with the same number of phases. This process minimizes minor phase delay and provides better green progression, however, the greater number of clusters increases the number of break points and increased network delay.

The City planned to use the 1.5GC system to evaluate current time-of-day plans in the network both on a cluster-basis and a network-wide basis, to evaluate event traffic conditions for both small and large events, to monitor volumes and trends, and to fine tune both timing plans and time-of-day schedule. Event conditions would be evaluated under different congestion levels to optimize event management opportunities. The City hoped to investigate the possibilities of using 1.5GC generated plans in place of real-time TMC operators for future smaller events.

3.1.3 The Field Operational Test

The FOT evolved directly from the initial system implementation in Anaheim, with adaptive control identified as a prospective element of the control system. The initial area selected for implementation included the four major event sites in the City (Disneyland, Edison Field, the Anaheim Convention Center, and the Arrowhead Pond), all of which are major traffic generators located within a few miles of each other. There are, in essence, two separate areas with Disneyland and the Convention Center located west of the I-5 freeway on Katella Avenue and Edison Field and the Pond located east of the I-5 (straddling the SR-57 freeway and Katella Avenue). As the project evolved, questions developed relating to the continuity of these two diverse areas (the first in a hotel/recreational environment, the second in an office/industrial setting). These questions were resolved when Disney's plans to build a second theme park and the City's plan to expand the Convention Center necessitated major infrastructure changes in the western half of the network, effectively precluded SCOOT implementation at this time.

3.2 SCOOT Adaptive Signal Control

Adaptive control continuously assesses and adjusts signal timing because the traffic conditions fluctuate on a regular basis. The British Government and three major signal companies in Britain developed a commercially available adaptive control technique, the Split, Cycle and Offset Optimization Technique (SCOOT). SCOOT attempts to alter traffic signal timings according to current traffic demand by application of an on-line traffic model. The British signal companies have the SCOOT software available under a licensing agreement.

Research and field experience has shown that traffic control can be improved through coordination of traffic signals. Early coordinated systems used historic traffic counts from different times of day to produce fixed time plans. TRANSYT (Robertson and Gower, 1977; Wallace *et al.*, 1983) optimization has been perhaps the most successful method of producing these plans. SCOOT measures the real-time traffic demand on all roads in a given coordinated network and optimizes the signal timings for that measured traffic. SCOOT's responsive method of control shares the same basic concepts as TRANSYT, including optimization criteria; it can be described as an on-line TRANSYT. In SCOOT, the primary objective is to minimize the sum of the queue lengths in the area. This criterion is converted into a Performance Index (PI) which is used to evaluate alternative courses of action. Detectors monitor a combination of flow and occupancy that enables SCOOT to model traffic flow and make systematic adjustments to signal settings in real time, making SCOOT more reliable than off-line TRANSYT optimization using field survey or historic counts. SCOOT has been tested and evaluated in a number of field trials using the floating car survey technique. Siemens reports that SCOOT shows reductions of approximately 15 percent in delay compared with timings calculated by TRANSYT. Other control systems have not reported improvements upon TRANSYT by such a margin. System benefits associated with SCOOT include:

1. SCOOT uses an on-line model of traffic behavior, from data continuously obtained from on-street detection, to predict stops and delays within the network.

2. SCOOT is a traffic responsive system that has shown to give the greatest benefits compared with any previous system.

3. SCOOT is successfully operating in a large number of varying cities throughout the world, such as Beijing, China, Santiago, Chile, and Oxnard, California.

3.2.1 Traffic Model

The SCOOT traffic model is based on data collected four times every second from vehicle detectors on the approaches to each junction, typically just downstream of the previous intersection, to 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. A few seconds prior to each phase change, SCOOT uses this advance arrival information to predict whether it is best to terminate the phase four seconds earlier, four seconds later, or leave as planned. This procedure is the SCOOT split adjustment logic. SCOOT simultaneously evaluates the advisability of altering the offset of the intersection with respect to the master by four seconds either way. In addition, the option of changing the cycle length of the entire system by four seconds in either direction is explored every few cycles. Typically, SCOOT makes about 10,000 small decisions in an hour for every 100 intersections in the system. These frequent small alterations in the timing plans adapt the signal to short-term fluctuations in traffic demand. Over a longer period of time (several minutes), the short-term adjustments accumulate but since the changes are small the disturbance to traffic is minimal. As Siemens reports, congestion is directly measured from the detector. If the detector is placed beyond the normal end of a queue on a street, it will never be occupied by stationary traffic unless congestion occurs. This enables the detector output to show congestion. Congestion is recorded, if any four seconds of data shows traffic standing on the detector for the entire interval. The number of intervals of congestion in any cycle is recorded.

3.2.2 Optimizers

The purpose of the traffic model is to predict the effect of signal settings on the overall traffic flow. In order to do this, three separate optimizers determine splits, offsets, and cycle time. Each optimizer is discussed below, as described by Siemens (1996).

<u>Split Optimizer</u>

The split optimizer works on the traffic model just prior to each stage change. It considers the effect of advancing, or holding the stage change and the effect this has on the green duration. The degree of saturation of all links controlled by the node is the test. Siemens defines the degree of saturation as "the ratio of the average flow to the maximum flow which can pass a stop-line". The ratio of the demand flow to the maximum possible discharge flow in SCOOT terms is the ratio of the demand of the cyclic flow profile to the demand of the discharge rate (saturation occupancy) multiplied by the duration of the effective green time. The split optimizer tries to minimize the maximum degree of saturation on approaching links. If the average degree of saturation over a five minute period is greater than 90 percent, the cycle time will then increase in order to give additional capacity to the critical node.

The split optimizer also takes into account congestion on the approach to the node. In order to do this, the proportion of the previous cycle that was congested is included with the degree of saturation used by the optimizer when making this decision. The congestion term will enable a congested link to obtain more green time depending on the congestion importance factor set for this link.

Offset Optimizer

Cyclic flow profiles are used by the offset optimizer to predict the queue length throughout the cycle. Once per cycle, the offset optimizer predicts the queue lengths for all the links upstream and downstream of a particular node. The effect of moving the nodes' phasing initialization time forward or backward by a small amount is predicted for these links. These predictions can be used to minimize the stops and delays in the area.

The cyclic profile considers the profile of the flow arriving at the stop-line after platoon dispersion, with the journey time from the loop to the stop-line having been taken into account. If the stage start time was delayed a few seconds, then the few vehicles that start queuing at the beginning of the red time in the diagram would not have to wait at all. Against this advantage, the optimizer has to consider the many vehicles in the diagram who are in the queue at the start of green. They would all have to wait a short extra time. The optimizer does this prediction for each link, and sums them together. The calculation is repeated for each of the three possible decisions: retard, stay, or advance the named stage start time. The choice is made to minimize delays and stops. The volume of traffic arriving while there is a queue gives the number of stops. The congestion on a link is also used in the offset optimizer so that the congested link is given priority over links without congestion. The degree of priority is related to the degree of congestion.

Cycle Optimizer

The cycle optimizer typically executes every five minutes when it computes the degree of saturation at all stop-lines for each node. If any (all) node(s) is (are) above (below) 90 percent saturated, then the minimum practical cycle time is increased (decreased) by a small fixed step. The optimizer considers all cycle times between the minimum and maximum practical cycle times for the critical node. These are considered trial cycle times. To reduce delays at very lightly loaded intersections, the cycle optimizer will double cycle these locations if the resultant delay is reduced. Because this can show reductions in delay if the cycle time is changed by large amounts, the cycle optimizer is the only optimizer that looks at the effect of large changes. However, large changes in cycle time are very disruptive, so SCOOT does not make the change in one step. The change is made in small steps, but the direction of movement will be chosen by reference to consideration of a larger change. The cycle optimizer operates on a region of nodes, chosen by the engineer, that have progression between them.

3.2.3 SCOOT Benefits

SCOOT's effectiveness was assessed by tests in five cities (Siemens, 1996). Surveys were conducted via "floating car" studies using specially instrumented cars to measure journey time and queue lengths throughout the day. Measurements were made two weeks before and after SCOOT installation, and the analysis took account of traffic flow levels.

The analysis concluded that SCOOT reduced the average journey times and queue lengths by approximately 8-12 percent. SCOOT performed best when dealing with heavy flows, close to saturation, and in unpredictable variations. SCOOT cannot, however, clear a large over-saturated network, but no traffic control system can. However, SCOOT slows the onset of congestion. Since SCOOT does not "age" in the way fixed time plans do, SCOOT should achieve savings in many practical situations as compared with a fixed time plan which can quickly become outdated. Although many efforts have been made to solve the problem of congestion, with varying degrees of success, SCOOT appears to play a major role in the development of traffic control and management, in an age of technical innovation.

3.2.4 SCOOT in Anaheim

The City of Anaheim planned to implement a SCOOT system on top of their existing UTCS. They planned to use the existing SCOOT technology with their existing infrastructure at the intersections around four of the major attractions in Anaheim: *Disneyland*, the *Anaheim Convention Center*, *Edison International Field of Anaheim* (formerly Anaheim Stadium), and the *Arrowhead Pond of Anaheim*). This component of the FOT was nearly terminated before any significant work occurred when the City of Anaheim and Siemens, the SCOOT provider, had difficulty agreeing to a contract, delaying this portion of the project for an entire year.

Although SCOOT exists as a stand-alone technology, each implementation must be customized for the specific location. Siemens adjusted the SCOOT system to operate with the existing controllers and existing inductive loop detectors. As a result of construction, the City of Anaheim eliminated the intersections surrounding Disneyland and the Convention Center from the project. The final SCOOT network is depicted in Figure 3. Furthermore, this SCOOT implementation could not change the SCOOT parameters from the City's TMC. The SCOOT system installation appeared to proceed fairly smoothly after Siemens and the City of Anaheim finally resolved their contractual issues.

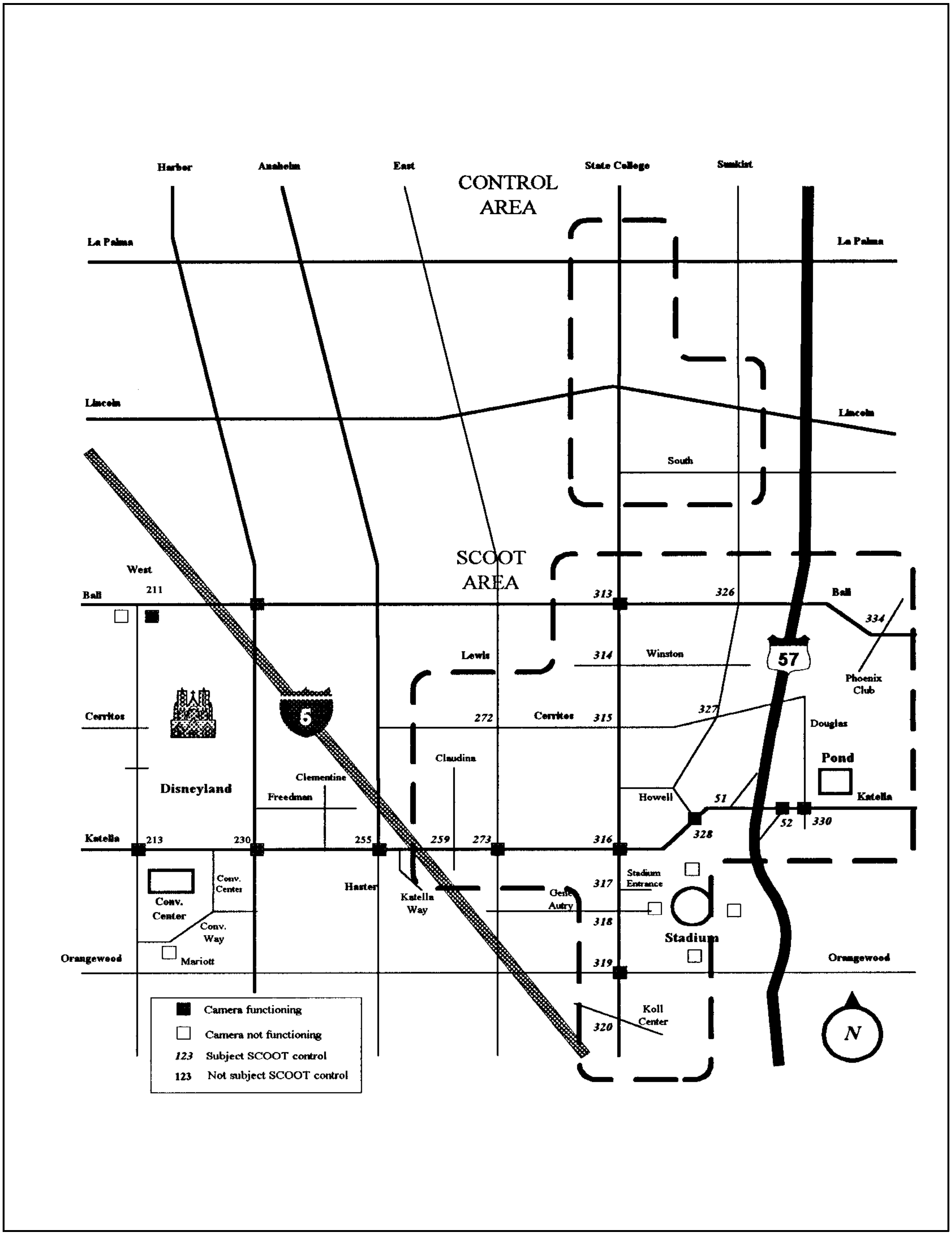

Figure 3.1 Map of the Anaheim FOT Study Area

3.3 1.5 Generation Control

Typically, a traffic engineer employs a modeling package to simulate and optimize real-world traffic patterns to create traffic signal timing plans. In a first generation system, the engineer would collect the data for the optimization software from the field (or possibly directly from the traffic control system, however, no direct importing of data into the optimization model was possible). A 1.5GC system bridges the gap between traffic data and traffic analysis. In addition to collecting real-time data from the traffic control system, the 1.5GC analyzes the performance of current control methods with the real-time traffic flows. This system provides traffic engineers with a set of tools to aid in the development of optimal control methods for current traffic conditions.

The 1.5GC system uses real-time traffic data to update files for the TRANSYT-7F optimization program. TRANSYT can be applied for optimization (any combination of cycle length, offsets, and splits), cycle length selection, or simulation only. In all modes of operation, TRANSYT calculates a Performance Index (PI) as a weighted sum of stops and delays obtained by simulating traffic flow in the network. In the optimization modes, the program uses the PI in a hill climbing algorithm, which although not guaranteed to lead to globally optimal settings, has in practice proved to be quite effective. TRANSYT can also be used to select an optimal cycle length for a network utilizing a brute force evaluation of performance indices for a range of cycle lengths. The various measures of effectiveness (MOEs) calculated by TRANSYT include delay, stops, queue lengths, and degree of saturation. 1.5GC executes the TRANSYT model and reports the results to the system operator. Although time-intensive, 1.5GC simplifies the process of developing timing plans and provides the traffic engineer with a mechanism to assist in the development of optimal control methods for existing traffic conditions.

The majority of the work in initializing the 1.5GC Plan Developer involves constructing the database, which includes street and detector specifications. Once this is accomplished, timing plans can be developed quickly. The process for generating a timing plan with 1.5GC, as described by JHK/Transcore (Transcore, 1997) is:

a. Use the Browser and Network Inspector to identify a network of intersections which are to be coordinated as a starting point for data entry. Enter database information (street names, intersection , detector, and approach details) pertaining to the network.

b. Use the Scenario Inspector to identify time periods that represent distinct traffic behavior patterns. JHK refers to these time periods as scenarios. Operators can define them using any combinations of range of times in the day, days of the week, dates of the year. Both flow patterns and timing plans are grouped by scenarios.

c. Use the Intersection, Approach, and Algorithm Inspectors to derive volume flow patterns for the network by defining relationships between detectors and intersection approach movements; these relationships are called flow algorithms. An algorithm is defined for each scenario on each intersection approach.

   Algorithms allow you to enter an equation made up of detector resources, constants, and math operators. JHK suggests that the detector resources for an approach algorithm be located either on the approach or downstream of it.

d. Use the Scenario and Plan Inspector to create and modify a plan, including selecting a model and a movement numbering scheme for the model.

e. Extract pre-existing timing plans from UTCS and use the model to generate a performance evaluation of the existing coordination timings.

f. Use the model to develop the timing plan for a particular network scenario. The model provides statistical information on the performance of the plan throughout the network.

g. Use the Measure Of Effectiveness (MOE) Comparison Utility to determine performance improvements levels predicted by the new timing plans over the pre-existing plans.

h. Use the Time-Space Editor to review and optimize the progression through the network.

i. Use the plan Inspector to install the timing plan in the Traffic Control System, which then allows you to download to the traffic signal controllers.

j. Monitor and evaluate the performance of the timing plan for proper cycle length, splits, offsets, and time-of-day operation.

k. Develop additional timing plans as required to meet the needs of the changes in the traffic flow which are detected by the detector resources.

As part of the FOT, JHK/Transcore planned to install a new version of 1.5GC based on an earlier unsuccessful version installed in the Anaheim TMC. The City of Anaheim anticipated that the new version would be useful as a traffic engineering tool, and planned to use 1.5GC to:

1. evaluate current time-of-day plans in the network on a cluster and a network-wide basis
2. evaluate special event traffic conditions for both small and large events to discover event management opportunities
3. monitor system trends and volumes

4. fine tune both the timing plans and the time-of-day schedule
5. eventually replace TMC staff utilized for smaller events.

Functionally, 1.5GC processing time is extremely excessive (a 31 intersection network required 4-5 hours to process while 3-4 intersections required 1 hour).

3.4 Video Traffic Detection System

Odetics' VTDS provides surveillance and control capabilities. At a cost significantly below VTDS alternatives, Odetics believed that their system will achieve wide-spread deployment. Theoretically, VTDS can provide area-wide surveillance and control for entire regions. Odetics designed their system as a single board product so that it can be plugged directly into existing signal controllers. This design makes VTDS compatible with existing equipment and simplifies maintenance. The FOT was to test the VTDS under different weather and traffic conditions using data from the Harbor and Katella intersection near the entrance to Disneyland. Although Odetics originally expected their VTDS to provide traffic counts in addition to presence detection, the final system implemented functioned in the presence mode only (please see MacCarley (1998) for technical details).

4. OBSERVATIONS AND INTERVIEWS

To achieve the FOT objective of adaptive arterial traffic control necessitates the identification, evaluation, and resolution of a wide variety of institutional barriers to successful project completion. While both federal and state policy are firmly supportive of the rapid deployment of new technologies in Advanced Transportation Management Systems, the actual deployment involves the integration of diverse technologies from a variety of competing vendors in local environments with little if any experience with such technologies. This suggests that a variety of learning curves must be traced, as the players deal with the technical issues, and necessarily, the institutional issues, of implementation. The focus of the assessment is to identify under what structure can advanced transportation management strategies be deployed so that their effectiveness is neither reduced nor confounded by limitations posed by institutional issues. The scope of potential institutional issues is necessarily quite wide.

For the Anaheim FOT, the assessment of institutional issues is clearly a basic evaluation task. The range of potential issues, however, makes the *a priori* identification of pertinent issues difficult. Therefore, a comprehensive range of institutional factors, both barriers and incentives, are considered as potential measures of effectiveness in the resultant qualitative evaluation.

4.1 Overview of Institutional Issues

This evaluation project is of particular interest not only for its potential to assess the effectiveness of applications of advanced traffic control technologies at both the individual component level and as an integrated system, but also, and of at least equal importance, to assess the relative role of institutional issues. Such issues are quite varied, but may be categorized in at least two related ways: first, by the nature of the issue (such as project administration) and, second, by stage in project deployment (system baseline, implementation, operations, maintenance, and transferability). After a brief, general overview of the nature of relevant institutional issues, a comprehensive assessment of the five major stages of the operational test are presented in terms of evaluation goals and objectives, as defined prior to evaluation and as modified as part of the evaluation process. The question of interest is through what structure and methods can the technologies in question be applied so that their effectiveness is neither reduced nor confounded by institutional limitations relative to the programming, implementation, and operations of such technologies.

<u>Administrative Issues</u>

These issues arise at the general administrative as well as at the project management level, both in operational and strategic management. Areas which are critical to assess include:

(a) initial needs assessment and initial funding
(b) inter-agency coordination and cooperation in both planning and operations
(c) coordination and cooperation with consultants in both planning and operations
(d) commitment from higher level agencies (county, state, federal)
(e) public relations

A number of key points which are applicable to all cooperative efforts are: the more players involved, the greater the communication problems; it is essential that participants have realistic expectations of what improvements are achievable and what an appropriate time schedule may be for those improvements; a strong project manager and/or a concerted effort at a higher level is necessary to ascertain that there is adequate planning and funding to ensure project success; and accomplishments don't end with initial implementation of a project - a level of continued effort is necessary to sustain a cooperative project.

<u>Leadership / Personnel Issues</u>

These issues may well be considered under administrative issues, but it is perhaps more useful to separate issues which are more individual-dependent, rather than process-dependent, although they are clearly interrelated. Leadership and personnel questions would also be expected to vary across FOT partners. Areas would include:

(a) agency advocates to assume leadership in project management and decision-making
(b) current and future staffing considerations (quantity and quality)
(c) existing and evolving institutional staffing policies
(d) indirect effects impacts on associated departments and agencies

These are critical but difficult to evaluate issues. An agency actively seeking commitment for traffic improvement projects with an active spokesperson leading the search will in general not only be more successful, but may provide the catalyst in generating new funds, new cooperative relationships, and new applications. Such a project's success may very well start with a pro-active project manager, but requires committed and qualified staff at all levels in all partners. Failure in personnel performance, at the project manager or staff level, has ramifications in overall project success, but these ramifications and their quantification are difficult if even possible to identify and assess. While it is not a goal to "point one's finger" at a particular participant, it is often necessary to address these issues in some manner.

Financial Issues

The overwhelming project characteristic which seems to define the feasibility of applications of new technologies is a readily available source of funds to (minimally) pay for the physical cost of implementation. While programs such as the federal field operational test program can fulfill this requirement, they typically do not address long-term financial impacts. Areas include:

(a) fiscal constraints, economic leverage for other related projects
(b) funds for planning, development, implementation, and operations
(c) future funding for continued operation, training, and maintenance
(d) unanticipated costs and unforeseen impacts
(e) city, county, state, and federal perspectives

The overwhelming project characteristic which seems to define the feasibility of applications of new technologies is a readily available source of funds to (minimally) pay for the physical cost of implementation. While programs such as the federal field operational test program can fulfill this requirement, they typically do not address long-term financial impacts.

Legal and Liability Issues

These issues have often created the greatest delay in applications of new technologies. Agreements between agencies where little if any precedent exists creates a rather lengthy approval process at all levels of decision-making. Relevant areas include:

(a) risk management
(b) lack of prior experience with contractual structure and issues
(c) existing and evolving institutional structure
(d) system liability (operations and maintenance concerns)

Risk management is a primary consideration in any municipal activity, and of particular importance in traffic operations due to obvious safety concerns. Nevertheless, legal agreements between the jurisdictions involved, although not as yet finalized as of the date of this summary report, appear to be more of a bottleneck to project progress rather than a real constraint. The combination of improved flow and safety through advanced traffic management with a large portion of the financial burden being covered from outside makes projects such as this appear favorable to both city traffic engineers and their city councils.

Technical Issues

While these issues are primarily assessed in the technical evaluation task, their impact on other institutional issues as well as on overall project performance is critical. Areas include:

a. impact on other infrastructure and/or operations within agencies
b. preferred system specifications
c. system compatibility
d. operations, analysis, and monitoring
e. training and maintenance

4.2 Evaluation Data

Data required for the evaluation of institutional issues are substantively qualitative, and as such, may often be somewhat subjective. To minimize bias in the interpretation of the data, it is important to gather data from alternative sources to see if some consensus, if not still subjective conclusions, can be drawn. The first source of data came via direct observation of project participants, primarily at formal project meetings but also informally over the duration of the project. Formal meetings were documented in meeting minutes which were independently recorded and shared by the Project Manager and by members of the evaluation team. There was a substantial amount of other documentation, associated with both the Anaheim FOT (proposals, technical memoranda, hardware and software documentation, etc.) and with prior related work in the City (see JHK, 1992; Recker *et al.*, 1992). Although Anaheim was one of the earlier FOT projects approved, various delays led to project completion after other FOTs had already been evaluated. Several reports documenting institutional issues associated with these projects were useful in drawing conclusions relative to Anaheim (see SAIC, 1994; Blythe and DeBlasio, 1995). Finally, all key project participants were interviewed to gain their opinions on the progress of the FOT and on the relative role of various institutional issues. The interviews were structured around a series of questions addressing anticipated institutional issues (see section 4.1). Three separate but overlapping sets of questions were utilized depending on the level of involvement of the interview subject (high-level administration/oversight, project management and engineering, and operational staff).

4.3 Overview of Project Events

In 1993, the FHWA obligated the Anaheim FOT funds to Caltrans. The City's involvement dates to decisions made by the City's Principal Traffic Engineer in 1991 to move into adaptive control. JHK/Transcore, who served as the City's system manager since the TMC opened, recommended SCOOT. In this management capacity, JHK/Transcore was involved in all FOT tasks involving changes to the TMC, in general, and to UTCS, in particular. The City amended the existing contract with JHK/Transcore because the FOT was to modify the existing signal system. Siemens began discussing Anaheim's adaptive control needs in 1993, however, their formal involvement began in November 1995 when they received the City of Anaheim's request for proposal (RFP). In January 1996, the City of Anaheim selected Siemens as the SCOOT vendor, however, Siemens did not begin work on the project until January 10, 1997, and then they started without a formal contract because insurance issues had not yet been resolved. Siemens believed that contract issues would be readily resolved because contract negotiations had finally progressed to detailed discussion. Eagle Signal became involved in the project given Eagle's expertise with US controllers and to provide a local presence.

Caltrans combined with the City of Anaheim and Odetics to respond to the FHWA's RFP, and played a key role in developing the proposal. In the summer of 1994, Caltrans and the FHWA formed a partnership agreement that allowed federal money to flow from the state to Anaheim (and to other FOT project locations). Then, in November 1994, Caltrans and the City of Anaheim signed their contract. The project was originally designed to be completed in 18 months, including the evaluation; the final project duration was 3.5 years (Table 1 summarizes the event time line).

Table 4.1 Anaheim FOT Event Time Line

1992		
May	_	Federal Register (57,90) announces *IVHS Field Operational Test Program*
July	_	Federal Register (57,139) announces *Participation in the IVHS Field Operational Test Program RFP*
October	_	Initial FOT proposal submitted to FHWA
December	_	Proposal accepted for FY 1993 Operational Test Program funding
1993		
May	_	Memorandum of Understanding signed by the State of California (Caltrans District 12 and California Highway Patrol, Border Division), the Orange County Transportation Authority, and the Cities of Irvine and Anaheim
June	_	Updated Project Work Plan submitted to FHWA
July	_	Selection of PATH Evaluation Team
September	_	Preliminary Evaluation Team proposal submitted to PATH
November	_	First unofficial FOT/EOT meeting in Anaheim
1994		
March	_	Preliminary approval of evaluation contract; Caltrans pre-award audit
June-August	_	Initial and revised evaluation proposals submitted to PATH
October	_ _	Evaluation Team contracts approved as sub-contracts to PATH Evaluation Oversight Team charter presented by JHK and Anaheim
November	_	VTDS demonstration at monthly Anaheim FOT meeting
December	_	Final evaluation proposal submitted to PATH

Table 4.1 Anaheim FOT Event Time Line (cont'd)

1995

March	_	Odetics selected an intersection for their Vantage VTDS test and began work on a field test plan
April-June	_	JHK developed a *Site Analysis Plan* Draft
June	_	PATH partner agreements completed
	_	Contract amendment between Caltrans and Anaheim for a twelve month extension executed by City and forwarded to Caltrans for execution
	_	Evaluation Team submitted *Evaluation Work Plan* Draft
	_	Modifications of the *Proposed EOT Charter* submitted
	_	Odetics submitted installation plans to the City; Anaheim approved plans; Odetics used CSC to begin installation of cameras
July-Sept	_	JHK submitted *Final Design Report*, *Preliminary Operations Plan*, and a *Draft RFP* for the SCOOT System
	_	Odetics submitted draft of the *VTDS Field Test Plan*
October	_	JHK submitted *Design Interface Requirements* Draft
November	_	JHK stated that 1.5GC will be used to update signal plans "on the fly" to define a new baseline
	_	JHK completed review of existing 1.5GC package
	_	SCOOT Vendor RFP advertised/distributed
	_	FHWA distributed their *SCOOT -Project Completion Plan* Draft
	_	Odetics selected fiber optic for communications
	_	Data from VTDS will be compared to loop detector data]
	_	FHWA and BAH hold review meeting for FOT projects in ATMS
October - December	_	Odetics defined fiber optic system configuration
	_	Odetics completed their *Field Test Plan*
December	_	SCOOT Vendor proposals due; SCOOT Vendor interviews
	_	JHK begins work on 1.5GC Modifications - design and development
	_	Siemens selected as the SCOOT Vendor
	_	Partners/EOT approve *Task C Evaluation Work Plan*

Table 4.1 Anaheim FOT Event Time Line (cont'd)

1996

January	_	Evaluation Team's contract receives a one-year no cost extension
	_	Odetics submitted *Site Analysis Report* Draft
February	_	Siemens attends meeting and performed a SCOOT demonstration
	_	Eagle (a US corporation) will handle the SCOOT/controller interface
	_	Caltrans contract with PATH extended
	_	In March, Caltrans will address the JHK and Siemens contracts
	_	Siemens plans to start in early March; however, 20% of their budget may extend beyond the end of June. Caltrans considers whether to grant an extension into the next fiscal year
March	_	1.5GC scheduled for delivery to Anaheim
	_	Odetics to begin VTDS installation
	_	Siemens contract is still in negotiations
	_	PATH contract with Caltrans still to be finalized
April	_	JHK completed installation of 1.5GC
	_	14 percent of SCOOT detectors operational
	_	Anaheim determining turning volumes for the test area
May	_	1.5GC Training
	_	Anaheim begins in-house testing of 1.5GC
	_	System detector status similar to prior month's
	_	Caltrans sent amendment to Anaheim for a six month extension; Anaheim City Council to act on it before the end of June
	_	SCOOT contract goes to the City Attorney for final review; planned to go to the City Council in June
	_	FHWA approves *Task C Evaluation Work Plan*
June	_	1.5GC initial testing
	_	City hopes to take Siemens contract to the City Council in July
	_	Anaheim works with JHK to resolve problems associated with implementing the test networks
	_	Evaluation Team identified locations for video-tape data collection
	_	Evaluation Team met with Anaheim Permits Department
July	_	1.5GC in-house testing completed
	_	JHK provided Anaheim with a revised version of the 1.5GC software

Table 4.1 Anaheim FOT Event Time Line (cont'd)

1996 (cont'd)

August	_	Odetics installed video camera subsystems and the fiber optic communications system
	_	City still negotiating contract extension with Odetics
September	_	Siemens contract not resolved; SCOOT FOT status is questionable
	_	Odetics might not have funds to participate in the evaluation
	_	Odetics' VTDS is found to operate in presence mode and cannot provide vehicle counts at intersections
	_	1.5GC results show that a 31 intersection network required 4-5 hours to process while 3-4 intersections required 1 hour
	_	Detector loops not completely operational
October	_	Siemens contract remains unresolved (contributing factors include differences in US and UK attorney terminology, disagreement over licensing, and whether there is sufficient time to complete the project)
	_	Partners/EOT approve final *Video Test Suite*
November	_	Principal Traffic Engineer, TMC Manager, and FOT Project Manager leaves the City of Anaheim for another position elsewhere
	_	Delivery of sample VTDS system for evaluation
December	_	VTDS field data collection at Odetics facility
	_	Official end of Odetics contract

Table 4.1 Anaheim FOT Event Time Line (cont'd)

1997

January	_	The field evaluation tentatively set for October in the Arena and Stadium area; the Disneyland & Convention Center will be dropped from the project due to extensive reconstruction
	_	Siemens agreement accepted and signed on January 14, 1997; however, insurance concerns must to be resolved
	_	SCOOT work will be completed by June 27, 1997
	_	98% of the loops are operational (all should be by February)
	_	Eagle assigned the SCOOT contract by Siemens as a US subsidiary
	_	Frank Tom steps down as the federal monitor and is replaced by Sylvia Tot from the FHWA LA Office for ITS Projects
February	_	Siemens leery of substituting VTDS for conventional inductive loops in the Disneyland area
	_	Concerns about police pre-emption during special events arise
	_	Siemens' SCOOT system software operational; however, Eagle needs to translate the UK commands to US commands
	_	SCOOT hardware will arrive in late-April
	_	Siemens contract still not finalized due to insurance concerns
	_	JHK to be finished with Toe modifications by the mid-March
March	_	Siemens wants to install new SCOOT detectors at selected locations and recommends detectors for the left turn pockets at Katella and Douglas
	_	JHK needs firmware from CSC to continue the integration with UTCS
	_	Evaluation Team distributed Task A Evaluation Field Test Plan
	_	Evaluation extension and budget increase approved by Caltrans
	_	Presentation of preliminary VTDS evaluation results to Partners
April	_	JHK to add system log to identify police pre-emption in field
	_	New Katella and Douglas left turn loops installed. All loops are operational within the SCOOT area
	_	City Clerk mailed the final signed Siemens agreement
	_	Final Evaluation contracts concerns resolved
	_	Evaluation Team distributed preliminary VTDS evaluation data
	_	JHK working on the SCOOT/1.5GC interface
	_	City agrees to hire a TOW student as an intern
	_	UPS has lost the SCOOT Apple workstation

Table 4.1 Anaheim FOT Event Time Line (cont'd)

1997 (cont'd)		
May	_	Evaluation Team made preliminary presentation of VTDS results
	_	JHK continued work on 1.5GC upgrades for SCOOT interface
	_	SCOOT firmware and equipment functional at three intersections; all SCOOT equipment has been installed
	_	Remote switching between UTCS and SCOOT available
June	_	JHK encountered only a few problems related to SCOOT integration
	_	Siemens works with City to resolve communication and detector problems
	_	Evaluation Team formally presents VTDS evaluation results
	_	Odetics criticizes evaluation methodology
	_	A cellular phone purchase facilitated the completion of field calibration
	_	SCOOT is running on all 18 intersections in the SCOOT network
	_	Presentation of final VTDS evaluation results to partners/EOT
July	_	JHK holds Softgraph training
	_	New Principal Traffic Engineer assumes position
October	_	Delivery of first draft Task C Evaluation Report
Oct - Nov	_	SCOOT evaluation field tests
December	_	Caltrans/PATH approval of Task C Evaluation Report
1998		
January	_	FHWA/BAH complete review of Task C Evaluation Report
February	_	Final Task C Evaluation Report submitted
March	_	Official end of Evaluation Team contracts
April	_	Preliminary presentation on Task B Institutional Evaluation Report
May	_	Preliminary presentation on Task A Technical Evaluation Report

June-July _ Draft Task A and Task B Final Reports submitted for review

4.4 Interviews with Key FOT Participants tc "4.4 Interviews with Key FOT Participants " \l 02

As part of the institutional evaluation, key project participants were interviewed by members of the evaluation team. The interview process began in January 1997, with final interviews and follow-ups occurring in June 1998. The decision was made to interview key individuals from all the agencies and firms that participated in the project, with the exception of participants from Odetics, since this firm was involved in only the VTDS component of the FOT and had minimal interactions with many other participants (an assessment of institutional aspects of this component of the FOT can be found in the Task C Final Report (MacCarley, 1998). Individuals who were interviewed included participants from the City of Anaheim, JHK/Transcore, Siemens, Eagle Signal, Caltrans headquarters, and the FHWA. Additionally, the evaluators interviewed selected FHWA administrators in Washington to obtain a national view of the project. Under some circumstances, the evaluators conducted follow-up interviews to clarify certain concerns.

The interviews were structured on a series of questions common to each defined groups of participants (some questions were common between groups). These three groups were (1) high level administrative participants, (2) project management (key agency and firm participants), and (3) engineers and technicians. Each person in these groups was separately interviewed by a single member of the evaluation team. During these interviews, an open format was utilized to encourage greater depth and breadth of discussion. Initial interviews averaged 1.5 to 2 hours. Copies of the questions are provided in an appendix, however, please note that the respondent did not see the questions prior to or during the interview.

Brief summaries of background and project role are provided for each interviewee in the next section, followed by summaries of the interviews organized by general topics as defined by the predetermined questions. Several specific issues generated more intense, interrelated discussion; these issues are summarized as cross-cutting issues in section 4.8. Findings associated with the interviews are synthesized with other qualitative data in the following chapter summarizing the overall findings of the institutional evaluation by project objective.

4.5 Participants tc "4.5 Participants " \l 2

A brief description is provided of the roles played by key FOT participants who were interviewed.

1. Mike Freitas (Chief, Fleet and Rural Systems Branch, FHWA) manages the Booz-Allen & Hamilton contract for the FOT program. To provide evaluation assistance for the FOT evaluators, he instigated this contract in June 1994. He participated in some of the technical reviews of FOT proposals.

2. Alberto Santiago was Chief, Traffic Systems Branch, FHWA, but left for a position with National Highway Institute during the project. His involvement in the FOT program began in 1991 after ISTEA passed, and he participated in the evaluation of several FOT proposals. As a recognized ITS expert, he provided technical assistance to the national FOT program. His interest in the Anaheim FOT was driven by his expertise in traffic control, particularly in adaptive control. He expressed personal interest in this project, its interfaces, and the questions it hoped to answer.

3. Frank Cechini (ITS/Information Technology Engineer, FHWA) served as the FHWA project manager for the Anaheim FOT. As project manager, his role was to insure the completion of the FOT according to the stated goals and objectives and, most importantly, to insure the completion of an unbiased evaluation.

4. Richard Macaluso, Caltrans Office of New Technology, served as the contract manager (federal funds passed through Caltrans to the City of Anaheim). He also handled all of the technical reviews for Caltrans. His involvement with the FOT commenced in March 1994 when he assumed responsibilities to establish the initial contracts, handle invoicing issues, and manage budgets.

5. Jim Paral was Principal Traffic Engineer for the City of Anaheim from 1992 through November 1996 when he left the City for another opportunity. He was involved in virtually all stages of the evolution of the FOT. Originally hired in 1989 to manage the TMC, Paral worked under Don Dey, then Principal Traffic Engineer, and assumed that position when Dey himself left the City for another opportunity.

6. John Lower, Traffic and Transportation Manager for the City of Anaheim, initially served as the principal-in-charge for the FOT project, with Jim Paral reporting to him. Upon Paral's departure from the City in November 1996, Lower was named by Gary Johnson, Anaheim's Director of Public Works, as Project Manager. While he served as principal-in-charge, John spent most of his time on other City projects (including the I-5 widening and Disneyland expansion). As project manager, he was responsible for completing contractual extensions with Caltrans and contractual arrangements with Siemens.

7. John Thai, Principal Traffic Engineer for the City of Anaheim, joined the City in July 1997, filling the position vacated by Jim Paral in November 1996. He assumed responsibility for technical oversight for SCOOT implementation and operations.

8. Malcolm Slaughter, attorney for the City of Anaheim, advised the City on legal matters and on the Siemens contract, in particular. He represented the City in contractual matters, but was not concerned with technical issues and negotiations regarding SCOOT.

9. Chris Dahl, Associate Traffic Engineer for the City of Anaheim, handled equipment operations for the Anaheim FOT. He was in charge of traffic systems maintenance for the City, having worked for six years in this capacity.

10. Hoan Nguyen, a Systems Engineer for the City of Anaheim, was responsible for TMC maintenance and signal timing translation. He has been employed by the City since 1987 when the City established the TMC. He has a degree in electrical engineering.

11. Yo Baba, an Associate Traffic Engineer for the City of Anaheim, oversaw operations of the TMC during the FOT and assisted with administration and installation.

12. Mike Krueger served as Project Manager for JHK/Transcore, the contracted system manager for the City's traffic control system. He was responsible for the integration of SCOOT and UTCS and for the implementation of 1.5 Generation Control (1.5GC). From 1992 through February 1993, Alan Clelland had served in this capacity, and in October 1995, Glenn Havinoviski succeeded Krueger as project manager.

13. Glenn Havinoviski, JHK/Transcore, served as the overall system designer for the

Anaheim FOT, responsible for system architecture and functional requirements. He worked on the project from July 1995 to February 1996 and was also responsible for identifying deficiencies and requirements for 1.5GC. After Glenn left, Teresa Squires assumed his technical role and Krueger re-assumed the Project Manager role.

14. Teresa Squires, JHK/Transcore, was the On-Call Support Manager for the City of Anaheim TMC, filling this position since 1992. For the FOT, she concentrated on testing 1.5 GC and integrating SCOOT into the existing system.

15. Tim Allan, Siemens, served as the Project Engineer for SCOOT implementation. His involvement began in November 1995 in the development of the Siemens proposal in response to the City's RFP. His formal duties included SCOOT equipment tendering, procurement, and installation, and SCOOT implementation, validation, and training.

16. Mark Hudgins served as the Project Manager for Eagle, Siemen's US-based affiliate. In the original 1992 FOT proposal, Odetics selected Mark as part of the VTDS team, but he was not involved in this capacity. In January 1997, Mark assumed responsibility for contract management for Eagle, working with Siemens on the SCOOT installation.

4.6 Summary of Interviews tc "4.6 Summary of Interviews " \l 2

The evaluators organized each interview into sections based on broad areas of inquiry including (a) project goals and objectives, (b) implementation, (c) funding, (d) working relationships, and (e) summary comments. Each set of comments and responses, as expected, both shared commonalities and expressed differing opinions.

4.6.1 FOT Goals and Objectives tc "4.6.1 FOT Goals and Objectives " \l 3

The purpose of these questions was to elicit individual opinions on the evolution of the Anaheim FOT in terms of overall project goals and objectives. Questions related to the development of both initial and revised project goals, defined locally and relative to the national ITS program.

The Role of the Anaheim FOT

Most respondents believed that the Anaheim FOT held an important role in the national FOT program because it considered adaptive control, specifically SCOOT, using existing infrastructure. One respondent, however, said that it held relatively minimal importance because the FOT addressed a single technology rather than integrating multiple technologies. The evaluators asked high-level administrators to indicate the overall importance of entire statewide FOT program in California. While the national significance of individual FOTs varied, the California FOT program stood in the spotlight because other states tended to follow California's early response to ITS technology implementation. Additionally, many states followed Caltrans' specifications and the state had established a reputation for following through on projects.

All respondents focused on SCOOT in expressing their opinions for this FOT's selection as part of the national FOT program. Some reasons mentioned for its selection included field testing SCOOT in an existing network with protected left-turns and SCOOT's performance in a region with atypical peaks. Most participants, however, indicated the opportunity to investigate SCOOT within an existing infrastructure as the prime rationale for FOT selection. Some high-level respondents indicated that the FHWA's previous experience working with the City of Anaheim and the City's strong traffic background exerted a minor influence on their decision. These factors combined with the favorable weather conditions in southern California indicated that the project could be started and completed quickly. While FHWA remained relatively uninterested in VTDS, they hoped that it could tie into other technologies and provide greater reliability over conventional loop detectors.

Virtually all respondents who addressed potential national impacts focused on increased interest in adaptive control, particularly in applications using existing infrastructure. One respondent believed that this FOT could validate the use of adaptive control during special events. Another expected the FOT to test the capability of integrating foreign technologies with domestic systems. Finally, several comments focused on the outcomes of the evaluation: whether VTDS is ready to replace loop detectors and whether SCOOT represents an improvement over convention actuated control with time-of-day plans.

The evolution of the role of individual firms or agencies in the FOT was also addressed. This evolution is addressed from an historical perspective in a prior section of this report, incorporating information gathered as part of the interview process.

Goals of the Anaheim FOT

Responses relating to project goals were fairly detailed (see sections 2.3.1 and 2.3.3 for FOT goals and objectives) although it should be noted that the SCOOT provider, as an outside contractor, had no knowledge of the specific FOT goals and objectives. Over half of the interviewees stated that SCOOT performance within an existing infrastructure was the primary FOT goal while several others mentioned SCOOT performance during normal and/or special event conditions. Other goals related to SCOOT included the institutional issues related to SCOOT implementation, familiarity with SCOOT for U.S. practitioners, SCOOT transferability, and SCOOT algorithm performance. Overwhelmingly, the interviewees believed that the FOT was meeting these goals. The only comment addressing potential failure to meet defined goals related to contracting issues which had delayed the project and threatened project termination.

About a third of the respondents mentioned Video Traffic Detection System (VTDS), but few of them agreed on what VTDS was supposed to accomplish. Two respondents discussed the potential plan for VTDS to work with adaptive control (this was not attempted). Another remained unsure as to whether the initial goal expected VTDS to provide volume counts or simply presence detection (the final VTDS product evaluated performed presence detection only). While only three of the five respondents who mentioned VTDS as a project goal thought that the related goals were met, representatives of the firm providing this implementation product were not interviewed.

One third of the respondents mentioned the planned implementation of 1.5 Generation Control (1.5GC). One respondent mentioned the integration of SCOOT and UTCS as a goal, but the implementation was planned and completed in parallel rather than as a fully integrated system. Some respondents considered specific objectives such as the potential role of VTDS to maintain detection in construction zones or using 1.5GC and SCOOT to minimize staff time required for traffic operations. At this time, none of these operational goals have been obtained due to the limited implementation and evaluation of these technologies. Nevertheless, these respondents remained optimistic that long-term operations might see after-hour staffing requirements reduced.

Less than half of the respondents recalled any changes in the FOT's goals or priorities after the project started, however, the remaining respondents noticed a reduction in the scope of the project as a change. The City of Anaheim reduced the network for SCOOT implementation due to construction arising once the project was delayed. Several respondents suggested that 1.5GC had experienced a dramatic reduction away from the automatic generation of timing plans.

Most respondents believed that the FOT primarily involved implementation and operations. Siemens indicated that they had some development in response to implementation problems, and JHK/Transcore indicated that they had development tasks devoted to 1.5 GC although the algorithms already existed. Eagle stated that they were involved in some limited research and development on interfacing Anaheim's CSC traffic controllers with SCOOT. Respondent who indicated an R&D component provided ranges of effort in such tasks from 30 percent to as much as 90 percent for VTDS and 75 percent for SCOOT.

Evaluation Issues

As with many of the FOTs, it was initially unclear how project evaluation would proceed. Originally, JHK/Transcore planned to perform a self-evaluation of the project, and the City believed that an evaluator would be selected via a standard RFP process.

Only four respondents made comments regarding the evaluation team charter, but two people expressed comments about the evaluation procedure. The format for the Evaluation Team Charter was developed during the TravInfo FOT in northern California and was borrowed since the FHWA wanted to provide a mediation process between the evaluators and the partners. One respondent said the evaluation team charter played no role in the project since evaluation meetings were combined with general FOT partner meetings, while another felt like it highlighted the fact that the evaluation must remain independent. One respondent believed that the evaluation team became involved in the project much too early, and another believed that the meetings spent far too much time on the evaluation plan.

4.6.2 Implementation tc "4.6.2 Implementation " \l 3

This group of interview questions addressed the process of implementation, and considered project scheduling and deliverables, implementation costs, the contracting process, operational and maintenance policies, and technical issues in implementation.

Project Scheduling

Table 5.1 described each agency's assessment of its ability to maintain its project schedule. It also summarizes any problems that respondents for other partners may have identified. Overall, most agencies indicated that they maintained their schedules; where schedule delays were identified, respondents most often attributed these delays to contracting problems.

Table 4.2 Summary of Project Scheduling Problems tc "Table 4.2 Summary of Project Scheduling Problems " \f K

AGENCY COMMENTS FHWA The FHWA fully maintained its schedules and deadlines.
Caltrans Headquarters Caltrans experienced difficulties associated with the recent changes in the contract amendment process. See the Contracts section for further information. City of Anaheim All but one City representative indicated that the City did a fair job of maintaining its deadlines. The dissenting opinion believed that the City failed to maintain its schedule and needed contract extensions to complete the project. Delays associated with the request for proposals began the project's departure from schedule; problems magnified in ensuing months.

All outside respondents attributed significant delays in the project to the City's legal process in establishing a contract with Siemens.

Some delays were associated with the City undertaking construction activities or facing infrastructure problems which were not anticipated in the original project schedule.
JHK/Transcore Firm representative indicated that their firm maintained its deadlines. One representative indicated, however, that although their activity did not impact the schedule, the firm may have encountered delay had not other partners already extended their schedules.

Two non-JHK/Transcore respondents noticed some project delay due to the preparation of the SCOOT RFP by JHK/Transcore. Siemens The SCOOT implementation took 20-25 percent longer than originally anticipated because problems were encountered in translating from U.K. control to U.S. control. Eagle Eagle maintained its schedule, although some Eagle employees worked over-time, due to contract-related delays, to finish the project on schedule

Project Management

All partners emphasized that a breakdown in project management in the interval between the Siemens contract award and contract signing was a critical and potentially fatal stumbling block for the FOT. In fact, the SCOOT component of the project would not have been completed without the third and final contract extension. This delay also resulted in a reduction in the implementation time allotted to the Siemens/Eagle team and the City of Anaheim for readying the field equipment. One respondent, however, criticized the number of project extensions and complained that the project dragged as a result.

In November 1996, the City's Principal Traffic Engineer and FOT Project Manager left the City of Anaheim and, while FOT management responsibilities were quickly reassigned internally, a replacement for the open engineering position was not named for eight months. Prior to this change, some respondents identified a lack of coordination with respect to the contracting process, and half of the interviewees pointed to this change as one of the more critical events during the project. The new Project Manager needed to champion the cause of the project to obtain the final contract extension from Caltrans. It is quite possible, had not the required extension occurred entirely within the state fiscal year, that Caltrans may not have granted the extension and the project would have terminated. It is unclear what financial implication this would have had on the partners but it is relatively safe to say that SCOOT would not have been implemented.

The nature of this change in project management was detailed by two respondents, who stated that the original project manager was passive in his approach to management and that he was not sufficiently responsive to budget and invoice issues. His successor took a more active approach; after the changeover, the project moved through its revised schedule in a timely manner. At least one respondent believed that these problems occurred because the original project manager effectively accepted contract review and signing delays in the City's administrative offices, due to an excessive overall workload. With the engineer position unfilled for eight months, a variety of impacts were noted by respondents and their schedules. It is also important to note that, while both project managers were involved in the initial development of the FOT proposal, it was the first project manager who was primarily responsible for the proposal and for continuing the City's record of involvement in state-of-the-art applications in transportation.

Sixty percent of the respondents stated that maintaining an updated schedule did not influence their overall performance. One respondent referred to the schedule as useful, but unrealistic since it did not integrate all FOT participants. The project managers indicated that the schedule was required to maintain effectiveness by reflecting deadlines and identifying action items. These activities were more clearly defined in the last year of the project (at least one of the respondents stated that the schedule had effectively disappeared during 1996). Two contractor respondents indicated that internal, profit-related deadlines and interest provided motivation to independently maintain the project schedule.

Some partner activities impacted other partners' project tasks:

1. Siemens' SCOOT implementation was influenced by JHK/Transcore's assistance with data streams
2. the City of Anaheim prioritized their maintenance of SCOOT-related equipment.
3. When Odetics experienced difficulty in establishing wireless communications, JHK/Transcore stepped in as a sub-contractor and resolved these issues.
4. Some equipment purchases by Siemens and Eagle delayed JHK/Transcore's UTCS-SCOOT integration.
5. The City's integration of SCOOT with their CSC controllers and added SCOOT-related maintenance requirements extended the expected schedule for field implementation.

In general, most respondents believed that the partners were able to maintain their schedules and meet their deadlines, particularly after the resolution of various contractual problems.

Implementation Costs

Seventy-five percent of the respondents indicated that their firm or agency failed to anticipate all of the implementation costs. Table 5.2 summarizes the unanticipated costs incurred by each agency and firm. Siemens anticipated all implementation costs and was able to maintain their budget. Implementation costs for JHK/Transcore exceeded expectations when the project experienced an major year-long delay, a delay which increased personnel costs. Additionally, JHK/Transcore encountered unexpected equipment costs. One firm respondent stated that JHK/Transcore spent more time than anticipated in the TMC assuming the City's role as liaison with Siemens, partially due to the departure of the City's Principal Traffic Engineer and Project Manager, a position which was not filled for eight months. Eagle was involved in more training than anticipated. It is possible that the presence of the Principal Traffic Engineer and continuity in the project management position could have precluded some of these unanticipated costs.

The City of Anaheim failed to anticipate all of the implementation and maintenance costs associated with SCOOT implementation. Traffic maintenance personnel invested sixty percent of staff time for one year to make SCOOT operational. The City also had to purchase additional computers and a cellular phone to complete SCOOT implementation. Siemens requested the cellular phone and a PC to provide a terminal connection into the system. Alternatively, SCOOT validation could use a two-way radio, but this would require a dedicated channel to avoid signal interference and a staffperson in the TMC assigned solely to receiving information and making changes. From Siemens experience, validation could be carried out more effectively when the person in the field had direct access to the SCOOT model and the validation parameters.

Table 4.3 Unanticipated Implementation Costs

AGENCY	UNANTICIPATED COSTS	REASON/CAUSE
Siemens	None identified	Not applicable
JHK/Transcore	Increased personnel costs due to salary escalation Unanticipated equipment costs Assistance to Siemens during SCOOT installation	Contractual delays Open position for City Principal Traffic Engineer
Eagle	Extra travel costs Assistance with training	
City of Anaheim	Increase maintenance staff time Computer hardware, Cell phone	SCOOT field equipment requirements SCOOT validation

FOT Technologies

Respondents identified potential problems for all planned FOT technologies: SCOOT, VTDS, and 1.5GC.

SCOOT. Siemens stated that their inability to allow SCOOT to set offsets on anything other than the sync phases might have adverse effects on SCOOT's performance. Additionally, Siemens felt that the location of the loop detectors might cause some problems, and that these older inductive loops were not representative of the state-of-the-art as experienced in the U.K. (note that the existing detector system was defined in the RFP as that which would be utilized in the FOT). Siemens was forced to deactivate SCOOT's ability to upload/download SCOOT parameters from their proposed system because it would have involved a great deal of potentially dead-end development. Furthermore, the U.K. to U.S. translation forced SCOOT into using higher minimal cycle lengths than desirable. Finally, Siemens was concerned that a potentially poor evaluation resulting from the defined sub-standard implementation, might be taken negatively by potential clients.

Half of the respondents expected SCOOT's performance to be affected by the substandard detectorization. One expected these effects to be minimal while others expected a significant degradation in performance. Several did not feel qualified to assess the potential effect of substandard detectorization on SCOOT performance (noting that this was a potential task for evaluation). Two respondents dismissed the significance of the detector location problem, believing that other factors were a greater concern, specifically SCOOT's inability to control the offsets except with the sync phase and the lower than anticipated reliability of the data transmission system.

Other respondents mentioned other SCOOT concerns, including:

1. SCOOT/UTCS integration problems, especially regarding controller firmware
2. SCOOT's lack of system detectorization on freeway ramps in the project network that could cause a conflict with freeway operations.
3. SCOOT's incremental change might not be adequate for special events.

VTDS. Only three respondents mentioned VTDS, however, the decision to not interview Odetics personnel obviously precluded their comments. Opinions expressed mentioned the relatively unimportant overall role of VTDS in the FOT and the performance of the Odetics system in providing vehicle presence and not vehicle counts.

1.5GC. The 1.5GC control system received significant attention from many respondents. The original 1.5GC implementation project began in 1992 prior to the City's FOT proposal. This earlier version was not successfully implemented but the City hoped that the continued development of the system could both provide validated baseline signal timing plans and a means for data collection in evaluating SCOOT; it was thus continued as a component of the overall FOT project. Respondents suggested that, although the new version was operational, it failed as a practical tool (due to data requirements, dependence on system detectors, and computational time, the latter excessive despite the acquisition of a faster computer platform). Three respondents indicated that by April 1998, the TMC ceased 1.5GC operations. One respondent indicated that 1.5GC never functioned "on the fly", an ability that 1.5GC was expected to possess to function as a "man-in-the-loop" control system (between the first and second generation control systems such as UTCS and SCOOT, respectively).

In summary, over half of the respondents believed the current UTCS/1.5GC system and SCOOT were complementary, with two respondents viewing the existing UTCS system as a solid backup system. Two individuals mentioned the ability of 1.5GC to create timing plans, and mentioned potential interaction of this system with both UTCS and SCOOT. One individual expected the City to be able to dynamically switch between systems and another expected SCOOT to use the UTCS system's existing graphics and database. Several respondents believed that, with the existing UTCS system operating separately from SCOOT, the interface points between the SCOOT and UTCS networks might not perform well.

Operational Policy

Respondents were asked what changes, if any, they expected to see in TMC operational policies. Comments were varied with no real consensus on what policy changes would be needed or could be beneficial. Comments included:

1. three respondents felt that an operational policy was needed for 1.5GC
2. two respondents expected the City to increase their usage of 1.5GC while a third never expected to see it used.
3. three respondents suggested that TMC staff would require more training to utilize SCOOT, and one hoped to see a more positive attitude towards new tools and greater motivation to take risks and develop new policies.
4. two individuals mentioned the system's inability to upload/download SCOOT parameters as a limitation on future operational policy.
5. two respondents expected SCOOT to change operational policy for special events, ideally reducing staff assignments for minor events and handle freeway diversions without police intervention.
6. one non-City respondent expected the City to use UTCS for event operations and SCOOT during normal operations.

Maintenance Policy

Respondents were also queried as to what changes in maintenance policy were expected; seventy-five percent expected the City to change its existing policies. These respondents focused on the need for not only more training on multiple systems but also on developing a new maintenance policy that reflected the requirements of maintaining the increasingly complex system. The SCOOT system required certain changes, such as the need for additional personnel and a higher priority on maintaining SCOOT detectors.

The City desires to develop a new maintenance policy, but an increased budget is required to implement these changes. With respect to VTDS, the City of Anaheim needed to provide maintenance technicians with training for handling video and the equipment necessary to properly maintain the system. Currently, Odetics handles VTDS maintenance and training. With the SCOOT network tested in the FOT, the City of Anaheim needed to increase maintenance staff from four to six); with the planned expansion to the originally proposed network, the City will need seven or eight personnel in the maintenance department (see the summary of funding concerns for related maintenance issues). The City also recognizes a need to develop an active policy directed toward rigorous preventative maintenance and the development of emergency procedures.

4.6.3 Financial Issues

Every respondent indicated that the budget was sufficient to complete the project as planned, however, many of the agencies incurred non-budgeted expenses. The delays associated with this project increased administrative costs for Caltrans and other Partners. JHK/Transcore incurred non-budgeted expenses in serving as liaison for the City with Siemens and with SCOOT integration taking longer than anticipated. They also had unanticipated upgrade requirements for 1.5GC and mentioned the increase in the number of monthly meetings with the extended contracts. Eagle experienced non-budgeted expenses including increased travel and legal issues. The FOT budget failed to include money for maintenance; the maintenance department spent twenty percent of its entire 1997 budget on SCOOT. Additionally, the FOT failed to budget for expedited loop maintenance and repair as well as the increased maintenance requirements for SCOOT loops. The City also purchased two new computers and a cellular phone in addition to incurring increased staff time in the public works and the accounting departments. While working on the contracting issues, the City Traffic and Transportation Manager spent between four and six hours per week on this project. After this task, the project only required one to two hours per week.

Several respondents anticipated that a similar budget would be adequate to repeat this implementation in a similar situation, however, most indicated that budget modifications would be necessary, especially for the City of Anaheim. One respondent did not see a need to alter the SCOOT budget, but suggested that budgets for VTDS and 1.5GC might require at least twice as much money to insure full functionality. Several respondents recommended increasing the budget for integration. Another respondent expected maintenance to need a significant budget increase to repeat the implementation process in a similar situation.

Each interviewee was asked to indicate one aspect of the project that they would change if given a ten percent increase in their budget. One third of the respondents indicated that they would have spent the increase on improving the UTCS and SCOOT interface. Another third indicated that an improvement in TMC graphical user interface was warranted. Other suggestions included:

1. installing inductive loops in standard SCOOT locations and adding detection for left-hand turns.
2. extending integration time for additional testing and training.
3. collecting more evaluation data for the documentation and standardization of the implementation process.
4. expanding the SCOOT network to more intersections
5. making loop maintenance a standard activity rather than an intense project specific effort.

4.6.4 Working Relationships

In this part of the interview, each subject was asked both general questions relating to personnel issues and to comment on working relationships with each of the other agencies and firms.

The City of Anaheim. All respondents expressed concerns about the City of Anaheim's staff at one point of the project or another. All respondents believed that the change in project management that occurred had a positive impact on the project, serving as a catalyst to a project in serious trouble. One respondent stated that long-term relationships with the original project manager may have led to greater leniency in maintaining the project schedule. Another respondent indicated that the new manager demanded more accountability and approached action items vigorously. During 1996, one respondent felt a distinct lack of enthusiasm for the project from City employees.

Some TMC staffing concerns were expressed, including concerns about the number of temporary staff in the TMC (given SCOOT system requirements for knowledge of traffic systems) and about the lack of a Principal Traffic Engineer during SCOOT implementation (motivating and prioritizing the TMC team was judged difficult during this period). Various partners were impacted during this period. For example, JHK/Transcore assumed the City's role as liaison with Siemens. Finally, several non-City respondents mentioned the City's performance in contractual matters as being a key concern.

JHK/Transcore. As systems manager for the City, the initial role of JHK/Transcore was somewhat in the background. Nevertheless, Siemens had tremendous appreciation of JHK/Transcore and their impacts on the project, particularly as their role as liaison for SCOOT implementation came to the forefront. Although Siemens seemed completely satisfied with JHK/Transcore's performance, several other respondents expressed some concerns, including some difficulty in maintaining the project schedule and a perceived diminishing of their role over the course of the project. Respondents were aware of the defined responsibilities of JHK/Transcore in handling 1.5GC modifications and UTCS/SCOOT integration.

Siemens and Eagle. Siemens received almost universal praise for their work on this project, although one respondent suggested that Siemens needed to be on-site longer than they were (suggesting an entire year). JHK/Transcore believed their relationship with Siemens had a positive impact on the FOT and their own performance. Additionally, JHK/Transcore presence facilitated implementation by providing familiarity, contributions to problem solving, and a local contact for Siemens. JHK/Transcore believed that Siemens may have had difficulty without their assistance in completing SCOOT implementation (for example, Transcore's expertise with UTCS greatly facilitated system integration). Other respondents were pleased that Siemens was focused on correcting problems and that they maintained a presence after the contract ended to improve SCOOT operations. Interaction between Eagle and Siemens was limited prior to this project; this project contributed significantly to the further development of this relationship.

Odetics. Although the evaluators chose not to ask specific questions about Odetics, two respondents indicated that they observed a decline in Odetics' interest towards the end of the project. One of these respondents expressed his belief that no attempt was made to integrate VTDS with adaptive control, and that this occurred when Odetics decided to proceed quickly through their work tasks (note that the final proposal only mentioned the potential of such an integration and that Odetics proceeded on the approved schedule and that their work was not delayed as most other Partner tasks were). One respondent indicated a concern with the relative size of the VTDS budget (accounting for over half of the overall budget).

FHWA. None of the respondents thought that FHWA influenced their overall performance of the FOT, with several respondents noticing that FHWA concentrated their efforts primarily on the evaluation. One respondent indicated that this FHWA focus on the evaluation reflected national interests rather than a focus on the specific technologies. Another stated that FHWA time was directed toward maintaining the evaluation schedule rather than the partner's schedule. One respondent believed the FHWA impacted the FOT by directing the focus of the project into using existing infrastructure as opposed to focusing on a test of a full SCOOT implementation.

Caltrans. None of the respondents believed Caltrans impacted either their performance or the overall FOT. One respondent thought that the Caltrans might have had an indirect effect on the funding and contracting problems encountered in this FOT. Caltrans expedited the accounting side of the project after the change in project management occurred, but few respondents mentioned Caltrans' project responsibilities.

The Evaluation Team. None of the respondents believed the evaluation team had a significant effect on the FOT's outcome, however, most of the interviewees mentioned evaluation topics. The evaluation team role was recognized as the evaluation of the FOT's goals and objectives, the successes and failures of the entire project, and the technical and institutional impacts of implementing SCOOT in a UTCS system (as well as the effectiveness of VTDS). Only half of the respondents recognized PATH's role as the formal evaluator (with evaluation team members officially sub-contractors to PATH).

4.6.5 Concluding Interview Comments

The last portion of each interview dealt with general queries as to the effect of various issue categories on the FOT project's overall performance. These issue categories followed those defined in the Evaluation Plan for the Institutional Assessment.

Administrative and Financial Issues

Each interview subject realized that administrative issues, specifically not addressing contractual issues effectively and efficiently, threatened project continuation. Several respondents attributed this problem to the lack of a dominant project manager, a situation that was partially resolved when the City appointed the City Traffic and Transportation manager to the open position. Some respondents elaborated, indicating that in early 1996, City attorneys lost the SCOOT contract. The rigidity of Caltrans fiscal year requirements also threatened the project; however, the Partners successfully argued that an extension within the current fiscal year would allow the project to be completed without confounding state contractual and budget concerns. When this contractual issue was resolved, Siemens found it difficult to provide Anaheim with the proper insurance documentation because the City's legal department continuously changed their requirements. Furthermore, the project required the City to float consultant payments until reimbursed by the state, a factor which could have financial implications in smaller municipalities. The Field Operations Supervisor required a fifteen percent budget increase to maintain SCOOT as deployed in the study area and estimated that City-wide deployment would require a fifty percent budget increase.

Personnel Issues

Half of the respondents indicated that the project lacked leadership at times during implementation due to changes in the project manager position and the vacancy in the City's Principal Traffic Engineer position. Several respondents commented that they were surprised that the position was not rapidly filled. At times during implementation, City staff was observed as over-burdened. Several respondents thus suggested that the City needed to increase TMC personnel, particularly adding personnel with greater experience and qualifications in traffic operations. A City respondent indicated that there was a lack of dedication to the project from signal maintenance staff. One respondent suggested that had the City's signal maintenance department been brought into the project at an earlier date, perhaps some of these issues could have been addressed.

In general, respondents believed that the number and quality of personnel assigned to the project were positive influences on project implementation. Several individuals suggested that additional personnel may have improved the implementation process for SCOOT, including a person from Siemens in communications and a City or Siemens person with SCOOT experience for on-going training and operational needs. One respondent believed that additional personnel could have advanced the development of both 1.5GC and VTDS, with potentially positive project impacts. Other personnel comments included:

1. future SCOOT training may be problematic, especially for the many part-time interns employed in the TMC
2. TMC operators needed substantial hands-on experience with SCOOT to effectively utilize that system vis-a-vis UTCS.
3. project management may be better placed in the private sector (suggested from both an implementation and an evaluation perspective).

<u>Legal and Liability Issues</u>

The primary legal issue involved a range of contractual matters, the greatest of which was the difficulties in the City/Siemens contract (discussed in a prior section). Respondents also indicated that legal issues affected work by both JHK/Transcore and Siemen because of copyright and ownership issues. Siemens accepted full liability during implementation. A representative of FHWA suggested changing the FOT process to contracting directly with the lead agency for design-build projects and design-build-operate projects to avoid some of the problems that impeded progress on this and other FOTs.

Technology Issues

Respondents were fairly equally split in assessing technology integration. While one third thought that FOT technologies were fairly independent, the remainder considered SCOOT integrated with existing UTCS. Half of this later group mentioned several integration issues such as problematic differences between English and American traffic control systems (especially differences in firmware) and somewhat anticipated problems of installing SCOOT into an existing system. It should be noted that most of those who considered SCOOT as independent also felt that there were UTCS system constraints which did affect SCOOT.

Field operations could have used additional personnel due to the necessary system changes required for SCOOT implementation. The City allocated all of its maintenance personnel to establish full functionality in the test area. It was difficult to assess continual expenses in maintaining a new technology versus one-time implementation expenses since the degree of field maintenance for SCOOT versus UTCS was not known.

Evaluation Issues

Several suggestions were made relative to evaluation issues; these can be categorized as relating to the evaluation process or to what was being evaluated. Relating to the process, responses included improving the evaluation by increasing funding which would allow for improvements in the quantity and quality of field data and having SCOOT implemented and validated sooner which would allow for more time for training and practice prior to the evaluation.

Relating to what was being evaluated, several respondents called for a greater focus on a 1.5GC implementation that would allow for a meaningful evaluation while others recommended that SCOOT be the only technology or that a greater effort be dedicated toward establishing a better design for the existing system. All respondents recommended that their agency or firm participate in future field operational tests; Table 5.3 summarizes the reasons for this support.

Table 4.4 Reasons for Recommending Participation in Another FOT

Agency	Reasons
FHWA	System testing was an important element of the implementation process.
Caltrans	Caltrans remained interested in testing the new technologies.
Anaheim	FOT provided the City a valuable learning experience and additional funds. The FOT accelerated capital improvements and provided a method to transition from UTCS.
Siemens	The SCOOT vendor role suited this firm in an ideal manner.
Transcore	FOTs provided experience with new technologies.

<u>Operational Issues</u>
While over half of the respondents believed the partners adequately planned for the operations, maintenance, and training needs of the new system, all of the City TMC staff believed that the project failed to plan adequately. The City staff emphasized the underestimation of the training needs, the overestimation of their operators' ability to switch to a new system, and the maintenance needed to meet SCOOT's requirements. One respondent remained concerned about the reduction in the scale of the network; he thought the construction schedule which caused the reduction should have been coordinated with the FOT project. Future questions relating 1.5GC and SCOOT were also anticipated.

SCOOT performance thresholds varied with City staff who suggested reductions of delay and stops ranging 0 to 10 percent relative to UTCS to continue or expand SCOOT operations. Since the City was pleased with the performance of the existing UTCS, one source said that SCOOT would need to show a significant improvement to replace UTCS, although a second respondent suggested that operators' workload constraints were equally important measures of effectiveness in comparing the two control systems.

Very different opinions were expressed relative to the performance required for use of 1.5GC, not surprising given the failure to implement a functional version of that control system. Original expectations for 1.5GC were high and, despite the problems and redefinition of system capabilities, many respondents were supportive of the continued development of this system. Potential benefits mentioned included reduction in staff time, improvement in traffic performance, and the ability to use 1.5GC to develop a timing plan management policy.

Opinions also varied relative to VTDS (again note that Odetics personnel were not interviewed). Some respondents did not feel that the system evaluated was accurate enough for the City to continue its use, while others believed its performance needed to be improved. Two respondents preferred a system with greater capabilities such as providing counts (versus presence detection) or other advanced features (such as area-wide tracking, turn movements, and queue measurements). At least one respondent indicated that the City may opt for the most inexpensive detector system, whether it be loops or VTDS, as long as effective presence detection was provided.

Anticipated Overall Project Results

A Federal respondent interviewed early in the project believed that the national FOT program would fail to meet its overall goals, but that the Anaheim and Irvine adaptive control projects had a good chance for success. Another federal respondent thought the local projects might influence national implementation.

The interviewees saw many potential short-term local benefits from the FOT. Two expected the FOT to provide better signal coordination and to improve handling of minor unstaffed events. Another expected SCOOT to prove itself as a viable alternative to UTCS, while another believed that management of special events would be improved even if 1.5GC did not prove itself.

The interviewees also shared opinions regarding potential long-term outcomes. Over half of the respondents believed that the Anaheim SCOOT system would be expanded to cover the entire City network using small incremental improvements. Another three sources indicated that this FOT might lead to the implementation of adaptive control or SCOOT in other areas throughout the United States. Other responses included suggestions that the FOT would provide a better overall understanding of SCOOT and that the project would improve inter-agency cooperation on related projects.

Siemens believed that this FOT would unlikely contribute to the technological development of SCOOT; however, Siemens found it potentially important to marketing as a showcase system. All of the partners except Siemens believed that the FOT was important in terms of SCOOT's operational development (Siemens stated that the Toronto project held greater importance). Some respondents believed that the FOT might impact SCOOT in operational terms by forcing it to adapt to domestic systems, leading to the deployment of SCOOT in the United States. Opinions also diverged relative to SCOOT's financial development, since Siemens regarded this as only a standard sized contract.

In operational terms, this FOT provided an opportunity for 1.5GC to demonstrate its potential abilities. While this FOT initially represented a critical step in the operational development of 1.5GC, JHK/Transcore no longer viewed this step as critical.

4.7 Cross-Cutting Issues

Three cross-cutting institutional issues surface upon review of participant interviews. These are in the areas of project management, the contractual process, and technical limitations.

4.7.1 Project Management

All partners emphasized that a breakdown in project management in the interval between the Siemens contract award and contract signing was a critical and potentially fatal stumbling block. In fact, the SCOOT component of the project would not have been completed without the third and final contract extension. This delay also resulted in a reduction in the implementation time allotted to the Siemens/Eagle team and the City for readying field equipment.
In November 1996, the City's Principal Traffic Engineer and FOT Project Manager left the City of Anaheim and, while FOT management responsibilities were quickly reassigned internally, a replacement for the open engineering position was not named for eight months. Prior to this change, some respondents identified a lack of coordination with respect to the contracting process, and half of the interviewees pointed to this change as one of the more critical events during the project. The new Project Manager needed to champion the cause of the project to obtain the final contract extension from Caltrans. It is quite possible had not the required extension fit entirely within the state fiscal year that Caltrans may not have granted the extension and the project would have ended. It is unclear what financial implication this would have had on the partners but it is relatively safe to say that SCOOT would not have been implemented. The nature of this change in project management was detailed by two respondents, who stated that the original project manager was passive in his approach to management and that he was not sufficiently responsive to budget and invoice issues. His successor took a more active approach;

after the changeover, the project moved through its revised schedule in a timely manner. It is also important to note that, while both project managers were involved in the initial development of the FOT proposal, it was the first project manager who was primarily responsible for the proposal and for continuing the City's record of involvement in state-of-the-art applications in transportation.

4.7.2 Contractual Matters

In September 1993, the FHWA obligated funds for the Anaheim FOT to Caltrans, who began development of their contract with the City, with the sub-contract to Anaheim to follow. It was recommended that these contracts be developed in parallel so that the ground work could be finished when the Caltrans contract was completed. Caltrans also conducted a pre-award audit of this project, a process that caused some delay in contract award.

During the course of the project, Caltrans executed three contract amendments; each time, Caltrans executed no-cost extensions for the project. The original cooperative agreement length was from August 16, 1994 to June 30, 1995; Amendment 1 extended the agreement until June 30, 1996, Amendment 2 further extended it until December 31, 1996, and finally the third amendment extended the agreement until June 30, 1997. Unfortunately, the State contract amendment process had been recently changed, with the new process requiring amendments to pass through two additional levels of bureaucracy within Caltrans, with final approval from the Deputy Director. The difficulties associated with this amendment process introduced considerable problems for the FOT. Several respondents recommended changes at the state level to expedite the contracting process. Respondents suggested that a contract similar to the LA Spread-spectrum FOT, where Caltrans simply forwarded funds, might solve some of the problems. Furthermore, handling amendments within the program could improve things. The City experienced difficulties dealing with a foreign company when working on the contract with Siemens. The City of Anaheim also spent considerable time in early 1996 negotiating with Disney regarding their park expansion plans.

The Deputy City Attorney advised the City on the Siemens contract. Typically, the City Attorney's office dealt with a local division of multinational companies as opposed to an overseas office; however, this office rarely contacted outside agencies directly. The Deputy City

Attorney did not recall having direct contacts with Siemens, stating that all communications occurred through the Traffic Engineering department. He further suggested that, in general, contract approval proceeded more smoothly with the City Attorney as an active participant in the negotiation process. He also suggested that all parties investigate legal issues at the beginning of the project to avoid legal problems and maintain project schedules.

The City's Traffic and Transportation Manager attributed a significant portion of the delay to a breakdown in communication between the traffic engineering department and the City Attorney's office. The Manager had frequently encountered problems with the City Attorney's office, but these problems were readily solved when directly addressed. The change-over in project management coinciding with the threat of project termination due to contractual delays seemed to reawaken the City. A Siemens' representative did not recall the contracting process being a problem on any prior Siemens project; however, as a technical representative, he stated that he was not qualified to recommend changes to this legal process. The FHWA monitor felt that FHWA should have created greater initiative on the part of other agencies with regard to contractual matters. It was also suggested that contractual headway appeared to be made each month when the project meeting date approached.

The evaluation team asked interview participants to recommend potential changes to expedite the contracting process. Most respondents wanted to see the contracting process simplified and all participants take a more pro-active approach in this area. Several respondents recommended increased attentiveness by the project manager and contracting agency, particularly with respect to the City contract approval process. Some comments were made relative to time lost resolving licensing requirements. One respondent suggested that this issue perhaps should have been waived or resolved at a later point to expedite the contract process. Several respondents attributed the change in Project Manager and having a key position vacant during the contracting process as a major causal factor in delay. Finally, it was suggested that alternative contracting vehicles be considered, such as private firms or universities, again as a means of expediting the contracting process.

4.7.3 SCOOT Technical Concerns

A subset of those interviewed were directly involved in technical concerns associated with SCOOT implementation, including operator acceptance, training, and SCOOT operational problems. After the original SCOOT training, none of the TMC staff members felt comfortable with SCOOT operations. The staff members wanted to see training include more hands-on practice and feedback as well as an increase in the depth of the training course. Other problems were identified with the first training session, including City staff schedules that precluded continuous attendance, differences in U.K. traffic control style and terminology, and the resulting limitations in communications between the instructor and trainees. Staff was divided on the utility of SCOOT manuals, particularly for more advanced system functions.

One staff member participated in a second training session after some experience with SCOOT had been gained. He strongly believed that this second training session was much more useful, but he suggested that the follow-up sessions be held more closely together (several months had passed between these sessions). After Siemens completed installation and testing in August 1997, the City had virtually no communications with them regarding SCOOT operations, due primarily to the eight hour time difference between the offices of Siemens' and the City.

The TMC staff remained divided over many issues surrounding SCOOT operations and performance. Only one staff member felt confident in SCOOT's ability to improve traffic conditions; others expressed reservations, especially with regard to accommodating left turns. The SCOOT system installed had incomplete graphics which made operation more difficult (note that this issue was a problem with integrating the City's existing graphic displays with SCOOT real-time data).

Each TMC staff member described the basic concept behind SCOOT operations somewhat differently. Similarly, their opinions differed on the utility of the SCOOT manual in problem solving. Staff opinions also varied on when SCOOT should be utilized (although only limited operational experience had been accrued at this point). Only one staff member felt confident in SCOOT's ability to improve traffic conditions; others expressed reservations, especially with regard to accommodating left turns. Finally, the staff offered varying opinions on the differences between UTCS and SCOOT (one found UTCS menu system more user-friendly as compared to SCOOT's windows-like environment, another thought that significant training was required and may limit use of SCOOT, and a third believed that the adaptive nature of SCOOT would lead to more widespread application and operator acceptance).

After Siemens completed installation and testing in August 1997, the City had virtually no communications with them regarding SCOOT operations, primarily due to lack of e-mail and international phone access and the eight hour time difference between Siemens' office and the City of Anaheim. As a result of staff's unfamiliarity with the system and lack of technical support, they spent three days trying to locate and solve the 7:30 pm shut-down encountered during the evaluation. The City's new Principal Traffic Engineer was forced to assume greater hands-on experience with the system in an attempt to resolve basic operational problems and to further address continuing problems when Siemens returned in April 1998. Note that this individual did not join the City and the project until July 1997 and necessarily had to learn not only SCOOT but all operational aspects of the Anaheim TMC. This lack of continuity contributed to both the occurrence of problems and delays in resolving them.

Eagle assisted Siemens with the SCOOT implementation, developing a front-end processor for SCOOT to communicate with intersection controllers. There were communication problems associated with these links to the CSC field controllers. Eagle also assisted Siemens with hardware installation and developed the switch to change operations from SCOOT to UTCS.

Siemens was aware that some communication problems remained after the initial implementation. Personnel resources were limited and a variety of technical limitations were inherited (including obsolete modems), however, the primary source of problems related to the checksums used with the existing equipment. The checksums utilized were not as rigorous as state-of-the-practice and were considered inadequate by Siemens for their needs. Random data flows such as traffic data are even less reliable in the checksum, and the data required for proper SCOOT operations required a reliability of one error in 360. Prior to the SCOOT implementation, the City of Anaheim system operated with a one in 100 error rate. In March, Siemens learned of these communication problems and returned to Anaheim in April. During this visit, the Siemens and Eagle team resolved the communication problem. Siemens experienced a great deal of difficulty handling the communication problems associated with what they considered a "vintage" system. Operational problems not attributed to limitations in existing data communications seem to be attributed to limitations in personnel communications because of the time difference and lack of direct phone assistance. The compressed time frame for implementation clearly impacted the project; nevertheless, communication limitations, both hardware and personnel, are considered important impacts as well.

4.8 TMC Operations - An Insider's View

As part of the evaluation process, a graduate student research assistant functioned as a staff member of the Anaheim TMC. The primary purpose was to provide an insider's view of daily operations of the TMC, under non-event and event traffic scenarios, both in the before analysis period (without SCOOT) and after SCOOT was activated and the formal technical evaluation was underway. It was also an efficient method by which to observe (a) current and evolving TMC operational policies, (b) implementation of FOT technologies, and (c) staff reaction to these technologies. The following is a brief activity summary of this member of the evaluation team while functioning as a staff member of the lead agency for the FOT.

4.8.1 Baseline TMC Operations

Duties of Anaheim Traffic Management Center include real time traffic control and the development, testing, and evaluation of traffic response plans. The TMC employs four full-time and several part-time staff. Full-time staff includes a Principal Traffic Engineer (the TMC Director), an Associate Traffic Engineer, a Signal System Engineer, and a Transportation Coordinator. Part-time employees include a Computer Operator and several TMC interns.

The Principal Traffic Engineer supervises all TMC work and oversees TMC contracts, budgets, and personnel. The Associate Traffic Engineer and the Signal System Engineer operate the UTCS-based traffic signal system, maintain system communications and databases for signal timing, and monitor traffic conditions at critical locations. The three staff engineers each have bachelor degrees in electrical engineering and have at least five years experience in traffic system management; they each have taken training courses in traffic operations. The Transportation Coordinator prepares and coordinates the schedule for events operation. He is also in charge of the Changeable Message Signs (CMS) system and the Highway Advisory Radio (HAR) system. The primary task of part-time interns is to dispatch calls to and from residents, field technicians, and the Anaheim Police Department. They serve as TMC operators during events. The Computer Operator also performs graphics and mapping tasks for TMC software. Most interns are undergraduate students in Civil Engineering. The TMC does not provide formal training for these interns; rather, their training is obtained "on-the-job" from experienced interns. This includes basic training on UTCS operation, especially with respect to operational policies during special events. In general, they are not trained relative to the operation aspects of UTCS nor relative to developing signal timing plans.

Non-event Situations

In non-event conditions, the TMC is staffed from 7:30 am to 5:30 pm. Since UTCS, the current traffic control system, has been in use for some time, the system generates few problems. Primary on-going work tasks thus involve maintenance of other elements of the traffic control system such as signals, detectors, and controllers. Given system stability, little time is consumed in adjusting signal timing. Daily, the TMC receives numerous complaints and/or suggestions (20 to 30 per day) regarding the city's traffic control system from local residents and visitors; problems are also reported by field technicians or police officers. The most commonly reported problems are related to signal operations (e.g. non-functioning bulbs, flashing signals, equipment failures). The problems regarding detectors and signal timing (such as excessively short or long phasing) are also frequently reported. Calls related to a signal equipment malfunctions are conveyed to the contracted signal maintenance firm. If mechanic problems are found in a signal detector, controller, or CCTV camera, the operator informs field technicians.

Event Situations

The wide variety of events and activities in the City attract many visitors to Edison Field (the Stadium), The Arrowhead Pond (the Pond), the Anaheim Convention Center, and, of course, Disneyland. The original FOT study area encompassed all of these major attractors; the final implementation excluded areas adjacent to Disneyland and the Convention Center, thus, the following pertains to operations at the two sport arenas.

Activities at the Pond or the Stadium usually start between 7 pm and 8 pm, with inbound vehicles entering the area about 2 hours before events, producing significant increases in PM-peak traffic congestion and changes in typical traffic patterns. A manual prepared by TMC engineers describes procedures for traffic operation for special events, including both inbound and outbound operation for the Pond, the Stadium, and for combined events. One operator staffs the TMC for such event operations. About two hours before an event, the event operator calls the Caltrans District 12 TMC (D12 TMC) to place messages on Caltrans Changeable Message Signs (CMS) on SR-57 and I-5 to guide drivers to appropriate entrances and exits for an event. Subsequent activity includes directing CCTV cameras to observe traffic condition at critical intersections. Event traffic will change the traffic pattern of the road network. A minor road during a non-event condition may become a major road during an event. In response, the operator must modify the UTCS system via upload-download procedures, based on observed inbound volumes and queue lengths, to implement an appropriate timing plan. In general, event procedures are well-established and function well.

4.8.2 TMC Operations with SCOOT

SCOOT was installed, tested, and fine-tuned by Siemens, who also provided four days of training to TMC staff. The first two days focused on SCOOT operational procedures, while the last two days focused on database and system management. All TMC staff attended the first two days, with training beginning with the theoretical background of SCOOT followed by the introduction of SCOOT commands. The last two days of training were directed to staff who will manage and maintain the system. The Evaluation Team did not believe that this training was sufficient for SCOOT operators to acquire suitable knowledge of the system in such a short time period. Operators who were part-time interns did not understand the theory nor connect it to operational aspects. Furthermore, the documentation provided by Siemens does not provide sufficient information regarding operation procedures, particularly regarding common operational problems and strategies to resolve such problems.

During training, only little discussion was observed between TMC staff and Siemens. At the time, it was unclear precisely what role SCOOT would play since the existing UTCS system was maintained in the study area (SCOOT was switched on/off on demand). It was thought that Siemens' training was for basic operations only, despite the specific application of SCOOT in this FOT to special event conditions in a sub-standard (by design) implementation. It is estimated that, with the exception of the Principal Traffic Engineer, operational staff only spent approximately one hour on practicing SCOOT. Their training experience suggested that the system would run independently once activated. No training was directed toward problem solving. For example, a system communication problem was identified by the evaluation team during the field study. By executing commands to record SCOOT messages while monitoring and recording traffic conditions, several intersections were identified where SCOOT was deactivated after 7:30 pm. Signal timing for selected intersections was compared with SCOOT estimates and were found to be inconsistent. Furthermore, some intersections were found to be disconnected or isolated from SCOOT operation based on SCOOT system messages. TMC staff were not trained nor were they given sufficient experience to identify such operational problems.

4.8.3 Summary and Comments

The policy for Anaheim SCOOT operation was not clear. Some TMC staff apparently believed that they would not be involved in the SCOOT evaluation tests and that SCOOT would not be utilized after these field tests, .reducing their motivation to fully learn the system. In the initial operation period following implementation, it was evident that SCOOT requires an operator who can observe the system and clear problems. In this sense, SCOOT may not eliminate the need to staff the TMC during events.

The SCOOT Users Manual lists more than 500 SCOOT messages, most of which are Fault Messages. It is doubtful that an operator will understand all of these messages without more in-depth training or greater operational experience. More extensive training sessions and experience with the manuals could provide clearer procedures to operate the system and resolve problems. The TMC hires interns for daily operations. While base UTCS operations are stable and are not impacted by the limited experience of these interns, SCOOT appears to demand more significant skills and experience. SCOOT will be more difficult than UTCS for an intern to learn to operate.

5. SYNTHESIS OF RESULTS

The institutional assessment was defined in terms of five primary phases (or goals). Each of the technologies implemented, 1.5GC, SCOOT, and VTDS, are considered in each phase. General research hypotheses were developed for each phase, however, the nature of this evaluation task was primarily qualitative, thus conventional quantitative techniques were not utilized. Although the institutional evaluation proceeded in parallel with the technical evaluation, the former is process-centered versus the effectiveness orientation of the technical evaluation. The five phases, each representing one evaluation goals (and numerous objectives) are:

Goal 1. Establish Baseline Institutional Status
Goal 2. Assess Institutional Issues in System Implementation
Goal 3. Assess Institutional Issues in System Operations
Goal 4. Assess Project Transferability
Goal 5. Evaluate of Project Maintainability

The first phase involves an historical assessment of the institutional environment in which both current traffic operation systems and planned enhancements have developed. The preceding sections of this report have presented, first, a review of the evolution of the FOT proposal and, second, a general assessment of institutional issues (drawing from prior work evaluating the City's Traffic Management System). The results of the two primary evaluation approaches taken, a systematic "fly-on-the-wall" review of the FOT in terms of institutional catalysts and constraints and a series of comprehensive interviews of key project participants, are synthesized with historical and other empirical evidence to provide a general assessment of institutional catalysts and barriers associated with the Anaheim FOT. Summaries are presented for each of the five evaluation phases/goals, each incorporating information from all sources. A focus of the assessment was to identify under what structure can ATMS strategies be deployed so that their effectiveness is neither reduced nor confounded by limitations posed by institutional issues.

5.1 Goal 1: Establish Baseline Institutional Status

The original evaluation proposal included two objectives under this goal; several other "objectives" were added *a posteriori*.

Objective 1.1 Prepare an institutional assessment of prior related work in the study area.

As identified in the Background section, the City has an extensive track record in advanced technologies and methodologies for traffic control, including the FHWA Demonstration program establishing the integrated traffic management system, the Katella Avenue study, the FETSIM program, and participation with the California ATMS Testbed. The City has capitalized on institutional strengths while monitoring potential institutional limitations. The City's track record, and that of the partners in general, strongly suggested that the Partners were eminently qualified to proceed, and that all initial parties were cognizant of potential institutional problems. The only open issue, from both institutional and technical perspectives, was the yet to be defined interaction with the SCOOT vender and the subsequent performance of that system in a sub-standard implementation (the few prior domestic SCOOT implementations involved full detectorization). The City and the system manager were experienced with the 1.5GC system, so few implementation problems were anticipated (although evaluating a "man-in-the-loop" system presented several unresolved data collection issues). It was hoped that 1.5GC could be utilized to up-date the City's signal timing plans to provide a reasonable baseline for SCOOT.

Objective 1.2 Identify and assess the constraints present in FOT proposal development.

The City's adaptive control plans were established prior to the FOT RFP. Various funding mechanisms had been sought to implement each of the technologies; the FOT program provided an ideal program to greatly enhance local matching funds for system development. The project offered much beyond a basic performance testing of SCOOT. The proposal addressed the use of both SCOOT and 1.5GC in parallel to the existing UTCS system, providing an arena for assessing technical performance and institutional issues in deployment. Implementing SCOOT in an American city with a conventional distribution of system detectors and evaluating its resultant efficacy was a prime objective. Consultant suggestions to add limited detectorization were not implemented to adhere to this original goal. Neither 1.5GC nor the VTDS were considered by sponsors as important as SCOOT, but the City was able to successfully incorporate these technologies into the proposal. The City and major transportation agencies in Orange County signed a Memorandum of Understanding that provided the foundation which resolved many potential institutional problems. Here again the City's track record assisted. In summary, many potential constraints in developing the proposal were not present because the City prior experience and effectively resolved these issues prior to the start of the project.

Objective 1.3 Develop a baseline status of current and planned technologies.

A review of prior development and implementation associated with the Anaheim TMC was provided above. Certain points must be emphasized. First and potentially foremost, the City's vintage timing plans could inflate the performance improvement of either of the planned control technologies. Given the experience of the City's system manager, integration of 1.5GC and SCOOT into the existing control system was expected to proceed without major problems. Problems which were foreseen included the limited prior success with 1.5GC, extensive use of part-time TMC operators with limited experience, and Siemens limited domestic experience.

Objective 1.4 Develop a baseline status of the current transportation infrastructure.

There was some concern with inter-departmental communications between public works and traffic operations. Construction plans were not raised in a timely manner; when raised, little information was available. Status of the control system was indeterminant; despite requests for timing plan vintage, it took time to determine that only an informal field "assessment" was completed for unspecified intersections at unspecified times in the preceding few years. FETSIM documentation was not available from the City. The existing system would require that improved communications be established and loops made operational for proper operations. The proposed network had potential problems which could lead to inconsistencies in SCOOT implementation. There were no known compatibility issues with existing system controllers.

5.2 Goal 2: Assess Institutional Issues in System Implementation

The FOT proposed the field implementation of capabilities which may be considered as compatible (1.5GC) and incompatible (SCOOT) with the existing control system, from the perspective of a readily integrable system. The process required considerable cooperation and coordination between all parties. Specific areas include interactions between (a) the City and the Partners, (b) the City and its system manager (JHK, now Transcore), and (c) currently deployed and proposed technologies and their operators. Of equal importance are interactions within the agencies which manage special events systems within the study area.

Objective 2.1 Assess coordination between the City and the system provider.

Once contractual matters were resolved, a high level of coordination existed between the

City and system vendors (Siemens for SCOOT, Odetics for VTDS, JHK for 1.5GC). Significant problems did exist prior to approval of the SCOOT contract (due to differences in US and UK attorney terminology, licensing disagreements, and whether there was sufficient time to complete the project) and some communication problems existed after implementation (due to the time difference between Anaheim and the UK and the lack of TMC international calling privileges).

Objective 2.2 Assess coordination between the City and its system manager.

JHK, the City's system manager, clearly had played and continued to play a significant role in defining the proposal, selecting the SCOOT provider, and coordinating systems implementation. They provided much needed expertise while the City staff vacancy existed during SCOOT implementation. They were not, however, experienced with SCOOT and therefore could not anticipate many of the subsequent problems. They were also unsuccessful in implementing the 1.5GC system. It did not appear that the City was aware of the devolving nature of 1.5GC capabilities until late in the project.

Objective 2.3 Assess the impacts of inter-agency cooperation on systems implementation.

There appeared to be a high level of interagency cooperation between all FOT partners. The problems that arose were attributed to management, contractual, and technical issues. There was also a high level of cooperation with the Evaluation Team monitoring negotiations, contracting, planning and design, and implementation of proposed technologies.

Objective 2.4 Assess impact of implementing a new technology into an existing control system.

The primary implications involved operator acceptance and impacts on other functions. While there were some technical issues in system integration, these were resolved. TMC operators did not appear enthused relative to SCOOT, due to a variety of factors including resistance to change, limited training, lack of an operations policy, and current work loads (especially during special events). Maintaining the enhanced system was also seen to be a significant future problem, not just with respect to the added TMC hardware and software, but due to greater dependence on field instrumentation.

Testing a sub-standard SCOOT implementation sounded good *a priori*, but the degree to which it was substandard was not fully recognized until after system activation. It was also unclear what role 1.5GC would play. Initial plans to evaluate it as a SCOOT and UTCS alternative were dropped when its functionality became apparent.

Objective 2.5 Assess overall FOT Project Administration.

On a local level, project management was a critical institutional impediment. The project manager for the City of Anaheim changed at the beginning of project development, and again at the beginning of the SCOOT implementation process. The third project manager was quite successful in resolving contractual matters, re-establishing accountability, and pushing action items to bring the project in on time. Some responsibility for legal delays must rest upon the project manager. The FOT Evaluation Oversight Charter was an initial stumbling block from the perspective of the Evaluators who concluded that such a document presented limitations on an unbiased evaluation. It is somewhat ironic that oversight of the Partners may have prevented some of the project management, contractual, and technical problems that arose. On the Federal and State level, the laissez-faire approach of project monitors was a limitation. Oversight was particularly lacking when critical decisions had to be made (relative to 1.5 status, SCOOT legal issues, network problems, project schedule).

Objective 2.6 Assess staffing and personnel issues in the City.

SCOOT training was limited and there was a noticeable lack of continuity in City attendance. There was some concern regarding staff qualifications for multiple operating systems. Local knowledge of the baseline system was weak, despite the presence of the TMC. Staff dependency on the system manager, especially with respect to 1.5GC, may have limited them in gaining relative experience. Such limitations, however, may also be indicative of insufficient staffing (note that a member of the Evaluation team functioned as a system operator and contributed to the identification of SCOOT operational problems). Some institutional issues (legal, construction) appeared beyond the control of the traffic group, and it was uncertain what the Public Works Director's role was in dealing with City legal staff and City Council.

Objective 2.7 Technology Issues

Several technical issues were not anticipated; most important were those involving SCOOT communications. Neither the existing field communication system nor the City's CSC T-1 traffic controllers could provide full functionality for SCOOT. This is attributed to lack of domestic experience for the SCOOT provider (and of course the City). The VTDS system provided presence detection only, despite plans to provide full traffic counts. The VTDS was considered as still in development during the early part of the FOT (subsequent modification may have ameliorated these limitations). Similarly, the planned functionality of 1.5GC was never realized, despite years of on-going planning and development. Several operational problems in SCOOT resulted in part of the field test data being discarded since SCOOT had effectively shut down during data collection (the problem was resolved but limited the subsequent evaluation).

Objective 2.8 Legal & Liability Issues

Contractual issues in SCOOT licensing threatened deployment. Intervention of the City's third project manager and support of all project participants effectively accelerated resolution of these issues and a contract was in place in time to complete the implementation.

5.3 Goal 3: Assess Institutional Issues in System Operations

The development of operational policies for the arterial network were not formalized prior to system start-up (nor have they been since). It was anticipated that the effectiveness of these policies with respect to common institutional issues (such as personnel, liability, risk management, maintenance, etc.) as well as to preliminary operational problems would result in a dynamically developing set of policies for each independent technology, as well as for the system as a whole. It is possible that institutional barriers associated with each independent component preempted a system optimal operational policy with respect to technical efficiency. New experiences mixed with existing technologies in a complex institutional environment were expected to precipitate new reactions and new institutional policies.

Objective 3.1 Assess the evolution of operational policies relative to institutional issues.

Many issues addressed in system implementation contribute to potential issues in system operations. Unfortunately, there was no real shakedown period preceding evaluation and only limited experience with SCOOT since, therefore, it is not possible to draw formal conclusions. More critically, only a draft operation policy currently exists. This is particularly limited with respect to special event operations, one of the major reasons for testing SCOOT. SCOOT training is still considered inadequate, despite a second session several months after system startup. The lack of knowledge and training complicates system utilization. It is recommended that the City review task assignments and operational policies in the TMC. Finally, system displays do not provide TMC personnel with enough information while SCOOT is running.

Objective 3.2 Assess the impacts of inter-agency cooperation on systems operations.

There were limited operational problems impacting performance of local freeways. Lack of advance detectors on off-ramps leading to SCOOT controlled intersections initially caused spillback onto the freeway. Nevertheless, the high level of coordination between these agencies quickly identified and resolved the problem.

Objective 3.3 Assess the impacts of risk management on system operations.

Risk management is a primary consideration in any municipal activity, and of particular importance in traffic operations due to obvious safety concerns. The combination of improved flow and safety through advanced traffic management with a large portion of the financial burden from other agencies makes projects such as this favorable despite potential risks. The lack of a formal policy and commitment to SCOOT precludes formal conclusions.

5.4 Goal 4: Assess Project Transferability

Recommendations relative to project transferability necessarily require full consideration of all project components judged primarily by the ultimate indicators of success defined by measures of performance. Given technical feasibility of the various technologies and acceptable performance, the potential for success now becomes primarily defined by institutional concerns. Ultimate success in transferring these technologies is, of course, equally dependent on the transportation and institutional environment into which the transfer will be attempted. Only a relevant assessment of potential barriers (or catalysts) to success can be made.

Objective 4.1 Identify institutional barriers and catalysts with respect to project transferability.

The track record of Anaheim in related areas and the associated experience of City staff, as well as the overall climate toward advanced technologies in the City, County, and State, may limit transferability to areas where these conditions do not exist. Anaheim is not a conventional U.S. city, for both the presence of the above factors as well as the presence of the four major activity generators in the City. Institutional factors which may well be difficult barriers in most cities have been resolved in Anaheim well before the FOT was proposed. Barriers which were identified were judged as dynamic and difficult to project or address, such as turnover in key technical positions at critical stages of the project, and unprecedented legal issues.

Objective 4.2 Review prior institutional assessments in Anaheim and in related implementations to support the relative assessment of barriers and catalysts.

In a sense, the FOT itself is a test of transferability of an existing control system (SCOOT) to an implementation site for which the technology was not initially designed. Although SCOOT has been installed in a rather limited number of domestic locations, the Anaheim application is unique in its implementation in an area defined by traffic characteristics resulting from a high frequency of special events. Furthermore, in Anaheim SCOOT resides in parallel with an existing UTCS control system and utilizes only existing system detectors. As such, the evaluation of system performance is not directly comparable to other sites. The baseline system to which SCOOT can be compared is the existing UTCS system.

Objective 4.3 Assess technical barriers to transferability success.

It is important to reiterate that the intent of the Anaheim FOT SCOOT implementation was to test the system using standard domestic loop locations rather than recommended SCOOT locations. While the added cost of a full SCOOT implementation may preclude its widespread deployment in US cities, the limitations associated with the sub-standard implementation must be recognized. Given the technical difficulties in system implementation and initial operations, it is unclear to what degree loop placement has impacted SCOOT performance. This is a shortcoming of the evaluation effort imposed by the final project scheduling and budgetary constraints, and does not resolve this potential transferability issue.

Other Transferability Issues

Many factors affect SCOOT's transferability to other locations within the United States, some of which may be viewed as critical to a successful implementation. The City of Anaheim has provided substantial input relative to these transferability issues. Any agency interested in SCOOT should consider the manner in which these factors apply to their particular situation.

First and foremost, the United States (US) and the United Kingdom (UK) employ different traffic control styles. For example, the UK issues a green control bit to keep a signal green while US signals dwell in green until a force-off occurs. This difference in styles contributes heavily to the confusion felt by operators associated with the new system. When an operator is experienced with US style controllers, more time is required to adapt to the UK style (in addition to confusion introduced when switching between UTCS and SCOOT). Operators must learn new terminology for SCOOT; the command structure of SCOOT may impact an operator's ability to learn and use the new system. Even the writing style for a UK manual differs significantly from that for a US document.

An interested agency needs to survey their existing infrastructure to assess its ability to work with SCOOT. The existing infrastructure includes all of the controllers, loop locations, and communications equipment since any of these infrastructure components can affect SCOOT performance. The City's Principal Traffic Engineer does not believe that a TMC is required for SCOOT, but suggests that it may prove useful. If no or limited infrastructure exists in the area proposed for SCOOT application, then the new system can be more easily installed according to standard SCOOT specifications and guidelines, but the cost of such a system may be greater than that implemented in Anaheim. If infrastructure exists but fails to meet SCOOT guidelines, the agency needs to decide to replace it with SCOOT-recommended infrastructure or use the existing infrastructure and operate under probably suboptimal conditions. The City of Anaheim has decided to replace their existing infrastructure with SCOOT infrastructure.

The City of Anaheim observed significant problems associated with their operators' acceptance of the new system. The full-time staff complained that they did not understand it and it was not easy to use. Furthermore, new systems require a great deal of technical support and the staff need to use the support. The City of Anaheim's part-time staff may not be able to be trained to use SCOOT due to it's complexity as implemented. Current staff is reluctant to part with the existing traffic control software. SCOOT's graphical user interface (GUI) may pose problems for some operators because it needs improvements to become more user-friendly. The GUI needs to be adapted to U.S. rather than U.K. style control. Such improvements may help remedy operator acceptance problems.

Upon selecting SCOOT, an agency must decide upon the fate of any existing traffic control system. The agency can (a) replace the existing system, (b) operate the two control systems in parallel, or (c) integrate operations. Agencies must decide if they want or need area-wide SCOOT coverage. Individual intersections that run "free" normally will perform worse under SCOOT control. If an agency decides to extend SCOOT's coverage, the agency must also define any plans for system expansion. If finances or circumstances dictate controlled growth, then the system can expand in intersection clusters or by arterials.

5.5 Goal 5: Assess of Project Maintainability

An acceptable level of system performance defines a successful implementation only if such performance can be maintained. It is necessary to evaluate project maintainability; primarily, this involves maintenance of the physical system, continuity in administrative structure and policy, and suitable funding.

Objective 5.1 Identify and assess TMC and field hardware and software maintainability issues.

The City experienced difficulties preparing the infrastructure for the FOT. All major work required for the project was delayed until the City and Siemens approved their contract, therefore, the maintenance staff worked under the same reduced schedule that affected Siemens and Eagle. With the City's Principal Traffic Engineer position being vacant during SCOOT implementation, poor communications existed between field operations and TMC staff. This lack of communication exacerbated the maintenance staff's problems. The field operations staff found it impossible to meet some of Siemens' infrastructure expectations (given the vintage of field hardware such as 15-20 year-old cables). In response, Siemens reduced their communication expectations because the City's system seemed incapable of attaining them.

Objective 5.2 Assess feasibility of maintaining an operational test system in regular operations.

A complete assessment of project maintainability is not possible given the extremely limited period of system operation prior to and following the field test. Certain critical factors, however, were identified through the interview process (primarily with City staff) which suggest that there are unresolved issues in maintaining the system. The first such issue is, of course, whether SCOOT should be maintained. Technical assessment indicates marginal improvement in key performance measures. If maintained, direct observation and the interview process strongly suggest that additional and perhaps on-going SCOOT training is required. A key maintenance issue is the status of system detectors. Due to budget reductions, the City's loop detectors were not regularly maintained prior to the project; the cost of maintaining these loops (critical for SCOOT and UTCS) would be significant. The required communication infrastructure is expected to also require a greater maintenance effort. City traffic management must develop projected budgets and maintenance policies prior to fully addressing this objective.

Maintenance Issues and Cost Estimates Provided by the City of Anaheim

Many factors contribute to SCOOT maintainability, some of which are common to maintaining any traffic control system. Three critical areas require maintenance and sufficient budgetary resources: (a) SCOOT upgrade licensing, (b) TMC hardware and software, and (c) field hardware and software. These issues, their significance, and the associated cost estimates are provided by the City of Anaheim, and are included herein, without a critical evaluation.

The SCOOT installation in the City of Anaheim includes hardware installed in the TMC and the City's TMC staff is responsible for maintaining the SCOOT computer, including system backup (currently, the City performs a backup after any significant change to the database and each backup operation requires 30-60 minutes of staff-time to complete). The computer hardware itself requires maintenance and the City prefers handling most routine maintenance in-house. SCOOT requires numerous components to communicate properly with the in-field controllers. A CCU converts SCOOT commands to controller language and also converts information from the controller for SCOOT; this component requires $5-10,000 per year for improving and verifying operations, in addition to routine CCU maintenance. To switch operations between UTCS and SCOOT, the City uses a hardware switch that costs $2500, with an estimated 5-year life expectancy. Modems are utilized to communicate with field controllers (4 controllers per modem); each is replaced approximately every two years at a cost of $5-700 each. Digital to Optical Conversion Equipment converts modem signals to fiber optics for communications to the field hub; this requires $2500 per year to maintain. SCOOT also requires additional hardware for calibration purposes, including a lap top computer, a dedicated phone line, and a cellular phone. The City anticipates a 5-years life span for the laptop; the phone line and cell phone have monthly costs of $40 and $300, respectively.

Not only does the City plan to maintain the SCOOT software via a annual license, but they plan to ask Siemens to make SCOOT compatible with the new 2070 controllers. The SCOOT license costs $30,000 annually, but provides many critical support features. Siemens provides new software updates for the SCOOT computer and will continue to correct any bugs that occur. Additionally, Siemens provides unlimited technical support as well as one or two 1-2 day site visits to check on the SCOOT system. The City remains committed to changing their current controllers to state-of-the-art 2070 controllers. Unfortunately, SCOOt does not currently run with the 2070 software and Eagle must modify the CCU to translate SCOOT commands into 2070 protocols. The City estimates a one-time fee of $30,000 for these modifications.

The City needs to invest substantial funds to maintain field equipment, especially loop detectors.

The current SCOOT system incorporates eighteen intersections, but the City has plans to expand SCOOT to the entire network of 300 intersections. The City estimates annual expenditures of $1500 per intersection. Other field equipment includes the City's VTDS which costs about $2500 per intersection per year and field controllers which cost about $4200 per controller and last about five years. Finally, the TMC uses cameras throughout the City, with an associated cost of $8-10,000 per year. While the City currently has six cameras in the SCOOT area, they expect to increase camera coverage throughout the City with a total of forty cameras in five years. Finally, the City expects an increase in preventative and extraordinary maintenance related to SCOOT as well as an increase in the fine tuning required for system controllers, communications equipment, detector calibration, and modems. The regular preventative maintenance for SCOOT should be about three hours on a monthly basis per intersection. Extraordinary maintenance related to lost communications, failed system detectors, etc. may be up to four hours per intersection per month. Outside of the SCOOT system, the City needs to perform other routine maintenance on cameras, non-SCOOT intersections, construction damage, emergency calls, communication hits, and underground service alerts.

Many factors impact the future budgetary plans for the City of Anaheim. These include the signal maintenance budget, staff, and expansion. For a detailed justification of the City's maintenance needs, see Table 5.1 which shows the traffic signal maintenance budget and expenditures over the past ten fiscal years. The City anticipates a need for a new staff position to work exclusively with SCOOT; estimated salary and benefits are approximately $90,000 per year. Finally, the City of Anaheim expects to expand the existing system, with expansion cost estimates of $10-12,000 per intersection. Furthermore, the City expects to incur an additional capital expense for TMC equipment of $20,000 for every thirty intersections in the system.

TRAFFIC AND TRANSPORTATION DIVISION
BUDGET REDUCTION HISTORY
TRAFFIC SIGNAL MAINTENANCE

FISCAL YEAR	DESCRIPTION	ACCT. #	BUDGETED	% BUDGETED PREV. YEAR	AMOUNT EXPENDED	EQUIPMENT TOTALS
1988/89	Signal Maintenance Signal Damage	6235 6750	$556,854 $173,644		$530,100 $154,879	225 Signals
1989/90	Signal Maintenance Signal Damage	6235 6750	$573,900 $168,326	3% -3%	$453,398 $111,596	233 Signals
1990/91	Signal Maintenance Signal Damage	6235 6750	$703,783 $191,442	23% 14%	$988,577 $155,285	242 Signals, 9 CCTV Cameras 12 Solar Flashing Beacons
1991/92	Signal Maintenance Signal Damage	6235 6750	$547,645 $160,000	-22% -16%	$536,545 $157,697	248 Signals, 9 CCTV Cameras 7 CMS/Trailblazers 12 Solar Flashing Beacons
1992/93	Signal Maintenance Signal Damage	7725 8361	$604,567 $160,000	10% 0%	$549,055 $116,772	254 Signals, 9 CCTV Cameras 7 CMS/Trailblazers 12 Solar Flashing Beacons 6.5 Miles Fiber, 5 Fiber Hubs
1993/94	Signal Maintenance Signal Damage	7725 8361	$504,702 $120,000	-17% -25%	$507,924 $119,819	260 Signals, 18 CCTV Cameras 10 CMS/Trbzs, 1 HAR, 1 HAT 12 Solar Flashing Beacons 11.5 Miles Fiber, 7 Fiber Hubs
1994/95	Signal Maintenance Signal Damage	7725 8361	$457,459 $99,200	-8% -17%	$489,770 $102,462	261 Signals, 21 CCTV Cameras 23 CMS/Trbzs, 2 HAR, 1 HAT 12 Solar Flashing Beacons 23 Miles Fiber, 10 Fiber Hubs
1995/96	Signal Maintenance Signal Damage	7725 8361	$371,376 $90,000	-18% -9%	$426,697 $89,302	263 Signals, 21 CCTV Cameras 23 CMS/Trbzs, 2 HAR, 1 HAT 12 Solar Flashing Beacons 28 Miles Fiber, 10 Fiber Hubs 2 Video Detection Intersections
1996/97	Signal Maintenance Signal Damage	7725 8361	$405,654 $70,571	10% -22%	$378,435 $49,131	265 Signals, 21 CCTV Cameras 23 CMS/Trbzs, 2 HAR, 1 HAT 12 Solar Flashing Beacons 28 Miles Fiber, 10 Fiber Hubs 4 Video Detection Intersections
1997/98	Signal Maintenance Signal Damage	7725 8361	$379,998 $30,000	-9% -43%	$375,000** $42,000**	269 Signals, 31 CCTV Cameras 26 CMS/Trbzs, 2 HAR, 1 HAT 12 Solar Flashing Beacons 36 Miles Fiber, 11 Fiber Hubs 7 Video Detection Intersections

** Estimated for remainder of fiscal year.

Table 5.1 Anaheim Traffic Division Budget Reduction History

6. SUMMARY AND CONCLUSIONS

The administration of this project proved to be much more time consuming than anticipated, despite fairly extensive prior City experience with complex, multi-agency projects. This was due in part to a lack of precedence in developing legal agreements with international companies, and the necessary review and approval delays of city attorneys and councils. Initially scheduled to be completed within 18 months, it was not possible to commence the evaluation field study until almost 36 months after the evaluation contract was approved.

6.1 Baseline Findings

From a federal perspective, it was hoped that the FOTs would promote the development of ITS technology and provide a bridge between research and deployment. FHWA apparently assigned responsibility for deployment to the states. In the early phases of the FOT program, FHWA field staff were not fully prepared to handle evaluation issues and only limited central monitoring of individual FOTs was attempted. Federal sources suggested that the independent FOT evaluators had designed and conducted evaluations with mixed results; independent evaluators possibly had not met expected levels of performance in part because federal field officers could not provide sufficient monitoring and guidance. Most if not all of the FOTs have run behind schedule because of contractual problems. There was some sense that although the national FOT program would not meet all of its original goals, it had generated many ITS ideas and much experience with the deployment process.

Anaheim had committed to both SCOOT and 1.5GC well in advance of applying for the FOT program. The FOT project represented an opportunity for the City to obtain federal funds in support of their traffic control network. Several interview respondents suggested that 1.5GC was included in the FOT to provide additional funds to resolve its operational status. VTDS was brought into the project, in part, as an example of a public-private partnership, rather than as a necessary part of the package. Despite the City's long-term and comprehensive planning efforts, numerous problems precipitated from poor field maintenance, vintage timing plans, and unanticipated compatibility issues between domestic hardware and a foreign control system.

6.2 System Implementation

There were institutional ramifications of implementing a new technology into an existing control system, although most of these issues were technically-based. Coordination between City and Siemens was significantly impacted by the vacancy in the Principal Traffic Engineer position. Despite assumption of responsibilities by other TMC staff and, to some measure, by JHK, there was a decided lack of City experience and authority during the SCOOT implementation. A Siemens representative dismissed the significance of implementing SCOOT without detectors in standard locations but only because other factors represented a greater concern. SCOOT's inability to control the offsets except with the sync phase and field data communications (which were less reliable than Siemens had anticipated), represented the major areas of concern.

6.3 System Operations

A draft operating policy, which included full SCOOT usage except during special events, was implemented only at the end of the evaluation period, thus, no evaluation of operations under that policy was possible. Further training (April 1998) and experience was needed before the operating policy could be developed. Some difficulty was expected to be encountered in converting TMC operators to SCOOT primarily because operators were comfortable with the existing system and policy and saw no real advantages in converting. This provides further evidence that operator acceptance might represent a critical stumbling block, particularly when an existing control system exists in parallel to a new system. If management fails to commit to full-time SCOOT usage, then operator learning and acceptance may be slow or even not occur. If management commits to full-time SCOOT usage, then the learning curve could vary from three to six months depending on technical support. Finally, differences in manual style and terminology, as well as limitations in the user interface, may limit operator acceptance.

6.4 Project Transferability

The FOT was effectively a study in transferability -- implementing SCOOT, an "off-the-shelf" system, into a traffic management system which was not configured for standard SCOOT implementation. There is also the issue of transferability relative to the system as implemented. Siemens emphasized that they had sufficient experience with SCOOT to guarantee that they could deliver a SCOOT system within budget. This guarantee was made even in the unique environment in which the Anaheim system was to be deployed. To what degree advanced technologies which are not primarily off-the-shelf products can be similarly guaranteed is not known. This project, however, suggests that, in the case of systems such as the Odetic's VTDS and 1.5GC, products that are not widely deployed are essentially still in the research and development process and can encounter significant delays, cost overruns, changes in product specifications, and unsuccessful implementation. Despite a variety of implementation problems, both technical and institutional, SCOOT is functional. Given the sub-optimal system status during the evaluation period, further studies are required to assess actual performance impacts, but the results of this study do indicate that SCOOT can be deployed in place of or in parallel to US traffic control systems. Given the City's commitment to the continued implementation of SCOOT and VTDS, it is likely that more extensive experience with these systems will better define prospects and limitations with respect to transferability. In any case, from a lessons learned perspective, the results of this FOT should be of considerable value to other locations considering similar implementations.

6.5 Project Maintainability

While the primary goal of the funding agencies was the field evaluation of the new technologies, a key goal of the local agencies was to maintain the operational status of these technologies, if successful, beyond the test period. Significant costs, either unanticipated or simply not budgeted for beyond the formal test period, may potentially compromise project maintainability. These costs include TMC and field hardware and software maintainability. It is expected that the City will have to devote more time to training to continue to operate SCOOT effectively. The City has committed to expanding the original implementation and has developed initial cost estimates to maintain and expand the system as implemented in the FOT. These costs are significant. It is recommended that further field operational tests include post-project funding for maintenance of successfully-implemented systems.

6.6 Final Comments

The technical assessment of SCOOT's performance relative to the existing UTCS system is summarized in a separate document (see the Task A report, Moore *et al.*, 1999). Results suggest that improvement occurred where it was most expected, but the degree of improvement was significantly less than expected. The City is committed to the continued use of SCOOT, although an operational policy is still evolving. An assessment of the relative performance of SCOOT for event and non-event scenarios was limited due to system malfunctions during data collection. Field test results suggest that SCOOT performed comparable to current TMC operations of UTCS with active staff oversight during events, suggesting that the City's goal of reducing or eliminating staffing in the TMC during events may be feasible. At this time, however, the City has not committed to SCOOT operations during events.

Similar technical results could be drawn from the VTDS evaluation - the performance of the system tested was both limited and less than expected, although system cost was as proposed. The system provider has apparently replaced the product with an improved version which has been adopted by the City for deployment in construction zones. The 1.5GC system did not successfully meet its goals of either off-line plan generation in approximate real time or the generation of baseline plans for SCOOT comparisons. Nevertheless, the concept appears sound and participants were still supportive of the technology.

Two broad conclusions can be drawn. First, two of the three technologies implemented, SCOOT and VTDS, enjoyed limited success. Second, given these results, institutional and technical factors were identified which were critical in defining this performance. In this sense, the project was successful, although without more extensive observations under normal operating conditions, it may be premature to advise extended implementation in the City or elsewhere. Therefore, no formal recommendations are made at this time relative to potential success in transferring the technologies (although "lessons learned" in the implementation process should be most valuable to agencies considering implementing these or similar technologies). It is also difficult to fully assess system maintainability issues, due to the field test orientation of the project and the limited observation of system operations. Given information provided by the City, it is expected that fairly significant increases in traffic management costs would be realized if SCOOT operations were to be expanded. This report has summarized critical technical and institutional factors in system definition, implementation, and operations. The technical problems were judged as somewhat expected for a project of this scale. Institutional issues associated with project management and contractual matters were judged as unexpected and critical influences on the project. While they were ultimately resolved, their presence nearly terminated the project prior to final implementation. The degree of success for this FOT must be tempered by recognition of fundamental changes in project scope. The SCOOT network size was reduced by half; while necessitated by construction, this effectively removed the most critical (from both temporal and spatial perspectives) event site from the evaluation. The 1.5GC system was dropped prior to operational testing; necessitated by inability to achieve planned functionality, this failure was broader than the individual technology since this system was planned to be used to evaluate and update baseline timing plans in the City. Lastly, the functionality of the VTDS was reduced to presence mode only. Clearly, a fundamental limitation of ITS field operational tests is their inherent nature as research and development projects and not as pure operational tests. Some degree of project modification should be anticipated. What degree is a policy issue that project sponsors and promoters of these technologies must address.

7. REFERENCES

Blythe, KE and DeBlasio,AJ (1995). *ITS Institutional and Legal Issues Program: Analysis of ITS Operational Tests - Findings and Recommendations*, USDOT, DOT-VNTSC-FHWA-95-5 or FHWA-JPO-95-009.

Bowen,GT (1995). *ASTRID 3.3 User Guide*, Transport Research Laboratory, England.

Caltrans, City of Anaheim, and Odetics (1992). *A Proposal for Advanced Traffic Control System*, submitted to IVHS Corridors Program, FHWA Operational Test Division, Oct 19, 1992.

Caltrans, City of Anaheim, and Odetics (1993). *A Proposal for Advanced Traffic Control System*, submitted to IVHS Corridors Program, FHWA Operational Test Division, June 7, 1993.

Federal Register (1992a). *Intelligent Vehicle Highway System (IVHS) Field Operational Test Program*, Federal Register (57, 90).

Federal Register (1992b). *Participation in the Intelligent Vehicle Highway System (IVHS) Field Operational Test Program*, Federal Register (57,139).

FHWA (1996). *Implementation of the National Intelligent Transportation System Program - 1996 Report to Congress*, Joint Program Office for ITS, FHWA-JPO-97-026.

ITE (1985). *Transportation Control Systems Handbook*, ITE, Publication No. LP-123.

JHK & Associates (1992). *City of Anaheim Integrated Traffic Management Systems Demonstration Project - Implementation Report*, DOT-T-93-13, US Department of Transportation, Washington, DC.

JHK & Associates (1996). *1.5 Generation Control: Plan Developer User Guide*, prepared for the City of Anaheim, CA by JHK & Associates, Norcross, Georgia.

MacCarley,CA (1998). *Anaheim Advanced Traffic Control System Field Operational Test - Evaluation Task C: Video Traffic Detection System*, Final Report to PATH and FHWA.

Martin,PT and Hockaday,SLM (1995). *SCOOT - An Update*, **ITE Journal**, 65(1), 44-48.

Moore,JE II *et al.* (1999). *Anaheim Advanced Traffic Control System Field Operational Test - Evaluation Task A: Evaluation of SCOOT Performance*, Final Report to PATH and FHWA.

Recker,WW, McNally,MG, Neenan,B, Leonard,J (1992). *Interjurisdictional Coordination of*

Katella Avenue Traffic Signals, Final Report, prepared for the Federal Highway Administration, Publication DOT-T-93-24, Washington, DC.

Robertson,DI and Gower,P (1977). *User Guide to TRANSYT Version 6*. Transport and Road Research Laboratory, Report SR255, Crowthorne, England.

SAIC (1994). *IVHS Institutional Issues and Case Studies: Analysis and Lessons Leaned*, SAIC for USDOT, DOT-VNTSC-FHWA-94-15 or FHWA-SA-94-061.

Siemens Traffic Controls, Ltd. (1996). *SCOOT User Guide*

Skabardonis,A (1994). *Evaluation of the Fuel-Efficient Traffic Signal Management (FETSIM) Program: 1983-1993*, University of California, Berkeley, Research Report UCB-ITS-RR-94-11.

USDOT (1993). *Intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines*, DOT Document HTV-20, prepared by the MITRE Corporation (aka, the Mitre Guidelines).

Wallace,CE *et al.* (1983). *TRANSYT-7F User's Manual*. Prepared for FHWA, Office of Traffic Operations, Wahington,DC.