5. Conclusions

The conclusions below are those gathered from the planning and system development phase of the FOT, the Anaheim Special Event Test, and the I-5 Test.

5.1 Planning and System Development

The FOT was able to assess the portability, effectiveness, and institutional issues relating to the mobile surveillance and wireless communication system using evaluation plans and test procedures developed during the FOT. The biggest issue addressed during the FOT was the schedule delay in building and deploying the trailers. This was in part due to deficiencies in the planning process, the multi-stage procurement process, and to requirements being added to the trailer design and operation, even as the design and assembly of the trailers, relay site, and TMC equipment was occurring. Closely related to the planning issues was the issue concerning whether the FOT was developing prototype equipment or operational equipment that could support normal transportation management functions. As the testing progressed, some modification of the test procedures was necessary because the 170-controller data calculated from VIP measurements could not be displayed or reliably updated on the graphical user interface at the Caltrans District 12 TMC.

Three issues that affect the portability of the mobile surveillance and communications system became apparent. First, the size of the trailers limits where they can be placed in a construction zone or to support a special event. Second, since the configuration of a construction zone may change weekly or daily, the trailer is subject to frequent moves that are exacerbated by their size. Third, since only one relay site has been built, the areas in which the trailers can be deployed are limited. Subgrade placement is not possible because of line-of-sight restrictions. Two recommendations based on these findings are that: (1) road construction contractors be made aware early in the planning process for the need to allocate sites for the surveillance, and perhaps ramp meter, trailers in the construction zones; (2) additional or supplemental relay sites be designed and deployed in areas from which Caltrans desires video and VIP data.

Institutional issues, such as sharing of video and data and paying for trailer transportation and setup, were raised and satisfactorily resolved. Other issues, such as liability for accidents that occur while a trailer is on private property or accidents that occur while Caltrans equipment is used by another jurisdiction, were also resolved satisfactorily.

Additional conclusions from the planning and system development phase are summarized below.

5.1.1 Planning

The execution of the FOT would have benefited from planning that acknowledged that additional requirements and tests could possibly emerge as the FOT progressed. Had the possibility for additional requirements been considered and formally communicated to the partner agencies and companies earlier in the planning cycle, some of the encountered delays could have been better accommodated or reduced.

5.1.2 Project Schedule

Allotting more time in the schedule for each increase in scope in the trailer's design or function would have allowed Hughes to adequately design, fabricate, and test each component of the trailer system. Furthermore, changes in scope should have been limited. Some date on the schedule should have been chosen as a cut-off after which no further design changes were permitted. Belated design modifications aggravated the already difficult task of systems integration and delayed some subsystems tests. Lack of early testing prevented early discovery of some problems and, subsequently caused the schedule to slip, thereby creating delays for other FOT tasks.

5.1.3 Procurement Process

The procurement process had a significant impact upon the project schedule as much of the FOT focused on trailer systems integration. The procurement was many faceted. Hughes researched and recommended items for purchase, Caltrans approved the items, and UCI purchased the approved items for Hughes to assemble and integrate into the trailers, TMCs, UCI, or relay site. This process became cumbersome at times, thereby contributing to project delay. Difficulties included misconceptions regarding the division of procurement responsibility and mid-project changes to technical specifications. The problems with the procurement process were compounded by some vendors who were unable to supply items in a timely manner. Allowing the primary contractor a more direct method of parts procurement, perhaps through a project credit card, for items costing less than some predetermined amount would have been helpful.

5.1.4 Prototype Equipment Versus Operational Equipment

There appeared to be a conflict between the desire of Caltrans to have completely developed operational equipment upon completion of the FOT and the FOT objective to develop and build a prototype unit for evaluation purposes, which could be improved upon if necessary. This issue sometimes resulted in conservative specifications, such as the need for the surveillance trailer to withstand a 70-mi/h (113-km/h) wind. On the other hand, there was a desire to save money that led to purchasing equipment that failed to fulfill requirements, such as the original radio transmitter/receiver pair to control the meter-on sign.

5.1.5 Cost Centers and Personnel Year (PY) Allocations

Funds and personnel were not initially provided to the Caltrans or Anaheim maintenance or electrical departments for FOT planning and routine trailer maintenance. Consequently, personnel supervisors in these departments resisted, and in some cases refused, to allocate time and resources for these tasks. This continued to impact the utilization of the trailers, until funds were allocated for their upkeep and transport. Therefore, special cost centers should be created and funded early in the program to facilitate design, maintenance, and transportation during and after the FOT.

5.1.6 Trailer Hitch Redesign and Replacement

The design requirements for the trailers failed to specify the Caltrans hook-and-pintel trailer hitch. Consequently, the originally installed ball hitches had to be replaced. A mechanism for raising and lowering the hitches on the trailers was also needed to accommodate the different heights of the tow vehicles. The project delays caused by installation of an improper hitch could have been avoided if Caltrans maintenance was invited to review and approve the trailer design.

5.1.7 Charging and Maintenance of Batteries

One of the major contributors to test delays once the trailers were deployed was the poor performance of the analog control system that maintained the charge in the primary trailer batteries. The analog control did not provide repeatable turn-on and turn-off of the generator and, hence, failed to maintain the battery voltage. The analog control system was replaced with a microprocessor-based system that corrected the lack of repeatability in generator control and battery charge. After the FOT was completed, an extensive redesign of the generator, batteries, charging system, and power distribution architecture was completed. The new power system was installed in the six surveillance trailers, but was not evaluated as a part of the FOT.

5.1.8 Automatic Mast Retraction

The decision to modify the surveillance trailer mast to include automatic mast retraction caused significant delays and introduced logistical challenges. Introduction of this modification after the trailers were already assembled and deployed delayed its implementation and impacted the FOT schedule.

5.1.9 Data Capture

Polled 170-controller data from the surveillance trailers were not fully integrated with the District 12 TMC software to allow their display on a workstation graphical user interface (GUI). The evaluators also observed that the polled 170-controller data from the permanent inductive loops were not always updated in a periodic manner. Another issue that affected the transmission of 170-controller data to the TMC was based on a Caltrans observation that the wide area communications controller crashed intermittently and then rebooted itself. This behavior was more frequent as the number of surveillance trailers online increased from one to six. Remedies were attempted, but the VIP data remained unavailable from the GUI for the duration of the FOT. Consequently, the I-5 Test Evaluation Plan was modified to bypass this interface. Two laptop computers were used instead to poll and record data from the 170 controllers in the surveillance trailers (VIP data) and roadside cabinets (ILD data).

5.1.10 Shared Camera Selection and Control Among Agencies

The original design of the communications network was not fully compatible with the desire to allow several agencies to share and control their own access to real-time traffic information. Consequently, the video switching and control system was modified midway through the project to add video control by the Anaheim TMC.

5.1.11 Relay Site

Establishing the relay site became a critical path task, as it was an integral part of the wireless communications system used to transmit video and data from the trailers to the TMCs and UCI-ITS Laboratory. Site development required multiple steps beyond determining the best location. These included negotiating access to space, securing liability coverage, taking responsibility for any possible increase in property taxes, and providing reasonable upkeep to the site and equipment.

The current relay site limits trailer deployment to the 5-mi (8-km) radius surrounding the Union Bank building in Santa Ana, CA. Caltrans has been presented with five options for extending the communications area. A determination should be made as to which option is most suitable and that option should be implemented.

5.1.12 Trailer Security System

Operation of the security system presented challenges during the initial stages of the project. Early communication between project staff and the CHP was incomplete. Consequently, the responsibility and actions required of CHP officers to trailer security alarms was unclear and the exact locations of some of the surveillance trailers was unknown to them. Perhaps the most serious problem identified with the security system was the initial procedure by which the TMC operators were detecting and responding to alarms. The TMC "attention" tone would sound dozens of times each day simply because a status notification was being transmitted. It required no immediate action, as would an intruder-initiated security alarm. Consequently, the TMC staff lost interest and stopped checking the security system output. This problem was remedied by suppressing the alarm when normal status was reported.

5.1.13 Technical Training

The partners failed to reach an early understanding regarding the level and amount of training that would be provided to Caltrans and Anaheim personnel. Some personnel nominated for training could not obtain permission to attend because training time could not be afforded. Some personnel available for training did not get adequate advance training and thus became heavily dependent upon on-the-job training. Many of those that did receive advance training required refresher courses because the initial training was completed many months prior to the first trailer deployment and, hence, the first opportunity to apply the skills they had learned.

5.1.14 Trailer Transport and Setup

Trailer transport and setup became more efficient as personnel gained experience working with the trailers. A major issue uncovered early in the FOT was the need to better contain trailer functional requirements. Imposing additional requirements (e.g., adding eight stabilizing plates to support the signal heads and meter-on sign on the ramp meter trailer) added weight that increased the ramp meter trailer load to the point where it exceeded the maximum design load. A solution may be to equip the ramp meter trailers with larger tires or dual tires.

5.2 Anaheim Special Event Test

The Arrowhead Pond hockey games provided an opportunity for testing the functionality and effectiveness of the mobile surveillance trailers in a special event setting. The trailers were placed in strategic locations near traffic signals to assist traffic officers and TMC operations personnel during the traffic egress period that followed each game. The Anaheim Special Event Test showed that there was value in deploying the surveillance trailers to a special event location. The operators at the Anaheim TMC found the imagery of traffic flow from streets normally without video cameras an asset in controlling the phases of traffic signals. Caltrans received information about traffic approaching freeways in advance of it entering the freeway.

The objectives of the test were satisfied as shown by the findings below.

5.2.1 Objective 1: Portability

5.2.1.1 Transportation

After the trailers were initially transported to the special event sites, subsequent moves were more easily accomplished. Site selection procedures required substantial time to survey the region, locate potential sites, perform signal testing, secure the necessary permits and permissions, and determine the best way to maneuver the trailer into position. It took about an hour and twenty minutes to transport the trailer a few miles, set it in place, and make it operational at a previously selected site.

5.2.1.2 Trailer Readiness

The trailers required frequent maintenance of propane fuel, battery water, oil, and other expendables. When routine maintenance is neglected, the trailers become unusable. The myriad of complex equipment in each of the trailers requires detailed maintenance procedures such as those recommended by Hughes in Appendix B. Down time can be reduced by placing each trailer on a revolving maintenance schedule. Such a procedure will ensure that no two trailers are off line for maintenance during the same period. Construction of future trailers should incorporate features that support easy maintenance by field personnel, such as improving access to components that require maintenance (such as the batteries).

5.2.2 Objective 2: Effectiveness of Trailers for Special Event Management

The trailers perform well in a city special event setting when site survey and site selection are performed properly. Carefully positioned trailers produced imagery that was valuable to event traffic managers. Once a camera was operating, its control and image quality remained constant from day to day. Darkness had a detrimental effect on the clarity of the image from the color surveillance camera. However, higher sensitivity color cameras can be purchased to upgrade the system. If trailer placement is suboptimum, the view may be unsatisfactory due to improper camera angle or distances to the areas of interest. The large size of the trailers may lead to less than optimum trailer placement.

5.2.3 Objective 3: Benefits of Additional Surveillance

The additional video surveillance provided by the surveillance trailers assisted TMC personnel in performing traffic management functions. The data suggest that the additional video may reduce the traffic egress time from a special event. However, this conclusion must be verified with additional testing for two reasons: (1) a limited amount of data was collected during the Anaheim Special Event Test and (2) the historical database, with which the data from the added video surveillance was compared, may not be accurate.

5.2.4 Objective 4: Resource Sharing Institutional Issues

The advantages, disadvantages, and costs associated with resource sharing between Anaheim and Caltrans were evaluated. The surveillance trailers provide tactical, strategic, and historical data to aid in traffic management. Tactical data are obtained in real time from the cameras and aid in controlling signal timing. The trailers serve as a strategic asset since they can be incorporated into plans that are developed for special event traffic management. Finally, the data obtained from the trailers can be stored in a database for later recall. Most, if not all, of the institutional disadvantages can be overcome with planning. Budgets can be provided for personnel who transport and operate the trailers. The Anaheim Special Event Test showed that security, permission to use private land, and liability concerns can be resolved if there is a desire to use the trailers. Perhaps the most serious disadvantage noted was that the benefits may not be commensurate with the amount of human, time, and fiscal resources that were expended. This concern may be ameliorated if a higher priority application for the trailers surfaces.

5.2.5 Objective 5: Information Sharing Institutional Issues

The advantages of information sharing were recognized by Anaheim and Caltrans. The camera images allowed Caltrans to better manage freeway operations from the traffic flow due to the special event. Both agencies learned more about the other's operations. The disadvantages were overcome by arranging procedures to share the common video assets. The primary cost item for Anaheim was to provide personnel and space for the installation of the antennas and radios that receive the video imagery.

5.3 I-5 Test

The I-5 Test demonstrated that mobile surveillance and ramp meter trailers can be deployed along freeways to control ramp-metering rates during rush hours and transmit video imagery to TMCs and research facilities. The most troublesome technical issue during the I-5 Test was the reliability of the portable power generation system. It was eventually redesigned toward the end of the FOT. Two items impacted the start of the test once the trailers were deployed. They were (1) the initial lack of ramp signal synchronization with vehicle demand and control commands from the surveillance trailer and (2) the failure to communicate the requirement for displaying a long yellow signal before the initial red ball when the ramp meter is first turned on. The first problem was remedied by reducing the transmission rate of the commands. The second was fixed when the requirement was finally communicated to and understood by the software developer. A problem that persists, however, is the lack of 100 percent detection of all vehicles at the VIP ramp demand detector. This issue should be investigated further. Perhaps the problem can be solved by adding an even greater number of detection zones before the stop bar. The multiple detection zone technique is used for VIP presence detection at arterial traffic signal stop bars.

The reliability of the ramp meter hardware and software improved substantially during the course of the evaluation once data transmission timing problems were identified and remedied. Although there are issues concerning the accuracy of the VIP mainline data as compared to the data from the permanent ILDs and the requirement to detect all vehicles at a ramp signal stop bar, the VIP mainline data do appear accurate enough to control local-responsive ramp meter rates during rush hours. One drawback may be the larger mainline traffic volume measured by the VIP and its impact on the level of service that is reported. Therefore, a method of compensating for vehicle overcount by the VIPs is needed in order to report valid results. If the ramp-metering function is to become operational, then a technique to ensure vehicle presence detection approaching 100 percent must also be found.

The objectives of the I-5 Test were satisfied as shown by the findings below.

5.3.1 Objective 1: Portability

5.3.1.1 Power System

The most prevalent problem uncovered during the I-5 Test was frequent discharge of the surveillance trailer battery because the automatic generator start system that sensed the battery voltage was not functioning properly. Consequently, the generator had to be jump started from an automobile battery. At other times, the generator could not be started at all and service personnel had to be called. The reliability of the Culver Drive trailer when operating on commercial power supported the conclusion that the generators and portable power system, in general, were the most troublesome part of the surveillance trailer system.

5.3.1.2 Ramp Meter Signal Synchronization with Commands

Loss of ramp meter signal synchrony with vehicle demand on the ramp and with the synchronizing signal from the surveillance trailer delayed the start of the I-5 Test. The problem was fixed by reducing the transmission rate used to send commands between the surveillance and ramp meter trailers. Another change that alleviated this problem was to decrease the delay in sending commands to the ramp trailer to 100 milliseconds from 5 seconds.

5.3.1.3 Ramp Signal Sequence at Turnon

Another design issue that delayed the start of the I-5 Test was due to a misunderstanding between Caltrans and the system designers as to how the ramp meter signal sequence must operate when it first turns on. The Caltrans requirement to have a relatively long yellow phase follow the initial green ball was initially not conveyed to or understood by the system integrators.

5.3.1.4 Transportability

The ease of trailer transportation and setup improved as the maintenance personnel gained experience with the procedures. The hitch times were less than 10 minutes when the trailers were functioning properly and all of the parts required for the operation were at hand. The set in place times were larger when the ramp meter trailers were part of the deployment. Time was needed to unload the signal heads and meter-on sign from the trailer and erect them at the desired locations. Usually a boom truck and a crew of at least five were required to unload and assemble the signal heads.

5.3.2 Objective 2: Effectiveness of Trailers for Traffic Management

5.3.2.1 Camera Image and Control

Once the cameras and communications links were operational, camera control and picture quality were consistent from each venue. Exceptions occurred when strong winds moved the antennas or the mast accidentally dropped because the locking pins were not fully extended.

The stops on the surveillance camera should be adjusted during trailer setup to ensure that the camera can rotate to provide imagery of the mainline upstream and downstream traffic flow.

Higher sensitivity color surveillance cameras should be sought to provide better imagery on poorly lighted roads.

The pan and tilt unit for the surveillance camera should be upgraded to a model that can support more weight. The manufacturer reduced the weight limit on the selected unit after it was purchased. The tests showed it couldn’t raise the combined weight of the camera and enclosure if the loaded unit was tilted near its lower limit.

To prevent vandalism to the security camera’s video and power cables, the cables should be protected, e.g., by placing them in conduit. When the trailers are left unattended at a remote site for an extended period, they are more likely to be vandalized as evidenced by thefts that occurred after the FOT was completed.

5.3.2.2 Comparison of VIP and ILD Data

Since the District 12 ATMS software was not polling the 170 controllers in all of the trailers, or not polling them consistently, the VIP data percent up time at the District 12 TMC was low, approaching zero. Therefore, two laptop computers connected to the 170 controllers in the surveillance trailers and roadside cabinets were used to acquire data to compare VIP- and ILD-measured volumes and occupancies at the ramp meter evaluation sites.

The average percent differences between the ILD- and VIP-measured mainline volume and average lane occupancy are –22 and 8, respectively, based on data gathered during the fourteen runs completed in the I-5 Test. These accuracies appear adequate for the rush-hour ramp-metering application as shown by the tracking of the local-responsive metering rates produced by the ILD and VIP data. These errors were tolerable because a more restrictive metering rate (namely zero) than the prestored TOD rate was calculated by the metering algorithm from the ILD and VIP real-time data. Therefore, the algorithm reverted to the less restrictive TOD rate for both sets of data. To verify that the VIP data are sufficient to support local-responsive metering, additional data should be gathered during periods of lighter mainline traffic when the local-responsive algorithm will not clamp at the TOD limit.

The larger percent differences between mainline volume measured by the ILDs and VIP may lead to the reporting of erroneous levels of service on the mainline. This potential problem is caused by the VIPs over estimating the volume by as much as 53 percent or under estimating it by as much as 14 percent. It is more likely that the VIP will overcount when the camera is mounted as it was in this evaluation. Some method to compensate for the overcount should be developed.

ILD-produced local responsive metering rates for the afternoon runs at the Tustin Ranch Road and Jamboree Road sites appear erratic. The same behavior was not observed during the morning runs at these sites or at the morning or afternoon runs at the Grand Avenue site. This “afternoon effect” bears further investigation.

5.3.2.3 VIP Control of Ramp Signals

The ramp signals responded properly to vehicle demand an average of 85 percent of the time. This is not good enough for ramp-metering operation. A possible method to increase this average is to position the surveillance trailer such that the camera’s field of view (FOV) allows additional VIP detection zones to be created upstream of the stop bar and then connecting all the zones with OR logic. Another way to increase the camera’s FOV is by installing a wider FOV lens. This solution may, however, decrease the imaged size of the ramp on the monitor and thus make it more difficult to create multiple detection zones.

Daytime vehicle detection on ramps is sometimes affected by the relative color of a vehicle compared to the road surface.

Nighttime vehicle detection on ramps is affected by alignment of VIP detection zones and vehicle headlight beams.

Ramp overflow detection by VIPs will most likely require an additional camera to detect vehicles at the ramp entrance. However, lack of overflow detection is not deemed a critical issue by Caltrans District 12 engineers.

5.3.3 Objective 3: Freeway Deployment Institutional Issues

5.3.3.1 LPG Fuel consumption

The most likely estimate of LPG consumption by a surveillance trailer is approximately 0.00522 tank/hr or 0.460 gallon/hr. With an LPG cost of $1.75/gallon, the estimated cost of fuel is $0.80/hr for surveillance trailer operation.

5.3.3.2 GUI Trailer Location Updates

Each time a trailer is moved to a new freeway location, the field device database on the GUI at the District 12 TMC must be updated to reflect the new trailer location. If this task is not performed, the trailer icon on the TMC map display does not reflect the actual trailer location. However, if the trailer location icon is updated, the data gathered at the previous trailer location are automatically removed from the database. This may present a problem if it is necessary to retrieve the previous data for later use. A solution may be to add alpha characters or in some other way modify the trailer name each time the trailer is moved. In this manner, the computer program will think a new trailer has been added to the array. The drawback with this approach is that the display will eventually become cluttered with icons that represent nonexistent trailers.

5.3.3.3 GUI Trailer Cluster Icons

The trailer location icon cluster on the GUI consists of many closely spaced camera and detector icons. District 12 TMC personnel report difficulty in selecting the one icon they need from among the many in the cluster. It has been suggested that a single icon representing the trailer replace this cluster of icons. A mouse click to the new icon would trigger the image from the pan-tilt-zoom surveillance camera on the trailer. Buttons on this initial video window would then allow the other cameras and detector stations to be selected.

5.3.3.4 Traffic Management Plan

Each construction project is accompanied by a formal traffic management plan. If the surveillance trailers are included as part of a future construction zone traffic management plan, the contractor would be obligated to accommodate the trailer and protect it. However, there are not any current plans to use the surveillance trailers in future or ongoing projects.

5.3.3.5 Ramp Meter Trailers

There has been no experience to date using the ramp meter trailers in construction zones. There appears to be no current interest at District 12 in using the ramp meter trailers for a temporary ramp meter installation. One Caltrans engineer explained that Caltrans would prefer a permanent ramp meter installation to a temporary installation in order to ensure driver acceptance and compliance. It has been suggested that the ramp meter trailers be used to meter parking lot egress at special events.

5.3.3.6 Ramp Meter Timing Plan Development

Caltrans ramp meter engineers are interested in using the surveillance trailers to support the development of ramp meter timing plans. To develop a ramp meter plan, the controlling bottleneck needs to be identified. This requires a thorough analysis of traffic volume data that may not be available in some locations. Furthermore, manual traffic counts are labor intensive and, therefore, expensive. The surveillance trailers could be used to collect volume data that would otherwise be unavailable, thereby supporting the development of ramp meter plans.

5.3.4 Objective 4: Information Sharing Institutional Issues

5.3.4.1 Video Sharing

Shared control of a surveillance camera by allied agencies working from different sites is not uncommon. This occurs whenever there is an incident within range of a shared camera. District 12 TMC personnel report that primary control typically goes to whichever agency has superior camera control capability.

5.3.4.2 Research

The UCI-ITS laboratory is also interested in using the surveillance trailers to fill gaps in the available inductive loop database. To date, research personnel have not used the trailers to gather data. The current surveillance trailer design uses a 170 controller to poll the VIP for data at 30-second intervals. Therefore, data at less than 30-second intervals (of interest in some research projects) are not presently available.