
Highway Operations, Capacity, and Traffic Control
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# Transportation Research Record 1811

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Foreword

The 2002 series of the *Transportation Research Record: Journal of the Transportation Research Board* consists of approximately 650 papers selected from 2,000 submissions after rigorous peer review. The peer review for each paper published in this volume was coordinated by the sponsoring committee acknowledged at the end of the text; members of the sponsoring committees for the papers in this volume are listed on page ii. Many of these papers were presented at the TRB 81st Annual Meeting in January 2002, and draft versions were included in the Annual Meeting CD-ROM.

Additional information about the *Transportation Research Record: Journal of the Transportation Research Board* series and the peer review process appears on the inside back cover. All volumes of the 2002 *Record* series also will be released on a single CD-ROM available for purchase in early 2003.

The Transportation Research Board appreciates the interest shown by authors in offering their papers and looks forward to future submissions.
Field Operational Test of Integrated Freeway Ramp Metering/Arterial Adaptive Signal Control
Lessons Learned in Irvine, California

C. Arthur MacCarley, Stephen P. Mattingly, Michael G. McNally, Daniel Mezger, and James E. Moore II

A systematic evaluation of the performance and effectiveness of a field operational test (FOT) of an integrated corridor-level adaptive control system was attempted from fall 1994 through spring 1999 in Irvine, California. The FOT was conducted by a consortium consisting of the California Department of Transportation (Caltrans), the city of Irvine, and two private-sector consultants—National Engineering Technologies Corporation and Farradyne Systems, Inc., a division of Parsons Brinkerhoff—with the city of Irvine as the lead agency. The FOT was a cost-share funded by FHWA 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 traffic management systems in the city of Irvine and in Caltrans District 12. The evaluation originally entailed both a technical performance assessment and a comprehensive institutional analysis. This report of the Irvine FOT does not constitute a technical evaluation because of the failure of any of the planned technologies to be successfully implemented in the field. Because of the extended time frame associated with the project and the significant range of technical and institutional issues associated with the development and eventual failure of the FOT, a summary of project development, institutional barriers, and lessons learned is provided.

Achieving field operational test (FOT) objectives typically require identifying, evaluating, and resolving a wide variety of institutional barriers to successful project completion. Federal and California policy are firmly supportive of the rapid deployment of new technologies associated with advanced transportation management systems (ATMSs), but actual deployment involves integrating diverse technologies from a variety of competing vendors. Because local operators have little experience with ATMS technologies, they must learn to deal with technical and institutional implementation issues. The limitations institutional issues pose should not reduce or confound system effectiveness. Unfortunately, the scope of potential institutional issues is quite wide. The question of interest is “How can the institutional limitations on programming, implementing, and operating ATMS technologies be prevented from reducing or confounding such technologies’ effectiveness?”

This paper examines the technologies, circumstances, events, and results associated with FHWA’s city of Irvine advanced traffic control system intelligent vehicle-highway system FOT, integrated freeway ramp meter arterial adaptive signal control. This Irvine FOT evaluation is a part of the FHWA program to evaluate intelligent transportation system (ITS) concepts and technologies that have the potential to improve mobility, safety, and transportation productivity as well as reduce congestion and emissions on national highways (/).

BACKGROUND

The FOT was a cost-share funded by FHWA in cooperation with the California Department of Transportation (Caltrans), the city of Irvine, National Engineering Technology Corporation (NET); referred to here as the freeway consultant), and Farradyne Systems Incorporated, a division of Parsons Brinkerhoff (referred to here as the arterial consultant). A map of the study area in the city of Irvine is presented in Figure 1.

Caltrans’ involvement in the FOT spanned three separate entities. Caltrans Headquarters administered the contract and passed the federal funding to the city of Irvine. Caltrans District 12 (D12) in Orange County served as the agency responsible for freeway infrastructure and management. The Caltrans Traffic Operations Section developed the specification for the Model 2070 advanced traffic controllers (ATCs) used in the arterial element of the project.

The Irvine FOT was to have introduced several new technologies in the project area to create an integrated freeway/arterial corridor that adapted to real-time traffic conditions (2). The freeway components were designed by D12’s freeway consultant. These included a new centrally controlled, systemwide, traffic-responsive ramp-metering system, designated the systemwide adaptive ramp-metering (SWARM) system, and the D12 Transportation Management Center’s (TMC) operator decision support system (ODSS). SWARM and ODSS were components of the D12 ATMS created by the freeway consultant. The D12 ATMS would oversee the freeway by providing incident detection, surveillance, ramp metering,
and changeable message sign (CMS) control, whereas ODSS was supposed to provide real-time decision support for incident response. ATMS/SWARM replaces and supercedes many of the functions of the previously proposed ODSS, which replaced the originally proposed (3) freeway real-time expert system demonstration, an expert system developed by the University of California at Irvine (4–6). Functional features (only) of ATMS/SWARM were described by a freeway consultant (7).

The FOT's arterial components were provided from three sources: the arterial consultant, Caltrans TOS, and the city of Los Angeles Department of Transportation (LADOT). Caltrans TOS specified the Model 2070 ATC on which the arterial consultant's real-time adaptive signal control software package, optimized policies for adaptive control (OPAC), was expected to run. At the time FOT was proposed, the 2070 ATC was still under development and lacked final specifications and firmware for traffic signal control. About 2 years after the start of the test, LADOT was retained by the city of Irvine to provide the missing signal control firmware. Finally, the arterial consultant also provided the central control component of the proposed arterial system, the management information system for traffic (MIST), which was to provide network-wide supervisory control of the local OPAC-based arterial signal controls as well as an operator interface and CMS control. MIST's control decisions were to be subordinate to control actions on the corridor freeways initiated by the D12 ATMS, to which MIST was to be linked. The key hardware components of the integrated project are presented in Figure 2. Physically, ATMS/SWARM was implemented on a local network of HP UNIX workstations in the D12 TMC. MIST was intended to operate on a similar network of HP 9000 workstations in the Irvine Traffic Research and Center (ITRAC). Corridor control system logic is presented in Figure 3.

Communications between the two supervisory systems were a critical component of the proposed FOT and were to have been accomplished via one or more data links but were never fully specified. This
link represents the backbone of the integrated system. The hardware mechanization of this data link was not completed, and the exact information to be transmitted between the D12 TMC and the ITRAC remained undetermined. Working components of the data link, which have been demonstrated, included several telephone modem connections, the existing and possibly expanded Caltrans wide area network, and an existing fiber-optic high-speed data connection.

OUTCOMES

It is the consensus of the evaluators that no integrated control or control functions were implemented as part of this FOT and that no operational systems were implemented. SWARM was tested offline extensively in the D12 TMC but was never implemented because of operational and functional problems and (as reported by
D12 personnel) lack of an operator’s manual for the system. Actual ramp-meter control under SWARM/ATMS was not implemented. The city of Irvine installed 2070 controllers at 28 intersections per contract requirements. The arterial consultant provided and installed OPAC at one intersection and operated it off-line. Its potential to communicate with MIST was demonstrated, but, because communications with ITRACT were not operational, and MIST was not yet installed, it is unclear what control function was demonstrated. The arterial consultant ultimately delivered MIST to the city of Irvine, and a demonstration of only its user interface was conducted in February 1999, running on a workstation in the ITRAC. No Caltrans Headquarters, D12, or city of Irvine personnel attended the demonstration. Because data communications were not functional, no features of the system that depended on communications with OPAC at an intersection or with the D12 TMC could be demonstrated.

**FOT EVALUATION**

In this FOT, there is no system to evaluate and there is little in the way of individual components. Consequently, it is impossible to assess the ultimate deliverables of this FOT in terms of technical capacity. The assessment of institutional issues is the central evaluation task. Data required for evaluating institutional issues are substantively qualitative and inevitably somewhat subjective. It is important to gather information from multiple sources to minimize bias in interpreting data.

The first source was direct observation of participants over the duration of the project at formal project meetings and in less formal field situations. The project manager and members of the evaluation team shared independently recorded meeting minutes documenting formal meetings. Although approved early, the Irvine FOT evaluation trailed the evaluations of other FOTs because of various delays. Several reports documenting institutional issues associated with these projects provided a second useful data source (8, 9). The Anaheim FOT evaluation (10, 11), which the same evaluation team completed concurrently with the Irvine FOT evaluation, was one of these sources. Finally, the evaluation team interviewed all key project participants to assess their opinions about the progress of the FOT and about the relative role of various institutional issues.

Interviews began in January 1997 and concluded with final interviews and follow-ups in March 1999. The team interviewed key individuals from all agencies and firms participating in the project, including participants from the city of Irvine, the arterial consultant, the freeway consultant, Caltrans Headquarters, D12, LADOT, and FHWA. The evaluators also interviewed selected FHWA administrators based in Washington, D.C., to obtain a national view of the project. In some cases, evaluators conducted follow-up interviews for clarification of certain issues.

The interview consisted of four sets of questions, one set for all participants, and another set for each of three groups of participants. These three groups are as follows:

- High-level administrative participants,
- Project management (key agency and firm participants), and
- Engineers and technicians.

The last portion of each interview addressed the effect of specific problems on the overall performance of the FOT project.

**FOT PARTNERS’ PERSPECTIVES: INTERVIEW RESULTS**

**Project Scheduling**

Table 1 presents 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, many agencies

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**TABLE 1 Summary of Project Scheduling Problems**

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<th>COMMENTS</th>
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<td>FHWA</td>
<td>The FHWA fully maintained its schedules and deadlines.</td>
</tr>
<tr>
<td>Caltrans Headquarters</td>
<td>Caltrans headquarters maintained its schedule. However, respondents said Caltrans headquarters could have facilitated earlier development of the memorandum of understanding with the City of Irvine.</td>
</tr>
<tr>
<td>City of Irvine</td>
<td>All City representatives indicated that the City did a fair job of maintaining its deadlines; however, it encountered some infrastructure problems due to new construction. Concerns from the other partners focused on slow decision-making, infrastructure problems related to new construction, and poor management.</td>
</tr>
<tr>
<td>Caltrans District 12</td>
<td>District 12 did not seem to encounter any delays; however, it did not provide a consistent presence early in the project. District 12 did not provide any technical review or leadership throughout the project.</td>
</tr>
<tr>
<td>NET (freeway consultant)</td>
<td>Although NET experienced technical problems with SWARM implementation, and its schedule slipped a little, NET finished SWARM before the end of the project.</td>
</tr>
<tr>
<td>PB/FSI (arterial consultant)</td>
<td>The arterial consultant did not realize the scope of work required to convert MIST from OS/2 to UNIX. Slow development of the 2070 specifications and firmware added to the delays, as did slow decision-making by project management.</td>
</tr>
<tr>
<td>LADOT</td>
<td>LADOT placed higher priority on this project than on others. City of Irvine respondents felt LADOT response time was quick and LADOT responded to all City needs. The arterial consultant respondents felt LADOT had a tremendous impact on its ability to finish tasks in a timely manner because the consultant was effectively beta testing Traffic Signal Control Program (TSCP) for LADOT.</td>
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indicated they failed to maintain their project schedules. However, respondents who identified schedule delays most often attributed those delays to other participants.

**FOT Technologies**

Respondents associated problems with all the planned FOT technologies: SWARM, OPAC, MIST, arterial response plan (ARP), and the 2070 ATCs.

**SWARM System**

Respondents reported two primary concerns about SWARM. First, Caltrans received neither the training nor the documentation needed to fully understand SWARM operations. Second, SWARM did not appear to work when Caltrans ran it. Caltrans tested SWARM functions over a 6-week period, but nothing related to SWARM ever appeared to work, and Caltrans never identified what SWARM did internally. Caltrans let SWARM run in the field on a small section of road for 2 days, but once again there was no indication SWARM was functioning. Caltrans did not find any evidence that SWARM was affecting any ramps. Interviewees also noted that SWARM's inability to save parameters might render it effectively unusable.

Despite these problems, D12 expected to use SWARM if it met current functional requirements and operated 24 h a day. Other Caltrans respondents expected SWARM to reduce delay on the freeway and be completely automatic and robust. The freeway consultant believed the entire ramp-metering system should switch to SWARM.

**OPAC**

The arterial consultant stressed multiple concerns about implementing the OPAC technology, and other participants questioned its validity as an effective algorithm. The arterial consultant expressed these worries:

- **City staff must understand and set up OPAC parameters, because the arterial consultant was not contracted to do this work.**
- **OPAC might have difficulty coordinating closely spaced intersections.**
- **An oversaturated arterial might overwhelm OPAC.**

The quality of data from the stopline detectors determines OPAC performance. The arterial consultant expressed further concerns that the FOT constituted a substandard OPAC implementation.

OPAC/MIST operations would have burdened the city's staff. Establishing timing pages appeared to be quite time intensive, and even the arterial consultant's technical team did not fully understand the process. Acceptable OPAC performance thresholds varied among city staff, who suggested OPAC should reduce delays and stops by 10% to 25% relative to the city's existing Multisonics system. City respondents indicated that they anticipate scrapping the OPAC system and returning to the existing Multisonics system.

**MIST**

The MIST system also elicited different opinions. The arterial consultant respondents stressed that the city of Irvine would need to invest adequate staff time to learn the new system and complete its implementation. The primary technical concern related to using too many devices on one communications channel. The agencies, in contrast, questioned MIST's overall functionality instead of specific correctable details.

**ARP Module**

Because FOT never tested the ARP module, its functionality remains unknown. Administrators and consultants stated simply that ARP might be routinely ignored. Although the team's opinions about ARP performance requirements differed greatly, a significant portion of them simply wanted to see it function.

**2070 ATCs**

Respondents expressed a variety of technical concerns about the 2070 ATCs. The consultants worried about 2070 stability and functionality, specifically that the central processing unit might not optimize OPAC completely. One participant from the city of Irvine worried about keeping up with frequent maintenance problems. Two other agency respondents were preoccupied with firmware functionality. They were concerned that the firmware might not work properly, or it might not work with an updated 2070 specification, especially with respect to the device drivers. The arterial consultant respondents observed hardware flaws such as electrical shocks and fires and blown modem cards. In their view, the 2070s were poorly manufactured: during an environmental test, one-third of the power supplies died.

**Integration**

More than three-quarters of the respondents believe this FOT was overly ambitious, including integration of too many untested new technologies, particularly the 2070 ATCs and SWARM. Most of the interviewees wanted to prove the technologies separately in smaller pieces before bringing them all together. Ideally, separate field operational tests would evaluate the 2070 controllers, the MIST conversion and OPAC, and the SWARM system.

More than a quarter of the participants recommended scrapping MIST and OPAC altogether and replacing them with different technologies. MIST's inability to provide real-time management (actual performance is every 30 s) and OPAC/MIST's lack of quality control make them unattractive for future implementations. Further, neither system was year 2000 compliant.

**Project Management**

Interview respondents were sharply divided along jurisdictional lines over project management. The city of Irvine and the freeway consultant, the two partners responsible for project management and system coordination, think the project management and schedule were extremely useful. All other parties think the project lacked overall management and reported that the schedule served no purpose because most participants did not use it, refer to it, or adhere to it.

Administrative concerns focused on leadership and decision making. Respondents thought that, because the city of Irvine was in charge, it did not have to answer to anyone and had no need to con-
sult with any other partners in making decisions. The city of Irvine demonstrated very little administrative follow-through and required considerable time to complete decision-making tasks, especially about the ARP, the 2070 software and hardware, and CMS hardware. One-quarter of the participants noticed that the project stalled repeatedly while waiting for technical decisions on technology selection. According to respondents, the city's poor project administration hindered the entire project.

Participants suggested several significant changes to the FOT process to address administrative issues, including the following:

- Require software developers to put up a bond, as construction contractors do.
- Require an initial systems requirements document designed to fit existing budgets. The document should cover functions and features of the technologies involved.
- Remove the cost-sharing requirement when the FOT is really a research and development project.

Clearly define decision-making authority by empowering the group, an independent party, or FHWA to make binding decisions needed to move the project ahead. A representative of FHWA suggested changing the FOT contracting process to design and build, and operate projects to avoid some of the problems on this and other FOTs.

Operational Issues

Respondents almost unanimously believed the partners failed to plan adequately for the operations, maintenance, and training needs of the new system. Half the respondents emphasized that both the freeway consultant and D12 forgot to include SWARM system training in the FOT. This appeared to be the most critical omission during the planning phase. Three of 10 respondents noted that the 2070 controllers required more maintenance than did the existing controllers.

The city of Irvine did not plan adequately for the transition to a new system in that it appeared to be unprepared to care for the system or to add intersections after the FOT was completed. However, the city blamed these difficulties on the software configuration and inadequate training. The city admitted that it did not understand MIST or OPAC operations. The arterial consultant provided training, but city staff were unable to attend on a consistent basis. The arterial consultant recommended follow-up training after an initial burn-in period. The burn-in period never occurred, so no additional training was needed.

All the partners except the city of Irvine thought the FOT was an important step in developing a citywide, state-of-the-art traffic control system and in expanding citywide 2070 use and MIST coverage. In financial terms, FOT helped the city, which wanted to replace its existing traffic control system, by providing new 2070 controllers; five CMSSs; additional speed, occupancy, and headway loop detectors; and other hardware. City respondents believe Irvine benefited operationally because it worked with D12 and obtained a more responsive system with more tools.

EVALUATORS' PERSPECTIVE: WHAT REALLY HAPPENED?

The evaluation team believes the following circumstances imposed binding constraints on FOT's success.

Caltrans' Role in Technology Choice

Originally, the arterial consultant wanted to use OPAC on arterials to accommodate freeway dumps forcing traffic onto city streets, although they ultimately recommended OPAC for modeling vehicle queues on freeway ramps. If the arterial consultant successfully modified the algorithm, OPAC would have set ramp-metering rates based on the ramp queues. Caltrans did not like this approach, and, during the proposal process, Caltrans changed certain objectives and partners. For example, Caltrans tried to eliminate OPAC completely and use a National Transportation Communications for ITS Protocol (NTCIP) installation and its own ramp metering. Caltrans unilaterally selected the freeway consultant to replace the University of California at Irvine on the project because of the consultant's existing statewide relationship with Caltrans.

Developing Firmware for 2070 ATCs

The city wanted to use 2070s as opposed to ATCs for a variety of reasons. First, it did not want to place both ATC and Multisons controllers in one cabinet. There was no room. Second, Caltrans was committed to providing support for 2070s in the future. During this key decision-making stage, the city consulted with Caltrans Headquarters and LADOT but excluded the other FOT partners, specifically the arterial consultant. In hindsight, one member of the arterial consultant firm believes the consultant should have demanded using ATCs with specific firmware with which the consultant was familiar.

At the time of the proposal, the partners realized that no 2070 firmware existed, but the city of Irvine volunteered to obtain it. Three entities were developing 2070 firmware at the time, including LADOT. Selecting the firmware provider required a great deal of time. According to city respondents, everyone knew that the LADOT controller software worked and had been used during the 1994 FOT research and development phase. However, there was no prototype available to allow development of device drivers. The city selected LADOT because its price was low, both had worked together in the past, and the city did not have to pay a license fee. The arterial consultant remained staunchly opposed to the LADOT firmware throughout FOT, because respondents thought public agency software represented a high risk and was not sufficiently available. Ultimately, the development of firmware required diverted FOT funds because it was not part of the budget.

Problems with use of the 2070 ATCs began during Caltrans' tests. This prevented the city of Irvine from establishing a final prototype until early 1996, not 1994 as was assumed in the FOT proposal. Caltrans Headquarters handled the 2070 hardware development but continually changed its specifications. The first prototype from Caltrans Headquarters was provided over a year late, in the middle of 1995. As a result, the arterial consultant's software coding efforts became extremely difficult. Device drivers posed a problem for both the arterial consultant and LADOT. LADOT involvement began in 1994, when it developed software on its own for what turned out to be the wrong hardware prototype. The need to reach agreement on data exchange between the traffic signal control program (TSCP) and OPAC slowed implementation of OPAC. As a result, LADOT changed its firmware to try accommodating OPAC's needs. Instead, the change constrained optimum operations.

The city sometimes had difficulty reading all its infrastructure for the arterial consultant. The CMS firmware also created significant problems. Changes and bugs at different points during the project might have cost the arterial consultant as much as an entire month of delays.
Converting MIST to UNIX

At the proposal stage, one of the partners insisted on a UNIX platform for MIST. The arterial consultant spent considerable time implementing the platform change to a UNIX system and 2070 controllers. Developing the server, timing pages, and TSCP was associated with these tasks. This change in platform and controllers sharply constrained further development of the OPAC algorithm. In the end, the only contribution of OPAC research associated with this project was the addition of cumulative delays and stops to the algorithm.

Testing the SWARM System

SWARM lacked necessary documentation, and its failure management and malfunction scheme needed redesign. SWARM and all pertinent reports were tied to the conclusion of the freeway consultant’s ATMS project, which hindered the development of these additional systems. The freeway consultant was responsive to many requests but refused all requests that “required a major redesign” or documentation. The freeway consultant last responded to D12 in late summer 1998. Major problems with the algorithm included the consultant requirement that SWARM be implemented on one ramp at a time (as opposed to freeway section by section) and lack of permanent memory to store the setup parameters at each ramp meter. Turning SWARM off thus required that all ramp parameters be reentered, a process for which no documentation existed. Caltrans respondents do not believe the freeway consultant anticipated the extensive testing that D12 performed on SWARM.

The freeway consultant did little follow-up work on the D12 SWARM system. As a result, D12 had to wait for completion of ATMS2, the District 7 (Los Angeles) SWARM system, before it could begin retesting ATMS and SWARM. District 7 would perform most of the testing of ATMS2, with D12 stressing the importance of a future evaluation of SWARM before statewide deployment.

CONCLUSIONS AND LESSONS LEARNED

Significant lessons were learned during the course of the Irvine FOT. Two of these lessons are particularly prominent:

- It is important to incorporate detailed technical specifications in contract documents, and
- There is a strong need for complete technical review and an appropriate level of technical understanding on the part of the contracting agency.

Greater attention to these two elements would have significantly increased the likelihood of identifying and preventing the problems that led to FOT’s major delays and, ultimately, to the failures in delivery and implementation encountered in the Irvine FOT. For example, the Caltrans 2070 controller was specified as the platform for OPAC under the 1994 (final) (3) proposal revision. The proposal did not specifically address whether the 2070 would replace the existing Multisonics controllers or would be installed in addition to the existing controllers. The proposal also did not specify what entity would be responsible for the signal actuation software that would be required for the ultimate configuration, which would consist of either the Multisonics controller and the 2070 or the combined functions operation of just the 2070. These ambiguities led to contractual disputes between the arterial consultant and the city of Irvine and ultimately were the source of the most significant project delays.

The arterial consultant clearly expended a great deal of effort on the FOT and reported losing a considerable amount of money. The freeway consultant met contract deliverables by providing over 30 status reports and specification documents, many duplicate and irrelevant to successful execution of the project. The problems that might realistically have been avoided include the following:

- Dependence on the 2070 controller, which had not yet been fully specified or delivered, could have been avoided. Depending on a controller that was still in development complicated the software porting tasks required of the arterial consultant and was cited by this consultant as the primary reason for delays. An independent entity (LADOT) was brought in to supply custom signal control software that could communicate with OPAC and MIST.
- The need for signal control (actuation) software, which facilitated joint implementation of the intersection control and OPAC modules on the 2070 controller, could have been avoided if these functions had remained split between the Multisonics and 2070 controllers. The arterial consultant had assumed this split configuration.
- The integration deliverables to be performed provided by the freeway consultant were largely decoupled from, and independent of, the arterial consultant’s work. Integration must occur concurrently with other implementation activities. If the involved parties had considered complete integration important to the project’s completion, the freeway consultant’s continued involvement should have continued after its contract expired in 1997 through a new contract agreement, in anticipation that the arterial consultant’s deliverables might be delayed well beyond that time.
- The contractor should establish the nature of the documentation required instead of the vendors doing so. This would have helped to avoid the problems associated with the freeway consultant’s choice to provide large quantities of mostly irrelevant status reports and specifications for systems that would never be implemented, while declining to provide an operator’s manual for the SWARM system software.
- A schedule of formal design reviews, tied to contract milestone payments, should be incorporated in partner contracts. This is typical in similar contracts administered by the Department of Defense and the Department of Transportation.
- Success of large technical projects such as the Irvine FOT is usually facilitated by assigning the program manager full responsibility and authority. The Irvine FOT was characterized by a desire for consensus that translated into nebulous project authority and a circular review structure. This led to loss of coordination, project direction, and morale.
- It is essential that technical leadership have direct access to the actual software development personnel in any project that involves the development of large integrated software packages with multiple developers and responsible entities. In the Irvine FOT, attempts to achieve coordination only through high-level management contacts led to miscommunications, unrealistic lead-time requirements for simple changes, and extensive development delays.
- Coordinating systems information and dissemination to all parties required the contribution of a systems engineer. A systems engineer might have been able to address some of the arterial consultant’s problems with LADOT, which had to supply the device driver for the consultant’s systems. LADOT made as many as 20 revisions to the TSCP. This imposed 300 to 400 h of delay and undocumented costs to the arterial consultant.
- Provision for independent technical evaluation and review should be incorporated into the original program proposal and all participating partners’ contracts. Including evaluators early in the
process, and a clearer standing of the evaluation team within the context of the project, would have led to more productive use of evaluation resources. Evaluators might be consulted about the specifications, work plan, and deliverables in the partners’ contracts before approval. In the Irvine FOT, the evaluators were not permitted to see the partners’ contracts until after the project was terminated, over 5 years after the fact.

- The actual FOT deliverables and timetable were never fixed; evaluation man-hours were wasted meeting ad hoc requests from the FOT partners to repeatedly update evaluation work plans for systems that were never deployed. The evaluation team complied with these requests in an unsuccessful effort to encourage reciprocal responsiveness from the FOT partners. The objective of the evaluation should have been allowed to focus on ensuring technical and institutional performance instead of assessing the consistency of FOT with nationwide ITS objectives.

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